Climate Change Impacts on Southeast Asian Agriculture

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Abstract

Despite the extensive interest in measuring the economic impacts of climate change in general, there is very little empirical research on Asia. This study extrapolates results from India and selected experiments to the rest of Southeast Asia in order to measure the impact of climate change on agriculture in this region. The study examines a variety of climate change predictions and climate response functions. The impacts could vary from a small benefit to a loss of 37% of agricultural GDP by 2100. More research is clearly needed to refine the estimates of impacts in this region and to identify potential adaptation options for farmers and governments.

Over the last 10 years, a great deal has been learned about the impacts of climate change on market and nonmarket sectors. For example, the market sectors expected to be vulnerable to climate change are agriculture, coastal development, energy, forestry, and water (Pearce et al., 1996). The key nonmarket sectors are terrestrial ecosystems, human health, and undeveloped coasts (Pearce et al., 1996). More recently, it has also become clear that most of the market sectors have a hill-shaped relationship with temperature. Locations that are cool will likely benefit from warming, locations that are temperate will have modest effects, but locations that are already hot will be damaged (Mendelsohn et al., 2000; 2004; Tol 2002). Low latitude regions of the world will be vulnerable to climate change because they have large agricultural sectors and because they are already hot. Southeast Asian agriculture is especially important amounting to over 50% of all low latitude agriculture. Potentially, a large fraction of the global damages from climate change could fall on this sector in this region. This study consequently focuses on the impacts of climate change to Southeast Asian agriculture.

We rely in this paper on a global impact model, GIM, developed to measure country level impacts of climate change (Mendelsohn et al ., 2000). The model evaluates the impacts from predicted changes in climate over time according to a number of different climate models. These changes are then evaluated with two climate response functions. One climate response estimate comes from a Ricardian analysis of Indian agriculture (Mendelsohn et al., 2001) and the other estimate comes from experimental crop simulation models (such as Adams et al., 1999). The results are extrapolated to all the countries in the region. By comparing the predicted outcomes from the current climate with several possible climate scenarios from Atmospheric Oceanic General Circulation Models (AOGCM's), GIM computes the economic impacts of climate change.

I. Methods

The analysis begins by determining baseline agricultural net revenues, W, in each country. Net revenue per hectare is determined by a climate response function V(C). Two different response functions are used, one from the cross sectional literature and the other from the experimental simulation literature (see Mendelsohn and Schlesinger 1999). The initial baseline agricultural income of each country is equal to the predicted net revenue from current climate, C_0, times the amount of farmland, N:

$$W(C_0) = V(C_0) *N \qquad 1)$$

The model then evaluates a new climate, C_1, and predicts a new net revenue per hectare, which is again multiplied by the number of hectares of farmland. Subtracting the new net revenue from the baseline net revenue yields an estimate of how agricultural net revenues in each country will change with climate change:

$$\Delta W = W(C_1) - W(C_0) = V(C_1) *N - V(C_0) *N$$

In this study, the cross sectional response function is derived from a Ricardian study of India (Mendelsohn et al., 2001). The response function is a quadratic combination of seasonal temperature and precipitation variables. It was estimated using district data from India that includes soils and other control variables. The welfare impact of climate change is assumed to be simply a function of climate. The functional form of the impact model is therefore:

$$\Delta W = [\sum AT(1) + BT(1)^2 + DP(1) + EP(1)^2] - [\sum AT(0) + BT(0)^2 + DP(0) + EP(0)^2]$$

where T(0) is a vector of the current seasonal temperatures, P(0) is a vector of the current seasonal precipitation, T(1) is a vector of the future possible seasonal temperatures, P(1) is a vector of the future possible seasonal precipitation, and A, B, D, and E are vectors of coefficients.

The experimental response function depends on annual temperature and precipitation (see Mendelsohn and Schlesinger, 2001). The response function was estimated from agricultural-economic simulation results (Adams et al 1999). The crop simulation results are more climate sensitive than the cross sectional results. We believe this difference can be attributed to the inclusion of adaptation in the cross sectional models which is largely missing in the crop simulation models.

Another important factor in the response of agriculture is carbon fertilization. The higher levels of carbon dioxide in the atmosphere are expected to increase crop productivity. Carbon fertilization effects are integrated into crop simulation results as they are included in many experimental outcomes. However, the cross sectional models cannot measure carbon fertilization. Carbon fertilization effects had to be added to the cross sectional predictions separately. We assumed that doubling would increase crop productivity by 30% in the cross sectional model (Reilly et al 1996). Carbon fertilization continues to be a source of controversy in the literature, however, as some researchers find that CO_2 field experiments yield lower returns than greenhouse studies suggest.

For purposes of this study, we define Southeast Asia to include Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Taiwan, Thailand, and Vietnam. This includes countries on the Asian continent as well as island countries nearby. We do not include northern Asian countries because they are expected to have very different responses to climate change. Specifically, they are expected to either benefit or be hardly affected by climate change. For a more complete discussion of climate impacts to all countries, see Mendelsohn et al., 2004.

II. Results

We test three different climate scenarios for 2100 from AOGCM's: the PCM model (Washington et al., 2000), the CCSR model (Emori et al., 1999), and the CCC model (Boer et al., 2000). Table 1 provides average temperature and precipitation measures for each model. The temperature changes range from +2.7˚C to +5.4˚C across the three models. Precipitation increases in PCM and CCSR but decreases in CCC. These three climate models were chosen to exhibit a wide range of plausible future climate scenarios.

Under the current climate, with increases in productivity, agricultural incomes are expected to grow to $561 billion in Southeast Asia by 2100. However, as shown in Table 2, net revenues will change if climate changes. The changes vary widely across the three scenarios. According to the experimental climate response function, the mild and wet warming of PCM, will increase agricultural revenues in Southeast Asia by $35 billion per year, a 6% benefit. The CCSR scenario would cause net revenues to fall by about $60 billion per year, an 11% loss. Finally, the CCC scenario would cause $219 billion of damages to Southeast Asian agriculture which is a 39% loss. According to the cross sectional model, the climate effects are much smaller. The PCM scenario leads to only $9 billion of benefits, the CCSR to only $6 billion of damages, and the CCC scenario to only $10 billion of damages. This is a wide range of possible net aggregate impacts.

Further, the regional impacts are not spread evenly across all countries. First, the magnitude of the impacts depends upon the size of the agricultural sector in each country. The two countries with the largest impacts, India and China, also have the largest agricultural GDP. With the experimental response function, Indian agriculture can lose up to $87 billion in the CCC scenario and China another $32 billion. Together, the losses in these two countries amount to over one half of the damages in the region. With the cross sectional response function, the damages are much smaller but these two countries still account for two thirds of the regional damages.

However, another important perspective to keep in mind is the fraction of agricultural GDP lost by each country. For example, with the experimental response function, China loses only 14% of its agriculture in CCC, but India loses over half, and Thailand loses all of its agricultural GDP. Other countries that are predicted to lose all their agricultural GDP with the experimental response function in CCC include Cambodia, Laos, and Vietnam. Of course, the impacts are predicted to be much smaller with the cross sectional model but the percentage losses still vary across countries.

The third important factor in climate impacts is the climate scenario. With the CCC climate scenario, agricultural impacts are deep and for some countries, devastating. However, with the CCSR scenario, impacts are much less serious and with the PCM scenario, they are actually beneficial. It matters a great deal which climate scenario actually unfolds.

3. Conclusion

This paper examines a number of climate warming scenarios for Southeast Asian agriculture. The study relies on climate response functions from both the cross sectional literature and the experimental simulation literature. Although the cross-sectional study was done in India, much of the evidence is interpolated to the region. Using three alternative climate warming scenarios that range from mild to severe, the study calculates a set of impacts for each country in Southeast Asia.

The analysis finds that the agricultural impacts depend on four factors: the response function, the size of the agricultural sector, the initial temperature and precipitation, and the climate scenario. The experimental response function predicts much more dramatic consequences than the cross sectional response function. Countries with larger agricultural sectors suffer larger impacts. Impacts as a fraction of agricultural GDP increase the hotter a country is currently. Finally, the climate scenario itself is critical. Mild scenarios are predicted to be beneficial, moderately warm scenarios only slightly harmful, and extreme scenarios will cause substantial harm.

Although this study provides some initial indication of the importance of climate change to agriculture in this region, the range and the potential size of the potential effects suggests that further empirical research needs to be done. Economic studies of more than just India need to be included in order to provide a more accurate estimate of what will happen to the region. Currently, a set of studies is underway in both Africa and Latin America to determine climate change impacts and adaptation opportunities in those regions[1]. A similar empirical study needs to be conducted in the Asian region to improve the accuracy of the analysis for Asia. The study must also go beyond just measuring the impacts and identify adaptation options for farmers and governments.

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Table 1

Climate Scenarios in 2100 for Southeast Asia

	Current	CCC	CCSR	PCM
Temperature (C˚)	23.7	28.1	27.0	25.9
Precipitation (mm/mo)	15.2	13.6	16.4	18.1

Table 2
Agricultural Impacts to Southeast Asia
(Billions of USD)

(Billion USD/yr)	AGR GDP*	CCC	CCSR	PCM
Bangladesh	16.0	-0.1 to -9.4	-0.1 to -3.7	-0.1 to -0.5
Cambodia	0.2	-0.0 to -0.2	-0.0 to -0.2	-0.0 to 1.1
China	230.5	-5.6 to -32.2	-2.0 to 7.0	7.6 to 30.5
India	164.9	-1.1 to -86.7	-1.5 to -47.8	0.5 to -4.6
Indonesia	38.4	-0.3 to -25.5	-0.2 to 3.3	-0.1 to -4.3
Laos	0.2	-0.0 to -0.2	-0.0 to -0.2	0.0 to 0.2
Malaysia	4.2	-0.4 to -5.9	0.1 to -0.4	0.3 to 4.2
Myanmar	11.5	-0.2 to -1.1	-0.2 to -2.7	0.0 to 1.3
Nepal	3.4	-0.0 to -0.5	-0.0 to -0.5	0.0 to 0.3
Pakistan	19.3	-0.2 to -15.8	-0.2 to 0.5	0.5 to 1.8
Philippines	14.6	-0.5 to -8.8	-0.1 to -2.7	0.4 to 1.0
Sri Lanka	3.4	-0.0 to -1.8	0.0 to -0.6	0.0 to 0.4
Taiwan	30.5	-0.0 to -0.1	0.0	0.0
Thailand	19.6	-1.5 to -19.6	-1.6 to -11.1	-0.3 to 3.7
Vietnam	4.0	-0.1 to -4.0	-0.1 to -2.2	0.1 to 0.7
Total	**560.7**	**-9.9 to -218.8**	**-5.9 to -61.6**	**9.0 to 35.8**

*Total projected value of agricultural GDP in 2100 at current climate.

Endnote

[1] Global Environment Facility (GEF) and the World Bank are funding a cross-sectional study being led by Rashid Hassan of CEEPA, Pretoria, South Africa of 11 African countries. The World Bank is also funding a cross-sectional study led by Emilio Ruz, Procandino, Montevideo, Uruguay of 7 countries across South America.