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A framework for integrated assessment of food production economics in South Asia under climate change

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ABSTRACT

Agriculture is a sector vulnerable to climate change. The potential decline of crop yields from this vulnerability has important policy implications for food security in South Asia. In this study an integrated assessment modelling framework is proposed to link a global economic model with global climate models via an econometric model of crop productivity. It is then used to examine the impact of climate change on food security in individual South Asian countries by exploring the interaction between climate-induced productivity change and changes in food production and food prices. The results of our simulations suggest that unfavourable climate change can reduce food production significantly from the historical trend and create upward pressure on food prices. This, in turn, will have serious adverse impacts on food security in the South Asian region.

1. Introduction

Climate change has posed a major threat to human development and economic growth, and agriculture could be the most vulnerable to it. Despite modern technologies, weather is still a key determinant of agricultural crop yields. There have been increasing concerns among experts over the link between food security and climate change in recent years (Schemidhuber and Tubiello, 2007; Food and Agriculture Organisation (FAO), 2008; Intergovernmental Panel on Climate Change (IPCC), 2007 and 2014). The High Level of Panel of Experts, HLPE (2012, p.7), notes that “food insecurity and climate change are, more than ever, the two major challenges humanity is facing today, and climate change is increasingly perceived as one of the greatest challenges for food security”.

The vulnerability to climate change and its resulting food insecurity differs from one region to another in the world. In a recent publication, the FAO (2015, p. xi) notes that “crop productivity impacts are expected to be negative in low-latitude and tropical regions”. Its introductory chapter further emphasises that “climate change impacts on food security will be worst in countries already suffering high levels of hunger and will worsen over time” (Elbehri and Burfisher, 2015, p.19).

South Asia has been recognised as one of the world's regions most vulnerable to climate change (World Bank, 2012, 2013). Warming observed in the region has been between 0.016 °C and 1.0 °C; countries in the region have witnessed numerous short term extreme weather events such as heatwaves, cyclonic storms, droughts and floods in the last two decades (see for example, Sheikh et al., 2014). These natural disasters have caused catastrophic losses to life and property, as well as interrupting crop growth and reducing yields (Sivakumar and Stefanski, 2011). As highlighted by the World Bank (2010a, p.28), for instance, erratic monsoon weather conditions in India during 2009 reduced production of the main crops, leading to higher food prices.

The impacts of climate change on food security in South Asia can be far-reaching because agriculture plays an important role in South Asian economies. Over 70% of people in the region live in rural areas dominated by agriculture, and these people account for about 75% of the poor in the region (World Bank, 2013). Agriculture contributes nearly 18% of the region's gross domestic product (GDP) and employs more than 50% of its population (World Bank, 2013, p.125). Poverty in this region has been consistently high: it is home for the largest proportion of the world poor, at around 43% (Bandara et al., 2011). The level of hunger in South Asia is also alarming, as it is the second highest in the world, at 18.1, according to the latest Global Hunger Index (Welthungerhilfe et al., 2014). Considering the

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fact that South Asian is a low latitude and tropical region with a high level of domination of primary agriculture in terms of GDP and employment creation, climate change impacts stand out as a major policy concern for food security.

This study presents an integrated assessment modelling (IAM) framework for policy analysis of food security in South Asia, which links a newly developed global computable general equilibrium (CGE) model at the CISRO for global integrated assessment of climate change (Cai et al., 2015) with global climate models via an econometric model of crop productivity. The modelling framework is then applied to examine the impact of climate change on food security in individual South Asian countries by exploring the interaction between climate-induced productivity change and changes in food production and food prices.

The rest of this paper is organised as follows: Section 2 provides a brief review of the literature; Section 3 presents the IAM modelling framework step by step; Section 4 presents the results; Section 5 undertakes a sensitivity analysis; Section 6 briefly discusses limitations of the model; and Section 7 presents concluding remarks.

2. Literature review

The commonly used food security definition is the one adopted in 1996 at the World Food Summit. According to this definition, "food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life" (FAO, 1996). Four basic pillars of food security are identified from this: namely, availability, access, utilisation and stability. Climate change affects all these dimensions of food security (FAO, 2008). Evaluating the impact of climate change on these pillars of food security is a very complex and difficult task, which requires an integrated assessment modelling (IAM) approach that can address all biophysical and socioeconomic aspects of the problem.

The IAM approach, which provides a unified framework to integrate trans-disciplinary knowledge about human societies and the biophysical world, is now a well-established tool in evaluating linkages between the human and the natural system (Schwantitz, 2013). As noted in Hamilton et al. (2015, p.226), "it is broadly recognised that the interconnectedness of our world requires integrated rather than piecemeal approaches to resolving complex environmental issues, particularly in view of the increasing speed and pervasiveness of connection associated with globalisation". This approach has proved its value in analysing alternative environmental policies, assessing the costs and benefits, and communicating with stakeholders (Laniak et al., 2013; Kelly et al., 2013). A recent special issue of *Environmental Modelling and Software* has demonstrated various applications of integrated modelling to, for example, natural disaster and infrastructure (Akbar et al., 2013), and land use change and water systems (Nino-Ruiz et al., 2013; Welsh et al., 2013; Mohr et al., 2013). In particular, integrated assessment modelling offers a holistic understanding of the impacts of climate change on farming and sustainable agriculture (e.g., Rivington et al., 2007; Warren et al., 2008; Bergez et al., 2013; Muth and Bryden, 2013; Kalaugher et al. 2013).

Elbehri and Burfisher (2015) have provided a survey of methods, results and gaps in economic modelling of climate change. They highlight the need for an integrated modelling approach in evaluating climate impacts on food security. Furthermore, they emphasise the advantage of applying CGE models that have the "ability to describe and differentiate the effects of long run trends in population and productivity growth from climate change shocks on the supply and prices of food in the future". Nelson and Shervely (2014) have also emphasised that this kind of quantitative modelling is an essential part of understanding the economic impacts of climate change. For example, Carrera et al. (2015) combines spatial analysis with a global CGE model to evaluate the direct and indirect economic impacts of flood events. In a recent modelling exercise under the Agricultural Model Intercomparison and Improvement Project (AgMIP), six CGE models and four partial equilibrium models have been called on to investigate the impacts of climate change on agricultural production (see, e.g., von Lampe et al., 2014; Nelson et al., 2014), using crop yield predictions by global crop yield simulation models. However, global crop yield simulation models require high-resolution climate and soil data and intensive calibration of the model (Grassini et al., 2015). This entry barrier limits the application of such models in integrated assessment modelling.

With regard to food security in South Asia, Lobell et al. (2008) have used statistical crop models and climate projections for 2030 from twenty general circulation models to examine the climate change impact on production and adaptation policies related to twelve food insecure regions in the world. They find that South Asia crops are in need of attention and adaptation efforts. Hertel et al. (2010) have applied a CGE model, GTAP, to study the welfare and poverty implications of climate change. Their results indicate that food production in South Asia is expected to decline due to the effects of adverse climate change, which will likely slow down the progress of poverty reduction in the region. Bandara and Cai (2014) have also investigated the impact of climate change on South Asia by using the dynamic version of the GTAP model. Their results suggest that South Asia is vulnerable to climate change in terms of food production and food security. The studies of Hertel et al. (2010) and Bandara and Cai (2014), however, have some limitations because they have used estimates based on scattered agricultural productivity data available in the literature. There could potentially be inconsistency across the different estimates, and it is important to have econometrically estimated productivity data based on the historical relationship between climate variation and agricultural crop yields in South Asia for a meaningful and systematic study.

This paper fills a gap in the literature by proposing a simplified, self-contained approach for integrated assessment of food security in South Asia under climate change. We focus on the economics of food production, and investigate the potential impacts of climate change on the regional economy through the rice and wheat markets. The approach links GTEM-C, a global CGE model, newly developed at the CSIRO, for global integrated assessment of climate change (Cai et al., 2015), with global climate models via an econometric model of crop productivity similar to those of Lobell and Burke (2008), Lobell et al. (2008), Schlenker and Roberts (2009), and Lobell et al. (2011).

Compared to the simpler approach of Hertel et al. (2010) and Bandara and Cai (2014), our IAM approach improves the credibility and transparency of the modelling work as the crop yields projections are consistently estimated and are replicable by other researchers. Compared to the modelling exercise under AgMIP, our IAM approach uses an econometric model that can be estimated using data that are publically available from the FAO and other international research institutes. This lowers the entry barrier and allows wide application of our approach, thereby improving the credibility and transparency of our modelling work as it is replicable by other researchers. Our paper also contributes to the ongoing debate on the impacts of climate change on food production and food security.

3. Methodology

3.1. General framework: overview

Elbehri and Burfisher (2015, p.61) emphasise that there is need

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