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Adaptation of Agriculture and the Food System to Climate Change: Policy Issues

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As defined by the Intergovernmental Panel on Climate Change, adaptation includes a set of actions to moderate harm or exploit beneficial opportunities in response to climate change. To date, little research has addressed public policy options to frame the nation's approach to adapt to a changing climate. In light of scientific evidence of extreme and unpredictable climate change, prudent policy requires consideration of what to do if markets and people fail to anticipate these changes, or are constrained in their ability to react. This issue brief is one in a series that results from the second phase of a domestic adaptation research project conducted by Resources for the Future. The briefs are primarily intended for use by decisionmakers in confronting the complex and difficult task of effectively adapting the United States to climate change impacts, but may also offer insight and value to scholars and the general public. This research was supported by a grant from the Smith-Richardson Foundation.

Policy Recommendations

Agriculture and the food system are likely to be substantially affected by both climate change and greenhouse gas emission policies. Although these sectors are dynamic and have demonstrated significant ability to adapt, many important related questions remain unanswered.

Studies have likely underestimated the impacts of climate change on agriculture and the food industry, and thus the importance of possible adaptations in mitigating the effects of the change. Assessments of agriculture have been limited in both scope and relevance because of limitations of the data and models used. For example, studies of production agriculture have neither adequately accounted for impacts of pests and diseases on crops nor adequately addressed impacts on important climate-sensitive sectors such as specialty crops, horticulture, livestock,

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poultry, and rangelands. The impacts of climate change on transportation infrastructure and the food processing industry, and the effects of greenhouse gas mitigation policies, have also not been studied adequately.

A comprehensive assessment of existing and likely future policies on agricultural adaptation is called for. Many existing policies are likely to affect the ability of U.S. agriculture and food sector to adapt to climate change. These include the following.

- Agricultural subsidy and trade policies reduce incentives for agricultural producers to respond to economic and environmental changes. Production and income insurance policies and disaster assistance provide some protection against climate variability and extreme events, but to some extent may also reduce the incentive for farmers and ranchers to take adaptive actions.
- Soil and water conservation policies and ecosystem services protect water quality and enhance ecosystem services such as wildlife habitat, but also may reduce flexibility to respond to climate change by reducing the ability to adapt land use and to respond to extreme events.
- Environmental policies and agricultural land use regulation, such as those addressing the location of animal production facilities and disposal of waste, are likely to affect the costs of adaptation.
- Tax policies affect agriculture in many ways, and could facilitate adaptation, for example, by treating capital depreciation and investments needed to offset greenhouse gas emissions favorably.
- Energy policies and greenhouse gas mitigation policies are likely to have many impacts on agriculture as a consumer and as a producer of energy. Development of new bio-energy production systems and greenhouse gas offset policies may benefit agriculture and facilitate adaptation. The increased cost of fossil fuels associated with greenhouse gas mitigation policies will adversely affect incomes of farmers in the near term, but in the longer term encourage adaptation.

The public sector has a potentially important role in facilitating agricultural adaptation to climate change, just as it did in making the investments in research and development that led to the success of U.S. agriculture in the twentieth century. A key question for policy is whether climate change justifies an expanded public role in agriculture or whether markets can stimulate adequate responses to the adjustments that will be required as the climate changes. Areas for public activity may include the following:

- estimating adaptation costs and reassessing impacts;
- research and development on breeding climate-resilient crop and livestock varieties;
- assessing the impact of climate change on insect pests, weeds, and diseases and their management;
- developing resilient livestock waste management technologies;
- adapting confined livestock and poultry processes to climate change and extremes;
- studying the effects of adaptation strategies on ecosystem services;
- providing public information on long-term climate trends; and
- assessing implications of energy policies and greenhouse gas mitigation policies for agriculture and the food sector.

Introduction

One of the most important sectors of the economy, U.S. agriculture depends heavily on climate. Farms and ranches are also the largest group of owners and managers of land that impacts ecosystem services, such as greenhouse gas (GHG) mitigation, water quality and quantity regulation, and wildlife habitat and biodiversity conservation. In addition, agriculture is playing an increasingly important role in the energy sector through biofuels production. Consequently, the impacts of climate change on agriculture, and agriculture's ability to adapt to and mitigate the impacts of climate change, are critical issues for agricultural households as well as the general public and public policy decisionmakers.

This policy brief summarizes the findings of a longer report on the potential impacts of climate change and the potential for the U.S. agricultural sector to adapt to climate change (Antle 2009), and then addresses the policy implications of these findings.

Impact Assessment and Adaptation

Agricultural production and productivity depend on the genetic characteristics of crops and livestock, soils, climate, and the availability of needed nutrients and energy. Various elements of the entire agriculture and food system are particularly sensitive to climate change:

- soil and water resources
- crop, livestock and poultry productivity
- farm structure, income and financial condition
- waste management for confined animal production facilities

- ecosystem services from agricultural landscapes
- food quality and safety
- market infrastructure
- food processing and distribution.

Researchers use crop and livestock growth simulation models to analyze the possible impacts of climate change and increases in atmospheric carbon dioxide (CO_2) concentrations (known as CO_2 fertilization) on crop and livestock productivity. Temperature and precipitation, key drivers of agricultural production, operate on the highly site-specific and time-specific basis of the microclimate in which a plant or animal is located.

Several methodologies have been used to estimate possible impacts of climate change on agriculture. Most studies use *integrated assessment* models, which combine process-based crop and livestock models that simulate the impacts of climate change on productivity with economic models that simulate the impacts of productivity changes on land use, crop management, and farm income. Some studies instead use statistical models based on historical data to estimate effects of temperature and rainfall on economic outcomes, and then use these models to simulate future impacts of climate change. Some integrated assessment models also link the farm management outcomes to environmental impact models to investigate impacts such as those on water use and quality, soil erosion, terrestrial carbon stocks, and biodiversity. The data presented here are derived from the recent U.S. assessment of climate change impacts on agriculture (Reilly et al. 2003), which used an integrated assessment model.

Research suggests that in highly productive regions, such as the U.S. Corn Belt, the most profitable production system may not change much; however, in transitional areas, such as the transitional zone between the Corn Belt and the Wheat Belt, substantial shifts may occur in crop and livestock mix, in productivity, and in profitability. Such changes may be positive if, for example, higher temperatures in the northern Great Plains were accompanied by increased precipitation, so that corn and soybeans could replace the wheat and pasture that presently predominate. Such changes also could be negative if, for example, already marginal crop and pastureland in the southern Great Plains and southeast became warmer and drier. Another key factor in agricultural productivity is the effect of elevated levels of atmospheric CO_2 on crop yields. Some studies suggest that higher CO_2 levels could increase the productivity of small-grain crops, hay, and pasture grasses by 50 percent or more in some areas (and much less so for corn), although these effects are likely to be constrained by other factors, such as water and soil nutrients.

According to the U.S. assessment study, the aggregate economic impacts of climate change on U.S. agriculture are estimated to be very small, on the order of a few billion dollars (compared with a total U.S. consumer and producer value of $1.2 trillion). This positive outcome is due to positive benefits to consumers that outweigh negative impacts on producers. Impacts on producers differ regionally, and the regional distribution of producer losses tends to mirror the productivity impacts, with the Corn Belt, Northeast, South, and Southwest having the largest losses and the northern areas gaining. The overall producer impacts are estimated to range from –4 to –13 percent of producer returns, depending on which climate model is used. Some statistical modeling studies have produced estimates of much smaller impacts on U.S. agriculture. For example, the study by Deschênes and Greenstone (2007) finds positive impacts on the order of 3 to 6 percent of the value of agricultural land and cannot reject the hypothesis of a zero effect.

LIMITATIONS OF INTEGRATED ASSESSMENT AND STATISTICAL MODELS

Both integrated assessment models and statistical models have been used to assess climate change impacts, and both have a number of significant limitations, which are discussed in detail in Antle (2009). One is the difficulty in quantifying the costs of adaptation. Although modeling studies have attempted to quantify the impacts of climate change on physical quantities of production and their economic value, few if any have addressed related costs. These would include adaptations to production agriculture, additional research and development of crop and animal varieties, and changes in or relocation of capital investments such as crop storage infrastructure, confined animal facilities and waste management investments. If the rate of climate change (and therefore the costs of adaptation) were relatively high, then the net benefits of adaptation would also be lower, and less adaptation would occur.

Early studies of climate change impacts on agriculture did not account for possible adaptations, and tended to find relatively large adverse impacts. Subsequent integrated assessment and statistical studies incorporated benefits of adaptation but largely ignored the costs of adaptation, and found that adaptation could largely offset the adverse impacts. Thus, if the costs of adaptation are much higher than these studies assume, they may be over-estimating the amount of adaptation that would occur, and the early estimates made without adaptation may be closer to actual outcomes than those that ignore such costs.

Another potentially important limitation of both types of models is their use of average climate and economic data, rather than that on climate variability and extreme events. This limitation is due in part to design of the economic models, and in part to the limitations of the general circulation models used to simulate climate change. The climate models are not capable of producing simulations of changes in weather variability and extreme events with spatial resolution or time scales relevant to most agricultural systems. Consequently, the models cannot fully simulate the potential effects of changes in weather patterns that would affect agriculture.

For example, neither the integrated assessment models nor the statistical models can simulate the effect of changes in the distribution of rainfall during a growing season, or the effects of extreme weather events, such as heat waves, on crop or livestock production.

In addition to inherent limitations in the models, the cited assessments do not consider many of the potential impacts of climate change on food transportation, processing, and distribution sectors mentioned above. In particular, none of the assessments has considered the costs of relocating input distribution systems, crop storage and processing, or animal slaughter and processing facilities. Nor have studies assessed impacts of GHG mitigation policies on costs in production agriculture or on input production and distribution, output transport, or food processing and distribution systems. Recent experience with higher fossil fuel costs suggests that these impacts may be more important for farmers and food consumers than those on productivity. Thus, by ignoring possible impacts of future mitigation policies, the assessments carried out thus far have actually ignored some of the most important long-term implications of climate change.

Policy Issues

The evidence on likely impacts of climate change on agriculture and the food sector suggest two aspects of policy that need to be evaluated. First, many existing policies affect agriculture and the food sector, and many of these are likely to affect adaptation. Climate change is not likely to be the focus, but it does make sense for policy design to take adaptation into consideration. Second, public policy may have a role in facilitating adaptation of agriculture and the food sector.

POLICY DESIGN AND ADAPTATION

As yet no systematic effort has been made to evaluate the effects of these existing policies on adaptation. Several existing policies and their possible effects on adaptation are described here.

Agricultural subsidy and trade policies. Agricultural subsidy programs for major commodity crops, such as wheat, corn, rice, and cotton, as well as trade policies, such as the import quota on sugar, were established in the 1930s and continue today. The structure of these programs has changed over time, but a common feature is reducing flexibility by encouraging farmers to grow subsidized crops rather than adapting to changing conditions, including climate. In addition, because the United States produces a large share of many of these commodities, these policies have the unintended consequence of distorting global markets and discouraging efficient allocation of resources in other parts of the world.

Production and income insurance policies and disaster assistance. The history of both private and public crop and insurance schemes for agriculture and disaster relief programs is a long one. The most recent legislation, enacted in 2008, continued existing crop insurance subsidies, introduced a new revenue insurance program, and established a permanent disaster assistance program. Such insurance could be one way to address increasing climate variability and climate extremes associated with climate change. Whether this response is appropriate to climate change is an open question that deserves further study. In any case, it is clear that public subsidies for crop or revenue insurance and disaster assistance, like other types of agricultural subsidies, will reduce the incentive for farmers and ranchers to adapt to climate change.

Soil and water conservation policies and ecosystem services. Over time U.S. agricultural policies have shifted from commodity subsidies alone toward a variety of policies that provide subsidies for protection of soil and water resources and the provision of ecosystem services. For example, the Conservation Reserve Program, established in 1986, has led to more than 30 million acres of land being taken out of crop production and put into permanent grass and tree cover through cost-sharing conservation investments and long-term contracts to maintain conserving practices. Although these policies protect surface water quality from soil erosion and chemical runoff, and enhance a number of ecosystem services, such as wildlife habitat, they also reduce both flexibility to respond to changes in climate over time by reducing the ability to adapt land use, and the ability to respond to extreme events. For example, farmers are not allowed to use CRP lands for grazing or to harvest grasses as animal feed, even when severe droughts reduce viable pasture and range lands, despite the fact that in many places this could be done on a temporary basis without substantially affecting the environmental benefits of the CRP. In some cases, the secretary of agriculture is authorized to waive these rules. Changes in program design, such as more flexible administrative rules, and better targeting of the policies toward lands with high environmental value, could facilitate adaptation.

Environmental policies and agricultural land use. Many environmental policies affect agricultural land use and management. Policies governing the management and disposal of animal waste from confined animal feeding operations are an important example with clear implications for adaptation. Both state and federal laws regulate the siting and management of these facilities. As noted above, changes in average climate and climate extremes are likely to significantly affect the viability of these operations in some locations, for example, where waste ponds become vulnerable to extreme rainfall events and floods. Environmental regulations raise the cost of relocating facilities and thus have the unintended consequence of discouraging spatial adaptation. Including benefits of climate adaptation in regulatory design could lead to policies that both protect the environment in the current climate and facilitate adapting to a future climate.

Tax policies. Numerous tax policies affect agriculture, including those on income and assets. Tax rules could facilitate adaptation in a variety of ways, for example, by accelerating the depreciation of assets, and by encouraging investments that reduce greenhouse base emissions. However, creating such policies for climate adaptation alone may prove difficult to implement, because many other types of economic and technological changes may also lead to capital obsolescence and favorable tax treatment in all such cases may not be desirable.

Energy policies. The increasing public interest in domestic sources of non-fossil-based energy has already led to significant policy developments, such as subsidies for corn ethanol, and is likely to have important implications for both food and fuel prices and for adaptation. Further developments in biofuels will change even more the way land is used for food and fuel production, affect adaptation, and be affected by related energy policies, such as requirements for use of renewable energy. Development of other energy technologies, such as animal waste for energy production, may reduce the net costs of adapting these systems to climate change.

Greenhouse gas mitigation policies. Policies that constrain greenhouse gas emissions have the potential to affect agricultural operations as both emitters and as suppliers of offsets to emissions, depending on how such policies are designed and implemented. For example, recent legislative proposals have imposed certain limits on the use of offsets, but also excluded agricultural operations from emissions caps. Moreover, because agriculture and the food system are relatively intensive fossil fuel users, any policy that effectively raises the cost of fossil fuels will have potentially important impacts on these industries.

POLICIES TO FACILITATE ADAPTATION

The record shows that the success of U.S. agriculture in the twentieth century depended on complementary investments in physical and human capital and agricultural research and extension, many of them publicly funded through institutions such as land grant universities. Complementary policies have also fostered the conservation of natural resources and the adoption of more sustainable management practices. This experience suggests that that the U.S. agricultural sector is capable of adapting to a wide range of conditions and adopting new technologies as they become available. As long as the rate of climate change is relatively slow and predictable, we can expect the same to be true with future climate change. Important questions remain, however, about how effectively the sector could adapt to rapid changes in average climate or increases in extreme events.

The substantial role the public sector has played in facilitating agricultural development raises a number of questions about appropriate policies in the context of climate change. The justification for public funding of infrastructure, research, and information systems was based on economies of scale as well as the public good aspect of basic research needed to develop agricultural technologies. Although a substantial public role remains in infrastructure, research, and outreach, it has diminished over time as private institutions have become increasingly capable of providing these services. A key question for policy is whether climate change justifies an expanded role in these areas or markets can stimulate adequate responses to the adjustments that will be required as the climate changes. Several aspects of adaptation and the possible role for public sector involvement follow:

- *Estimating adaptation costs and reassessing impacts.* As noted above, the analysis has largely ignored the costs of adaptation for agriculture and the food industry. Besides contributing to accurate impact assessments, data on costs of alternative adaptation strategies are needed to inform both private and public decisionmakers. Costs should be evaluated under alternative scenarios for the rate of climate change, climate variability, and the occurrence of extreme events. Most research so far has been devoted to the impact on grain crops. Much more research on impacts and costs of adaptation in other agricultural systems is needed, particularly for livestock and other economically important products, such as vegetable and fruit crops.
- *Identifying adaptation strategies and related research needs.* Among the areas that merit attention are vulnerability of crops and animals to climatic extremes, breeding resilient crops and livestock varieties, effects of climate change on pests and diseases and their management, and more resilient livestock waste management technologies, and biofuels production.
- *Identifying and estimating the vulnerability of ecosystem services to climate change and adaptive responses*. Agricultural land-use practices are known to have important impacts on the provision of ecosystem services. As yet, the impacts of climate change on ecosystem services have not been quantified systematically on a regional or national basis. Research is needed to evaluate the effects of alternative adaptation strategies on ecosystem services.
- *Providing public information about long-term climate trends and their economic implications.* A great deal of public information is available on short-term weather forecasts, but more public awareness of long-term climate trends and forecasts may be needed. As a public good, this information may need to be supported with public funds.
- *Implications of climate change and mitigation policies for agriculture and the food sector.* As yet, virtually no research has been undertaken on identifying and quantifying potential impacts or adaptation strategies for the food sector. Included in such an analysis would be costs of adapting the food distribution system to a warmer climate and potential impacts on the prevalence and control of food-borne pathogens. The dependence of this sector on fossil fuel–based energy also suggests that GHG mitigation policies could have substantial impacts on the national and global food system as it presently operates. As yet, these issues have not been addressed in impact assessment studies.

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