Economics Bulletin

Volume 37, Issue 4

Economy-wide Implications of Climate Change in Burkina Faso

Patrice Rélouendé Zidouemba
Nazi Boni University of Bobo-Dioulasso

Abstract

Economic development in Burkina Faso is potentially vulnerable to climate change, given the country's dependence on rain-fed agriculture. We used a computable general equilibrium model to estimate the economic impacts of climate change, assuming that it will lead to an increase in variability and a decline in the average of agricultural yields as well as an increase in the average and in the instability of the world food prices. Climate change is found to reduce national welfare, with urban poor households being the most affected. However, there is a wide variation across scenarios in terms of the magnitude of the impacts, highlighting the need for multi-sectoral approaches that consider climate uncertainty. Our analysis of adaptation options indicates that investment in agricultural research and extension and irrigation development, particularly when combined, are potentially effective means of mitigating the damage caused by climate change in Burkina Faso.

The author would like to thank the anonymous referees and the editor of the journal for useful comments and suggestions on the original version of this article.
Citation: Patrice Rélouendé Zidouemba, (2017) "Economy-wide Implications of Climate Change in Burkina Faso", *Economics Bulletin*, Volume 37, Issue 4, pages 2797-2808
Contact: Patrice Rélouendé Zidouemba - patrice.zidouemba@gmail.com.
Submitted: September 30, 2016. **Published:** December 01, 2017.

1. Introduction

The agricultural sector is of great importance for the Burkina Faso economy. Almost 80% of employment comes from this sector; agricultural GDP accounts for 35% of the total GDP, while 57% of export earnings are made up of agricultural products (Zidouemba and Gerard 2017). This sector is still vulnerable due to the agro-ecological characteristics of the country, the small size of the farms, poor access to knowledge of good farming practices, and limited investments in irrigation (Faurès and Santini 2008).

Agricultural production in Burkina Faso is dominated by rain-fed agriculture. As in most countries of sub-Saharan Africa, rain-fed agriculture covers more than 90% of the cultivated land. This situation exposes agricultural production to high climatic variability. Several factors explain the poor development of irrigation. These include low demand for irrigated agricultural products, limited access to the market, low financial incentives for agricultural intensification, poor soil quality, and its degradation. The high cost of irrigation is also an important factor explaining the low development of irrigated systems (Inocencio 2007).

Burkina Faso agriculture is characterized by low yields compared to the average for the sub-Saharan Africa. Unlike the Asian countries, which experienced a significant increase in yields due to the green revolution of the late 1970s and early 1980s, per capita food production and yields have stagnated in Burkina Faso (Tittonell and Giller 2013). This failure to increase yields is often attributed to heavy dependence on rain-fed agriculture, low population densities that make infrastructure more expensive, low fertilizer use and land degradation (World Bank 2008, Zidouemba and Gérard 2015).

In Burkina Faso, rural poverty contributes 92% to the incidence of national poverty while about 80% of the rural poor are still subsistence farmers (INSD 2015). The high rates of population growth in the rural areas raise the issue of poverty reduction and increase the pressure on agricultural production and natural resources. With a population growth rate estimated at 3% per year, the population of Burkina Faso should be doubled by 2050 and agricultural production should increase by no more than 2% per year. This would imply a sharp increase in food imports (Alexandratos et al. 2006).

The World Bank underlines that the major challenge of agricultural economies such as Burkina Faso is to ensure that agriculture plays a role in driving the economic growth and reducing poverty (World Bank 2008). However, as in the other countries in the world and particularly in sub-Saharan Africa, the sector is already exposed to climate variability, and this could worsen under climate change (Zidouemba 2017).

Extreme climate events are not new to agriculture, but their frequency is expected to increase due to climate change (Schmidhuber and Tubiello 2007). Easterling et al. (2007) cite several studies that predict a higher frequency of extreme weather events in sub-Saharan Africa, with serious consequences for agricultural production and household food security. This is particularly disturbing since the region is heavily dependent on rain-fed agriculture. The climatic variability, particularly severe floods and droughts, are likely to adversely affect the economic activity. The reports by Wassmann and Dobermann (2007) show that sub-Saharan Africa has experienced a series of extreme precipitation events linked to climate change. In this respect, Burkina Faso will be seriously affected as well.

While, there is now a growing consensus that climate change will tend to cause increased variability in rainfall (FAO 2008, Wheeler et al. 2000, Schar et al. 2004), the impact of climate change on agricultural yields remains highly uncertain even within the same country. Predictions from simulation models range from a sharp decline in yields (Schlenker and Lobell 2010) to a slight decrease (Nelson 2009) and even a more or less significant increase (Butt et al. 2005). A study by Parry et al. (1999) shows that climate change does not have a significant impact on global food production. Schlenker and Roberts (2009) even showed that corn, soybean and cotton yields will increase at high temperatures of 29° C, 30° C and 32° C, respectively.

Moreover, the world food markets may present greater price volatility because of a greater unpredictability in world agricultural production (Zidouemba 2017). Indeed, price volatility is mainly driven by unpredictable weather conditions (OECD and FAO 2011), a situation that might jeopardize farmers' earnings and the access to food for both rural and urban consumers.

Fortunately, adaptation strategies can mitigate the impacts of climate change. In most cases, adaptation strategies take place at the farm level, where most decisions are made. The most common coping strategies are crop selection and diversification, investment in irrigation, improvement of agricultural practices (efficiency in input use and better utilization fertilizer) and soil and water conservation (small-scale water collection and management) (Calzadilla et al. 2013).

The development of irrigation and the improved agricultural productivity have proved effective in this regard. By allowing farmers to increase their level of production, irrigation contributes to lower food prices. In the same vein, Lipton, Litchfield, and Faurès (2003) analyze the conditions under which irrigation has positive effects on poverty reduction. Faurès and Santini (2008) estimate that improving agricultural productivity can help the poor rural out of poverty in many ways. Land-based households benefit from improved agricultural yields; landless households, but allocating their labor force to agricultural activities benefit from an increase in the demand for agricultural labor and wages; landless households not allocating their labor force benefit from a larger supply of agricultural products resulting in lower food prices. The Urban farmers also benefit from the improved agricultural productivity due to higher demand for agricultural products. The agricultural processing and food marketing sectors also grow due to the increase in agricultural activities. The national economy benefits from the irrigation investment.

Burkina Faso has the potential for expanding irrigation and increasing agricultural productivity. The potential of irrigation remains largely under-exploited. It is estimated that the irrigated agricultural land accounts for only 0.81% of the total area harvested and 14.9% of the irrigable potential (OECD 2012). Yields of the main grain crops are estimated at only 25% of maximum achievable yields (Mutegi and Zingore 2013).

Many studies have measured the economic costs of climate change for developing countries like Burkina Faso. Most of these studies focus on agriculture and measure impacts using econometric analyzes or crop models. A study by Somé et al. (2012) estimated that Burkina Faso is likely to experience a decline in agricultural productivity by up to more than 25% by 2050 compared to its 2000 level. Crop models can overestimate the economic costs of climate change because, by focusing solely on production, they tend to exclude market-based coping mechanisms (Arndt, Asante, and Thurlow 2015). To overcome this limitation, crop models are sometimes combined with partial equilibrium models that capture demand and supply responses via commodity markets. A recent study using a partial equilibrium model is that by

Jalloh et al. (2013). These authors show that climate change is likely to significantly reduce food production in Burkina Faso.

The objective of this study is to fill this gap by using a computable general equilibrium model to simulate the likely impacts of climate change on the Burkina Faso economy as well as adaptation strategies at the national level.

The next section describes the economy-wide model and the design of the climate change and adaptation policy simulations. Section 3 presents our results, and we conclude in Section 4 by discussing climate change's implications for economic development in Burkina Faso and identifying areas for further research.

2. Modeling Economic Impacts

2.1. Economy-Wide Model

The analysis of the economic impacts of climate change is carried out using a computable general equilibrium (CGE) model. The CGE models are adapted to the analysis of climate change for at least three reasons. First, they simulate the functioning of a market economy, including labor, capital, goods, and services markets. They can, therefore, assess how changes in economic conditions can be mediated by prices and different markets. Secondly, the CGE models ensure that all the economic constraints are met, which is crucial for long-term projections of climate change. Finally, the CGE models represent a "simulation laboratory" to examine quantitatively the different channels of transmission of the impacts of climate change on the performance and the overall structure of the economy.

The model used in this study is a dynamic version of the model developed by the International Food Policy Research Institute (Lofgren, Harris, and Robinson 2002). It is calibrated by a social accounting matrix (SAM) for Burkina Faso, newly built for the year 2013.

The CGE model identifies 66 production sectors, 27 of which are in agriculture and 25 in industry. Representative producers maximize their profits by combining intermediate inputs with land, labor, and capital. We use conventional production functions with constant elasticity of substitution (CES) which allow an imperfect substitution between the factors of production. The labor market is segmented into three groups: salaried workers, family farm labor, and non-farm labor. Given the low unemployment rates and limited investment in Burkina Faso, we assume that workers of any category, capital, and land are fully employed, i.e. their supply is set at the reference levels while real wages and rates of return adjust to maintain balance. Labor, capital, and land are fully mobile between sectors. This great flexibility of production factors allows a strong endogenous adaptation to climate change.

The expected impacts of climate change can be influenced by trade and fluctuations in market prices. A decline in food production following declines in agricultural yields might be offset by an increase in food imports. We make assumptions that producers supply their products to different national markets for goods and services through a CES aggregation function. International trade is considered by allowing production and consumption to shift imperfectly between domestic and foreign markets depending on the relative prices of imports, exports, and domestic products. To do this, we use the CES functions for imports and constant elasticity of transformation (CET) functions for exports. Given that Burkina Faso is a small economy, world prices are fixed, and the current account balance is maintained fixed by a flexible real exchange rate.

Households in the model are disaggregated into rural and urban households and per poverty status (poor and non-poor). In total, there are 4 representative households in the model. Factor incomes are distributed based on households' factor endowments. Households save and pay taxes and the balance of income is used for consumption expenditure. The latter is based on a linear expenditure system (LES) of demand, which allows for non-unitary income elasticities.

Government revenues (from taxes and foreign aid) are used to purchase services, such as public administration, health, and education. The balance of its budget is assumed to be ensured by public savings adjustment.

In equilibrium, the factor rental rates adjust to ensure that the total factor supply is equal to the total factor demand. In the goods and services market, the balance implies that the total supply of goods and services equals the demand for private and public consumption, investment, intermediate consumption and demand for transaction services. This balance is ensured by flexible prices of goods and services. Finally, we opted for a savings-driven investment closure, i.e. investment adapts to available savings in the economy.

2.2. Simulating Climate Impacts

Climate change is assumed to affect agricultural production in the CGE model via annual deviations in agricultural yields obtained by a uniform probability distribution. The parameters of the uniform distribution depend on the scenario considered. In the reference scenario, no shocks on agricultural yields are applied. Four alternative scenarios representing climate change are then considered. The first scenario assumes an increase in crop yield annual variability due to more frequent extreme meteorological events. The annual growth rates of agricultural yields fluctuate around an average of zero percent. Yields growth is assumed to fluctuate between a lower limit of -3% and a higher limit of + 3% (Figure 1). This scenario is designed to assess the yields instability aspect associated with climate change.

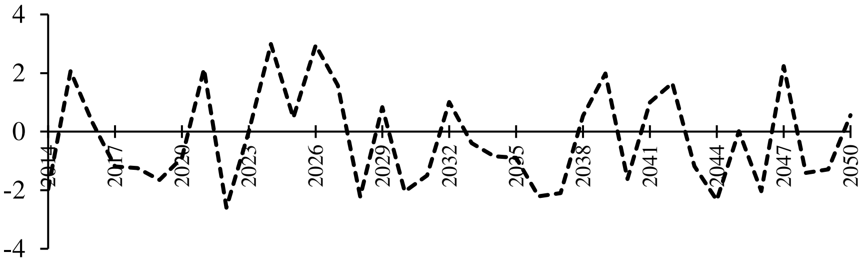

Figure 1: Annual yield deviations from baseline with a mean deviation of 0% (%)

In the second scenario, we assume the same level of yield instability but with a negative average growth of -2 percent per year (figure 2). Thus, the parameter representing the growth of yields always follows a uniform probability distribution as in the previous scenario, but with a lower bound of -5% and a higher limit of + 1%. This means that despite the decline in the average yield of crops, it is always possible to achieve yield growth in a year characterized by relatively good rainfall or a significant decline in a year characterized by a meteorological disaster.

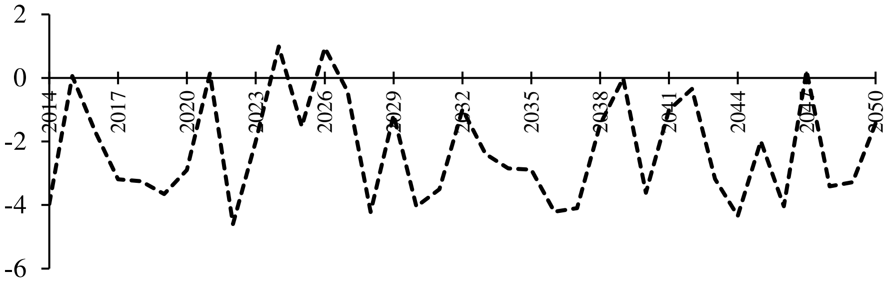

Figure 2: Annual yield deviations from baseline with a mean deviation of -2% (%)

The third scenario assumes an increase in the average growth rate and instability of world food prices. We assume that the new boundaries of the probability distribution are -1% for the lower bound and + 3% for the upper bound. The shocks imposed on world food prices are shown in Figure 3.

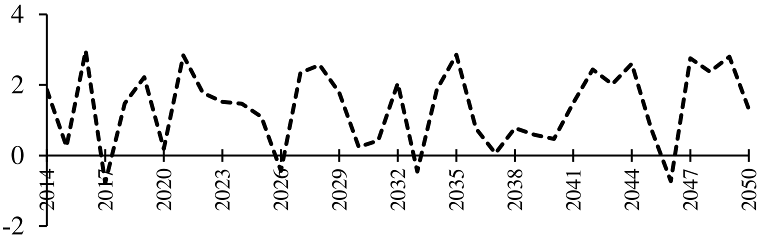

Figure 3: Annual world food prices deviations from baseline (%)

Finally, the fourth scenario is a combination of scenarios 2 and 3. Climate change is then assumed to result in higher yield volatility, lower average yields, and higher and more unstable world food prices.

More specifically, we shock the shift parameter on the crop production functions, thus simulating a change in the total factor productivity (TFP). The computable general equilibrium model, then determines the quantities of labor, capital, and land to devote to each agricultural or non-agricultural sector based on relative profitability. These resource reallocations represent some autonomous coping action undertaken by farmers and non-agricultural producers in coping with climate change effects. In other words, while producers are not able to anticipate climate changes (this is not modeled in this paper), they are able to partly adjust their crop production levels in response to climate change.

Autonomous adaptation also operates in other non-agricultural sectors of the economy, via the reallocation of workers between disaggregated industrial and service sectors. The economy also adapts to climate change by adjusting the quantities of imports and exports. Moreover, the dynamic specification of our model captures the adjustment path of adaptation mechanism.

It is essential to emphasize here that autonomous adaptation to climate change entails costs that can be significantly high. For example, when agricultural yields decline, adaptation will involve the allocation of additional productive resources (labor, capital, land) in agriculture to compensate for lower production and higher food prices. To the extent that agriculture is a low-productivity sector in Burkina Faso, this reallocation of factors to agriculture means a fall in average GDP per worker. It is one of the advantages of the CGE models compared to other methods of estimating the economic impacts of climate change.

3. Simulation Results

3.1. Baseline "No Climate Change" Scenario, 2013–2050

Before analyzing the impacts of climate change, it is necessary to ensure that the economy moves in a reasonable way over the simulation period, i.e. between 2013 and 2050. The structure of the economy of Burkina Faso is likely to be modified by 2050. If such changes are not observed in the baseline simulation, it is likely that the impacts of climate change assessed with the CGE model are underestimated or overestimated. For example, like in most developing countries, it must be observed a slower growth of the agricultural sector than the industrial and service sectors (World Bank 2017). This should lead to a smaller share of agricultural GDP in total GDP in the long run. If this is not verified in our benchmark simulation, we may overestimate the impact of lower agricultural yields caused by climate change. Conversely, the share of industry in the economy should increase to materialize the process of industrialization of the Burkina Faso economy.

In the baseline scenario, the national GDP increases at a rate just under five percent per year until 2050. The share of agriculture in the total GDP decreases from 35.8% in 2013 to 31.1% in 2050. In contrast, the share of industrial GDP increased from 19.7% to 27.5% over the same period. The share of services decreased slightly from 44.5% to 41.4%. All the impacts listed below for the alternative climate change scenarios relate to this new baseline year of 2050.

3.2. Climate Change Impacts

Table 1 reports the climate change impact channels on the gross domestic product of Burkina Faso. As discussed in the previous section, Scenario 1 represents the impact of increased variability in agricultural yields. This translates into a decline in agricultural GDP of -2.1 percent in 2050 compared to the "no climate change" scenario. The Impacts are larger in the rain-fed agricultural sectors than in the irrigated ones. For example, the GDP of irrigated maize drops by only 4.4 percent, while the GDP of rain-fed maize drops by 9.7%. The same observation can be made from rain-fed and irrigated rice. In scenario 2 where the yield variability is combined with a decline in an average yield, the impacts are just amplified. The national GDP declines by 2.7%, whereas this figure was only 0.5% in the scenario 1. The decline in the agricultural sectors' GDP is reflected in the decline in the agroindustry's GDP, but not in other industrial sectors' GDP. This is explained by the fact that agriculture is the main supplier of raw materials for the agro-industrial sectors. In Scenario 3, where the average level and variability of world food prices are assumed to increase, the impacts are significant in almost all sectors of the economy. Finally, in Scenario 4, where all the climate change impact channels combine, the effects are devastating. The National real GDP decreases by -7.2 percent. All aggregated sectors are experiencing a decline in activity. The industry decreases by -4.4 percent and services by -5.2 percent.

Changes in agricultural production have spillover impacts on production in the downstream, non-agricultural sectors. For example, agro-processing in the manufacturing sector is indirectly affected by a reduction in the supply of raw materials. Agro-processing is also affected by rising levels and instability in the world agricultural prices. This increases the cost of access to raw agricultural inputs and supply markets. In the first two scenarios, "Other industries" benefit partly from the decline in agriculture, as this decline releases labor that migrates towards these sectors. When the shocks become significant, like in Scenario 4, the decline in farm incomes is so large that demand for industrial products declines too, leading to a decline in the level of activity in these non-agricultural sectors. The variation in the relative importance of different impact channels for different sectors underscores the importance of a multisector approach. The dependence on a single-sector analysis may lead to an incorrect assessment of the impacts of climate change. Similarly, spill-overs between sectors, such as product and labor markets, underline the importance of economy-wide assessment of climate change impact.

Lower GDP at market prices in all scenarios leads to lower levels of total absorption. Total absorption is the total value of goods and services consumed in the economy. It includes both private and public spending on social services like health and education and public investment in schools and clinics. Absorption can be therefore the best aggregate measure of national welfare and is more comprehensive than private consumption alone.

Table 2, disaggregates the effect of climate change on the household consumption levels. All household types are adversely impacted in each of the four climate change projections. However, distributional effects are unevenly felt across the household groups. The Urban households are the worst affected because they are net buyers of food products, whose prices rise because of climate change. For the rural farmers, this adverse effect is partly offset by higher agricultural incomes.

Table 1. National and Sectoral GDP Impacts.

	Shares (%)		**Change in GDP by 2050 (%)**			
	2013	**2050**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Real GDP at market prices	100.0	100.0	-0.5	-2.7	-5.0	-7.6
Absorption	114.7	105.8	-0.4	-2.5	-6.9	-9.4
Private consumption	52.6	52.7	-1.3	-4.4	-4.6	-8.8
Exports	25.8	37.0	0.3	-0.5	-2.8	-3.6
Imports	-40.5	-42.8	0.3	-0.5	-7.8	-8.5
Real GDP at factor cost	100.0	100.0	-0.5	-2.7	-4.5	-7.2
Agriculture	35.8	31.1	-2.1	-8.8	-3.8	-12.3
Rainfed corn	5.6	5.6	-9.7	-11.6	-1.9	-12.2
Irrigated corn	0.1	0.1	-4.4	-16.5	-1.1	-16.1
Rainfed rice	1.4	1.5	-7.4	-13.1	-2.1	-13.8
Irrigated rice	1.8	1.9	-3.4	-12.0	-2.4	-12.8
Millet	4.5	4.4	-6.4	-12.1	-2.6	-13.4
Sorghum	7.4	7.4	-0.9	-7.5	-2.8	-9.3
Fonio	0.1	0.1	2.0	-6.9	4.2	-1.6
Tuber	8.3	8.4	-8.0	-15.4	-1.5	-15.3
Pulses	3.5	3.5	-2.3	-11.9	-1.6	-12.3
Peanuts	3.2	3.0	-7.9	-16.8	-0.2	-16.5
Cotton	7.9	5.7	-3.2	-20.9	2.5	-21.9
Oilseed	5.9	4.5	-3.2	-30.6	13.3	-23.4
Tomato	0.3	0.2	-4.2	-9.3	-2.5	-10.8
Onions	0.5	0.4	0.6	-8.4	-1.5	-8.9
Other vegetable crops	1.5	1.4	-5.5	-13.4	-1.7	-13.6
Mango	0.8	0.5	-7.0	-9.6	-13.2	-51.3
Cashew	1.0	0.3	-2.4	-18.6	6.7	-14.1
Fruit	0.3	0.3	-4.3	-10.2	-2.9	-12.0
Other crops	0.6	0.6	-3.8	-12.6	-2.5	-8.3
Cattle	11.4	12.8	0.0	-2.1	-7.5	-9.6
Camels	15.1	16.9	0.1	-1.7	-7.9	-9.6
Porcine	2.2	2.5	0.0	-1.7	-6.5	-8.3
Poultry	5.2	5.7	-0.4	-2.6	-6.2	-8.6
Other animals	0.1	0.1	0.0	-1.5	-6.6	-8.3
Forest	10.2	11.2	-0.2	-2.5	-7.6	-10.0
Fishing	0.6	0.7	-0.3	-1.8	-5.5	-7.4
Hunting	0.3	0.3	0.0	-1.6	-6.1	-7.9
Industry	19.7	27.5	0.5	1.6	-5.9	-4.4
Agro-processing	3.8	3.5	-1.1	-5.6	-4.4	-9.8
Oher industries	15.8	24.1	0.7	2.6	-6.1	-3.6
Services	44.5	41.4	0.0	-0.9	-4.2	-5.2

Source: Results from the Burkina Faso CGE model

Table 2. Household welfare impacts.

	Per capita income (US$)		**Change in real incomes by 2050 (%)**			
	2013	**2050**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Rural poor	209	321	-1.9	-8.2	-6.8	-14.8
Urban poor	255	391	-2.5	-9.2	-7.8	-15.0
Rural non-poor	402	595	-1.7	-7.1	-6.9	-13.4
Urban non-poor	804	1 174	-2.4	-8.5	-8.6	-14.1

Source: Results from the Burkina Faso CGE model.

3.3. Adaptation Policies

With climate change, autonomous adaptation strategies are implemented at the farm and economy-wide level through products and factors markets adjustments, as well as through international trade. Despite these stand-alone adaptations, the impact of climate change remains high. In this section, we consider three public adaptation policies to support autonomous coping strategies: first, we increase public investment in the agricultural research and extension system. More specifically, we raise the productivity of all the crops by ten percent in 2050 relative to the baseline. This is equivalent to a 0.25 percentage point increase in annual agricultural TFP growth over the period 2014–2050. Second, we extend the use of irrigation in agriculture by increasing the share of total cropland that is irrigated by 5 percentage points. New irrigation investments in the model are directed towards maize, rice, and pulses. We then increase the productivity of the irrigated land by 0.5 percent per year in these three sectors, which represents a 20% increase in land productivity by 2050. Expanding irrigation coverage, therefore, reduces the negative effects of climate change. The third adaptation policy is simply a combination of the first two, i.e. an increase in research and extension investments combined with an increase in irrigated agricultural areas. Given that these policies are already included in Burkina Faso's development plans (Burkina Faso 2016), investment costs have not been explicitly included in the model.

Table 3 reports changes in the real household consumption expenditure for climate change without adaptation scenario (Scenario 4, combining scenarios 2 and 3) and climate change with adaptation scenarios. The variations reported in Table 3 are relative to the baseline scenario without climate change in 2050. One can observe that both irrigation development and investment in research and extension tend to reduce adverse impacts on all categories of households considered in our model. The combination of the two policies makes it possible to substantially reduce the impacts of climate change and even improve the situation of non-poor in urban areas, as their consumption increases by 1.6 percent. The Urban poor consumption is only 0.4 lower than the baseline in 2050. The Urban people benefit more from these adaptation policies than the rural ones, just as they were the most affected by climate change. Reductions in welfare losses caused by climate change are more modest for irrigation policy not because of the high investment costs of irrigation projects (not included in our model) but because irrigation is concentrated in only three sectors. We could imagine an irrigation policy that extends to all sectors of crop production.

Table 3. Adaptation policy impacts.

	Changes in household consumption expenditure by 2050 (%)			
	Climate change in scénario 4	**Agricultural extension**	**Irrigation investment**	**Agricultural extension + Irrigation investment**
Rural poor	-8.9	-3.5	-6.5	-1.2
Urban Poor	-9.2	-4.4	-5.8	-0.4
Rural non-poor	-9.2	-3.8	-7.0	-1.4
Urban non-poor	-8.3	-3.9	-3.7	1.6

Source: Results from the Burkina Faso CGE model.

4. Conclusions

Analyzing the economic impacts of climate change is a difficult task because of these multiple channels – which can extend beyond the agricultural sector – and a high level of uncertainty. In this article, we examined the implications of climate change for economic development in

Burkina Faso until 2050. By assuming that climate change will lead both to a greater volatility in yields and international agricultural prices, a decrease in average yields and an increase in food prices, we impose these chocks on the total factor productivity and the world food prices.

Our results indicate that climate change will reduce the national welfare by 2050 compared to a baseline "without climate change". Estimates of this damage can range up to -9.4 percent of baseline absorption. These results underline the importance of considering intersectoral interactions and uncertainty. The negative impacts of climate change are unequally distributed among the different categories of Burkinabe households. The Urban households are the most affected. Our analysis suggests that investments in agricultural research and extension and irrigation, especially when they are carried out together, are likely to be effective in reducing the damage caused by climate change in Burkina Faso.

To the best of our knowledge, this study is the first to date to evaluate the economic impact of climate change on Burkina Faso. However, there are many aspects on which our study shows these limits which can be the subject of future research. First, we cannot attribute a probability associated with the eventuality of the various scenarios tested. Second, our sector coverage is incomplete. For example, we did not consider the effect of climate change on human health. Another limitation is the absence of home consumption in the model, which may lead to an overestimation of the impacts of climate change. Finally, our study is limited by its inability to include a distributive analysis to identify the vulnerable groups. Recognizing these limitations, our analysis suggests that climate change will have an adverse impact on Burkina Faso's economic development prospects. However, if adaptation policies are put in place, these negative effects of climate change will only cause a small deviation from the current development trajectory of Burkina Faso.

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