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Agricultural Impact of Climate Change: A General Equilibrium Analysis with Special Reference to Southeast Asia

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Abstract

Capitalizing on the most recent worldwide estimates of the impacts of climate change on agricultural production, this paper assesses the economic effects of climate change for Southeast Asian countries through 2080. The results suggest that the aggregate impacts of agricultural damages caused by climate change on the global economy are moderate. However, the uneven distribution of productivity losses across global regions would bring significant structural adjustments in worldwide agricultural production and trade, ultimately leaving the developing world as a net loser. With the anticipated declining agricultural share in the economy, a reduction in agricultural productivity would have small, but non-negligible negative impacts on Southeast Asia's economic output. However, the expected increase of crop import dependence in the coming decades would make most Southeast Asian economies suffer more welfare losses through deteriorated terms of trade. Depending on a country's economic structure, the negative effects are expected to be less for Singapore and Malaysia, but greater for Philippines, Indonesia, Thailand, and Viet Nam. For Southeast Asia to cope with the potential agricultural damages arising from the expected changes in climate the region must concentrate on reversing its current trend of declining agricultural productivity.

JEL Classification: D58, C68, Q54, Q11

Contents

1. INTRODUCTION

Recent scientific research has concluded that the increased atmospheric concentration of greenhouse gases will have significant impacts on the Earth's climate in the coming decades. Assuming no emission control policies, the Intergovernmental Panel of Climate Change (IPCC) predicted that average global surface temperatures will increase by 2.8ºC on average during this century, with best-guess increases ranging from 1.8 and 4.0ºC (IPCC 2007a). Global warming would alter natural climate and environmental systems in many ways, leading to an increased frequency of extreme weather events, rising sea levels, a reversal of ocean currents, and changes in precipitation patterns. These changes could impact social-economic activities, with serious implications for the well being of humans long into the future.

Agriculture is one of the most vulnerable sectors to the anticipated climate change. Despite the technological advances in the second half of 20th century, including the Green Revolution, weather and climate are still key factors in determining agricultural productivity in most areas of the world. The predicted changes in temperatures and rainfall patterns, as well as their associated impacts on water availability, pests, disease, and extreme weather events are all likely to affect substantially the potential of agricultural production. Literature on the economics of climate change suggests that although global crop production may be boosted slightly by global warming in the short term (before 2030), it will ultimately turn negative over the longer term (Bruinsma 2003; IPCC 2007b). Moreover, the impact of climate change on agricultural production is unlikely to be evenly distributed across regions. Low latitude and developing countries are expected to suffer more from the agricultural effects of global warming, reflecting their disadvantaged geographic location, greater agricultural share in their economies, and limited ability to adapt to climate change. In contrast, crop production in high latitude regions will generally benefit from climate change. In a recent global comprehensive estimate for over 100 countries, Cline (2007) predicted that global agricultural productivity would fall by 15.9% in the 2080s if global warming continues unabated, with developing countries experiencing a disproportionately larger decline of 19.7%.

Agriculture plays an important role in Southeast Asia, contributing to more than 10% of gross domestic product (GDP) in most regional economies, and providing jobs for over one third of the working population in the region. As is the case in other developing regions of the world, nearly three fourths of the poor in Southeast Asia reside in rural areas, and a large majority of them are dependent on agriculture. Consequently, agricultural development has important implications for the reduction of poverty in Southeast Asia. Moreover, the increased exposure of Southeast Asia's agriculture sector to international trade means that any climate change-related shocks in international markets for agricultural products will be easily transmitted to the region through trade channels.

This paper used a dynamic computable general equilibrium (CGE) model of the global economy to investigate the potential impacts of climate change on agriculture and the world economy, with a special focus on Southeast Asia. The CGE model is an economy-wide model that elucidates interactions among industries, consumers and governments across the global economy. The detailed region and sector disaggregation of the model makes it possible to capture the spillover effects of sector- or country-specific shocks. Climate changes impact an economy directly through the effects on that economy's agricultural outputs and indirectly through changes in the agricultural production of other countries. We established this distinction by comparing the scenario of agricultural productivity shrinkage in Southeast Asia to the scenario of agricultural productivity shrinkage in the rest of the world. The role of productivity growth in adapting to the climate change was also examined.

Section 2 of this paper discusses the relationship between climate change and agricultural production by reviewing the existing literature in which various modeling approaches have been employed to estimate the impacts of climate change on agricultural productivity. We then describe the specifications of the CGE model used in this study in Section 3. Section 4 assesses the impacts of climate change-induced global agricultural productivity decline on agricultural production, trade and macro-economy. The final section offers conclusions.

2. CLIMATE CHANGE AND AGRICULTURE

Climate can affect agriculture in a variety of ways. Temperature, radiation, rainfall, soil moisture and carbon dioxide (CO_2) concentration are all important variables to determine agricultural productivity, and their relationships are not simply linear. Current research confirms that there are thresholds for these climate variables above which crop yields decline (Challinor et al. 2005; Proter and Semenov 2005). For example, the modeling studies discussed in recent IPCC reports indicate that moderate to medium increases in mean temperature (1–3ºC), along with associated CO_2 increases and rainfall changes, are expected to benefit crop yields in temperate regions. However, in low-latitude regions, moderate temperature increases (1–2ºC) are likely to have negative yield impacts for major cereals. Warming of more than 3ºC would have negative impacts in all regions (IPCC 2007b).

The interaction of temperature increases and changing rainfall patterns determines the impact of climate change on soil moisture. With rising temperatures, both evaporation and precipitation are expected to increase. The resulting net effect on water availability would depend on which force is more dominant. The IPCC reports project that by the middle of the 21st century, water availability will increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics (IPCC 2007b). Some regions that are already drought-prone may suffer more severe dry periods.

Increases in atmospheric CO_2 concentration can have a positive impact on crops yields by stimulating plant photosynthesis and reducing the water loss via plant respiration. This carbon fertilization effect is strong for so-called C3 crops,[1] such as rice, wheat, soybeans, fine grains, legumes, and most trees, which have a lower rate of photosynthetic efficiency. For C4 crops like maize, millet, sorghum, sugarcane, and many grasses, these effects are much smaller. Other factors such as a plant's growth stage, or the application of water and nitrogen, can also impact the effect of elevated CO_2 on plant yield. Recent research based on experiments with the free air concentration enrichment method suggests a much smaller CO_2 fertilization effect on yield for C3 crops and little or no stimulation for C4 crops, in comparison with past estimates from studies conducted under enclosed test conditions (Long et al. 2005, 2006). Based on analysis of recent data, the IPCC reports suggest that yields may increase by 10–25% for C3 crops and by 0–10% for C4 crops when CO_2 levels reach 550ppm (IPCC 2007b). However, as a number of limiting factors were not included in the modeling and experiment analysis, considerable uncertainties still surround the estimates of carbon fertilization effect.

Besides temperature and carbon concentration, some other ecological changes brought on by global warming will have an impact on agriculture. For example, the patterns of pests and diseases may change with climate change, leading to reductions in agricultural production. Moreover, agricultural productivity will be depressed by increased climate variability and increased intensity and frequency of extreme events such a drought and floods. These factors further contribute to the difficulties in estimating the impacts of climate change on agricultural productivity.

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[1] Crops are generally divided into two groups, C3 and C4, depending on their efficiency of use of CO_2 during photosynthesis.

Quantitative estimates of the agricultural impact of climate change have predominantly relied on three approaches: crop simulation models, agro-ecological zone (AEZ) models, and cross-section (Ricardian) models. Crop simulation models draw on controlled experiments where crops are grown in field or laboratory settings simulating different climates and levels of CO_2 in order to estimate yield responses of a specific crop variety to certain climates, and other variables of interest.[2] These models do not include farmer adaptation to changing climate conditions in the estimates. Consequently, their results tend to overstate the damages of climate change to agricultural production (Mendelsohn and Dinar 1999). The second approach, AEZ analysis, combines crop simulation models with land management decision analysis, and captures the changes in agro-climatic resources (Darwin et al. 1995; Fishcher et al. 2005). AEZ analysis categorizes existing lands by agro-ecological zones, which differ in the length of growing period and climatic zone. The length of growing period is defined based on temperature, precipitation, soil characteristics, and topography. The changes of the distribution of the crop zones along with climate change are tracked in AEZ models. Crop modeling and environmental matching procedures are used to identify crop-specific environmental limitations under various levels of inputs and management conditions, and provide estimates of the maximum agronomically attainable crops yields for a given land resources unit. However, as the predicted potential attainable yields from AEZ models are often much larger than current actual yields, the models may overestimate the effects of autonomous adaptation. Cline (2007) observed that AEZ studies tend to attribute excessive benefits to the warming of cold high-latitude regions, thereby overstating global gains from climate changes.

The Ricardian cross-sectional approach explores the relationship between agricultural capacity (measured by land value) and climate variables (usually temperature and precipitation) on the basis of statistical estimates from farm survey or country-level data. This approach automatically incorporates efficient climate change adaptations by farmers. The major criticisms of the Ricardian approach are its ignorance of price changes and that it fails to fully control for the impact of other variables that affect farm incomes (Mendelsohn and Dinar 1999; Cline 1996).

Cline (2007) used both Ricardian statistical models and crop models to develop a set of consensus agricultural impact estimates through the 2080s for over 100 countries. He first developed geographically detailed projections for changes in temperature and precipitation through the 2080s based on a baseline emission projection from the IPCC's Emission Scenarios. Next, these climatic change projections were applied to the agricultural impact models to assess the effects of climate change on agricultural productivity. The final consensus estimates were the weighted average of the Ricardian estimates and the crops model estimates. Table 1 presents the major results of Cline's estimates.

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[2] For more information on crop simulation models, see Adams et al. (1990), Rosenzweig (1993), and Rosenzweig and Parry (1994).

Table 1: Projected Climate Changes and Their Impacts on Agricultural Productivity in the 2080s

Climate variables	Land area	Farm area
Base levels		
Temperature (ºC)	13.15	16.2
Precipitation (mm per day)	2.2	2.44
By 2080s		
Temperature (ºC)	18.1	20.63
Precipitation (mm per day)	2.33	2.51
Impacts on agricultural productivity (%)	Without carbon fertilization effect	With carbon fertilization effect
World (output weighted)	-15.9	-3.2
Industrial countries	-6.3	7.7
Developing countries	-21	-9.1
Africa	-27.5	-16.6
Asia	-19.3	-7.2
Middle East and North Africa	-21.2	-9.4
Latin America	-24.3	-12.9

Source: Cline (2007).

The climate models used in Cline's study predicted that under the IPCC's scenario A2,[3] atmospheric concentrations of CO_2 would increase to 735ppm by 2085 from a current level of 380ppm, and that global mean temperature would rise by 3.3ºC. Land areas would warm more than oceans, with the average surface temperature increasing by 5.0ºC weighting by land area and 4.4ºC weighting by farming area. By the 2080s, global agricultural productivity would decline by about 3% with carbon fertilization effect and by about 16% if the carbon fertilization effect did not materialize. These losses would be disproportionately concentrated in developing countries, which would suffer losses of 9% with carbon fertilization effect and 21% without carbon fertilization effect, in contrast to an 8% gain (with carbon fertilization effect) and 6% loss (without carbon fertilization effect) in industrial countries. The detailed estimates by country and region reported in Table 2 indicate that South Asia and Africa would be the two regions most harmed by climate change. In Southeast Asia, the damages of climate change to agriculture would also be severe, ranking from 15.1% for Viet Nam to 26.2% for Thailand if carbon fertilization effect did not materialize.

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[3] Scenario A2 is the second highest emission scenario among the six scenarios considered by the Third and Fourth Assessments Reports of the IPCC. Cline (2007) argued that scenario A2 should be viewed as an intermediate emission path as IPCC scenarios are biased towards underestimation of the future emission.

Table 2: Regional Impacts of Climate Change on Agricultural Productivity in the 2080s

	Without Carbon Fertilization Effect	With Carbon Fertilization Effect
Canada	-2.2	12.5
US	-5.9	8
Latin America	-23.6	-12.2
EU	-5.5	8.6
Australia	-26.6	-15.6
New Zealand	2.2	17.5
PRC	-7.2	6.8
Japan	-5.7	8.4
Korea	-9.3	4.3
Indonesia	-17.9	-5.6
Malaysia, Singapore	-22.5	-10.9
Philippines	-23.4	-11.9
Thailand	-26.2	-15.1
Viet Nam	-15.1	-2
India	-38.1	-28.8
Other South Asia	-25.3	-14.1
Central Asia	-0.8	13.9
Rest of Asia	-25.6	-15.6
Sub-Sahara Africa	-28.3	-17.6
Rest of the world	-14.5	-1.7

Source: Author's calculation based on Cline (2007).

3. THE MODEL

The model used in this study was a dynamic, CGE model of the global economy. It was built on the LINKAGE model developed at the World Bank (van der Mensbrugghe 2005; Anderson, Martin, and van der Mensbrugghe 2006), and has its intellectual roots in the group of multi-country applied general equilibrium models used over the past two decades to analyze the global trade and environmental issues (Shoven and Whalley 1992; Hertel 1997). This section describes the major features of the model.

Production in each economic sector was modeled using nested constant elasticity of substitution (CES) functions and constant returns to scale was assumed. There were three types of production structures, depending on activities. Crop sectors reflected the substitution possibility between extensive and intensive farming. Livestock sectors reflected the substitution possibility between pasture and intensive feeding. All other sectors reflected the standard capital-labor substitution.

The study assumed differentiation of products by regions of origin; i.e., the Armington assumption (Armington 1969). Top-level aggregate Armington demand was allocated between goods produced domestically and an aggregate import following a CES function. In the second level, the aggregate import was further disaggregated across the various trade partners using an additional CES nest. On the export side, it was assumed that firms treat domestic markets and foreign markets indifferently. Thus the law of one price would hold; i.e., the export price was identical to that of domestic supply.

Incomes generated from production were assumed to accrue to a single representative household in each region. Households maximized utility using An Implicitly Direct Additive Demand System (AIDADS) (Rimmer and Powell 1996). AIDADS is a demand system which allows the marginal budget shares to vary as a function of total expenditure. Recent work by Yu et al. (2004) has demonstrated the superiority of AIDADS over other demand systems in projecting food demand, especially for long-term projections involving a wide range of countries.

All commodity and factor markets were assumed to clear through prices. There are five primary factors of production: agricultural land, skilled labor, unskilled labor, capital, and natural resources. Agricultural land and the two types of labor were assumed to be fully mobile across sectors within a region. Some adjustment rigidities in capital markets were introduced through the vintage structure of capital, under which the "new" capital was fully mobile across a sector, while "old" capital in a sector could be disinvested only when this sector was in decline. In the natural resource sectors of forestry, fishing, and mining, a sector-specific factor was introduced into the production function to reflect the resource constraints. These sector-specific factors were modeled using upward sloping supply curves. For other primary factors, stocks were fixed for any given year. The numeraire of the model was defined as the manufactured export index of the high-income countries, which was held fixed.

The model was recursive dynamic, beginning with the base year of 2004 and being solved annually through 2080. Dynamics of the model were driven by exogenous population and labor growth and technological progress, as well as capital accumulation, which was driven by savings. Population and labor force projections were based on the United Nations' (UN) medium variant forecast. As the UN population forecast covers only 2005–2050, the growth rates of population and labor forces were assumed to decline exponentially at a rate of 2% per year. The household savings rate was set as a function of economic growth and demographic changes, which were drawn from a global cross-country analysis by Bosworth and Chodorow-Reich (2006). Technological progress was assumed to be labor-augmented, so the model could reach a steady state in the long run.

The model was calibrated to the Global Trade Analysis Project (GTAP) version 7, using twenty-one countries/regions and nineteen sectors. There was a heavy emphasis on agriculture and food, which account for ten of the nineteen sectors. Six Southeast Asian countries are explicitly modeled as individual regions in the model.

4. SIMULATIONS AND RESULTS

A baseline scenario from 2004–2080 was constructed under the assumption that there would be no climate change impacts on economic activities. The baseline scenario provided a reference growth trajectory for examining the effects of climate change-induced agricultural damages. In the baseline, GDP growth up to 2013 was exogenous, derived from the International Monetary Fund's (IMF) medium baseline projection. For each region, an economy-wide, labor-augmented productivity grew endogenously over the simulation period of 2005–2013 to match the pre-specified GDP growth path. After 2013, the productivity growth rate was held fixed at the level of 2013 up to 2040, and then declined by 1% per year afterwards. The supply of agricultural land was assumed to be fixed in high-income countries and to grow by 0.12% annually in Asia and 0.2% annually in Latin America, Africa and other regions.

The baseline scenario projected a high rate of world economic growth over the next seven decades, with global GDP growing by an average of 3.1% per year over the period of 2010–2050, and slowing down to 2.5% per year between 2050 and 2080. The average annual growth of Southeast Asia over 2010-2080 was 1.1 percentage points higher than that of the world average, and its share in global GDP increased from less than 2% in 2004 to 4.1% in 2080. Growth was accompanied by rapid structural change in developing countries. The share of agricultural value added, in volume terms, would decline from nearly 10% in 2004 to 3.8% in 2080 in Southeast Asia. Even though some Asian countries like India and Viet Nam had trade surpluses in agricultural products in the base year, they would become net importers in the next decade because of the combined effects of economic growth, industrialization, and land constraints. However, Thailand, the Philippines and Central Asia were expected to maintain surpluses in agricultural trade over the projection period.

In the counterfactual scenario with agricultural damages, it was assumed that productivity in four crop agricultural sectors (paddy rice, wheat, other grains, and other crops) would be lower than that in the baseline scenario because of the projected changes in climate. Crop productivity shocks, which were Cline’s estimates without carbon fertilization effect as reported in the first column of Table 2, were imposed gradually over 2009–2080. The crop productivity shocks were assumed to be uniform across sectors. The impacts of climate change were assessed by a comparison of the counterfactual scenario with the baseline scenario.

4.1 Global Impacts

Table 3 presents the simulated impacts on global welfare, GDP, and agricultural production, which are reported as percentage deviation from the “no damage” baseline. The table indicates that global real GDP would decline by 1.4% by 2080 as a result of the predicted impacts of climate change on agricultural productivity. India would suffer the largest GDP loss of 6.2%, followed by Sub-Sahara Africa, other South Asian countries, and Central Asia. Although the estimated productivity losses from Cline’s study were modest for the overall Central Asia region, high agricultural shares in some of the region’s national economies account for the relatively large loss of GDP in Central Asia. Southeast Asia would see a drop in real GDP of 1.4%, similar to that of the world’s average. New Zealand is the only region in the model that would experience a real GDP increase in response to the climate change-induced global agricultural adjustment.

Table 3: Impact on Global Welfare and Production, 2080
(% change)

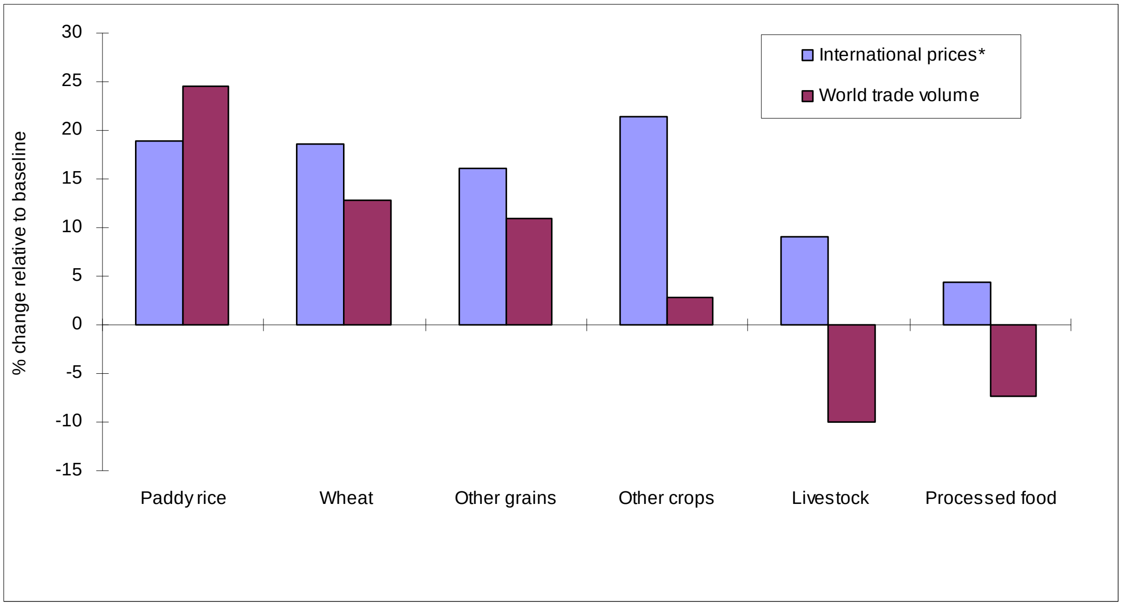
	GDP	Welfare (EV as % of GDP)	Terms of Trade	Sectoral Output						
				Crop	Agriculture				Livestock	Processed food
					Paddy rice	Wheat	Other grains	Other crops		
World	-1.4	-1.3		-7.4	-9.1	-6.8	-7.8	-7.3	-5.9	-4.6
Australia	-0.3	-0.6	-0.4	-42.9	-12.8	-66.7	-42.5	-40.6	7.1	-0.2
New Zealand	0.2	1.5	2.7	140.6	31.4	38.2	12	156.2	-11	-3.8
Japan	0	-0.2	-0.4	1.9	-4.7	6.8	43.7	3.5	0.5	2.2
PRC	-1.3	-1.1	-0.2	-0.1	-0.5	4.2	-0.5	-0.2	-1.9	-3.6
Korea	-0.2	-0.6	-0.5	-5.1	-4.8	0.4	-10.6	-5.6	-1.4	-0.4
Southeast Asia 6*	-1.4	-1.7	-0.4	-17.3	-16.5	-36.3	-12.6	-17.9	-1.4	-4.5
India	-6.2	-5.2	-1.8	-24	-11.5	-24.7	-36.7	-24.1	-19.1	-29.1
Rest of South Asia	-1.9	-2.7	-4.1	-19.5	-16	-29	-24.6	-19.2	-3.1	-10.8
Central Asia	-1.9	-1.5	1.8	49.7	12.8	66.9	5.1	48.9	-10.9	-0.5
Rest of Asia	-0.4	-0.7	-0.4	-18.4	-20.8	-46.9	-40.5	-14.3	1	-5.2
Canada	-0.2	0.2	0.8	22.1	0.9	17.7	5.1	34.6	-15.3	-1.6
US	-0.1	0	0.4	5.1	21.3	10.5	0.9	6.9	-7	-0.3
EU	-0.2	0	0.4	21.4	12.9	32	17	20.7	-10.1	3.6
Latin America	-1.7	-2.1	-0.8	-24.3	-12.2	-40.5	-23.4	-24.3	-2.7	-5.2
Sub-Sahara Africa	-2.2	-3.2	-1.3	-29.6	-23.6	-61.6	-22.2	-31.3	-0.8	-4.3
Rest of the world	-1	-1.2	-0.5	-10.1	-5	-16.1	-13.1	-7.9	-4.7	-2.1

*Including Indonesia, Malaysia, Philippines, Singapore, Thailand and Viet Nam.

Source: CGE model simulation results.

Aggregate welfare effects, which were measured by the sum of equivalent variation of the households and real investment, generally followed the changes in real GDP. However, international price adjustment played a role in determining the distribution of global welfare losses. After incorporating agricultural damage, international prices of crop products were expected to increase by 16–22% relative to the price of manufacturing exports of high-income countries, reflecting the inelastic demand structure of agricultural products (Figure 1). The resulting changes in terms of trade would benefit net agricultural exporting countries, but damage net agricultural importing countries. As shown in the second column of Table 3, New Zealand's welfare gained as much as 1.5% of GDP, much higher than its GDP expansion, due to its improved terms of trade. In Canada and the European Union (EU), improvements in terms of trade more than offset the direct losses from agricultural productivity reduction, leading to slight welfare gains. Central Asia would benefit from changes in terms of trade. However, for other regions the deterioration of their terms of trade would amplify the effects of agricultural damage. Generally, the resulting welfare losses would be larger than GDP decline.

Figure 1: Impacts of Climate Change on International Prices and World Trade of Agricultural Goods, 2080



*Prices are deflated by price index to manufacturing exports of high income countries.

The detailed world agricultural production simulation results suggest that global crop production would shrink by 7.4% by 2080, which is less than half of Cline's estimate. This is partly due to the declining weight of developing countries, which would be more adversely impacted by climate change than developed countries, in global agricultural production over 2004–2080. In Cline's original estimate, agricultural output values in 2003 were used as weights to obtain the estimate for global impact. The reallocation of resources across sectors also partially offset the direct impact of agricultural productivity slowdown, contributing to the smaller magnitude of crops output contraction. In regions where the impacts on agricultural productivity are small or positive, crop production would expand. New Zealand's crop output would increase the most, by 141%, because of its higher agricultural productivity under climate change and relatively small crop share in its economy. Central Asia, the EU, US, and Japan, would see crop production rise by 5–50% in response to the crop price hikes. In general, the crop production expansion would come at the expense of the livestock sector, with land and other production resources being diverted toward crops sectors.

Crop production in South Asia, Latin America and Sub-Sahara Africa would be the most adversely affected by climate change. The decline of crop output in Southeast Asia would be more moderate, but still significant at 17.3% by 2080. The negative impact of climate change on crop production in East Asian countries would be modest, ranging from 0.1% for the People's Republic of China (PRC) and 5.1% for the Republic of Korea.

As downstream sectors of crop agriculture, the production of livestock and processed food would also decline with rising input costs. World output of livestock and processed food would shrink by 5.9% and 4.6%, respectively. Again, cross-region variation exists. The production of these two sectors would drop significantly in India, but rise in Japan. Australia and the EU would also see output expansion of livestock and processed food, respectively, reflecting their stronger comparative advantage in these products as a result of climate change. The shifting comparative advantage induced by climate change would have important implications for international patterns in agricultural commodities. Global trade in crop agriculture would increase, but trade in livestock and processed food would shrink (Figure 1).

4.2 Impacts on Southeast Asian Countries

Table 4 reports the macroeconomic effects of the projected slowdown in agricultural productivity on six Southeast Asian countries. It is not surprising that the impact on real GDP was very modest for Singapore, given the small agricultural sector in its economy. However, the GDP contractions in Thailand, Viet Nam, and the Philippines were much more significant, ranging from 1.7% to 2.4%. The welfare losses were generally larger than GDP reductions, except for Viet Nam, which would experience a slight improvement in terms of trade. Both consumption and investment would decline compared to the baseline scenario. The incorporation of agricultural productivity damage would hamper agricultural exports of Southeast Asian countries, leading to a reduction of their aggregate exports. Consequently, aggregate imports would also decline to maintain the current account balance.

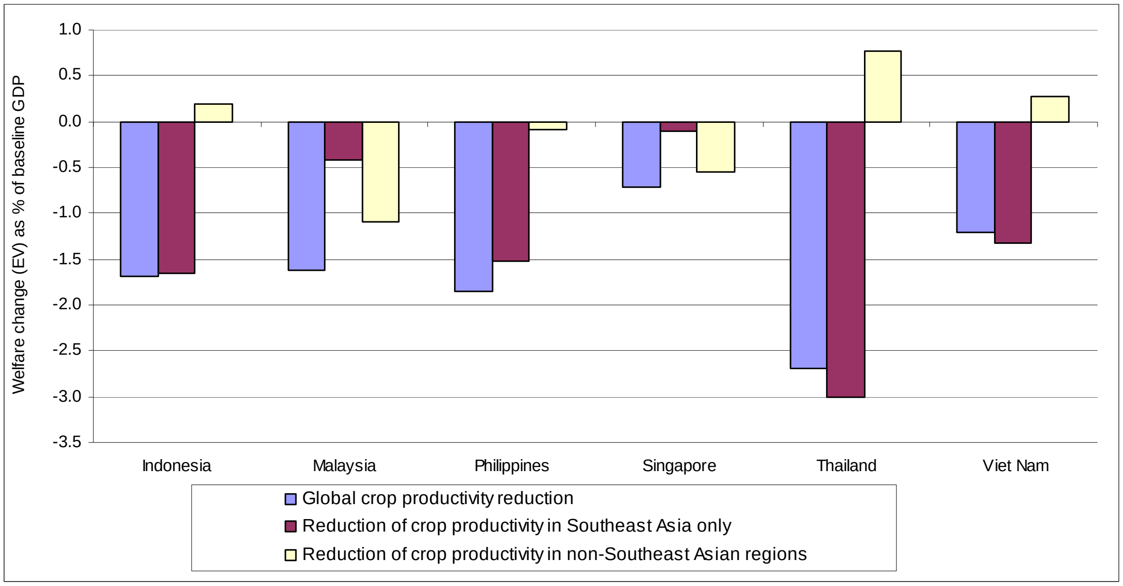
Table 4: Macro-economic Impacts of Climate Change on Southeast Countries, 2080 (% change)

	Indonesia	Malaysia	Philippines	Singapore	Thailand	Viet Nam
Real GDP	-1.4	-0.9	-1.7	-0.3	-2.4	-1.7
Welfare (EV as % of GDP)	-1.7	-1.6	-1.9	-0.7	-2.7	-1.2
Terms of Trade	-0.5	-0.7	-0.9	-0.2	-0.3	0.1
Consumption	-1.9	-1.8	-2.5	-0.8	-3	-1.9
Investment	-0.9	-2.2	-2.4	-0.8	-2.5	-0.9
Exports	-0.9	-0.7	-0.7	0	-2.5	-1.7
Imports	-1.4	-1.5	-1.6	-0.3	-2.7	-1.5
Factor prices						
Capital	-2	0.3	0.2	-0.2	-0.9	-1.5
Unskilled labor	-1.5	-1.6	-2	-1	-4	-1.6
Skilled labor	-2.8	-1.8	-2.6	-1.2	-3.3	-2.3
Land	9.6	4.9	0.9	-8.7	-4.3	3.9

Source: CGE model simulations.

To get a sense of the contribution of agricultural production slowdown in other regions to welfare losses in Southeast Asia, we ran two additional scenarios in which the climate change-induced agricultural productivity shocks were applied to Southeast Asia and other regions separately. The welfare effects of these two scenarios are presented in Figure 2. It is clear that that domestic productivity reduction would be the major source of welfare losses of Indonesia, Philippines, Thailand, and Viet Nam. Actually, Indonesia, Thailand, and Viet Nam would benefit slightly from the agricultural production contraction in rest of the world. However, in Malaysia and Singapore the shocks from rest of the world would dominate total welfare effects because of their small agricultural sectors and their high dependence on imports for agricultural supply.

Figure 2: Decomposition of Welfare Impacts, 2080



The pattern of changes in production factor gains and losses is specific to each country. In general, following negative agricultural productivity shocks, the average return to agricultural factors of production would rise relative to non-agricultural production factors, because of the inelastic demand of agricultural products. This is evident from the smaller wage decline received by unskilled labor than skilled labor, and the rising rate of return to agricultural land in most Southeast Asian countries. Singapore and Thailand are two exceptions with declining rates of return to land, mainly due to their high use of intermediate crop inputs in their crop production.

The impact on agricultural and food production and trade is shown for each Southeast Asian country in Table 5. All countries would see output losses in all crops sectors, except for rice production in Malaysia. Livestock output would increase in Thailand and Singapore, partly because declining land returns in the crops sectors would lead to the conversion of some arable lands to pastures. The production of the processed food sector would expand in Malaysia and Singapore, reflecting their relatively higher efficiency in the use of crop inputs in production.

Table 5: Impacts on Agricultural Production and Trade in Southeast Countries, 2080 (% change)

	Indonesia	Malaysia	Philippines	Singapore	Thailand	Viet Nam
Output						
Crop agriculture	-13.4	-13.4	-22.5	-47.6	-29.4	-11.1
Rice	-15	1.6	-11.9		-36.3	-13.6
Other grain	-9.9	-52.6	-13		-26.5	-0.1
Other crops	-13.4	-31.1	-25.6	-47.6	-27.4	-7.4
Livestock	-4.4	-2.6	-0.3	105.1	12.6	-5
Processed food	-6.4	5.5	-4.2	12.7	-0.9	-14.2
Exports						
Crop agriculture	-25.3	-49.2	-56.7	-49.2	-59.4	10.3
Rice	-17.1	-51.2	-73.2		-41.5	46.8
Other grain	-39.9	-74.6	-48.8		-58.2	-11.2
Other crops	-25.1	-49.1	-56.7	-49.2	-60.3	9.8
Livestock	1.9	21.9	57.5	117.6	82.1	20.6
Processed food	-7.3	4.8	-7.4	13.8	-1	-21.6
Imports						
Crop agriculture	8.7	4.7	24.3	-0.4	11.9	-9.3
Rice	15	50.6	34.1	1.5	13.9	32.8
Wheat	-2.7	15.6	17.7	2.2	4	-15.3
Other grain	30.8	3.3	42.8	7.4	69	-27.6
Other crops	13.6	3.2	34.1	-0.6	12.1	-6.8
Livestock	-9.9	-16.4	-25.2	-4.2	-24.3	-12.2
Processed food	-13.6	-14	-12.4	-1.9	-16.1	-16.7

Source: CGE model simulations

As a result of the rising producer prices relative to other regions in the world, the crop exports would shrink significantly for all Southeast Asian countries except Viet Nam. Viet Nam would experience export expansion in rice and other crop products due to its stronger comparative advantage in crop production and smaller reduction in agricultural productivity relative to other Southeast Asia countries. Similarly, the imports of crop agricultural products would rise for Southeast Asian economies. As a consequence, the import dependence of Southeast Asia's crops sector in 2080 would rise from 23.3% of baseline to 25.8% under the climate change scenario. Southeast Asia's grain self-sufficiency ratio in 2080 would decrease by 2.4 percentage points to 84.1% (Figures 3 and 4).

Figure 3: Import Dependence of Crop Agriculture, 2010–80

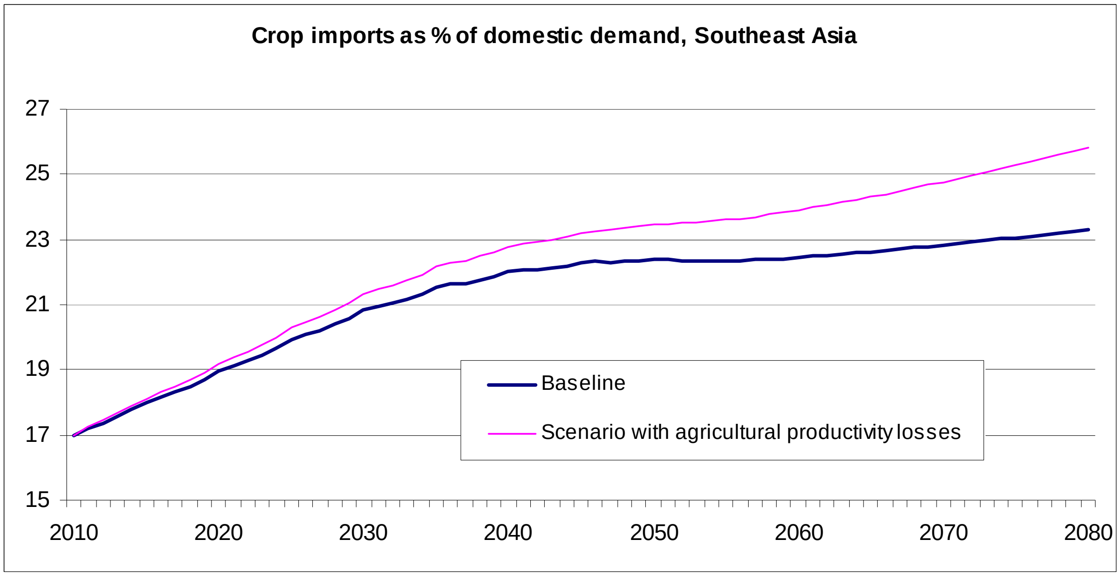
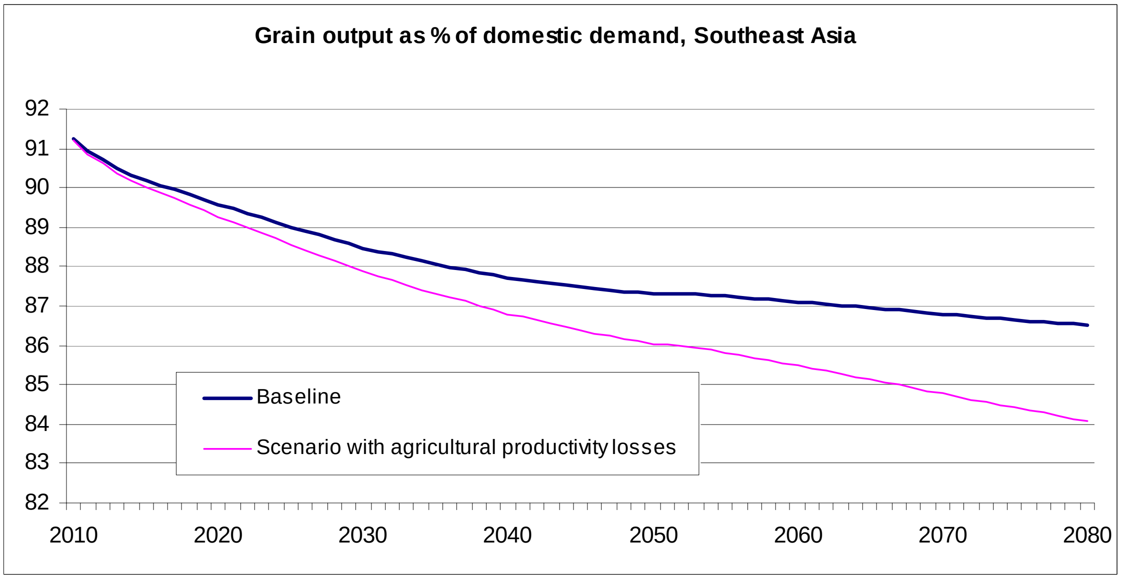


Figure 4: Grain Self-sufficiency Ratio, 2010–80



4.3 Sensitivity to the Assumption About Baseline Agricultural Productivity Growth

In the baseline scenario, agricultural productivity was assumed to grow at the same rate as the manufacturing and services sectors. However, in recent decades, there has been significant slowdown in agricultural technological progress. In the 1960s and 1970s, world grain yields rose at an annual rate of 2.7%. This rate has slowed to 1.6% in the past quarter century. The languishing agricultural productivity growth is especially evident in Southeast Asia. A recent global estimate of agricultural productivity by Ludena et al. (2007) shows that total factor productivity (TFP) growth rates in the crops sector in East and Southeast Asia have lowered from 0.99% in 1970s to -0.67% in 1980s and -0.48% in 1990s. This negative productivity growth pattern is expected to continue for the next two decades as a result of low levels of expenditure on research and development. For example, Anderson, Pardey, and Roseboom (1994) report an agricultural research intensity (research expenditures as a share of agricultural GDP) for the Asia and Pacific region outside of the PRC and India in the early 1980s of 0.32. This is about one sixth the research intensity in developed countries and only half that in Sub-Saharan Africa (Hertel et al. 2008).

Given the considerable downside uncertainty to our assumed baseline agricultural productivity growth for Southeast Asia, we developed an alternative baseline scenario with slower productivity growth in Southeast Asia's agricultural sectors—specifically, one percentage point lower on annual average than the original baseline, thereupon repeating the scenario of incorporating agricultural damages. The key simulation results are presented in Table 6. Since the results for non-Southeast Asia regions are little changed from our original results, only revised results on GDP and welfare of Southeast Asian countries are reported.

Table 6: Impacts of Climate Change under Alternative Assumption about Baseline Agricultural Productivity Growth, 2080 (% change relative to alternative baseline)

	Real GDP	Welfare (EV as % of GDP)
Southeast Asia	-1.3	-2
Indonesia	-1.5	-2.4
Malaysia	-1	-1.8
Philippines	-1.7	-2.4
Singapore	-0.3	-0.7
Thailand	-2	-2.8
Viet Nam	-0.9	-1.4

Source: CGE model simulations.

Because of the slower agricultural productivity growth in Southeast Asia, its agricultural share of GDP in 2080 was smaller under the alternative baseline in comparison with the original baseline. This lead to more muted impacts on aggregate output, as shown in the first column of Table 6. However, because long-term agricultural import dependence was larger as a result of slower agricultural productivity improvement in the alternative baseline, most Southeast Asian economies were more vulnerable to the rise in world prices of agricultural products. Southeast Asian economies' losses in terms of trade, and thusly welfare, were generally larger. Therefore, the results from the alternative simulations suggested that agricultural technological progress would be important for Southeast Asia to cope with the potential risks from global climate change.

5. CONCLUSIONS

Climate change is an increasingly significant global challenge and its negative impacts have been already felt in some regions of the world. This paper uses a global CGE model to assess the long term economic effects of climate change. The results suggest that the aggregate impacts of agricultural damages caused by climate change on the global economy are moderate. However, the impacts are not evenly distributed across the world. Developing countries would bear disproportionately large losses arising from climate change. Some significant adjustments in global agricultural production and trade, and consequently the distribution of income, may be accompanied by the changes of climate.

Southeast Asia is an important agricultural producer and consumer and plays a major role in the world market via several agricultural products. With the anticipated decline in agriculture share of GDP, the aggregate output losses from climate change-related agricultural productivity reduction would be modest for most Southeast Asian countries. However, import dependence on crop products would rise for Southeast Asia in the coming decades. This increasing exposure to world agricultural markets would make Southeast Asian economies suffer more welfare losses through the deterioration of terms of trade. This effect is especially significant for Malaysia and Singapore.

It is important to mention that there are great uncertainties in both the scientific projections and technical, social, and economic prospects. Therefore the results presented in this paper are only illustrative. Their purpose is to provide insights on the direction and order of magnitude of the potential medium- and long-term impacts, and reveal some key potential driving forces in determining these impacts. They do not represent forecasts for the future.

One major uncertainty is the technological progress in agriculture. Agricultural productivity growth has been, and will remain to be, the most important line of defense for global food security. However, in the past two decades, productivity gains from the Green Revolution have shown signs of being exhausted. If the rising demand of agricultural products, driven by population and income growth, runs a close race with technological progress in the future, the impacts of agricultural damage arising from climate change could be substantial (Zilberman et al. 2004; Cline 2007). This is especially pronounced in Southeast Asia, where productivity growth in the crop sector has been negative since 1980. Reversing this trend of declining agricultural productivity would be an important component for a Southeast Asian strategy to cope with the potential risks from the expected changes in climate.

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