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Compounding food and income insecurity in Yemen: Challenges from climate change

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ABSTRACT

This paper provides a model-based assessment of local and global climate change impacts for the case of Yemen, focusing on agricultural production, household incomes and food security. Global climate change is mainly transmitted through rising world food prices. Our simulation results suggest that climate change induced price increases for food will raise agricultural GDP while decreasing real household incomes and food security. Rural non-farm households are hit hardest as they tend to be net food consumers with high food budget shares, but farm households also experience real income losses given that many of them are net buyers of food. The impacts of local climate change are less clear given the ambiguous predictions of global climate models (GCMs) with respect to future rainfall patterns in Yemen. Local climate change impacts manifest itself in long term yield changes, which differ between two alternative climate scenarios considered. Under the MIR scenario, agricultural GDP is somewhat higher than with perfect mitigation and rural incomes rise due to higher yields and lower prices for sorghum and millet. Under the CSI scenario, positive and negative yield changes cancel each other out. As a result, agricultural GDP and household incomes hardly change compared to perfect mitigation.

Introduction

Climate change can impact countries' economies and people's food security through various channels. Rising temperatures and changes in rainfall patterns and evaporation affect agricultural yields, of both rainfed and irrigated crops (Kang et al., 2009). The unchecked rise of sea levels leads to loss of land, landscape and infrastructure. A higher frequency of droughts may impair hydropower production, and an increase in floods can significantly raise public investment requirements for physical infrastructure (Stern, 2006; World Bank, 2007; Garnault, 2008; Yu et al., 2010a, 2010b). These sector-level impacts will have knock-on effects on other sectors and thus impact economic growth, household incomes and food security. As a relatively dry, food importing country with an important agricultural sector, Yemen is a prime candidate to be affected by virtually all of these channels. Preparing for these challenges at the very lowest (individual and household food security) and highest (national economy) levels requires an understanding of how the economic situation may evolve within Yemen's particular situation.

Naturally, many of these channels will be in operation everywhere to varying degrees. Combining such effects for all countries leads to changes in global food supply, trade flows and commodity prices (Nelson et al., 2010; Verner and Breisinger, 2013; Parry et al., 2004). For example, Nelson et al. (2009, 2010) project that global food prices are bound to increase as a consequence of climate change induced effects, on top of other driving factors such as continued high population growth and changing food consumption patterns. Thus, taking higher food prices into consideration is likely to be important for any climate change impact assessment at the country level. Depending on the net import or export position of countries and the net producing and consuming status of households regarding the specific commodities concerned, the agricultural sector, household incomes and food security are likely to be affected differently. Yet, despite the potentially significant effects of climate change induced changes in world commodity prices, existing country level economic impact assessments have largely neglected this global dimension (Maddisson et al., 2007; Mall et al., 2006; World Bank, 2010).

The present paper provides an evaluation of both local and global impacts of climate change for a particular country, Yemen, focusing on the impacts on agriculture and household food security while accounting for economy-wide repercussions. To allow for such a comprehensive assessment, we employ an integrated

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modeling framework that combines biophysical and economic models. While relying on existing models, the paper provides methodological value added by linking these models in a novel way. In particular, the integration of a household consumption model, which enables us to establish a link between climate change and food insecurity, constitutes an innovative feature of our approach.[1]

Yemen is an interesting case in point because both global and local climate change impacts are likely to matter for its future development, given the country's high levels of poverty and food insecurity. Yemen imports between 70% and 90% of cereals and is a net importer of most other food items, too (Ecker et al., 2010). It is also the poorest country in the Arab world, with an estimated 43% of Yemenis living in poverty in 2009 (Breisinger et al., 2011). Calorie deficiency is prevalent among 32% of the population, and nearly 60% of preschool children were chronically malnourished in 2009 (Breisinger et al., 2010). The 2011 uprising and the sharp declines in oil exports have further increased the number of poor and food insecure people (World Bank et al., 2012). Climate change may thus add to the already severe development challenges that Yemen is facing.

The remainder of the paper is structured as follows. Section 'Modeling framework' introduces the empirical framework of the study and describes its major components. Section 'Impacts of climate change' presents the results of the climate change impact assessment covering the period 2010–2050. Section 'Summary and policy conclusions' summarizes the main findings and provides some policy conclusions.

Modeling framework

The analytical framework used in this paper integrates various models ranging from the macro to the micro-level of the economy and from processes that are driven by economics to those that are essentially biophysical in nature. In a first step, simulations of future climate conditions (temperature and rainfall) from global climate models are spatially downscaled and fed into a crop simulation model which assesses the changes in yields for crops in different agro-ecological zones.[2] Outputs from the crop simulation model feed into the International Model for Policy Analysis of Agricultural Trade (IMPACT) model of the International Food Policy Research Institute which projects climate-related changes in world food prices. Both the simulated yield changes and the price projections then enter a Dynamic Computable General Equilibrium (DCGE) model to assess the local and global impacts of climate change on Yemen's economy. Finally, simulated changes in household total expenditures from the DCGE model are employed to perform simulations of changes in household food security levels.

Local agricultural impacts: Crop simulation model

Yield changes are determined for the six major agro-ecological zones in Yemen (see Fig. A1 in Appendix A). Six crops important to Yemen are considered: maize, millet, sorghum, wheat, potatoes, tomatoes, and other vegetables. The projected yields come from simulations using the Decision Support System for Agrotechnology Transfer (DSSAT) crop modeling framework. The DSSAT model is an extremely detailed process-oriented model of the daily development of a crop, from planting to harvest-ready (Jones et al., 2003). It requires a large amount of input data, such as daily maximum and minimum temperatures and precipitation. Using this data, the model is able to step through the prospective growing season and model how the plant grows, uses water and nutrients, responds to the weather, and ultimately accumulates mass in the harvested portion of the plant. This specificity make the crop models a very powerful tool for assessing the potential effects of climate change on crop yields at a very local geographic level, which can then be aggregated for use in economic models.[3]

The most important inputs for this application were the choice of planting dates and the climatic conditions. The planting dates were chosen via a two-step process. First, the generally prevalent planting seasons were determined by region: The evidence suggests that planting occurs roughly in July in the higher altitudes and roughly in March in the lower ones. This target planting month was used as the middle of a three-month window, with yields predicted for each month in the window. Within each month, two planting dates were used and all the resulting yields averaged together. Finally, the overall yield was taken as the highest of the three-monthly yields. This approach allows for some diversity in the timing of planting (as is expected in the real world) as well as some flexibility given that the target planting month might not be quite correct in all locations.

To capture future climate conditions, we use results of two global climate models as available from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Randall et al., 2007). Specifically, for the future climates around the year 2050, we apply estimates of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) model and of the Model for Interdisciplinary Research on Climate (MIROC) for the IPCC scenario A1B (referred to as CSIRO and MIROC scenarios hereafter). We chose these two model scenarios because they contain all input data that need to be fed into the DSSAT model (which is not the case for many other models and scenarios) and both belong to the family of medium greenhouse gas emission scenarios. These spatially downscaled climate projections show that temperatures are expected to rise over their baseline counterpart under both the CSIRO and the MIROC scenarios [Jones et al., 2010]. However, the variation in temperatures over their baseline equivalents – both minimum and maximum – differs between the two scenarios. Under the CSIRO scenario, variations are limited for both the minimum and maximum temperatures. CSIRO monthly maximum temperatures do not rise beyond 1.7 °C above baseline maximum temperatures and rise 2.31.7 °C above baseline for the average monthly temperatures. Under the MIROC scenario, the variations are far greater for both the minimum and maximum temperatures. For nine months out of the year, the MIROC scenario predicts a more than two degree rise of temperatures by 2050 in minimum temperatures over the baseline, and in May, the MIROC scenario predicts that minimum temperatures will rise over their baseline values by over 3 °C. Maximum temperatures are also expected to increase over their baseline values under the MIROC scenario. For four months out of the year, MIROC temperature highs are expected to rise more than 2 °C over their baseline equivalents.

Variation in average monthly rainfall across Yemen, as predicted by the CSIRO and MIROC scenarios, is only significant for the latter one, while average monthly rainfall (in mm) of the CSIRO

[1] In this paper, household food security is defined narrowly, focusing on household access to sufficient food in terms of dietary energy. Hence, the food (in)security indicator is calorie consumption/deficiency. Calorie-deficient people mark the extreme cases of food insecurity. An insufficient calorie intake causes a feeling of hunger.

[2] For more information on the downscaling methodology, see Breisinger et al. (2013).

[3] While there are other crops grown in Yemen such as fruits and qat, these could not be incorporated in the analysis. The same level of detail that provides the power for crop models like DSSAT also makes it costly to develop them. In particular, it is easiest to build models for annual crops. Several of the most important crops in Yemen are perennials. Unfortunately, there are very few crop models for this type of plant and none of those are included in the DSSAT framework that we utilized. However, we perform sensitivity tests later in this paper to estimate the implications of not being able to include those crops.