The Impact of Global Warming on U.S. Agriculture

by Anthony Fisher

Contrary to previous estimates, new statistical results suggest Ê
that the impact of global warming on U.S. agriculture may be negative and substantial. Ê

In industrialized countries such as the United States, much of the economy may be fairly well sheltered from the effects of changes in climate that researchers now believe likely to arise later in this century due to increased atmospheric concentrations of greenhouse gases. Aside from disruptions caused by extreme climatic events such as storms or floods, most sectors of the economy no longer depend directly on climate for their functioning. A major exception is agriculture, where climatic variables such as temperature and precipitation are direct inputs to production.

The Econometric Approach to Estimating the Impacts of Climate Change on U.S. Agriculture

There are a number of ways to estimate the impact of the projected warming and changes in precipitation. An agro-economic approach examines the effect on crop productivity of experimentally controlled changes in water, temperature and other possible influences on yield, such as soil characteristics. This approach is, however, subject to the criticism that it overlooks adaptations or adjustments that farmers might make to changes in climate variable – for example, changing the crop mix to something more suited to the new conditions. Recent work in this area has tried to allow for this sort of adjustment. It is possible to use existing variation, across regions down to the county level in the U.S., in temperature, precipitation, soil quality and so on, to estimate a relationship between agricultural land value, on the one hand, and these input variables on the other. Presumably farmers have adjusted their crop choices to reflect long run climate and other differences in different areas. The estimated relationship can then be used to predict the impact on farmland value of projected future changes in the climate variables, holding constant other influences on value such as soil quality, and even socio-economic variables such as population and income level in a county. When this is done, researchers have found that the likely impact of the temperature and precipitation changes associated with a doubling of atmospheric concentrations of greenhouse gases, principally carbon dioxide from the combustion of fossil fuels, on the value of farmland in the U.S. is quite modest, and may even be positive. One recent study summarizing and reviewing work in this area concludes that the warming associated with a doubling of atmospheric concentrations of greenhouse gases will result in a net gain of $8.4 billion annually for the U.S. economy, with the largest

Glacial melting is another expected impact of global warming.
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component a benefit to agriculture of $11.3 billion (other impacts are negative).

I am currently engaged in work with my colleague, Michael Hanemann, and graduate student, Wolfram Schlenker, to adopt the econometric or statistical approach of relating farmland value to climate and other influences. We come to strikingly different conclusions. The main reason for the difference can be understood by looking at California agriculture. Precipitation during the growing season is virtually nonexistent. Yet California agriculture is (sometimes) profitable, and the value of farmland here is quite high relative to other areas. The explanation, of course, is that crop yields are not related to precipitation during the growing season. Instead, they depend on irrigation, from stored ground or surface water. For surface water especially, what matters is how much snow falls in the Sierras, and when it melts and runs off into streams that feed the large surface reservoirs that in turn supply local irrigation districts. A statistical analysis that simply relates local precipitation to local crop yields, or the value of local cropland, may – and has – come to the misleading conclusion that the relationship between precipitation and value is negative, since in California and the arid west generally some very high-valued farmland receives little or no rainfall during the growing season.

Is Irrigation The Solution?

Consider a scenario in which over the next several decades the atmospheric concentration of greenhouse gases doubles, and average temperature in the U.S. rises by about five degrees Fahrenheit (we have already, over the 20th century, seen a rise of about one degree). To compensate for the higher temperatures, farmers in areas without irrigation would invest in irrigation facilities, as was done earlier in California and elsewhere. Proponents of the econometric approach might argue – indeed, have argued – that this is taken into account in the estimated relationships. Currently irrigated farmland has a high value because the investment in irrigation was profitable, and was undertaken for that reason, as were other adjustments to climate. This is true, but is misleading as a guide to the impact of future warming. The difficulty is that existing irrigation facilities have been heavily subsidized. For example, in California it has been estimated that even after decades of operation, farmers have paid just 18% of the capital, operations and maintenance cost of the federal Central Valley Project. It is clear that, at a minimum, subsidies of this magnitude to agricultural water users – which have in the past been capitalized into the value of the land – are unlikely to be forthcoming in the future, due to changes in what we might call the fiscal climate.

Apart from the issue of subsidies, it appears that irrigation water will be more expensive in the future than it has been in the past. Again drawing on the California experience, the State Water Project delivers water from a storage and conveyance system constructed in the 1960s to irrigation districts in the Tulare Lake Basin at a wholesale cost of about $80 per acre-foot. However, the State Water Project has only about 60% of the supply capacity originally planned in 1960. If the system were now completed, current estimates are that the new water would cost on the order of $300-$450 per acre-foot. For both reasons, cost increases and reduced subsidies, the net benefit, as reflected in the value of agricultural land, from the construction of new irrigation facilities, is likely to be much less than what can be inferred from a statistical study that reflects historic costs and subsidies.

Results, Qualifications and Further Work

One way to proceed, in these circumstances, is to do the statistical analysis on just areas of rainfed, as opposed to irrigated, agriculture. For the U.S., this involves nearly 80% of the counties (2334 out of 2938), so there is no shortage of observations. When we do this, we find that the estimated relationship between precipitation during the growing season and farmland value is no longer negative. With the costless, or very low cost, option of irrigation out of the picture, the effect on farmland value is unambiguously negative. Under various different weighting schemes for the individual county observations, undertaken for technical reasons, the distribution of damages associated with a doubling of the atmospheric concentration of greenhouse gases converges around a median figure of $215 billion. This is the estimated loss in value of agricultural land. Assuming a real interest rate of

While agriculture has in the past relied upon irrigation as an adaptation in hot, dry climates, this may not be an attractive option in responding to future climate change.

Photo from **California Agriculture, UC DANR**

5%, this translates into an annual loss of just under $11 billion, as compared to the previous estimate, noted above, of an annual net gain of just over $11 billion.

The $11 billion loss estimate needs to be qualified, or at least further interpreted. To derive an estimate for the U.S. as a whole, the impact of warming on irrigated areas, prominently including California, must be added back in. If this is positive, the loss to U.S. agriculture as a whole would be reduced, perhaps even transformed into a net benefit, as in the earlier estimate. Research we are undertaking for California suggests that this will not be the case. Warming is expected to lead to changes in the pattern of precipitation that will have a negative impact on agriculture in the state, apart from any impact due directly to temperature. The mix of rain and snow, during the winter rainy season, will shift to somewhat more rain, and less snow, than under present conditions. The snow that does fall in the Sierras will melt and run off somewhat earlier in the year. Thus less water will be flowing into the reservoirs, and available for agriculture – and other uses – when demand is highest, in the late spring and summer. On the other hand, winter rain and early spring snowpack runoff into the reservoirs can be expected to exacerbate flooding, much as in the winter of 1997 when an unusually warm storm system moving through the state dumped heavy rains, rather than snow, in the mountains and resulted in major flooding up and down the Central Valley. Adding in an estimate of the impact of warming on existing irrigated areas in the U.S. is thus unlikely to reduce the $12 billion in losses estimated for non-irrigated areas, much less to convert the losses to gains.

Another qualification to the results does however suggest that they may overstate the magnitude of potential losses from warm- ing, and also has implications for policy. By excluding irrigation as an option in areas currently without it, we do not allow for the possibility that the cost of construction and operation of new irrigation infra- structure may be less than the losses otherwise suffered. Clearly it is not appropriate to assume that new irrigation will be forthcoming at historic costs, and under historic subsidies, but it is certainly possible that in some areas at least the full cost will be less than the losses without it. This is a question to be investigated on a region-specific, indeed a project-specific, basis. What is indicated is a benefit/cost analysis of new water projects, where the benefit is the loss in value to agriculture and other sectors predicted to result without the project.

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