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Climate Change, Total Factor Productivity, and the Tanzanian Economy

A Computable General Equilibrium Analysis

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Climate Change, Total Factor Productivity, and the Tanzanian Economy: A Computable General Equilibrium Analysis

Mintewab Bezabih, Muyeye Chambwera, and Jesper Stage

Abstract

This paper analyzes the economic impacts of climate change-induced adjustments on the performance of the Tanzanian economy, using a countrywide CGE (computable general equilibrium) model. The general equilibrium framework enables comparison of the effects of climate change to the overall growth of the economy because responsiveness to shocks is likely to depend on the macroeconomic structure of the economy. Effect of overall climate change on agricultural productivity is projected to be relatively limited until approximately 2030 and become worse thereafter. Our simulation results indicate that, despite the projected reduction in agricultural productivity, the negative impacts can potentially be quite limited. This is because the time scales involved and the low starting point of the economy leave ample time for factor substitutability (i.e., replacing reduced land productivity with increased use of capital and labor) and increased overall productivity. This indicates that policies that give farmers opportunity to invest in autonomous climate adaptation, as well as policies that improve the overall performance of the economy, can be as important for reducing the impacts of climate change in the economy as direct government policies for climate adaptation. The study results can inform policymakers when choosing between direct climate-change adaptation policies or measures aimed at strengthening the fundamentals of the economy, as ways of insulating against external shocks.

Key Words: climate change, agriculture, total factor productivity, Tanzania, CGE model

JEL Classification: Q18, C02

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Climate Change and Total Factor Productivity in the Tanzanian Economy:A Computable General Equilibrium Analysis

Mintewab Bezabih, Muyeye Chambwera, and Jesper Stage*

Introduction

In this paper, we examine the general equilibrium implications of climate change for Tanzania, a low-income country in eastern Africa. The importance of analyzing climate change in this context stems from the possibility that responsiveness to shocks is likely to depend on the macroeconomic structure of the economy. Accordingly, we examined the economic impacts of climate change-induced adjustments using a countrywide CGE (computable general equilibrium) model for Tanzania.

Because of its prominent potential impact on economic outcomes and its global nature, climate change is increasingly becoming one of the critical domestic and global environmental policy concerns (Aldy et al. 2009).[1] Hence, understanding the economy-wide impacts of climate change for a given country is critical both in designing national adaptation strategies and in formulating effective global climate policy agreements. Particular to developing countries, quantifying the impact of climate change on the overall economy generates information is essential due to two main factors: the structure of their economies, which often make them extra

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[1] In addition to its domestic and international dimensions, climate change policy is challenging due to the huge scientific uncertainties about the magnitudes and timing of climate change, as well as the extent to which human actions further exacerbate climate change, which characterize the climate change debate (IPCC 2007; Stern 2007; Aldy et al. 2009) There is also disagreement over the ultimate goals of climate policy, over the global division of responsibilities to individual countries. Calibration of domestic policies is inherently difficult because of multiple, and sometimes conflicting, criteria for policy evaluation (Aldy et al. 2009; Cao 2008).

sensitive to climate-related shocks, and the need to ensure genuine participation of developing countries in climate change agreements.

With regard to the participation of developing countries in a sensible way,[2] there is a need to generate sufficient quantitative information on the impact of climate change on their respective economies. Recent efforts in designing effective international strategies have been geared towards acknowledging diversity in terms of adaptive and mitigation capacities. Keohane and Victor (2010) argued that an understanding of the structural and interest diversity inherent across countries is needed for international regulation to be more effective. Cao (2008) argued for a new multistage climate policy framework that takes into account the "common but differentiated responsibilities and respective capabilities" principle in the United Nations Framework Convention on Climate Change (UNFCCC). Similarly, the São Paulo Proposal put forward arguments for a system with differentiated responsibilities, where developed countries make immediate commitments (though with successively increasing levels of stringency) and where needs-based financial and institutional provisions are put in place to enhance developing countries' capabilities for mitigation and adaptation (Haites et al. 2009).

The productivity of weather-dependent sectors, such as agriculture, is likely to be substantially affected by climate change (Sachs et al. 1999; Antle 2010). Hence, the brunt of the adverse economic impacts of climate change is expected to be borne by countries with large agricultural sectors in the tropics and subtropics where agricultural production is weather sensitive and adaptive capacities are low. Examples of partial equilibrium studies assessing the micro impacts of climate change on the performance of agriculture in developing countries include Rosenzweig and Parry (1994), Reilly et al. (1996), Reilly and Schimmelpfennig (1999), Kates (2000), Kurukulasuriya et al. (2006), Seo and Mendelsohn (2008) and Deressa (2007).

Given the importance of agriculture for gross domestic product (GDP), employment, and livelihoods in many developing countries, the impacts of climate change on agriculture are likely to reverberate throughout the economies of these countries. Indirect effects are likely to be felt, not only in sectors concerned with processing and distributing agricultural products, but also in many other sectors of the economy by impacts on income and consumption. In sum, because climate change may affect various sectors of the economy directly or indirectly, interactions

[2] Previous international agreements and protocols are often criticized for failing to address some core issues in climate change-related negotiations, including effectively engaging developing countries and implementing cost-effective policy instruments (Cao 2008).

between different sectors must be studied to assess the impacts of climate change on agriculture. CGE models are well suited to depict interactions between agriculture and other sectors of the economy.

An additional appeal of the CGE model as a tool for assessing economic shocks is that it is easy to incorporate changes in other features of the economy, such as total factor productivity. Economies subject to significant external shocks have been shown to respond differently to the shocks. In a study of the impact of oil price shocks in 43 developing countries in the years 1973–1978, Balassa (1985) found significant differences among countries in the rate of economic growth, indicating different responsiveness to the shocks. Such differentials in responsiveness are attributed not only to the adjustment policies applied, but also to differences in investment rates, the rate of growth of the labor force, and the initial trade policy stance, as well as the level of economic development and the product composition of exports. It is likely that countries' responses to climatic changes will similarly be affected by a wide range of factors that are not limited to the explicit adjustment or adaptation policies enacted.

Despite this, the literature on general equilibrium analysis of climate change contains few studies in Africa so far. Accordingly, the objective of this paper is to add to the African context that includes a general equilibrium analysis of the impact of climate change. We simulated the future development of the Tanzanian economy over a 75-year period under two different scenarios for total factor productivity growth: one with the post-independence average and one with the average for the last decade. We incorporated climate change into the model by letting land productivity decline over time and compared the outcomes for a 75-year period.

The rest of the paper is structured as follows. Section 1 presents a review of the Tanzanian economy and the potential impacts of climate change on its different sectors. Section 2 outlines the general equilibrium model used in this analysis and shows how climate change is included in this model. Section 3 shows the results of the impact of climate change and section 4 concludes.

1. Background: The Tanzanian Economy and Climate Change

Africa's vulnerability to climate change is both a function of the continent's complex climate system and of that system's interaction with socioeconomic challenges, such as endemic poverty, poor governance, limited access to capital and global markets, ecosystem degradation, complex disasters and conflicts, and urbanization—all of which may undermine communities' ability to adapt to climate change (Boko et al. 2007). Accordingly, the effect of climate change on the performance of Tanzania's economy is likely to be a function of both the structure of the macroeconomy and sector-specific vulnerability. This section outlines the structure and performance of the Tanzanian economy and the potential impacts of climate change on vulnerable sectors.

1.1 Performance of the Tanzanian Economy: A Recent History

Mainland Tanganyika and Zanzibar joined to form the United Republic of Tanzania (URT) in 1964. With the Arusha Declaration of 1967, Tanzania's economic policy shifted toward promoting self reliance. As most of the Tanzanian economy was (and still is) based on agriculture, this entailed massive interventions in farming. Farmers were relocated to newly established villages; all land became state property and sale, purchase, and rental of land were prohibited; hiring of farm labor was strongly discouraged; and price regulations ensured that crops selected by the government were promoted to the exclusion of other crops (Bevan et al. 1989). In addition, banks and insurance companies were also nationalized, as were most of the small shops in rural areas that sold consumer goods to farmers.

The results were dismal. Black markets for food crops grew dramatically in importance. Consumer goods were heavily rationed in rural areas; thus, there was little for farmers to spend additional money on and little reason to produce more than absolutely necessary. Agricultural production, both of food crops and cash crops, declined as a result. Food shortages became more common in urban areas, even in the informal markets (ibid.). High export prices for coffee and large inflows of foreign aid supported Tanzania's economy during a large part of the 1970s, but when coffee prices declined toward the end of the decade, the Tanzanian economy collapsed. During the 1980s and early 1990s, Tanzania implemented a series of structural adjustment programs under the overview of the International Monetary Fund and the World Bank (Sahn et al. 1997).

Like many other African countries whose economies were subject to a structural adjustment policy in the 1980s and 1990s, Tanzania has experienced rapid economic growth over the past decade through a combination of sound macroeconomic policies, sector reforms, public and private investments, and a boom in agricultural exports. In particular, since 1995, Tanzania has made major progress in economic reform and macroeconomic stabilization (Treichel 2005).

More than one-third of growth since 1996 has resulted from agricultural performance, another third reflects growth in services, notably trade and tourism-related services, followed by construction and manufacturing. The mining sector, while exhibiting high sectoral growth rates, did not contribute significantly to higher growth (Treichel 2005).

A simple, but useful indicator is total factor productivity (TFP) growth, which measures the part of economic growth that cannot be explained by increases in the use of factors of production, such as labor, capital, or land. Simply put, TFP growth measures the production increases which are caused by more efficient application of technology or more efficient use of existing inputs, rather than by increased use of input. TFP growth was negligible during most of the period after independence,[3] but has risen sharply in the post-reform period.[4] This is a clear indication that, from the late 1960s to the 1990s, there was little incentive for producers, such as farmers, to use their resources efficiently, and this negative effect on income generation was large enough to offset most of the impact of the huge public investments taking place in this period.

In the post reform period, TFP growth has continued to increase, indicating that capital and labor are being used far more efficiently than before. Some studies indicate that TFP growth has picked up even further in the last few years. (Nord et al. [2009] put it at over 3 % per year for the post-2000 period.) However, national accounts data are frequently revised for several years after being published, and there is a possibility that part of this increased production is in fact caused by increased use of land for agriculture. Moreover, even with the dramatic changes in the economic climate, it is by no means certain that the changes have translated fully into better opportunities for the individual smallholder. Little investment in Tanzania in the past 20 years has been in agriculture, suggesting that, even though investment opportunities are perhaps better for farmers now, they still have trouble accessing funds that would make it possible to pursue those opportunities.

1.2 Tanzania's Vulnerability to Climate Change

Africa has experienced a 0.5°C rise in temperature over the course of the 20th century, with some areas warming faster than others (Eriksen et al. 2008). Predictions show that annual mean surface air temperatures are expected to increase between 3°C and 4°C by 2099, roughly 1.5 times average global temperatures (Boko et al. 2007). With respect to precipitation, an

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[3] World Bank and URT (2002) estimated TFP growth from 1960 to 1998 to be 0.3 % annually.

[4] Treichel (2005) estimated TFP growth from 1997 onward as 2.3 % annually.

increasing share of annual rains are expected to fall during intense precipitation events, while droughts may lengthen, with some regions becoming increasingly susceptible to drought and flooding (WWF 2006; Boko et al. 2007).

Particular to Tanzania, climatic projections show that annual temperatures may rise by 2.2°C by 2100, with somewhat higher increases (2.6°C) over June, July, and August, and lower values (1.9°C) for December, January, and February, with greater warming for the cooler months (June–August), compared to the warmer months (December–February). Annual precipitation over the whole country is projected to increase by 10% by 2100, although seasonal declines of 6% are projected for June, July, and August, and increases of 16.7% for December, January, February (Agrawal et al. 2003). Given variations in altitude, topography, vegetation, and coastal proximity, changes in rainfall patterns and temperature are expected to vary considerably from one part of the country to another (URT 2003).

Since most of the economic activities depend heavily on climate change-sensitive sectors, such as agriculture, livestock, fisheries, forestry, water, and unmanaged ecosystems, the possible impacts of climate change on these sectors is discussed below.

The country’s main economic activity is agriculture, an activity more vulnerable to climate change that employs about 80% of the total population. The adverse impacts of climate change in agriculture sectors include reduced crop yield due to drought and floods, and reduced water availability. Shifting of the seasonal rainfall, one of the predicted outcomes of climate change, may bring too much rain when it is not required, is predicted to damage plants. In addition, dramatically rising temperature trends, responsible for increased evapo-transpiration in the soil, may keep crops from maturing due to lack of enough moisture in the soil, and thus produce a shortage of food (Levira 2009).

Climate change is also expected to have a direct impact on livestock production through reduced water and forage. In addition, increased atmospheric CO_2 levels will result in changes in plant species and create favorable conditions for ticks, snails, blood-sucking insects, and other pests that will increase incidences of trypanosomiasis, liver flukes, and outbreak of armyworms (Mwandosya, Nyenzi, and Luhanga 1998). Furthermore, seasonality of rainfall, increased water scarcity, and overstocking of livestock will further shrink the rangelands, which are already overloaded in semi-arid areas, and create serious conflicts between farmers and livestock keepers. This will add to the already existing encroachment of agricultural activities in pastoral areas.

While many tropical fishes have evolved to survive in very warm waters, rising water temperatures as a result of climate change might affect those fish that have critical heat thresholds and cannot survive temperatures that exceed this threshold. An increase in mean temperature may also affect the dissolved oxygen concentrations, limiting oxygen supply (Fick et al. 2005). The resulting reduction in productivity is demonstrated at the stratified northern end of Lake Tanganyika, which supports a less productive fishery than the well-mixed southern arm and the main basins (Vuorinen et al. 1999). A comparative study of historical and current levels of primary production in the north end of Lake Tanganyika also indicates that current levels are much lower as a result of strengthened stratification (Verburg et al. 2003). Limited dissolved oxygen has also led to changes in the limnology of Lake Victoria and has negatively affected its fishery (Kaufman et al. 1996).[5]

The vegetation in the savannah grasslands of Africa may shift in structure and composition as a result of climate change. In particular, decreased precipitation would reduce the overall level of vegetation (Schiter and Higgens 2009; Berninger and Yirdaw 2008) and elevated temperatures and atmospheric CO_2 concentrations may lead to a dramatic shift toward tree-dominated biomass (IPCC 2002). In addition, changes in climate change will compel some species to shift to other areas and interfere with the natural ecological systems (Dias, Diaz, and McGlone 2003). Species also tend to respond to the effects of climate change and disturbance regimes individualistically with substantial time lags and periods of acclimatization. As a result, new assemblages of species that may be less diverse and include more weedy species could appear (IPCC 2007).

Such shifts in vegetation structure and composition will affect wildlife, which feed on the vegetation, and biodiversity. Tanzania is considered one of the premier tourism destinations in Africa (URT 2006), with its wildlife and coastal attractions providing the second-largest source of foreign exchange for the country after agriculture. About one-fifth of Tanzania’s surface area is devoted to conservation of some of the world’s greatest concentrations of large mammals (including elephants), a variety of birds, and indigenous flora. Wildlife is one of the most valuable living natural resources in the country and supports significant income and revenue from tourism (Mwandosya 2006; Mariki 2002) In addition, according to WWF (2006), climate

[5] This discussion is based on WWF (2006).

change has the potential to alter migratory routes of species that use seasonal wetlands (migratory birds) and track seasonal changes in vegetation (e.g., herbivores).

In addition, according to climate change studies done in Tanzania from 1994 to 1999 (Mwandosya 2006), it is predicted that climate change will provoke a general shift in forest ecosystems, in terms of changing forest types and species and distribution of forests. Indirect impacts are also expected as the CO_2 concentration in the atmosphere doubles: subtropical thorn woodlands will be completely replaced and subtropical dry forests and subtropical moist forests will decline by 61.4% and 64.3%, respectively (URT 2003).

Climate change will not only impact natural ecosystems and productive sectors, it will also affect human settlements. Some low-lying coastlines and river deltas of Africa are densely populated and will be affected by a rise in sea level associated with climate change. Other coastal settlements will be subjected to increased coastal erosion (Magadza 2000), as evidenced by the recent repeated floods in East Africa, including Tanzania, which highlighted the vulnerability of flood-plain settlements.

Climate change is likely to pose a significant negative impact on the tourism sector. Most hotels are located along the coastline and any increase in sea level will affect them severely. For example, the Kunduchi and Bahari beaches in Dar-es-Salaam have been so substantially eroded that a huge investment has been made to keep them usable (Mwandosya 2007). Already, climate change has affected the marine organisms of Africa. Coral reefs in the Indian Ocean have experienced significant bleaching since 1998, which has negative implications for fisheries, food security, tourism, and overall marine biodiversity (Desanker 2002).

2. Modeling Impacts on the Tanzanian Economy Using a Computable General Equilibrium Model

Computable general equilibrium models have been widely used for policy analysis in both developed and developing countries in the last three decades. CGE models consist of numerical models of all supply and demand relationships in an economy. A model baseline is then calibrated using current economic data, usually from a social accounting matrix (SAM), and the model can then be used to simulate the effects of external shocks, changes in economic policy, or changes in economic structure.

There are two types of CGE models. The “static” model simulates medium-term impacts of a change in economic conditions; the “dynamic” model simulates long-term impacts. In a static CGE model, it is assumed that firms and household adapt to the change by adjusting their production and consumption behavior. The solution to the numerical simulation shows the effects after this adjustment has taken place, but before it has had time to have longer-term impacts, such as on capital stocks, for example, through changes in savings and investment behavior. In a dynamic model, such longer term impacts are also included, along with other anticipated changes, such as changes in population structure and education levels.

CGE models are used to analyze the economy-wide and distributional welfare effects of economic changes. So far, however, there have been few cases where CGE models have been used to simulate the impacts of climate change in Africa. Winters et al. (1998) used CGE to model impacts of climate change on agriculture, and indirect general equilibrium effects of these agricultural impacts, on three model economies that were set up to reflect the main characteristics of typical African, Asian, and Latin American economies, respectively. The future sizes and structures of the three economies are projected using historic economic data and IPCC estimates. Juana, Strzepek, and Kirsten (2008) used a CGE model of the South African economy to study the impacts of changed water availability under a range of potential adaptation scenarios. Reid et al. (2008) used a CGE model to estimate the impacts of changed agricultural productivity and changed fish availability on the Namibian economy. Their study was a static analysis and can most fruitfully be seen as a set of baseline projections for the outcome that might occur if little adaptation takes place.

A recent World Bank study (2008) assessed the economy-wide impacts of climate change in Ethiopia by focusing on stochastic elements in general and extreme events in particular. A similar study by Arndt et al. (2009) modified a dynamic single-country CGE model to include stochastic elements that are characteristic of climate change and a representation of the sectors that are most likely to be affected, in order to evaluate potential adaptation policies in Ethiopia. Ethiopia is heavily dependent on rain-fed agriculture and its geographical location and topography, in combination with low-adaptive capacity, produce a high vulnerability to adverse impacts of climate change. In his analysis of the impacts of increase in temperature and reduction in precipitation beyond an ideal threshold in Ethiopia, using a CGE approach, Endeshaw (2008) showed that climate change has a significant negative effect on consumption and production in the rest of the economy through its impact on the major agriculture sector.

In Egypt, the potential impacts of climate change on the water resources of the Nile River and associated impacts on the Egyptian economy were studied using a recursively dynamic general equilibrium model. The results showed that the reduced water scenarios led to agriculture's declining share of GDP, a heavy burden on agricultural wage earners, and greater dependence on imports due to dramatically decreased grain production (Strzepek and Yates 2000).

In our study, we simulated the impacts of climate change-induced changes in land productivity of the Tanzanian economy in the 2010–2085 period. We used a dynamic CGE model with a social accounting matrix that has a detailed depiction of the production by sectors, including agriculture and manufacturing. Our research built on research done by the International Food Policy Research Institute (IFPRI)—the model is a dynamic extension of their generic CGE model (Lofgren et al. 2001; Robinson and Thurlow 2004).

Our social accounting matrix is an adapted version of a SAM originally developed by IFPRI researchers (Thurlow and Wobst 2003). The SAM represents the Tanzanian economy by activities, factors, and commodities. The activities (a series of different agricultural activities, as well as manufacturing and service sectors) employ a combination of factors of production: capital land and different types of labor classified by educational attainment. This generates income for the workers, capital owners, and land owners, and this income is then used for consumption of various goods. We made two important adjustments to the original SAM. One is that agricultural land is disaggregated by region, based on data from the Tanzanian agricultural smallholder survey, in order to provide better estimates of how the impacts on different types of farming might affect the economy. The other adjustment is that, since Tanzanian agriculture is generally not capital intensive but rather heavily dependent on labor and land inputs, most of the profits in agriculture (90%, as opposed to 70% in the original SAM) are assumed to be attributable to land rather than to capital inputs.

The basic CGE framework follows the generic IFPRI model closely. (See Lofgren et al. [2001] for a detailed description.) The static model is expanded into a dynamic model for 2010–2085 using a recursive framework. This means that the model is solved for an individual year, savings and investment rates are then used to update the capital stocks in various sectors, and the new values for the capital stocks are then used in the solution for the subsequent year. In addition to this, numerous other values are updated from one year to the next. To model the impact of climate change in the computable general equilibrium model, we let the productivity of land for various types of agriculture decline or increase, based on the estimates from Lobell et al. (2008) and Cline (2007). For 2010–2030, we let land productivity for different crops change each year by a twentieth of the overall change estimated by Lobell et al. (2008) for the overall period. For 2030–2085, we let land productivity change by the amount needed to bring the 2085 value to that predicted in Cline (2007). Since Cline's long-term projections are considerably more pessimistic than those projected by Lobell et al. for the short term, this meant that the productivity declines for most crops after 2030. For crops where Lobell et al. did not provide any estimates, we assumed a steady decline in productivity from 2010 to 2085. Please note that the impact of climate change is thus modeled as declining land productivity rather than as declining agricultural yields; this provided scope for agents to adjust by applying more labor and/or capital. As a fictitious “no climate change” baseline, we also ran the same simulations for the 2010–2085 period, under the assumption that none of these climate change-induced productivity changes took place.

In order to capture the effects of other long-term changes in the economy, we also let the population and the labor force grow during the entire period. Our projections followed the “medium” United Nations’ projections for 2010–2050 (UN 2009), after which both population and labor force are projected to continue growing by 1.6% annually (the population growth rate at the end of the UN projection period). We assumed that investment and government spending, as well as the government budget deficit, remained constant as shares of GDP. Two different scenarios were used for overall total factor productivity growth: 0.3% annual growth, the rate at which TFP has grown in the entire post-independence period; and 2.3% annual growth, the rate at which TFP has grown in the past 10 years. We thus simulated four scenarios overall, namely, two counterfactual scenarios without climate change and low and high TFP growth, respectively, and two with climate change and low and high TFP growth, respectively.

3. Results

In all four scenarios, total factor productivity growth mattered considerably more than climate change for the outcomes during the entire period. The opportunity for substitution, both between crops and between land and capital, meant that almost the entire effect of climate change itself can be offset. In the low TFP scenarios, however, per capita income remained low and, at the end of the study period, was projected to have risen by only about 110%, regardless of whether climate change took place or not (table 1).

Agriculture declined in importance in all four scenarios, but far more in the high-TFP scenarios (figure 1). By the end of the study period, agriculture accounted for less than 2% of GDP in the high-TFP scenarios, compared to about 14% in the low-TFP scenarios.

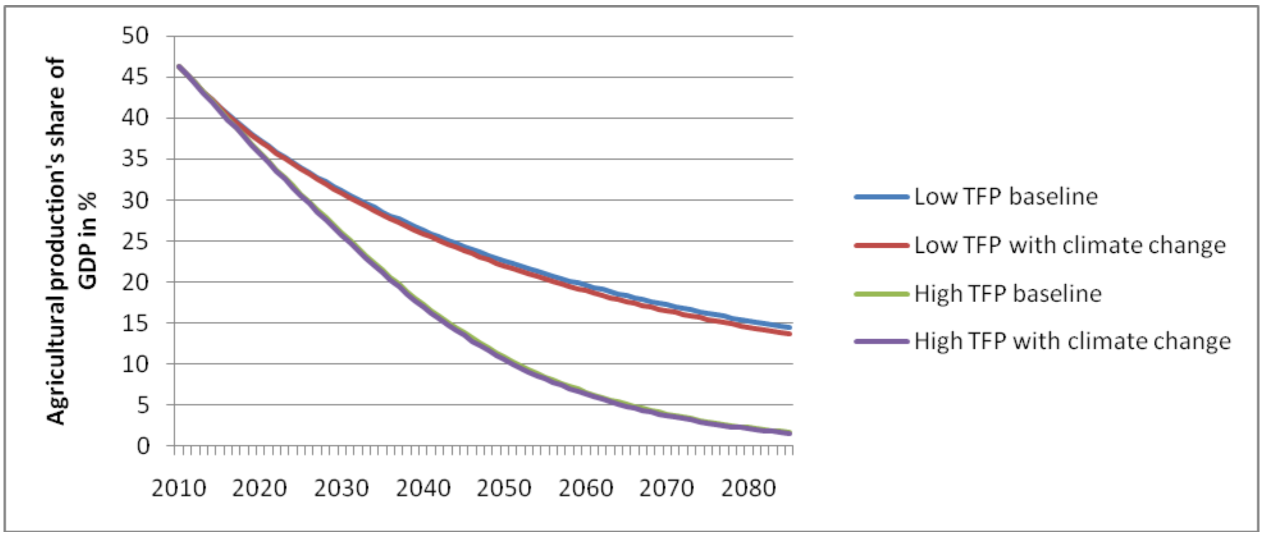
Table 1. Per Capita Income, 2020–2080

(Per capita income nearly doubled each decade, and by 2085 it was over 50 times what it is today.)

	2020	2030	2040	2050	2060	2070	2080
Low TFP growth							
Baseline	1.154	1.305	1.472	1.659	1.842	2.015	2.181
Climate change	1.151	1.299	1.460	1.640	1.814	1.978	2.134
High TFP growth							
Baseline	1.471	2.347	4.025	7.149	12.723	22.777	41.964
Climate change	1.467	2.337	3.996	7.075	12.562	22.451	41.330

Source: Authors' calculations.

Figure 1. Agricultural Production as a Share of GDP, 2010–2085



Note: Shares in the two "high TFP" scenarios follow each other very closely and appear as a single curve in the figure.
Source: Authors' calculations.

Looking at income distribution, finally, the results were largely similar for the four different scenarios (table 2). Land owners' share of national income declined in all four scenarios, while capital owners' share of income increased; both these trends were stronger in the high-TFP scenarios. Labor's share of national income remained almost unchanged throughout the study period in both low-TFP scenarios, but declined in the high-TFP scenarios. All these trends were the same, regardless whether climate change was included in the analysis or not.

Table 2. Shares of National Income Accruing to Different Factors of Production

	2020	2030	2040	2050	2060	2070	2080
Low TFP growth, baseline							
Labor							
- No education	0.037	0.037	0.038	0.038	0.038	0.038	0.038
- Some primary education	0.063	0.060	0.059	0.058	0.057	0.057	0.057
- Completed primary education	0.225	0.222	0.222	0.222	0.222	0.221	0.221
- Completed secondary education	0.093	0.093	0.094	0.095	0.095	0.096	0.097
Capital owners	0.391	0.406	0.413	0.418	0.422	0.426	0.431
Land owners	0.192	0.181	0.175	0.170	0.166	0.161	0.157
Low TFP growth, climate change							
Labor							
- No education	0.037	0.037	0.038	0.038	0.038	0.038	0.038
- Some primary education	0.063	0.060	0.059	0.058	0.057	0.057	0.057
- Completed primary education	0.225	0.223	0.222	0.222	0.222	0.221	0.221
- Completed secondary education	0.093	0.093	0.094	0.094	0.095	0.096	0.097
Capital owners	0.391	0.405	0.412	0.417	0.421	0.426	0.431
Land owners	0.192	0.182	0.176	0.171	0.166	0.162	0.157
High TFP growth, baseline							
Labor							
- No education	0.037	0.037	0.037	0.036	0.034	0.033	0.031
- Some primary education	0.062	0.059	0.056	0.053	0.051	0.049	0.046
- Completed primary education	0.224	0.221	0.219	0.212	0.204	0.195	0.184
- Completed secondary education	0.093	0.094	0.097	0.100	0.100	0.096	0.087
Capital owners	0.394	0.410	0.422	0.442	0.466	0.494	0.532
Land owners	0.190	0.179	0.169	0.157	0.144	0.133	0.121
High TFP growth, climate change							
Labor							
- No education	0.037	0.037	0.037	0.036	0.034	0.033	0.031
- Some primary education	0.062	0.059	0.056	0.053	0.051	0.049	0.046
- Completed primary education	0.224	0.221	0.219	0.212	0.204	0.195	0.184
- Completed secondary education	0.093	0.094	0.097	0.100	0.100	0.096	0.087
Capital owners	0.394	0.410	0.422	0.442	0.466	0.494	0.530
Land owners	0.190	0.179	0.170	0.157	0.145	0.133	0.122

Source: Authors' calculations.

4. Conclusions

There is a growing consensus among scientists and policymakers that climate change-induced weather variability could have tremendous impacts on the performance of agriculture. Whether this actually happens or not, however, will depend crucially on how society responds to these changes in the climate.

The combination of already-fragile environments, dominance of climate-sensitive sectors in economic activity, and low autonomous adaptive capacity in specific regions implies a high vulnerability to the harmful effects of global warming on their agricultural production and food security, water resources, human health, physical infrastructure, and ecosystems. Recent authoritative scientific assessments have emphasized that, even under the most optimistic assumptions about the success of future global mitigation action, an acceleration of adaptation efforts in developing countries over the next decades is essential to build resilience and reduce damage costs (World Bank 2008).

This report examines the potential impacts of global climate change on agricultural production in Tanzania. Using an economy-wide computable general equilibrium model, we simulated the scenarios of agricultural productivity change induced by climate change up to the year 2085.

If Tanzania puts policies in place that enable farmers to respond to the changes in climate, there is ample time to adapt to such changes, and our results indicate that the impacts can be kept to a minimum. Despite the huge loss in land productivity indicated by some projections, farmers can adapt over a 75-year period, such that the overall impact on national income will be limited to losses of a few percent.

Per our results, given policies that permit farmers to adapt, other factors are likely to matter far more for livelihoods in Tanzania. The country has experienced sluggish economic growth during most of its post-independence period, largely linked to extremely low growth in total factor productivity, but this has changed in the last 10 to 15 years. Our simulations indicated that, if the country returns to its earlier state of low TFP growth, income growth will remain stagnant. On the other hand, if the trends of the last 10 years continue, Tanzania will be a middle-income country by the end of 2085.

We, therefore, conclude that without significant progress in productivity and overall economic growth within a reasonably short span of time, direct climate-change mitigation measures will be needed. However, our results also showed that overall economic development—and policies that make factor substitutability easier—are as important in reducing the burden of climate change as direct mitigation measures. If Tanzania puts policies in place that make it easier for its farmers to carry out adaptation measures on their own accord, this can considerably reduce the need for large scale adaptation projects on the side of the government.

Several caveats are in order. CGE models tend to be quite sensitive to the assumptions used—and dynamic models especially so—particularly when the simulation period is as long as it is here. In addition to this, rural markets for outputs, inputs, and factors of production in poor, developing economies, are known to be incomplete and are characterized by thinness (e.g., Gabre-Madhin 2001), systematic imperfections, or outright absence (e.g., de Janvry, Fafchamps, and Sadoulet 1991). This naturally drives wedges between selling and buying prices, so the uniform input and output prices used in CGE models can be strong assumptions in such settings. In addition, while CGE models treat sectors and subsectors as uniform entities and the results reflect aggregate outcomes as such, intrasectoral and regional heterogeneities might call for measuring individual level impacts of climate changes. Microsimulation models coupled with CGE modeling have been used for this purpose (e.g., Chitiga and Mabugu 2008; Davis 2009). Future climate impact studies could consider such extensions. Our CGE simulations also ignored the impacts of occasional extreme weather events and focused only on the impacts of changes in the average weather.

Nonetheless, our results suggest that the scope for Tanzania to cope with climate change may be greater than generally believed. Policies that enable farmers to borrow for investment when needed will let them build up better capital stocks and enable them to replace some of the lost land productivity. Policies that develop markets for new agricultural products, reducing the dependence on individual middlemen, will allow farmers to switch more easily to new crops when climate change causes the old crops to cease being profitable. Some climate change is probably unavoidable now, but well-targeted rural development policies can—especially if outside support is forthcoming—reduce the impacts dramatically.

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