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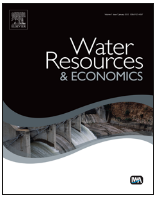

Climate change and agriculture: Impacts and adaptation options in South Africa

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ABSTRACT

South Africa is likely to experience higher temperatures and less rainfall as a result of climate change. Resulting changes in regional water endowments and soil moisture will affect the productivity of cropland, leading to changes in food production and international trade patterns. High population growth elsewhere in Africa and Asia will put further pressure on natural resources and food security in South Africa. Based on four climate change scenarios from two general circulation models (CSIRO and MIROC) and two IPCC SRES emission scenarios (A1B, B1), this study assesses the potential impacts of climate change on global agriculture and explores two alternative adaptation scenarios for South Africa. The analysis uses an updated GTAP-W model, which distinguishes between rainfed and irrigated agriculture and implements water as an explicit factor of production for irrigated agriculture. For South Africa to adapt to the adverse consequences of global climate change, it would require yield improvements of more than 20 percent over baseline investments in agricultural research and development. A doubling of irrigation development, on the other hand, will not be sufficient to reverse adverse impacts from climate change in the country.

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1. Introduction

The impacts of climate change on agriculture are a key reason for concern. It is now widely acknowledged that adaptation would help to alleviate the worst of the potential impacts. In this paper, we take adaptation beyond the usual crop management and selection, and investigate the effects of expanded irrigation and accelerated technological progress. We focus on a single country, South Africa, and analyze whether an economy can be studied in isolation from its trading partners.

Climate change would modify agricultural productivity through five main factors changes in precipitation, temperature, carbon dioxide (CO_2) fertilization, climate variability, and surface water runoff [1]. Crop production is directly influenced by changes in precipitation and temperature. Precipitation is the main source of all freshwater resources and determines the level of soil moisture, which is a critical input for crop growth. Moreover, precipitation is the main contributor of yield variability because it is much more variable than potential crop evapotranspiration, the factor that determines crop water requirements. Based on an econometric analysis of US agriculture, Reilly et al. [2] found that higher precipitation levels lead to a reduction in yield variability. Therefore, higher precipitation will reduce the yield gap between rainfed and irrigated agriculture, but it may also have a negative impact if extreme precipitation causes flooding and water logging [3].

Temperature and soil moisture determine the length of the growing season and control the crop development and water requirements. In general, higher temperatures will shorten the frost periods, promoting cultivation in cool-climate marginal croplands. However, in arid and semi arid areas, higher temperatures will shorten the crop cycle and reduce crop yields, because higher temperature leads to increased crop water requirements [4]. Higher atmospheric concentrations of carbon dioxide enhance plant growth and increase water use efficiency (CO_2 fertilization), especially for the C3 crops, and so affect water availability [5–7].

Climate variability, especially changes in rainfall patterns, is particularly important for rainfed agriculture. Soil moisture limitations reduce crop productivity and increase production risk in rainfed farming systems. Although the risk of climate variability is reduced by the use of irrigation, irrigated farming systems depend on surface runoff or groundwater availability, which are subject to change under climate change. Increased climate variability and droughts will affect livestock production as well, through disrupting feedstock supply or even limited water for animal drinking.

Following the rapid expansion of manufacturing and mining industries over last several decades, agriculture's share in GDP in South Africa is barely 4 percent (2001–2002 period). However, despite the small share of agriculture in the overall economy, the sector accounts for almost 10 percent of total employment in the country and about one-third of total production is exported [8]. Agriculture in South Africa is often perceived as a successful sector, and most of the agricultural production is dominated by medium- to large-scale farms. However, South Africa has a dual agricultural economy, comprising well-developed commercial farms and a large number of small-scale subsistence farms. Commercial farms are mainly large-scale, capital intensive and export oriented, accounting for around 90 percent of the total agricultural production and covering about 86 percent of the country's cropland. Subsistence farms, in contrast, rely on traditional methods of production and are labor intensive, employing around 86 percent of the total farm labor [9].

Despite the global scale of climate change and the fact that food products are traded internationally, climate change impacts on agriculture have mostly been studied at the farm [10], the country or the regional level [11,12,13]. Studies of climate change impacts at the global level indicate that the inclusion of CO_2 fertilization is likely to offset some of the potential welfare losses generated by climate change [14,15,16]. Global models have also been used to study the role of adaptation in adjusting to new climate conditions [11,17,18]. The results suggest that farm-level adaptations might mitigate negative impacts induced by climate change.

However, none of these studies include water as an explicit factor of production. The present approach, based on the GTAP-W model [19], avoids this limitation. By introducing irrigation water as a factor of production in irrigated agriculture, the model supports the analysis of expected physical shortage/abundance of water supply for irrigated crops (blue water). In addition, changes in rainfall (green water) patterns are modeled by changes in the productivity of rainfed and irrigated land. The distinction between rainfed and irrigated farms is crucial, because rainfed and irrigated agriculture face different climate risk levels.