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RESEARCH ARTICLE

The Impact of Climate Change on Agriculture in Asia

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Abstract

Asian agriculture is responsible for two thirds of global agricultural GDP. There have been numerous studies exploring the impact of climate change on crops in specific locations in Asia but no study has yet analyzed crops across the entire continent. This study relies on a Ricardian study of China that estimated climate coefficients for Chinese crops. These coefficients are then used to interpolate potential climate damages across the continent. With carbon fertilization, the model predicts small aggregate effects with a 1.5°C warming but damages of about US$84 billion with 3°C warming. India is predicted to be especially vulnerable.

Key words: agriculture, climate change, Asia, Ricardian

INTRODUCTION

Asia is the most populous continent on earth accounting for 63% of the global population. With the green revolution, however, Asian farmers account for 67% of global agricultural productivity. The region is food self-sufficient. However, will Asian agriculture nonetheless succumb to future global warming? This paper examines the temperature sensitivity of Asian agriculture and forecasts likely outcomes if climates do warm.

There are four sources of information about the sensitivity of farms to climate (IPCC 2007; Mendelsohn and Dinar 2009). 1) Agronomists have conducted controlled experiments in greenhouses with different temperatures. 2) Agronomic crop simulations model key grains such as maize, wheat, soybeans, and rice. 3) Cross sectional studies of yields of specific grains have been conducted across different climate zones. 4) Cross sectional economic models have been estimated using land values and farm net revenues across climate zones. All of these studies find that crops are sensitive to changes in temperature (IPCC 2007; Mendelsohn and Dinar 2009). The consistency of these findings suggests that there is high confidence that crops are potentially vulnerable to climate change. The key question in this paper is not whether climate change might affect crops in Asia but rather what is the magnitude of this impact.

Although there have been numerous studies in Asia, the results are scattered. For example, there are many studies exploring how climate change may affect crops and farmers in China (Wang *et al*. 2009, 2014; Chen *et al*. 2013; Holst *et al*. 2013) and India (Kumar and Parikh 1998; Sanghi and Mendelsohn 2008) as well as other Asian countries (Seo, Mendelsohn and Munasinghe 2005). Yet, a comprehensive study across all of Asian agriculture has yet to be done. The purpose of this study is to fill this gap until a comprehensive study can be conducted. The sensitivity function between crop net

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revenue and climate from China (Wang *et al*. 2009) are extrapolated to neighboring countries in Asia in order to get some sense of the magnitude of potential impacts. The complete list of the 29 Asian countries in the study is in Appendix. The Middle East is not included as well as several islands in Asia.

The precise magnitude of the impact of climate change will clearly depend on the magnitude of the climate change being considered. With the RCP 6.0 emission scenario, climate change models predict a wide range of warming of between 1.4 to 3.1°C by 2100 (IPCC 2013). We consequently examine both a mild warming of 1.5°C and a more extreme warming of 3°C above the 1960-1990 climate normals. Because this change in climate does not occur until 2100, we look at agriculture as it will likely be in 2100 and compare outcomes with the current climate (1960-1990) versus these warmer scenarios.

METHODOLOGY

This analysis relies on the Ricardian method to estimate farm climate sensitivity (Mendelsohn *et al*. 1994). The Ricardian model assumes that each farmer wishes to maximize income subject to the exogenous conditions of their farm. Specifically, the farmer chooses the crop and inputs for each unit of land that maximizes:

$$Max\ \pi=\sum_i P_{qi}Q_i\,(X_i, L_i, K_i, IR_i, C, W, S) -\sum_i P_x X_i -\sum_i P_L L_i -\sum_i P_K K_i -\sum_i P_{IR} IP_i \qquad (1)$$

Where, π is net annual income, P_{qi} is the market price of crop i, Q_i is a production function for crop i, X_i is a vector of annual inputs such as seeds, fertilizer, and pesticides for each crop i, L_i is a vector of labor (hired and household) for each crop i, K_i is a vector of capital such as tractors and harvesting equipment for each crop i, C is a vector of climate variables, IR_i is a vector of irrigation choices for each crop i, W is available water for irrigation, S is a vector of soil characteristics, P_x is a vector of prices for the annual inputs, P_L is a vector of prices for each type of labor, P_K is the rental price of capital, and P_{IR} is the annual cost of each type of irrigation system.

If the farmer chooses the crop that provides the highest net income and chooses each input in order to maximize net income, the resulting chosen net income will be a function of just the exogenous variables:

$$\pi^*=f\,(P_q, C, W, S, P_X, PL, P_K, P_{IR}) \qquad (2)$$

With perfect competition for land, free entry and exit will ensure that excess profits are driven to zero. Land rents will consequently be equal to net income per ha (Ricardo 1817; Mendelsohn *et al*. 1994). The Ricardian outcome will be strictly a function of variables which are exogenous to the farmer.

The functional form of eq. (2) that was used in China is the following linear form:

$$\pi^*=B_0+B_1T+B_2T^2+B_3P+B_4P^2+\theta Z \qquad (3)$$

Where, B_i and θ are vectors of estimated coefficients, T is a vector of seasonal temperature, P is a vector of seasonal precipitation, and Z is a set of control variables. The reason a wide set of control variables were included in this empirical study is to limit the possibility that there are omitted factors highly correlated with climate that would also affect net revenues (and therefore bias the climate coefficients).

We specifically examine two potential future scenarios for temperature. A modest scenario where temperatures rise 1.5°C and a more severe scenario where temperatures rise by 3°C by 2100. There is very little agreement across climate models about how precipitation will vary across countries in the future, so we do not look at changes in precipitation but rather focus entirely on temperature. The welfare effect, W, of a nonmarginal change in temperature from T_0 (current temperature) to T_1 (future temperature) can be evaluated with eq. (3) as:

$$W=\pi(T_1)-\pi(T_0)=[(B_1T_1+ B_2T_1^2)-(B_1T_0+ B_2T_0^2)] \qquad (4)$$

The effect of all the other variables cancels out in this comparison.

The analysis is conducted on agriculture as it is likely looks in 2100. The overall acreage of cropland is assumed to remain the same as it is in 2010. However, productivity per ha and demand is assumed to grow by 1% a year. In contrast, crop yields per ha have been growing at almost 2% a year for the last 50 yr. The 1% assumption implies that Asian agriculture will be two and half times larger in 2100 than today. If one, instead wished to predict the impact of climate change on today's crops, one would simply divide the results reported in the paper by 2.5. The productivity increase is not expected to change the climate sensitivity of the