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Climate change adaptation in agriculture: A computable general equilibrium analysis of land-use change in Nepal

Sudarshan Chalise*, Athula Naranpanawa

Department of Accounting, Finance and Economics, Griffith Business School, Nathan Campus, Griffith University, Queensland 4111, Australia

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ABSTRACT

This paper investigates the feasibility of changes in cropland-use as an adaptation strategy to minimise the economy-wide costs of climate change on agriculture. Nepal makes an interesting case study as it is one of the most vulnerable agricultural economies within South Asia. We develop a comparative static multi-household computable general equilibrium (CGE) model for Nepal, with a nested set of constant elasticity of transformation (CET) functional forms, to model the allocation of land within different agricultural sectors. Land transformation elasticities in these CET functions are allowed to reflect the ease of switching from one crop to another based on their agronomic characteristics. The results suggest that, in the long run, farmers in Nepal tend to allocate land to crops that are comparatively less impacted by climate change, such as paddy, thereby minimising the economy-wide impacts of climate change. Furthermore, the results reveal that land-use change tends to reduce the income disparity between different household groups by significantly moderating the income losses of marginal farmers. Therefore, it is suggested that policy makers in Nepal should prioritise schemes such as providing climate-smart paddy varieties (i.e., those that are resistant to heat, drought and floods) to farmers, subsidising fertilizers, improving agronomic practices, and educating farmers to switch from crops that are highly impacted by climate change to those that are not, such as paddy.

1. Introduction

A considerably growing body of literature on climate change has a common understanding on two major issues. First, given the importance of agriculture to employment and people's livelihoods in developing countries such as Nepal, the loss of agricultural productivity due to climate change is of great social and economic concern. Many socio-economic sectors besides agricultural value chains are also likely to experience indirect effects of discrepancies in income and consumption. As a consequence of these threats, climate change imposes additional stresses to the social and economic challenges that the poorest already face (IPCC, 2013), highlighting and accelerating their vulnerabilities, as their livelihoods depend on already overstrained climate-sensitive resources and their social welfare systems are weak. By directly depleting the agricultural resources that poor people depend on for their livelihoods, climate change increases their chances of falling into a cycle of poverty from which it is difficult to escape. In this situation, even optimal success in global action towards mitigating climate change will be insufficient to build resilience and compensate for the damage cost (IPCC, 2013; Nelson and Shively, 2014). An effective framework of potential adaptations is essential to eradicate the escalating poverty in developing countries (Arndt et al., 2011a; UNFCCC, 2015). In the absence of such a consolidated framework of adaptation options, it is likely that farmers will implement comparatively less-beneficial practices in the long term.

Second, it is important to implement locally led adaptations to climate change in agriculture, particularly when smallholders have inadequate access to official strategies. In this sense, farmers' practices, which are based on their ad-hoc experiences, such as changing crop patterns, improving grazing patterns, cultivating heat-resistant crops, using better fertilizers, and using rain-water harvesting for irrigation, can help to reduce the impacts of climate change. However, it is unknown what the maximum benefit smallholders in developing countries can enjoy from such adaptations (Claessens et al., 2012; Esham and Garforth, 2013).

Gradually changing the pattern of land-use from high-impact crops to low-impact ones is one of the best adaptation options that farmers in Nepal have been experimenting with to minimize the impacts of climate change. As climate-induced impacts are highly

* Corresponding author at: Department of Accounting, Finance and Economics, Griffith Business School, Nathan Campus, Griffith University, 170 Kessels Road, Nathan, QLD 4111, Australia.
E-mail address: sudarshan.chalise@griffithuni.edu.au (S. Chalise).

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variable among crops and croplands due to different agronomic conditions, farmers tend to supply more land to less-impacted crops in order to maximize their yields. Changing land-use is crucial not only for food security and the overall economic growth of the agricultural sector but also for helping the poorest people in developing countries to escape the cycle of poverty. However, significant challenges facing the farmers in developing countries are to understand the actual agronomic feasibility of switching crops and to experiment with land-use change practices that maximise farm revenue as well as food security. In this sense, a study on assessing the impacts of climate change and the benefits of the land-use change is important in the current literature.

Although there is clear evidence that agricultural systems in developing countries are highly vulnerable to climate change, there have been relatively few detailed studies carried out to examine the potential of climate-change adaptations on agriculture. Some partial equilibrium studies (e.g., Kumar, 2011; Mendelsohn, 2007; Saito, 2012; Seo et al., 2009) have attempted to assess the impacts of climate change and possible climate-change adaptations on agriculture at national and global levels. However, these studies have three major limitations. First, their results are skewed towards individual perceptions and practices, and the uncertainty and long timeframes allied with climate change limit the findings. Second, most of these studies emphasize crop production as one of the major characteristics of partial equilibrium analysis (as mentioned in Elbehri and Burfisher, 2015), and disregard direct and indirect linkages with the overall economy. Third, none of these studies has investigated climate-change adaptations in relation to differences between households.

A few studies consider the economy-wide impacts of climate change on agriculture. In an economy-wide approach, top-down computable general equilibrium (CGE) modelling is generally used (e.g., Bandara and Cai, 2014; Bezabih et al., 2011; Eboli et al., 2010; Robinson et al., 2014) for assessing the economic effects of climate change and evaluating the efficacy of climate policies. These studies have found that unfavourable climate change in several developing countries is not only likely to induce discrepancies in income and consumption but also bring about a huge decline in their overall economic performance.

Among the specification parameters affecting the quantitative and qualitative results of these CGE models, substitution and transformation elasticity of primary factors for various uses have a major influence (Palatnik et al., 2011). Several CGE models have used functions such as constant elasticity of substitution (CES) and constant elasticity of transformation (CET) for this purpose. The original ORANI-G model (Dixon et al., 1982) also uses a CES function as a factor composite for production, assuming a significant elastic CES sub-set for labour among several occupational skill groups. Such models assume that land is fixed for an industry, which we argue is extremely likely to result in over- or under-estimation of climate-change impacts due to the exclusion of land-transformation possibilities among crops. In developing countries, individual farmers and households operating at the micro-level make most of the land-use decisions to adapt to the threats of climate change. Therefore, in this paper, we attempt to model and assess individual decisions regarding land-use change among different industries in a more mathematical way.

We propose a simple model, based on the Nepalese economy that provides a general framework for allowing climate-change impacts and adaptation strategies to be tested. In contrast to the existing comparative-static CGE assessments of climate-change impacts on agriculture production (e.g., Arndt et al., 2011b; Bosello and Zhang, 2005; Hertel et al., 2009), the approach presented here is able to capture the possible land-use change for several crops.

Although recent studies (e.g., Fujimori et al., 2014; Hertel et al., 2010; Li et al., 2012; Palatnik et al., 2011) have used CET in land substitution systems, the results have some serious limitations. First, the results are limited to a few agricultural sectors where, we argue, there is an extreme chance of an individual sector controlling the model parameters. Second, these studies have not tested the possibility of crop switching with a range of CET values. This has created a serious gap in the policy recommendations, in which the implication of such beneficial land-use to local farmers is missing.

Therefore, the main objective of this paper is to modify the widely used assumption of "fixed land supply for a given industry", by allowing farmers to supply land to crops that are less affected by climate change, subject to any agronomic constraints; and to examine the economy-wide impacts of climate change-induced agricultural loss both "with" and "without" land-use change. The rest of the paper is organized as follows: Section 2 justifies the rationale of selecting Nepal as a case study, including a literature survey on climate-change impacts on Nepalese agriculture; Section 3 illustrates the methodology, including the empirical model and framework; Section 4 depicts the simulation results; and Section 5 offers some short policy discussion and conclusions.

2. Motivation and background of the study

We have purposefully chosen Nepalese agriculture to illustrate the economy-wide impacts of changing land-use pattern as adaptation strategy to climate change for a number of reasons. First, the agricultural sector plays a vital role in the economy of Nepal, particularly in the rural sector. Around 80% of Nepalese households are located in rural farms or regional areas, but only 50% of their income is generated from agricultural sources (World Bank, 2012), which is insufficient to provide a secure livelihood. Although the contribution of agriculture to the national GDP has been decreasing during recent years – from more than 50% in 1995 to about 35% in 2011/12 (CBS, 2014) – it is still one of the highest among South Asian countries. The agrarian societies in Nepal, who live primarily in rural areas, have the strongest bond with the ecosystems that are sensitive to climate changes. Besides agriculture, the livelihood of the rural population is closely linked to the forest, another climate-sensitive sector. More than 86% of the energy needs of the population are met by firewood, agricultural residue and animal wastes (CBS, 2014).

Second, due to the country's steep rugged topography, Nepalese agriculture is one of the most vulnerable sectors to climate change in South Asia (Bandara and Cai, 2014; Chalise et al., 2015). Limited arable lands, a rain-fed farming system and fragile land constructs result in frequent natural disasters. With regard to the climate-change parameters in Nepal, the regional climate-model projections show temperature increases of 1.6 °C–2.0 °C by 2030, 2.3 °C–2.9 °C by 2050, and 3.4 °C–5.0 °C by 2080 (Ahmed and Suphachalasai, 2014). These increases in temperature are likely to result in erratic precipitation, greater soil erosion and droughts in the future. Moreover, prolonged droughts could result in rapid evaporation and ultimately the drying of important water bodies in the mid-eastern parts of Nepal (Gurung and Bhandari, 2009), which would cause extreme starvation among the poor.

Third, Nepal has relatively low per capita income of USD 562 (CBS, 2014) and, therefore, has been categorised as a least-developed country by the World Bank and other international organisations. Nearly 25% of the population in Nepal live below the poverty line based on the well-known USD 1.25 per day poverty measurement. Hence, any adverse impacts on Nepalese agriculture as a result of climate change could be disastrous for those living below the poverty line, subsistence farmers in particular, as well as for the national economy in general. Consequently, Nepalese farmers are more vulnerable to climate-change impacts than farmers in more progressive countries, since they already have insufficient