

EXPLORING ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE: THE POTENTIAL OF CROSS-SECTIONAL ANALYSIS

BY ROBERT MENDELSON AND ARIEL DINAR

Scientists are confident of a link between greenhouse gas emissions, the increasing concentration of those gases in the atmosphere, and climate change. However, the final impacts from climate change are difficult to estimate, since we have no direct experience with new climates. Past climate change has been small and slow, making the impacts hard to discern. Further, technological changes have obscured signals from historic climate changes. Despite these difficulties, the impact literature has made many strides toward understanding and quantifying climatic impacts. Farmers, policymakers, and researchers know that most crops are highly sensitive to climate. We also know that ecosystems will shift over space in response to climate change, that energy costs will change, that sea level will rise, and that entire water cycles will change. Yet, the potential damages to some and benefits to others that these changes will cause remain difficult to determine. This note argues that cross sectional evidence provides important insights to policy makers both about the size of the potential impacts from climate change and about adaptation. Of course, cross sectional evidence is not the only source of information and policy makers should consider all available results.

Two lines of policy interventions are being considered to address climate change: (1) mitigation or abatement to reduce the underlying cause of climate change, and (2) adaptation to reduce the resulting damages from climate change. Both policy issues are being actively debated at international, national, and local forums. Mitigation, by reducing the emissions of greenhouse gases into the atmosphere, can reduce concentrations, and the resulting severity of climate change. Adaptation can radically affect the impacts of climate change. Early researchers assumed that little adaptation would occur and, consequently, predicted major damages. However, research has shown that people and governments can adapt to climate change. Farmers can change their crops and varieties. People can switch their energy systems and allocate water differently. Landowners can change the way they use land, for instance, by developing coastal zones differently. Governments can have a role in stimulating adaptation as an important policy response to climate change. If these adaptations occur, climate change may lead to much lower damages and even benefits in some circumstances and locations.

While the climate's relationship to ecosystems and to agriculture is apparent, researchers understand its interaction with rural poverty less clearly. The world notices extreme climate events—such as hurricanes, floods, and prolonged droughts—because they have dramatic impacts on the unfortunate people in their paths. For the poor, however, even small climatic changes can present an extreme burden—bringing hunger, disease, and even death.

Inadequate information makes monitoring the impact of climate change on poor rural communities difficult. Yet, the preliminary studies of the rural poor suggest that they are clearly vulnerable to changes in climate through its effect on local agricultural productivity. Many of the rural poor live in marginal areas with poor climates for growing food. Given the importance of agriculture to the rural poor, climate is a major existing problem for many of these people. Climate change could seriously exacerbate this problem.

Rural poverty is a fundamental concern for the World Bank. Land, water, and forests are essential natural resources that the poor around the world rely on for their livelihoods. The rural poor need to sustain the productivity of these resources, and



the World Bank can help by identifying what determines the future health of an economic sector and advise on policies that could mitigate foreseeable problems.

The World Bank has undertaken several studies using cross sectional evidence to measure climate impacts, examining farm performance across a broad range of climates. Cross sectional analysis examines how farmers, households, and firms in one location with one climate perform compared to similar actors in another location with a different climate. By seeing how, for example, farm performance changes with climate across many areas, one can estimate the long-run sensitivity of farm performance to climate. The advantage of this approach is that it fully captures how farmers adapt to the climates in which they live. The technique measures the long run net impact of climate change, including the costs and benefits of adaptation, while accounting for other explanatory variables, such as soil types, supporting institutions, infrastructure, agricultural services, etc. The difficulty with this approach is that it requires good data sources that may not always be available, especially in developing countries. This note explains alternative sources of some of the needed data and their application in analysis of climatic change impact and adaptation.

The cross sectional approach examines household behavior across a climate (temperature or precipitation) gradient. By observing how behavior changes as climate varies, the analysis can discern long-run adaptations that households are likely to make to climate change. One of the challenges of the approach is to separate climate effects from other phenomena that might differ across space. This may be especially important when conducting multinational studies where key policy and economic variables might vary by country.

Challenges of Information Gathering

The first challenge to this approach is finding reliable climate measures across space and time. Climate is long-run weather (about 30 years). Although there are excellent weather records in selected locations around the world (from weather stations), these observations are often made in cities and airports and are rarely distributed across farm or rural locations. Satellite records provide a new opportunity to measure climate carefully in remote, rural locations. Many available satellite data now cover a period of 20-25 years (see Box 1).

A second challenge is to control for other physical, economic, and policy variables that may also vary across space. For example, it is important to measure how soils vary across the landscape. Another important factor is access to irrigation water, which depends on proximity to rivers and streams, or



the availability of accessible groundwater. Economic factors such as proximity to markets, labor, and technology can also be very important. Finally, policy variables—such as trade restrictions, subsidies, and taxes—may be critical because they might make one region profitable and another marginal. Not accounting for such variables may yield biased estimates of the impact of and adaptation to climate change, and this could lead to erroneous policy recommendations.

In “Cross Sectional Analyses of Climate Change Impacts” that is reported here, Mendelsohn and his co-authors examine whether using individual farm data presents a promising approach for studying climate change. The study found that if the data is scattered across many climate zones, analyzing individual data looks highly useful. Even in a country as small as Sri Lanka, researchers successfully measured the effect of climate on net revenues per hectare. Findings suggest that it is more likely to capture farm-specific behavior by analyzing individual farm data than by using district-level or general census data. The Sri Lankan study illustrated the importance of precipitation in addition to temperature, which could indicate that what climate change does to the monsoons may be more important than the warming itself.

Challenges to Data Collection

Although a country can collect a wealth of information through its census, this tool has its limitations. First, census data is not consistent across countries, which limits multinational

studies. Second, a census often lacks critical variables or does not collect data with sufficient geographical detail. Countries must often collect additional detailed household and firm data in order to understand climate impacts and adaptations. By collecting this additional information, researchers and policy-makers can learn how farmers adapt to different climates and the outcomes of those coping mechanisms. For example, by collecting detailed farm information across climate zones, one can learn how climate affects net revenues per hectare. One can also see how farmers have made long-term adjustments to climate change by planting different crops, changing planting and harvest dates, installing irrigation systems, and changing livestock practices.

Weather stations provide very accurate measures of local weather; but they are not well dispersed across rural areas in the low latitudes. It is consequently useful to compare weather station data against satellite data for studies of rural activities such as farming. The climate between weather stations must be inferred using sophisticated interpolation methods whereas the surface pattern of satellite climate measures is observed. Although the satellites have difficulty measuring some relevant phenomenon such as precipitation, they have substitute measures such as soil moisture. Analyzing these two sources of information, the study found that satellite temperature data does a superior job explaining farm performance than weather station data but that weather station precipitation data outperformed satellite measures of wetness.

There are many ways to measure long-term weather including, most obviously, the average over many years. However, another question of great importance is if variations in the weather from year to year also matter. If some regions have steady weather every year whereas others are subject to sharp variations in weather; will this affect how suitable the area is for farming? How critical is the climate variance? If future climate variance increases, will this lead to damages or benefits? The analysis done to date shows that, depending upon the season, average weather is critical but variance is also important. High year-to-year climate variance during the growing season is generally harmful, but during the latent season, it can be beneficial (e.g., by reducing pest population).

It is important to know whether climate has an important role in determining rural income. Many studies have revealed that climate affects agricultural performance. Since agriculture is a primary source of income in rural areas, it follows that climate might explain variations in rural income. This was confirmed in the case of the U.S. and Brazil, where data on rural income was available for analysis. The very same climate variables that

explain farm performance also explain why some rural regions have higher income per capita than others. The results demonstrate the importance of climate to rural livelihood.

The study reported in this note suggests that mid to high latitude countries could well benefit from the warming expected in the next few decades. That same study also suggests that warming may have immediate deleterious impacts on developing countries that are mostly in the subtropical and tropical regions (low latitude countries). Agriculture is a large portion of GDP in many of these countries, and much of that is labor intensive. This type of agriculture appears to be especially sensitive to warming, due to the low level of technology available and the limited adaptation capacity. Many low latitude countries have a large, low-performing agricultural sector and they are already on the hot side of global temperatures. These countries are particularly vulnerable to further warming.

Policy Implications

Research on climate impacts has important policy implications because it measures the likely benefits of slowing climate change. Because reducing greenhouse gases is potentially very expensive, it is important to measure the consequences of abatement policies. If analysis indicates that abatement delivers very large benefits, then it is worthwhile to engage in costly abatement. However, if analysis indicates that the benefits of slowing warming are small, only more modest abatement efforts are warranted. Of course, with a difficult inter-temporal

BOX 1: HOW CAN DEVELOPING COUNTRIES GET AND USE SATELLITE DATA?

There are several sources of satellite data that can be used to analyze and monitor climate. The studies reported in this note relied on U.S. Defense satellites that fly over the poles in an orbit that sees each place on the earth in early morning and early evening. The satellites provide complete coverage of the earth's surface in a repeated pattern that controls for time of day. A series of these satellites have been observing the earth's weather since 1988 using microwaves. These satellites can measure temperature and soil moisture consistently for every location across the planet.

National Oceanic Atmospheric Administration-NOAA provides its raw daily satellite data for free through its Website: <http://www.nesdis.noaa.gov/datainfo.html> and www.saa.noaa.gov.

For a fee, several companies can interpret the raw data and generate more valuable indices for local agricultural districts. One such company, Commodity Hedgers (www.commodityhedgers.com), provided the climate products used in the Mendelsohn et al. study that is reported in this note.

problem such as greenhouse gases, there is a different desired strategy at each moment in time. In general, as the stock of greenhouse gases in the atmosphere increases, the damages associated with emissions are expected to rise. It is important not only to determine what abatement strategy is best at the moment, but also how that strategy should change over time.

A recent study indicates that damages from climate change may be the highest for low latitude countries (e.g., Mendelsohn and Williams 2004). Low latitude countries are expected to have higher damages because they are already very hot, they have a greater fraction of their economy in climate sensitive sectors (especially agriculture), and they have less resources and technology for adaptation. Unfortunately, low latitude countries are difficult to study because of the absence of complete information about them. One of the major problems facing global warming policy is that the regions most sensitive to climate change may be the most poorly studied. Developing empirically-based estimates of the impact of climate change in low latitude regions is consequently a critical issue for policymakers. It is particularly important for the World Bank to take special note of impacts in low latitude countries because of its commitment to the rural poor in these regions who may be especially vulnerable.

Another important policy question concerns adaptation. Very little is known about how private entities (farmers, households, firms) in the low latitudes will adapt to climate change. It is expected that they will adapt in some way because it is in their self-interest; however, it is not clear to what extent poverty, lack of information, and cultural factors may hamper that adaptation. It is also not clear how quickly people can adapt, although one assumes that adaptation on this scale is not instantaneous. Can poor farmers in low latitude countries change as climate changes over decades? Further, there is an important role for governments to play in adaptation. Governments can disseminate successful adaptation strategies. Governments can organize adaptations that are “public”, that jointly involve many beneficiaries. For example, many governments support research and development (R&D) to develop new crops and varieties. These efforts have already shortened rotations and made crops suitable for new areas and climates. Although R&D has not specifically targeted climate change, some R&D advances have already helped farmers cope with difficult climates. Irrigation projects that bring water to new areas are one such example of public adaptation. New varieties of soybeans, for example, have helped Brazilian farmers expand into previously unusable regions. Governments could provide a safety net, especially for the poor. For example, if small

farmers in the low latitudes will be harmed by warming in the near term, governments can provide alternatives, such as crops, technologies, management, and other employment opportunities that are more suitable for a warmer climate.

There may also be serious distributional consequences to warming. Although the agricultural sector in a country may well survive warming, marginal regions could become infertile. Because rural areas are especially dependent on agriculture, local climate impacts could be severe. Policymakers might want to develop strategies to help farmers caught in these precarious situations. For example, they might facilitate the development of alternative livelihoods, creating a more diversified rural economy that can better withstand climate change and weather shocks. Alternatively, they might want to encourage out-migration from areas that become unsuitable for farming.

The cross sectional studies discussed in this note can help policymakers prepare policy responses to climate change. The research can help policy makers carefully match solutions to each problem. Whether the issue is abatement, adaptation, or the distribution of impacts, thoughtful policies can make a very large difference to the final outcome. ■

Selected Reading

Kurukulasuriya, Pradeep and Shane Rosenthal (2003), *Climate Change and Agriculture, A Review of Impacts and Adaptations*, Environment Department Papers Climate Change Series Paper No. 91, June, Washington DC: World Bank.

Mathur, Ajay, Ian Burton and Maarten van Aalst (Eds.) (2004), *An Adaptation Mosaic*, World Bank Global Climate Change Team, Final Draft, February, Washington DC: World Bank.

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Robert Mendelsohn is the Edwin Weyerhaeuser Davis Professor, Professor of Economics, and Professor in the School of Management at Yale University.

Ariel Dinar is a Lead Economist in the Agriculture and Rural Development Department at the World Bank.

