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Southern Africa –Towards Inclusive Economic Development (SA-TIED)

SA-TIED is a unique collaboration between local and international research institutes and the government of South Africa. Its primary goal is to improve the interface between research and policy by producing cutting-edge research for inclusive growth and economic transformation in the southern African region. It is hoped that the SA-TIED programme will lead to greater institutional and individual capacities, improve database management and data analysis, and provide research outputs that assist in the formulation of evidence-based economic policy.

The collaboration is between the United Nations University World Institute for Development Economics Research (UNU-WIDER), the National Treasury of South Africa, the International Food Policy Research Institute (IFPRI), the Department of Monitoring, Planning, and Evaluation, the Department of Trade and Industry, South African Revenue Services, Trade and Industrial Policy Strategies, and other universities and institutes. It is funded by the National Treasury of South Africa, the Department of Trade and Industry of South Africa, the Delegation of the European Union to South Africa, IFPRI, and UNU-WIDER through the Institute's contributions from Finland, Sweden, and the United Kingdom to its research programme.

Towards Inclusive Economic Development in Southern Africa

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Economic implications of climate change in Mozambique

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ABSTRACT

Mozambique has been historically prone to natural disasters due to its geographical location, but over the past 20 years, the intensity and frequency of droughts, floods and cyclones has increased, negatively affecting the agriculture sector. These impacts are expected to worsen, as climatic conditions become hotter and drier. This study estimates the impacts of climate change on the economy of Mozambique using a dynamic computable general equilibrium model which forms part of a larger modelling framework called the Systematic Analysis of Climate Resilient Development. Specifically, the study investigates the impact of climate change on agricultural production, looking at implications for various crops and regions in the country. A probabilistic approach, considering a distribution of climate shocks, is used to evaluate the impacts of climate change, thus providing a range of potential impacts on the economy. Two global mitigation scenarios (unconstrained emission and level one stabilization (L1S)) and five key climate channels (i.e. crop yields, road infrastructure, hydropower generation, sea-level rise, and cyclones) are considered. The analysis shows that acute negative impacts are experienced in the agriculture sector, particularly for maize and cassava. For instance, under the L1S scenario the distribution mode of potential maize yield outcomes are estimated as -1.1%, 2.5% and 0 for the northern, central and southern regions. Successful global mitigation to the L1S level of reducing CO_2 concentration to 480 ppm by 2100 reduces the impact of climate change on the Mozambican economy as the GDP is expected to increase up to USD 6.0 billion. In fact, the L1S policy generates positive impact compared to the unconstrained emission, for roads, energy, sea-level and cyclone scenarios.

Keywords: climate change, agriculture sector, household welfare, Mozambique, CGE mode

1 INTRODUCTION

Climate change occurs due to direct or indirect human activity which modifies the atmosphere, or due to natural climate variability over time (FCCC, cited by Pielke Jr., 2004). It has a large impact on humanity and development, shifting development gains and worsening gender inequality as well as creating social and economic fragilities (Schramek and Harmeling n.d.). Specifically, it results in degradation of natural resources essential for production, thereny increasing losses in agriculture (crops and livestock), destroying infrastructure, and increasing prices.

Responding to the threat of climate change, the global United Nations Framework Convention on Climate Change (UNFCC) treaty was adopted in 1992, with the main goal of reducing greenhouse gas emissions. The convention resulted in several protocols and commitments for both developed and developing countries. Mozambique does not withhold from climate change mitigation efforts. In 2006 the government of Mozambique developed a Master Plan for Prevention and Mitigation of Natural Disasters to reduce vulnerabilities in communities, the economy and infrastructure. This plan was renewed in 2017. From the UNFCC and Hyogo Action Frameworks, Mozambique also developed the National Strategy for Adaptation and Mitigation of Climate Change.

Historically Mozambique has been prone to natural disasters (droughts, floods and cyclones) due to its coastline and location downstream of nine major rivers. According to the Instituto Nacional de Gestão de Calamidades, cited by USAID (2019), the past 35 years saw 75 disasters: 13 droughts, 25 floods, 14 cyclones and 23 epidemics. In the past 20 years the frequency and intensity of the disasters increased, worsened by climate change, jeopardizing the country's development efforts (PDRRD, 2017). For instance, in 2000–2001 the country was struck by floods and a cyclone, resulting in huge negative impacts on the economy estimated at USD 600 million, or a near 6% decline in gross domestic product (GDP) (PDRRD, 2017). Moreover, nearly 100 000 hectares of crops were lost (SARDC, 2000). In 2007, 277 000 hectares of crops were destroyed (World Bank, 2019). In 2015 floods and cyclone Chedza resulted in a loss of approximately USD 861 million (GFFDRR, 2019). In 2016 the country faced a drought due to El Niño, which resulted in food uncertainty for over 1.5 million people, and in 2017 cyclone Dineo struck, affecting nearly 550 000 people (PDRRD, 2017). In 2019, cyclone Idai originated losses of approximately USD 800 million, of which USD 260 million was from agriculture (World Bank, 2019). It is, therefore, important to develop and apply effective policies for mitigation of, and adaption to, climate change in Mozambique.

Besides the country's efforts to reduce the impact of natural disasters, Mozambique has low adaptation capacity, with high levels of poverty (68.7% of the population in 2008 and 62.7% in 2014 lived on below USD 1.90 per day), limited investments in technology, and fragile infrastructure including in the health and sanitation sectors. For example, Brida, Owiyo and Sokono (2013) found in their study that families practicing agriculture near the Limpopo, Save and Zambezi Rivers have limited ability to cope with and adapt to both floods and droughts.

In Mozambique, agriculture is the primary source of livelihoods in rural areas for 90% of the population (IOF, 2015). It is highly dependent on rain, with limited usage of technologies resulting in lower production levels. With changes in rainfall patterns, or climate variability, the rural population is at risk of starvation and poverty if it cannot adapt to cope with the effects of climate change.

This study estimates the impacts of climate change on the economy of Mozambique using a dynamic computable general equilibrium (CGE) model which forms part of a larger modelling framework called the Systematic Analysis of Climate Resilient Development (SACRED). The study builds on the analyses conducted by Arndt & Thurlow (2014) and Arndt et al. (2019) by looking at the agriculture sector impacts in terms of crop and region. The paper is structured as follows: Section 2 characterizes the agriculture sector in Mozambique and identifies the main agricultural policies and strategies adopted in the country. Section 3 briefly presents the SACRED modelling framework for Mozambique and provides a description of the scenarios modelled. Section 4 presents the key findings from the comparison of the impacts of the two global climate futures considered. Section 5 concludes with some considerations for adaptation policy.

2 THE AGRICULTURE SECTOR IN MOZAMBIQUE

2.1 General characterization

In Mozambique, 67% of the population live in rural areas (INE projections, 2020), with agriculture as their main economic activity (49.3%). In 2014/2015 the sector comprised approximately 4 million farming units, with farmers categorized as smallholder, medium and large (Table 1). The smallholder farmers are characterized by practicing subsistence agriculture, while medium and large farmers practice commercial agriculture oriented to market. Less than 10% of the arable land is in usage and farming occurs largely in flood-and drought prone areas (FAO, 2020).

Table 1: Number of farming units by farmer category

Farmer category	Number	% of total	Average cultivated area (hectares)
Smallholder	3 900 000	98.5	1.1
Medium	51 872	1.3	2.65
Large	728	0.02	74.2

Source: Anuário Estatístico Agrário (2016)

In 2015/2016 the main crops produced were maize, cassava, rice, sorghum, beans, peanuts, cotton and sugarcane. Maize was the main food crop accounting for 72% of the total small and medium farming units, followed by cassava and beans. According to Dias (2013), maize is the most important cereal and the main staple food in Mozambique's three regions (central, north and south). However, while the north and central regions produce surplus, the southern region is a net importer. In 2008 and 2015, the southern region accounted for only 10% and 12% of the total maize production in the country, respectively (Figure 1).

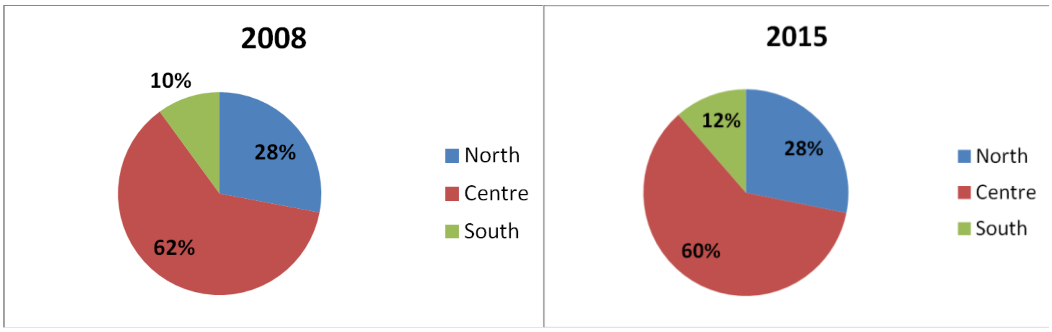


Figure 1: Percentage of maize production by region in 2008 and 2015
Source: Adapted from Dias (2013) and AEA (2016)

This may be explained by the difference in agro-ecological patterns (poorer conditions in the south), since the majority of farmers in Mozambique practice subsistence agriculture which is rain-fed, and thus highly dependent on rainfall patterns. Additionally, they use little in the way of improved technology (In 2015/2016 only 7% of smallholder farmers used improved maize seeds), and have limited access to agrarian as well as financial services. As a result, the agricultural productivity in

Mozambique is lower than the average in the southern African region. For example, from 2013 to 2017 the average productivity for maize was estimated in 0.75 ton/ha in Mozambique while the region's average was approximately 2 ton/ha (Cuvilas, Jirjis & Lucas, 2010).

Despite the low productivity, maize is the main food crop in Mozambique and cassava is the main starch source and the second staple food in the country (Costa and Delgado, 2019). According to Salvador, Steenkamp and McCrindle (2014), like maize, cassava is mainly produced by smallholder farmers in a rain-fed system (approximately 99%). In fact, cassava is highly tolerant of poor agro-ecological conditions, resulting in better yields than maize – approximately 50% higher (Donovan et al., 2011). Nonetheless, the yields (8 tons/ha) are still lower than in some African countries such as Ghana and Malawi (Costa and Delgado, 2019). In Mozambique, cassava production is concentrated in the northern and along the southern coast. The north produced a larger proportion of the total in 2015 (78%) than the central (6%) and southern (16%) regions (AEA, 2016).

In spite of poor results, agriculture is still an important economic sector in Mozambique, as it accounts for 25% of the country's GDP (2008–2018). However, the agricultural growth rate has been on average 4% from 2008-2018 (Figure 2). The slower growth in agriculture is related to low investments in agriculture research, deficiencies in providing agricultural services to farmers, insignificant access to financial services for farmers, and inadequate usage of fertilizers (BRR, 2017–2018).

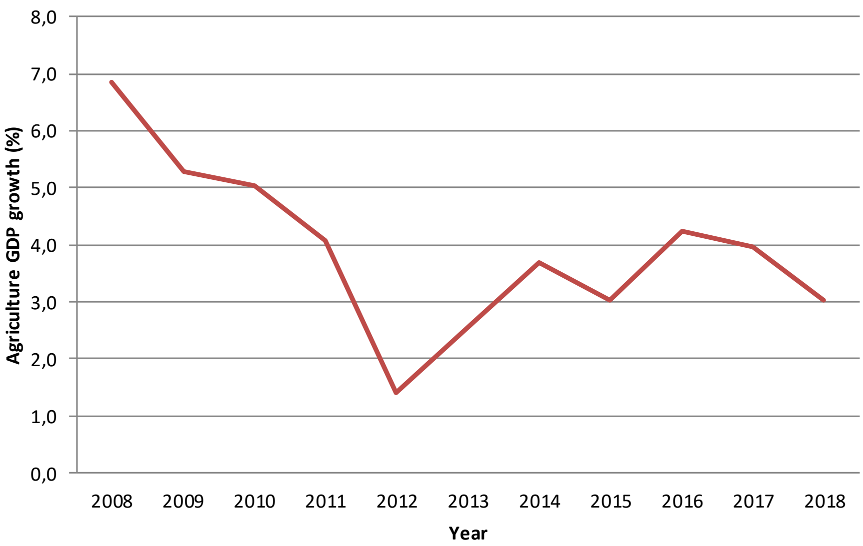


Figure 2: Agriculture gross product value growth (%) from 2008-2018
Source: World Bank Data (2019)

Because of the relevance of agriculture to the country's economy, the government of Mozambique developed several strategies and policies to improve the performance of the sector (as described in the following section). Moreover, the government designed projects to increase investment in research and technology transfer, improved some infrastructure, and developed a seed subsidies programme (Popat et al. 2017).

2.2 Agricultural policies and strategies

Mozambique has a solid and straightforward policy framework. The main priorities for the agricultural sector are set by the government´s five year plan (Plano Quinquenal do Governo – PQG). This is translated into a sector-wide strategic plan (PEDSA), which is entirely aligned with PQG and the priorities of the Comprehensive Africa Agriculture Development Programme. PEDSA details the sector goals and general targets, whereas an investment plan (PNISA) translates these objectives into detailed programmes, indicators and budgets. Lastly, a set of complementary strategies focus on cross-cutting issues such as gender and agriculture, rural development, food and nutrition security and land (CARE and Actionaid, 2017). PEDSA's main goal is to enhance the competitiveness of the agriculture sector through the advanced use and management of natural resources, enhancing both food security and productivity (MINAG, 2011). The idea behind PNISA was to ensure the implementation of PEDSA as well as to re-emphasize the importance of increasing the productivity of main food crops, halving the number of people affected by hunger, and reducing undernourishment (MINAG, 2013). One component of PNISA concerned natural resource management, a key entry point for the implementation and outreach of Climate Smart Agriculture practices (UKaid, et al. 2017)

Even though concerns about climate change have increased in Mozambique, current agricultural policies fail to address climate change issues. Nonetheless, the Mozambican government is committed to the international climate change agenda. Since ratifying the UNFCC, Mozambique has made strong efforts to incorporate climate change concerns in national development planning, including in the Agenda 2025 and the PQG. These policies clearly recognize that extreme climate events are one of the greatest threats to development and socioeconomic performance of the country (CARE, 2017).

One of the outcomes of this effort was the 2012-launched National Climate Change Adaptation and Mitigation Strategy (ENAMMC) for 2013–2025, a strategy which broadened the government's approach to climate change in suggesting actions which combine measures of adaptation and mitigation with the development of a low-carbon economy (Monjane, King and Rasmussen, 2018). ENAMMC aims to establish guidelines to build resilience, including climate resilience for both communities and the national economy, and to promote the development of a low-carbon and green economy through its integration into sectoral and local planning processes (MICOA, 2012). It also recognizes that conservation of agricultural land, as well as the promotion of resilient crops, is fundamental, and appeals for agricultural interventions adapted to each agro-climatic zone and their foreseen vulnerabilities (CARE & ActionAid, 2017).

in line with this effort, as a way to support and promote climate resilient agriculture in smallholder farming, the Ministry of Agriculture and Food Security (MASA) established the Climate Smart Agriculture Action plan 2015–2020 (CSA), which envisages approval of incentives for boosting climate-resilient agriculture, as well as strengthening the provision of extension services and enhancing knowledge management for adoption of climate smart approaches by farmers (MASA, 2014). The main purpose of the CSA is to not only bring to life the integration of agriculture development and climate responsiveness but also make it an efficient and reliable concept, providing food security and wider development objectives in a changing climate and increasing food demand (UKaid, et al. 2017).

3 METHODOLOGY

3.1 SACRED framework

Following Arndt and Thurlow (2014) and Arndt et al. (2019) this paper uses the SACRED modelling methodology. SACRED provides a consistent framework for assessing the temperature, precipitation and evaporation impacts of various climate models. In the framework, the outcomes from global climate circulation models are linked to biophysical models which are in turn linked to an economy-wide model to assess the economic impacts of climate change effects (see Figure 3). Arndt and Thurlow (2014) and Arndt et al. (2019) provide more detail on the modelling framework and the individual climate and biophysical models respectively.

The economy-wide model used in this analysis is a dynamic CGE model for Mozambique. Such models capture the structure of the economy and the interplay between various agents in the economy (DEA, 2016). The model for Mozambique is based on a 2007 social accounting matrix (SAM), which includes 31 activities and commodities. The agriculture sector is made up of nine crop sectors (maize, other cereals, root crops, pulses and oilseeds, horticulture, tobacco, cotton, sugarcane, other export crops such as tea) and one livestock sector. Crop and livestock sectors are captured by region. Three regions are included – north, central and south. The SAM includes eleven factors of production: four labour categories based on levels of education (less than primary, primary, secondary and tertiary); three land categories for each region; three livestock capital categories for each livestock activity; and one capital factor used by all other sectors. Households are represented by quintiles and geographical typology, where rural farm and non-farm households are further disaggregated by region.

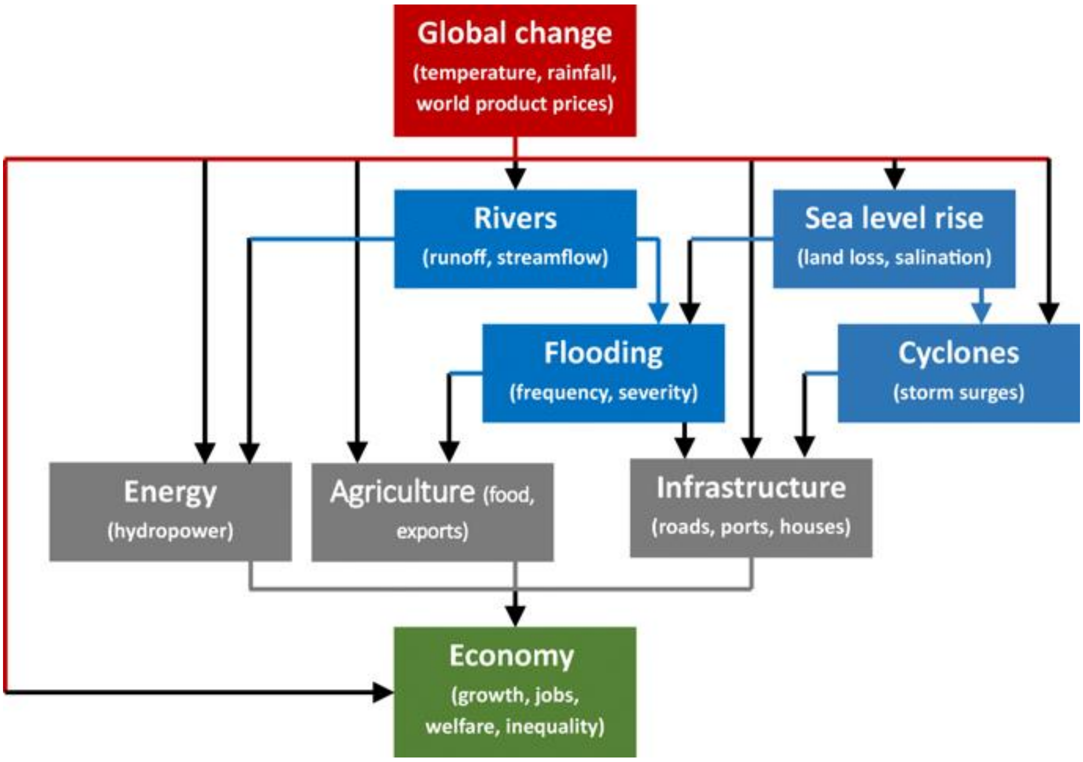


Figure 3: Schema of the analytical framework used
Source: Arndt et al. (2019)

3.2 Scenarios

The impacts of climate change are considered under two global mitigation futures. These are UCE, unconstrained on global emission scenarios, where policy actions are unable to limit greenhouse gas emissions, and L1S a level one stabilization, under which global efforts result in a reduction of greenhouse gas concentration to 480 ppm CO_2 equivalent by 2100 (Gebretsadik *et al.,* 2014). Within each global mitigation future, the temperature, precipitation and global prices for food and fuels for 426 (UCE) and 398 (L1S) potential climate scenarios are considered. The impacts of climate change are measured through five impact channels, namely agriculture, roads, hydropower, sea-level rise, and cyclones, which are modelled cumulatively, starting with agriculture. Scenarios are compared to a counterfactual of no climate change. Table 2 presents the climate channels modelled for each climate scenario. More detail can be found in Arndt and Thurlow (2014).

Table 2: Climate channels considered

Climate channel	Description
Baseline	Future weather patterns retain the features of historical weather variability.
Agriculture	Impose the impacts of climate change on crop yields.
Roads	Impose the effects of weather conditions, including flooding, on road stocks and maintenance costs.
Hydropower	Impact of climate change on annual hydroelectric power productions levels grounded on the capacity of available and planned infrastructure.
Sea-level rise and cyclones	Assess the marginal effect of storm surges from cyclones caused by sea level rise.

4 SIMULATION RESULTS

This section present results from the economic model. The results are reported by hybrid frequency distributions (HFD) plots, due to the large number of potential climate futures analyzed. The HFD plots are used as they provide the range of the possible impacts of climate change along with some measure of the probability (Arndt and Thurlow, 2015). This analysis focuses on the national and regional agriculture impacts of climate change, and specifically also looks at the impacts on maize and root-crops, as these are the primary crops produced in Mozambique and account for more than half of total agricultural production. Results are reported for both the UCE and L1S scenarios.

4.1 Agriculture

First considered is the value added impact in Agriculture (VAA) when only considering the impact of climate change on crop yields (agriculture climate channel). On aggregate, the impact of climate change on crop yields in Mozambique is likely to result in a 4% decline in VAA, with impacts potentially ranging between -10% and +5.0% (Arndt and Thurlow, 2015). Regionally, however, impacts differ. Figure 4 presents the regional impacts on VAA under the UCE and L1S scenarios. Under the UCE scenario, declines and increases in the VAA, relative to the baseline, are likely across all regions. Increases are, however, less probable in the centre region, where the probability of a positive impact is small (6%). Here the likely impact of climate change on agriculture is a 19% decline in VAA relative to the baseline, although impacts could be as larger as 6%. The northern region's agriculture production seems to be less affected by climate change. The mode of results shows a 0.6% change in VAA. A range of uncertainty however does exist around potential outcomes in the region, which could range between -18.5% and +16.2%. The VAA in the southern region is the most uncertain, with potential impacts ranging between -31.0 % and +32.0%.

If the world applies policies toward global CO_2 emission mitigation (L1S scenario), the range of all possible values of the VAA relative to the baseline tends to reduce, although both increases and decreases in the VAA outcomes are expected in all regions of Mozambique (Figure 4). The mode of the distributions for the L1S scenario is estimated at -3.2% and -1.8% for the south and centre regions, respectively. This indicates that the application of global effort mitigation shifts the distributions of the VAA relative to the baseline to the right side, resulting in a less severe impact. Uncertainty, as illustrated by the range of possible outcomes, decreases under the L1S scenario.

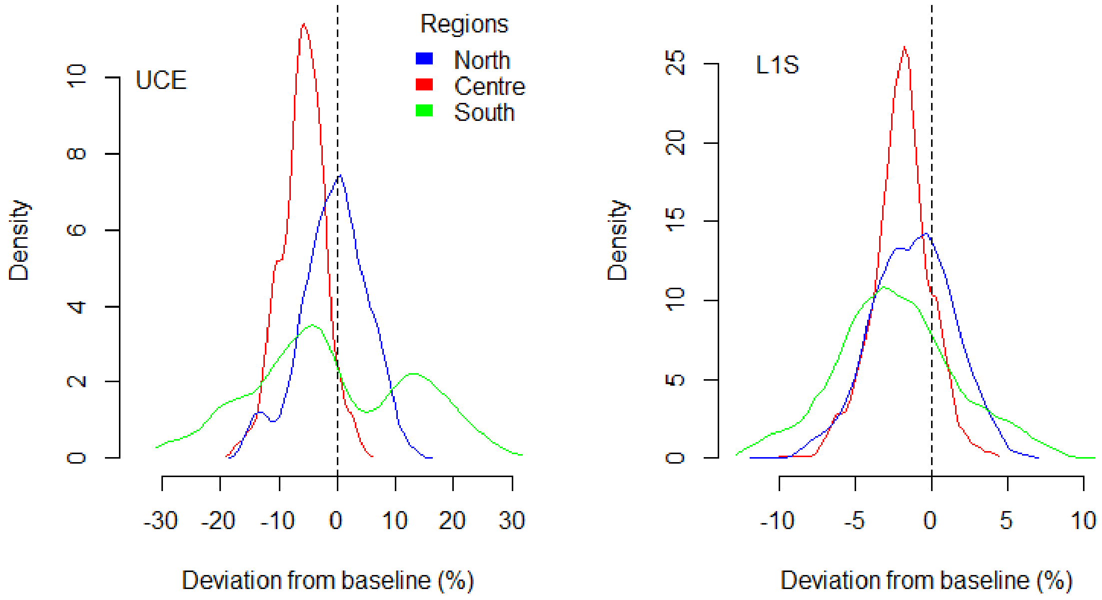


Figure 4: Value added in agriculture relative to the baseline for the agriculture channel, disaggregated by regions of Mozambique for the UCE and L1S scenarios.

Figure 5 illustrates the HFD plot of changes in yield from baseline for selected crops – maize and root-crops (representative of cassava), in each region for the UCE and L1S scenarios. Maize is the main food crop, accounting for 72% of the total small and medium farming units, followed by cassava (AEA, 2016). The horizontal axis represents all possible values of yield changes relative to the baseline, and the vertical axis represents density, which is a measure of likelihood. The vertical dashed line illustrates no climate change impact.

Under the UCE scenario, across regions in Mozambique climate change is more likely to result in a decline in maize yields. In the north, centre and south regions the (mode) impact of climate change on maize yields is -1.5%, -3.5% and -10.2%, respectively. The impact in the south region is, however, more uncertain, with impacts ranging between -20.0% and +40.0%. Similar trends are also observed for root-crops.

Under the L1S scenario, the HFD of the change in maize yield from baseline shifts to the right side as in the case of VAA. Although the mode of distribution for the north and centre regions remains negative (-1.1% and -2.5%), for the south region the mode of the distribution shifts to around zero. This implies that climate change impacts are less severe in maize crop yield for L1S than for the UCE scenario, especially for the south region, where the mode of the HFD is zero (no climate change impact).

Analysis of the HFD of change in root-crop yield under the L1S scenario shows that in all regions a decrease in root-crop yield is more likely to occur, especially in the south region, where the potential yield outcomes are all negative, ranging from -18.0% to -2.0%. Moreover, this region has the highest negative distribution mode (-7.3%). Under the L1S scenario, the range of change in root-crop yield outcomes in the northern and centre regions is smaller than that observed under the UCE scenario. Furthermore, the HFD for both regions shifts slightly to the right side, although the mode distributions remain negative. This suggestS that climate change will impact negatively less on root-crop yield in the north and centre regions if there are global policies toward reducing CO_2 emissions.

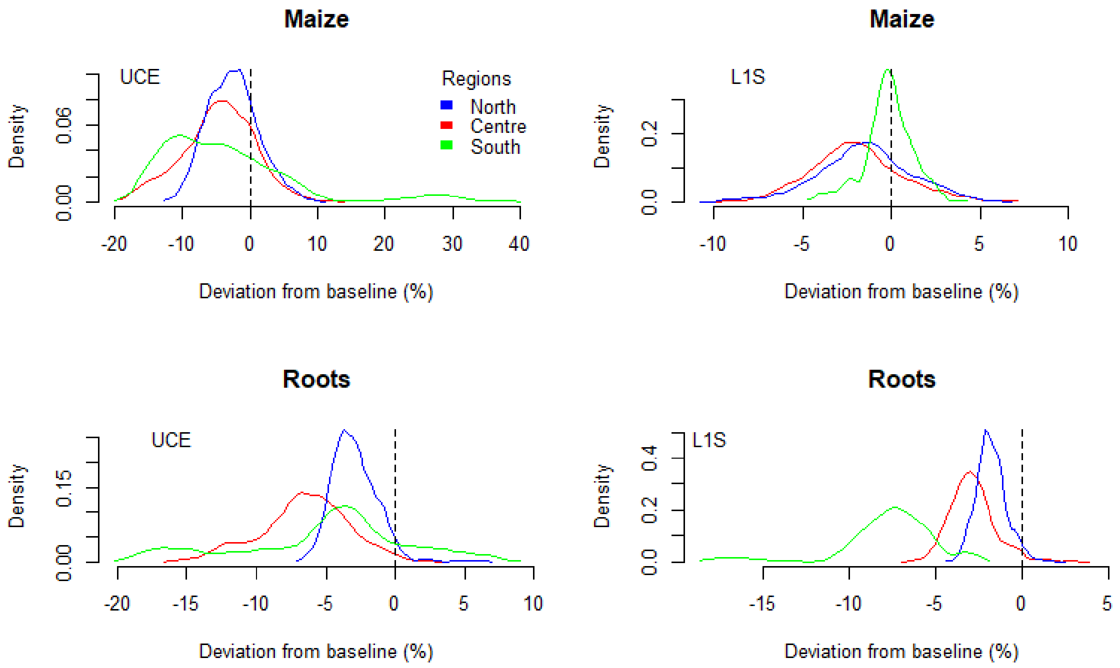


Figure 5: Change in maize and root-crop yields from baseline, disaggregated by regions for the UCE and L1S scenarios, when climate change only impacts on agriculture

The impact of climate changes on maize production is analysed through real gross value added (GVA) as the proxy variable for maize production. The analyses are carried out using both cumulative distribution function (CDF) and the HFD as reported previously. Figure 6 reports the CDF and HFD of the GVA given by percentage deviation relative to baseline for the three regions and the two scenarios. The horizontal axis represents all possible values of change in GVA from the baseline, and the vertical axis in CDF denotes probability.

For the UCE scenario, the centre region has the highest probability of experiencing a negative change in GVA relative to baseline, followed by the south region (Figure 6). The mode of distribution in the centre and south is -5.0% and -24.7% respectively. The impact in the south is, however, more uncertain, with a larger potential for extreme outcomes (lower = -50.0%; upper = +250%). The smallest probability to observe negative GVA relative to baseline was estimated for the north region, where the mode of the distribution is positive (+6.7%). This suggests that climate change is more likely to impact negatively on maize production for the south and centre regions under the unconstrained emission scenario, while the north region is more likely to observe positive impacts from climate change (although negative impacts are also expected). The positive impact expected on maize production in the north region apparently contradicts the results reported in Figure 5, where it is more likely to observe a decline in maize yield. There are two possible reasons for this. First, the decline in maize yield is not significant (mode = -1.1%), which means little impact on total maize production. Second, the majority of the smallholder farmers who dominated maize production practice an extensive agriculture, in which, despite low productivity, the total production is compensated for by extensive production areas.

Analysing the climate changes impact on maize production for the L1S scenario shows that the probability of experiencing positive change in GVA is higher for the south region than the others.

Moreover, uncertainty, illustrated by the range of possible GVA outcomes in the south region, decreases under the L1S scenario (lower = -18.0%; upper = +32.0%). Thus, a global policy mitigation effort to reduce CO_2 emission will impact positively on the south region. It seems that the south region is more sensitive to policies of global CO_2 emission than the centre and north, confirming that climate change impacts differ across Mozambique.

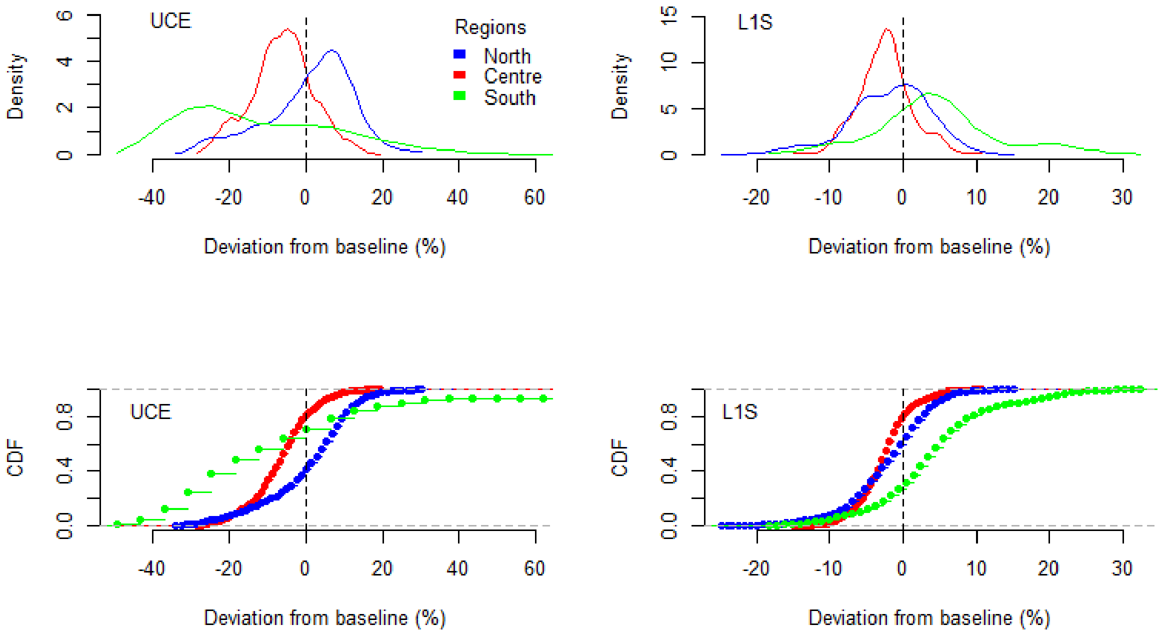


Figure 6: Change in maize production from baseline, disaggregated by regions for the UCE and L1S scenarios

4.2 Economic outcomes

This section presents the impacts of climate change on economic outcomes such as GDP and the net present value of GDP for both UCE and L1S scenarios. The results are first reported when climate shocks are only imposed on agriculture channel. Figure 7 illustrates both HFD and CDF plots of GDP given by percentage change from the baseline. The vertical axis in CDF reports cumulative probabilities while in HFD denotes density which is a measure of likelihood. The horizontal axis represents all possible GDP outcomes from baseline. In both UCE and L1S scenarios, losses and gains of GDP outcomes are expected. However, it is more likely to observe losses in GDP outcomes, with probabilities estimated at 91% and 96% for the L1S and UCE cases respectively. Under the UCE scenario the GDP outcomes range from –10.5% to +5.9%, with the distribution mode estimated as -3.8%. However, in the L1S scenario the range of GDP outcomes varies from –5.4% to +3.7%, which is smaller than that observed under the UCE scenario. Moreover, the distribution mode under L1S (-2.2%) is also small when compared to the UCE, although both modes' distributions are negative. This shows that climate change will impact negatively in both scenarios, although with more severity under the UCE.

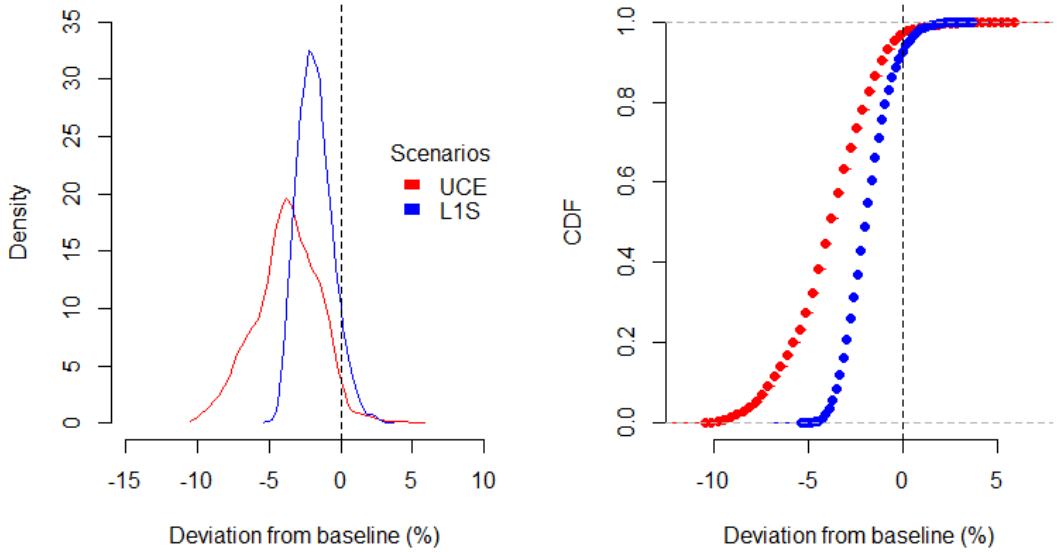
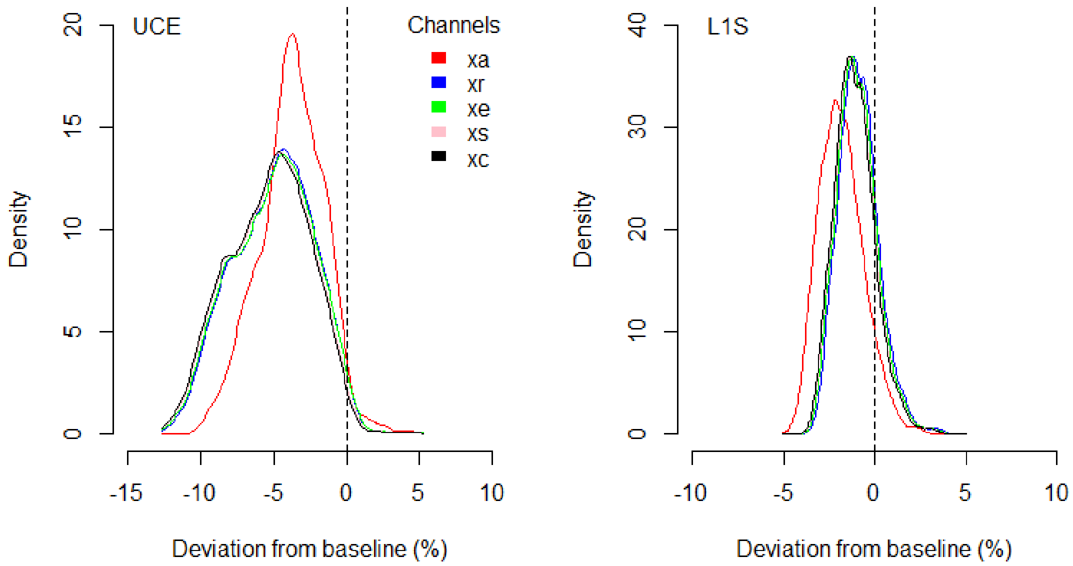


Figure 7: Change in gross domestic product relative to baseline under UCE and L1S scenarios in agriculture climate channel

Beside the assessment of climate change impacts on GDP when climate shocks are imposed only in the agriculture channel, analysis is also made of the effect of other climate shocks channels, such as roads, energy, sea-level rise, and cyclones, which are imposed cumulatively starting with agriculture. Figure 8 illustrates the implications of all shocks considered for total GDP in both UCE and L1S scenarios. The effects are cumulative as climate impact channels are added and imposed in the same order as presented in Table 2. Cyclone scenario includes all impact channels. The vertical and horizontal axes in Figure 8 are likewise described in Figure 7 for the HFD plot.

Under the UCE scenario, the effects on roads shifts the distribution slightly to the left side, resulting in a mode distribution of – 4.3%, where potential impacts range from –12.6% to +5.3%. This implies that the roads channel is the major potential source of impact, given that the cumulative effects of other channels do not “change” significantly the HFD form or the mode distribution, nor the range of GDP outcomes (Figure 8). The mode distribution for the cyclone channel, which includes all other channels, is estimated at – 4.7% and the GDP outcomes range from -12.6% to +5.3%. These measures are somewhat similar to those previously reported under the roads channel. Moreover, there are no strongly positive outcomes, given that the probability of observing gains in GDP is estimated at 2%. Analysis of the LS1 scenario shows a similar pattern to that obtained under the UCE scenario. However, in the LS1 case, the effects of roads shifts the distribution slightly to the right side, resulting in a mode distribution of -1.1%, in which the potential outcomes range from -4.0% to +5.0%. The mode distribution for the cyclone channel is estimated at – 1.4% and the GDP outcomes range from –4.2% to +5.3%, which do not differ significantly from the roads channel. Although positive outcomes are less likely to occur (probability estimated at 15%), gains in GDP are more expected under the L1S scenario than the UCE. Thus, if the world applies policies toward global mitigation efforts to reduce CO_2 emission it will impact positively, or less negatively, on Mozambique´s GDP than the scenario where the world does nothing.



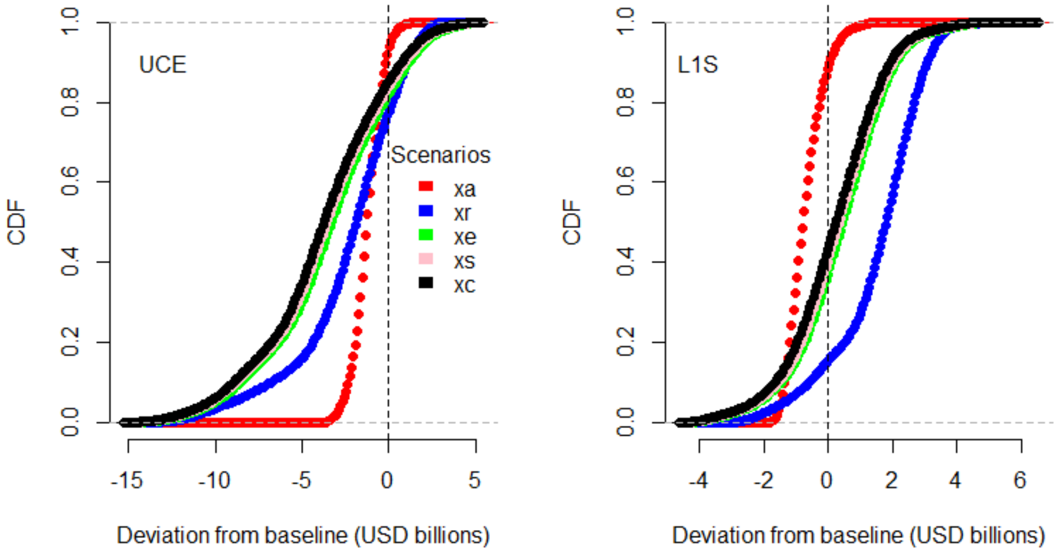
Note: xa – agriculture shocks; xr – agriculture + road shocks; xe - agriculture + road + hydropower shocks; xs - agriculture + road + hydropower + sea level rise shocks; xc - agriculture + road + hydropower + sea level rise + cyclone shocks

Figure 8: GDP outcomes from baseline under UCE and L1S scenarios for several climate shocks

These sustained losses (gains) are captured by calculating the NPV of GDP, considering all climate channels under the UCE and L1S scenarios. The CDF is used, as illustrated in Figure 9. The horizontal axis reports the outcomes of the NPV of GDP in USD billions and the vertical axis reports cumulative probabilities.

In the UCE global policy the outcomes of the NPV ranges from USD -3.9 to +2.2 billion when climate shocks are only imposed on agriculture. However, when the combined effects of agriculture and roads are considered (roads channel) the potential NPV outcomes expands dramatically ranging, from USD -15.2 to +5.0 billion. When other climate shocks are added cumulatively, reaching the cyclone channel which includes all impact channels, the NPV outcomes range from USD -15.2 to +5.4 billion, which is not too different from the roads channel. This means that the road channel is the major source of impacts, as stated early. The probability of losses in GDP (NPV < 0) is around 90% when climate shocks are only imposed on agriculture. However, when all climate channels are taken into account, that probability drops slightly, to around 85% – which is still high, although the potential negative outcomes expand up to USD 15 billion. This suggests that climate changes are likely to negatively impact on Mozambique's economy if the world does not apply policies toward CO_2 emission reduction.

Under the L1S scenario, the range of NPV outcomes is estimated from USD -4.0 to 6.0 billion when all shocks are cumulatively considered (cyclone channel). Furthermore, when climate shocks impact on roads and agriculture the probability of gains in NPV is approximately 80%. When other channels are included up to the cyclone climate channel the probability of gains in NPV drops to around 60%, which is still high. In general, although both gains and losses in NPV of GDP are expected, the L1S scenario has "better performance" than the UCE case. This pattern is consistent with what many authors have been claiming about the negative implications of climate changes on many economies if global mitigation efforts toward reduction of CO_2 emissions are not taken into account.



Note: xa – agriculture; xr - roads; xe - hydropower; xs - sea level rise shocks; xc -cyclone

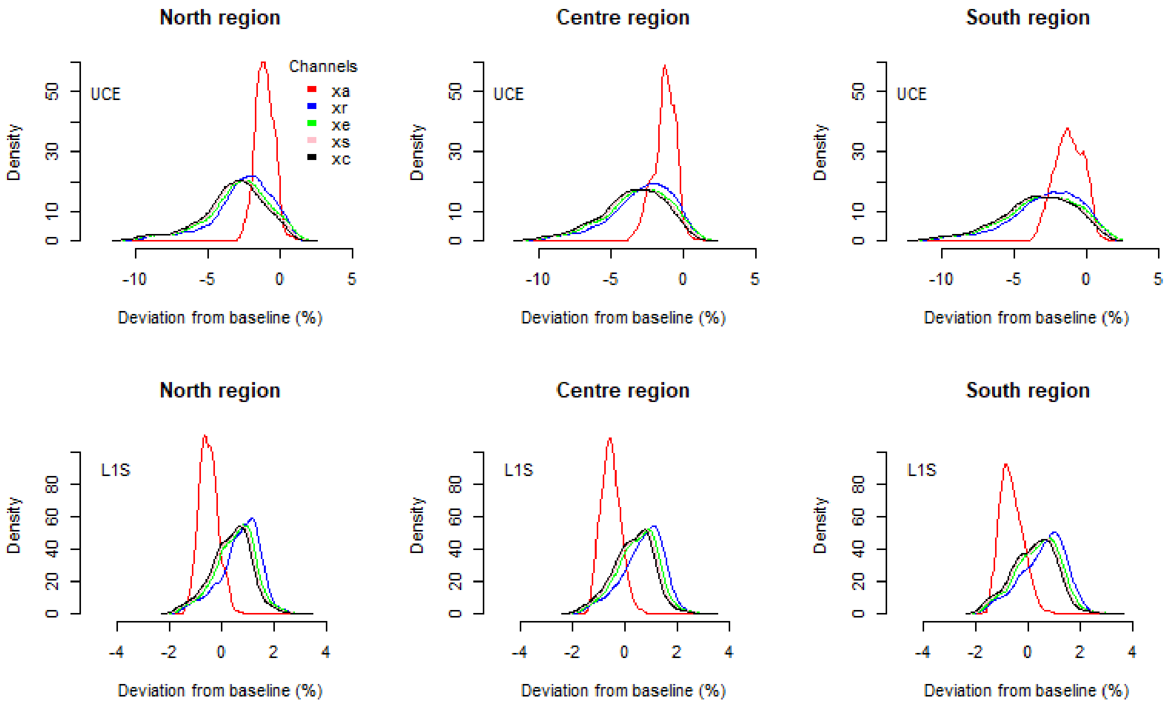
Figure 9: Net present value of GDP losses (gains) from baseline under UCE and L1S scenarios considering all climate channels (effects are cumulative)

4.3 Household welfare

The above analyses focused on indicators for the agriculture sector and economic outcomes. However, beyond the assessment of climate change's impact on agriculture and the whole Mozambican economy, the impact of climate change on rural household welfare is also estimated, measured by the change in household expenditures relative to the baseline scenario, which is illustrated in Figure 10. Each plot reports the HFD of household expenditures outcomes, considering all climate shocks channels in each region, for both UCE and L1S scenarios.

Under the UCE scenario, the potential outcomes of change in rural household expenditures relative to baseline varies slightly across regions, ranging from -4.0% up to +2.2% when climate shocks are only imposed in agriculture. Under this climate channel, the HFD mode was estimated at -1.16%, -1.31% and -1.35% for north, centre and south regions, respectively. The south region seems more likely to present the highest negative impact on household expenditures than the centre and north, but the differences in impacts between regions are small (less than 0.3%). Still in the UCE scenario, when climate shocks are imposed in agriculture and roads, the HFD plots shift to the left side in all regions, increasing the range of the percentage change in rural household expenditures. This range varies from -12.3% to +2.5%, with slight variations between the three regions.

When other climate channels are cumulatively added up to the cyclone channel, the range of potential outcomes does not change significantly, although the HFD plots shifts slightly to the left side, changing the mode distributions estimates to -2.7%, -2.9% and -3.6% for the north, centre and south regions, respectively. Although the negative impact increases when other climate shocks are added in each region, the differences between regions are still small (less than 1.0%). These results also show that the roads channel has the largest source of potential impacts, as noticed previously.



Note: xa – agriculture; xr - roads; xe - hydropower; xs - sea level rise shocks; xc -cyclone

Figure 10: Rural household expenditures relative to baseline in each region of Mozambique under the UCE and L1S scenarios considering all climate channels (effects are cumulative)

Analysing the L1S scenario shows a pattern similar to that previously described under the UCE case. However, under the L1S scenario, when climate shocks are only imposed in agriculture the potential outcomes of change in rural household expenditures range from -1.8% to +1.4%, with slight variations across regions. However, negative change is more likely in rural household expenditures outcomes in all regions, which suggests a worsening situation, although the change is less than 2.0%.

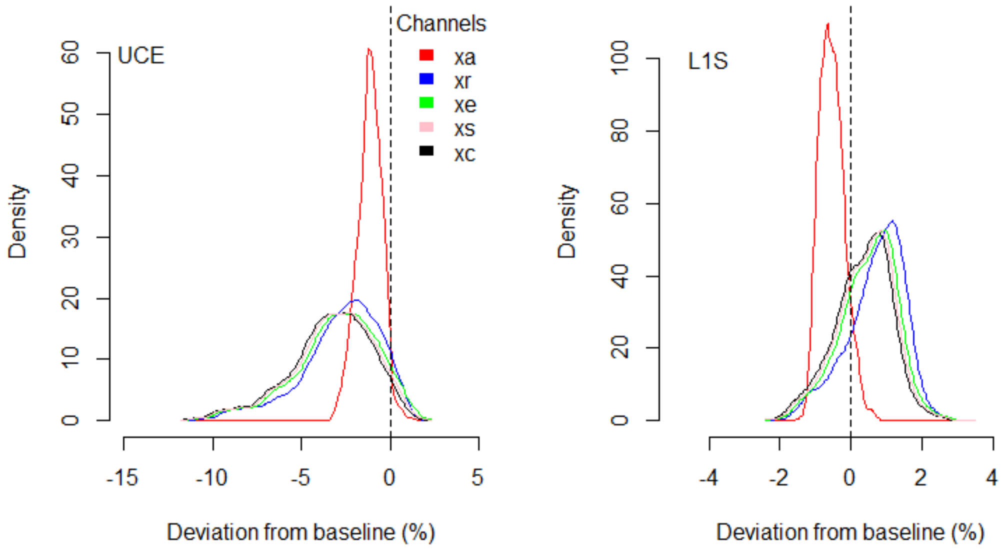
The effects of roads expand the range of change in rural household expenditures in all regions also in the UCE scenario. However, in the L1S case, the expansion shifts the HFD plots to the right side, resulting in a range of potential outcomes from -2.4% to 3.7%.

When climate shocks are imposed under the cyclone channel the mode distributions in all regions are positive, without substantial differences between regions. Moreover, the probability of positive outcomes in the percentage change of rural household expenditures is estimated at 68%, 66% and 61% for the north, centre and south regions, respectively. This suggests that if the world applies a global mitigation effort toward reduction of CO_2 emissions, climate change will impact slightly positively on household expenditures. (Household expenditure is strongly associated with the capacity of households to purchase goods and services.)

It is important to point out that the results reported above are only for rural households. Figure 11 illustrates the HFD for urban household expenditures using all climate impact channels for UCE and L1S scenarios.

In the UCE case the mode of distributions under all climate channels considered in the study is negative. Moreover, there is a greater probability of observing negative changes in urban household expenditures from baseline than positive ones. This indicates that climate changes impacts are more likely to be negative in all shocks considered. In addition, it is noticed that the HFD tends to shift to the left when climate channels are added, which indicates cumulative effects. This pattern is also observed for rural households under the UCE scenario.

Under the L1S scenario the outcomes of change in urban household expenditures relative to baseline ranges from -2.0% to 3.0%, with positive mode in all HDF except from the agriculture channel. When other climate channels are added to the agriculture channel, the result is a shifting to the right of all HDF, although with slight differences between the added channels (roads, energy, sea-level rise and cyclones). This suggests that if the world applies global mitigation efforts it will impact positively on urban household expenditures, and therefore their welfare, as with rural household expenditures (Figure 10).



Note: *xa – agriculture; xr - roads; xe - hydropower; xs - sea level rise shocks; xc -cyclone*

Figure 11: Change in urban household expenditures from baseline under UCE and L1S scenarios for all climate channels (effects are cumulative)

5 POLICY IMPLICATIONS AND POTENTIAL FOR ADAPTATION

The existing framework for managing climate impacts in Mozambique suggests that the priorities are: (i) strengthening of the early warning system; (ii) strengthening the capacities of agricultural producers to cope with climate change; (iii) improving understanding, and strengthening the management, of river waters; (iv) promoting actions to limit erosion and to develop sustainable fishery activities; (v) increasing resilience to the impacts of climate change, while minimizing climate risks to people and property; (vi) identifying and implementing opportunities to reduce GHG emissions; (vii) building institutional and human capacity and exploring opportunities to access technology and financial resources to implement the strategy.

Explicitly or implicitly, this framework shows a growing concern to include climate change in the agenda. The literature shows that several current initiatives in the agriculture sector in Mozambique envision building the resilience of smallholder farmers, but the lack of communication among projects as well as the overlap in coverage results in poor coordination. As a consequence, lessons are barely shared and learned, and synergies are not explored (Care and ActionAid, 2017). A tangible adaptation strategy demands a society that is prepared for and aware of the issues it faces. An effective strategy for climate change adaptation entails a coordinated approach, which is currently lacking. It is in the public interest for governments to provide timely information on expected climate impacts and enable appropriate coordination (Kerr and McLeod 2001).

Mozambique´s Climate Smart Agriculture (CSA) was produced to support and promote climate-resilient agriculture in smallholder farming, emphasizing extension services, knowledge management, coordination, and monitoring and evaluation. However, as suggested by Kerr and McLeod (2001), adapting to climate change must include providing a structure where there is room for agriculture to adapt land use and farming systems, while working with the practical consequences of a changing climate. A response action should consider strategic support to farmers to ensure food security, reducing the effects of climate change on poverty and hunger (FAO, 2018).

Several studies propose potential adaptation strategies that can lessen the potential risk of climate change. These include: (i) spreading information on conservation management practices; (ii) promoting agricultural drought management, encouraging management practices that identify drought as part of an extremely variable climate, instead of considering drought as a natural disaster; (iii) avoiding tying subsidies or taxes to type of crop and acreage; (iv) including water-wise irrigation systems; (v) reducing no-till agricultural practices; (vi) making initiatives to help small-scale farmers and other vulnerable groups to protect and promote agricultural production; (vii) empowering women and other marginalized social groups to overtake the additional barriers they face to adaptation; (viii) inclusive, transparent and accountable adaptation planning with the effective participation of especially vulnerable populations across the country; (ix) implementing seasonal climate forecasting (ISS, 2010; Kerr and McLeod 2001 and Smith and Lenhart, 1996). If extensively implemented, adaptation strategies in agriculture can potentially offset negative climate change impacts, and even improve the benefits of positive impacts (ISS, 2010).

6 CONCLUSIONS

This paper has analysed the economic implication of climate change in Mozambique, focusing primarily on the agriculture sector and household welfare. The analysis, based on both hybrid frequencies distribution and cumulative distribution functions, provides a comprehensive approach for decision-makers. The distribution of the selected variables used in the study tends to shift to the right side under the level one stabilization (L1S) scenario relative to the unconstrained emission (UCE) scenario. The results show that climate change impacts vary across Mozambique's regions, especially with regard to agriculture, depending on the type of global policies responding to climate change. In general, when the world does nothing toward reducing CO_2 emissions, the impacts of climate change are more severe than when global mitigation efforts are made.

Although both increase and decrease is expected in the Mozambican economy by 2050 in terms of net present value of GDP, losses in this macroeconomic indicator of up to USD 15 billion are more likely under the UCE scenario, while gains of up to USD 6 billion are more likely under the L1S scenario.

The study provides evidence for decision-makers to use in identifying and implementing opportunities to reduce greenhouse gas emissions.

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