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Climate Change and Agriculture: Economic Impacts

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Agriculture is arguably the most important sector of the economy that is highly dependent on climate. A large body of scientific data and models have been developed to predict the impacts of the contemporary and future climate. Since the first IPCC Assessment Report was published in 1990, substantial efforts have been directed toward understanding climate change impacts on agricultural systems. The resulting advances in our understanding of climate impacts have come from the collection of better data, the development of new methods and models, and the observation of actual changes in climate and its impacts. Such knowledge is critical as we contemplate the design of technologies and policies to mitigate climate change and facilitate adaptation to the changes that now appear inevitable in the next several decades and beyond.

This article briefly summarizes some of the key findings from the research on agricultural impacts of climate change, based on the recent IPCC Assessment Reports published in 2001 and 2007, and other recent work such as the recent U.S. assessment published in 2002 and the Council for Science and Technology report in 2004. In the remainder of this article, I discuss the substantial uncertainties that remain about actual and potential impacts of climate change on agriculture and its economic consequences. The paper concludes with some observations about linkages from impacts to policy.

The Current State of Knowledge

Early research on agricultural impacts led to some rather dire predictions of adverse impacts of climate change on food production, and the public perception that climate change may lead to global food shortages continues today. Although state-of-the-art at the time, the early predictions involved relatively simple data and methods, typically estimating the effects of increases in average annual temperature on yields of a limited number of crops at a limited number of locations, and extrapolating the typically negative effects to large regions.

With advances in data and models, most assessments of the impacts of climate change on agriculture predict that the world's ability to feed itself is not threatened by climate change. The most recent IPCC report on Impacts and Adaptation finds that climate change is likely to have both positive and negative impacts on agriculture, depending on the region and the type of agriculture. Overall, the report predicts that during the present century there will be a "marginal increase in the number of people at risk of hunger due to climate change." (Easterling et al. 2007, p. 275). However, research also shows that this finding should not lead to complacency, as analysis also suggests that some of the poorest and most vulnerable regions of the world are likely to be impacted negatively, and in some cases, severely.

One of the most important advances made in response to these early studies was to recognize that economic agents – in this case, farmers and the various private and public institutions that support agriculture – would adapt to climate changes in ways that would tend to mitigate negative impacts and take advantage of positive impacts. Another important advance in research was to recognize that there would be substantially different local, regional and global impacts. As data and modeling capability has improved, it has become increasingly clear that there are likely to be substantial adverse changes in some particularly vulnerable regions, such as in the semi-arid tropics, but there is also likely to be positive changes in the highland tropics and in temperate regions (Parry et al 2004). As a result, the adverse effects in some regions are likely to be reduced through international trade with other regions that have been positively impacted. Collectively the regional and global impacts are not likely to be large, and may even prove to be positive.

Impacts at the farm level include changes in crop and livestock productivity, which in turn will lead to changes in the most profitable production systems at a given location. Research suggests that in highly productive regions, such as the U.S. Corn Belt, the most profitable production system may not change much, but in transitional areas such as the "ecotone" between the Corn Belt and the Wheat Belt, substantial shifts in crop and livestock mix, in productivity, and in profitability may occur. Such changes may be positive, for example if higher temperatures in the northern Great Plains were to be associated with increased precipitation, so that corn and soybeans could replace the wheat and pasture that presently predominate. Such changes also could be negative, e.g., if already marginal crop and pastureland in the southern Great Plains became warmer and drier. In addition to changes in temperature and precipitation, another key factor in agricultural productivity is the effect of elevated levels of atmospheric CO2 on crop yields. Some estimates suggest that higher CO2 levels could increase crop productivity substantially, by 50% or more, although these effects are likely to be constrained by other factors such as water and soil nutrients, particularly in the developing countries.

In the case of the United States agriculture, aggregate economic impacts of climate change are not expected to be large, although there will be important regional differences. Recent studies estimate that crop yield changes will tend to be positive, with some almost doubling, but most increasing in the range of 10% to 40% during this century. Regionally, the northeast, south and southwest benefit the least, and the upper Midwest and coastal Northwest benefit the most. In contrast, livestock production is expected to be reduced by 5-7% due to higher average temperatures. Economic impacts associated with agriculture in the United States appear to be positive overall, with estimates ranging from an annual loss of $0.25 billion to a gain of about $5 billion, depending on the climate scenario used, with consumers generally gaining from the increased productivity and producers generally losing. The regional distribution of producer losses tends to mirror the productivity impacts, with the Corn Belt, the Northeast and south and southwest having the largest losses (McCarl 2008).

The most vulnerable regions of the world are undoubtedly in the tropics, particularly the semi-arid regions where higher temperatures and reduction in rainfall and increases in rainfall variability could have substantially negative impacts, and in coastal areas that are likely to be flooded due to sea level rise. These impacts are likely to be most severe in isolated regions where transportation costs are high, incomes are extremely low, and most rural households are highly dependent on agriculture for their livelihoods and for their food. These adverse impacts are predicted to be most severe in parts of sub-Saharan Africa, and other isolated areas in southwestern and south Asia. Low-lying areas in south Asia, Indonesia, and other poor coastal regions are also likely to be severely impacted due to their vulnerability to sea level rise and a limited ability to adapt by moving to higher ground or making investments to protect vulnerable areas. As a result, the risk of malnutrition and hunger in the developing world, particularly in the highly vulnerable regions, is predicted to increase during this century (Parry et al. 2004).

Uncertainties

Despite the substantial advances in understanding of climate change and its agricultural impacts, many uncertainties remain. Of particular concern are some of the limitations of the general circulation models used to simulate climate changes, and the way those limitations may affect the predicted impacts of climate change on agriculture. Some of these limitations suggest that the generally optimistic predictions outlined above for the temperate regions of the world, may be too sanguine.

On the supply side, a critical limitation of GCMs is their ability to predict changes in climate with the spatial resolution needed to model impacts on agricultural productivity. As discussed in the companion article in this issue by Adams and Peck, changes in water availability are especially difficult to predict, particularly on the site-specific basis needed to quantify agricultural yield impacts. A related uncertainty concerns impacts on pests which are also highly sensitive to site-specific environmental conditions, and are not well-represented in the models used to predict yield effects.

Another key uncertainty that affects impacts on all biological processes, including agriculture, is the rate of climate change. The higher the rate of climate change, the higher will be rates of obsolescence of all types of capital, both produced and natural, and thus the greater will be the costs of adaptation be for farmers, the private sector providing technology and inputs to farmers, and for government institutions responsible for infrastructure and policy. A related, critical supply-side uncertainty is how technology will evolve so as to reduce impacts and facilitate adaptation. In the past, it has taken about 15 years to develop a new crop variety. A key question is whether biotechnology will speed adaptation and reduce vulnerability to drought, extreme temperatures and pests.

Another uncertainty on the supply side is the environmental consequences of adapting to climate change. One example is the increased pressures on water resources in arid regions. Another example could be the increase in population density and agricultural intensity in highland tropical areas where soils are often fragile and vulnerable to degradation.

On the demand side, impacts of changes in consumer incomes and in market infrastructure will be critical but highly uncertain factors. Given the predicted modest impacts of climate change on global food supply, the rate of economic growth is likely to be a key determinant of people's vulnerability to climate change. If the recent high rates of economic growth in many developing regions continues, vulnerability to the impacts of climate change will be modest. However, those regions that are not participating in this growth, such as parts of sub-Saharan Africa and isolated mountain regions in central Asia and Latin America, are at risk of greater vulnerability if local food production decreases and becomes more variable.

Conclusions and Policy Implications

While it is clear that climate change will affect agriculture in important ways, the evidence from the past several decades of research suggests that the aggregate impacts will be relatively small, but there will be important regional impacts, particularly in the poorest, most vulnerable parts of the tropics. Given the growing evidence that climate changes are taking place and that there will be substantial impacts on agriculture, there is a clear and compelling need for agriculture to adapt as discussed in the companion paper by Rose and McCarl in this issue of *Choices*. In addition, evidence suggests that agriculture could play an important role in mitigating greenhouse gas emissions as discussed by Schneider and Kumar. Thus, two key policy questions are related to the roles the public sector should play in facilitating adaptation and mitigation as discussed in Metcalf and Reilly.

To the extent that change is relatively gradual, all indications are that farmers in the industrialized countries such as the United States will be able to adapt through farm-level changes in crop selection, crop management, and appropriate capital investments. Likewise, the private sector technology supply industry should be able to effectively anticipate and plan for needed adaptations of crops, livestock, machinery and related capital equipment. One area where there is a clear need for public sector involvement is in public infrastructure, particularly ports and related transport facilities that may be adversely impacted by sea-level rise and changes in the geographic distribution of production. The more rapid climate change is, however, the more likely that there will be a need for public investment in adaptation research to complement private sector investments.

In the developing countries, there are many reasons why farmers and institutions supporting the agricultural sector will be less able to adapt to climate change than farmers and the food industry in the industrialized world, particularly in the poorest and most vulnerable areas. On the research side, the existence of climate change reinforces the already compelling case that can be made for public sector investment in agricultural research and outreach, for investment in physical infrastructure and human capital, and for strengthening both private and public institutions that support agriculture and rural development. General economic development will also play an important role by providing farmers and rural households with sources of income that are less dependent on climate than agricultural sources of income.

For More Information

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