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Can International Trade Mitigate the Impacts of Climate Change?

By Dave Donaldson

The warmer climates predicted by climatologists portend a grim future for many biological systems, such as agricultural plant life, on which human welfare depends. But just how much will economic living standards fall as some plants wilt in a hotter world? In a recent paper[1] with Arnaud Costinot (MIT) and Cory Smith (MIT), we estimate that if farmers are able to change what they grow in response to a change in their comparative advantages, then the overall impact of climate change on agricultural output will be small. Moreover, because of the small share of agriculture in total GDP, the expected impact on global GDP is considerably smaller.

Our estimates draw on a large body of work by crop scientists, which has provided a rich understanding of the implications of such climate change for crop yields, crop by crop and location by location (IPCC, 2007; Chapter 5). However, these micro-level predictions—one for each crop and location—are of little use on their own for the purpose of assessing the overall macro-level impact of climate change on agricultural markets. This is because, in a globalized world, the impact of micro-level shocks does not only depend on the average level of these shocks, but also on their dispersion over space.

If climate change were to affect all crops in all countries in a uniform manner, then world relative crop prices would be unlikely to change substantially and there would be little incentive for farmers to adjust which crops they grow, or for countries to adjust which crops they import and export.[2] By contrast, if climate change were to have a differential effect on crop yields both within and between countries, then adjustments through production and trade patterns could significantly dampen the adverse consequences of climate change. For instance, a country

1 "Evolving Comparative Advantage and the Impact of Climate Change in Agricultural Markets: Evidence from 1.7 Million Fields around the World," forthcoming in the *Journal of Political Economy*.

2 Under this scenario, relative crop prices could change if there were scale effects in production, or if the overall reduction in agricultural productivity were to change (via income effects from poorer farmers or substitution effects from a reduction in overall crop consumption) relative patterns of demand for each crop.

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About The Author

Dave Donaldson is an Associate Professor of Economics at Stanford University and a Research Associate at the National Bureau of Economic Research. His research concerns inter- and intra-national trade, with a particular focus on developing economies. He holds editorial positions at the American Economic Review, the Journal of Economic Literature, the Journal of International Economics, the Quarterly Journal of Economics and the Review of Economic Studies. Prior to joining Stanford in the Summer of 2014 Donaldson was an Associate Professor of Economics at MIT.

may stop producing a crop whose yields have fallen and import it in exchange for another crop whose yields have remained constant at home. In short, the macro-level consequences of climate change in a global economy are inherently related to how it affects comparative advantage—the relative capabilities for crop production, across crops and locations—around the world.

Surprisingly, little existing research has focused on whether climate change will affect comparative advantage, be it within or between countries. Because of this, the aggregate harm that will be done to agriculture by climate change remains an open question. To begin to fill this gap, we draw on a rich set of micro-level data from the Food and Agriculture Organization's (FAO) Global Agro-Ecological Zones (GAEZ) project. The GAEZ dataset uses agronomic models and high-resolution data on geographic characteristics such as soil, topography, elevation and, crucially, climatic conditions to predict the yield that would be obtainable—crop by crop—at 1.7 million high-resolution grid cells covering the surface of the Earth. The GAEZ dataset is available under both contemporary growing conditions and a climate change scenario used by the UN's Intergovernmental Panel on Climate Change (IPCC). By comparing productivity for a given crop under the two scenarios at each of these 1.7 million grid cells, we can therefore directly observe the evolution of comparative advantage across space, as predicted by climatologists and agronomists. Even a brief glance at these predictions demonstrates a striking degree of heterogeneity in the predicted effects of climate change both across crops and over space. For example, many regions are expected to see a differential productivity change in wheat relative to rice (the world's two most important crops), and this relative wheat-rice productivity change differs substantially across the 1.7 million grid cells. Further, the contours of the predicted effects of climate change on crop yields pay no attention to country borders. Within-country heterogeneity is therefore a central feature of the predicted impact of climate change on agriculture.

To go beyond the evolution of comparative advantage documented in the agronomic GAEZ data and quantify the economic macro-consequences of climate change, we need an economic model of agricultural markets that can predict: (i) where crops are produced and, in turn, which productivity changes are relevant and which ones are not; (ii) how shocks to the supply of crops affect prices around the world; and (iii) how changes in productivity and prices map into consumption and welfare changes. We therefore propose a general equilibrium economic model of production, consumption, and trade in which each country consists of a large number of "fields" with heterogeneous productivity across multiple crops. These are the theoretical counterparts of the 1.7 million grid cells in the GAEZ data. In this model, comparative advantage, i.e., relative productivity differences across crops and fields, determines the pattern of specialization within and between countries. Furthermore, potential barriers to trade (such as tariffs or transportation costs) prevent the full integration of agricultural markets across countries.

Naturally such a model contains a number of unknown parameters whose values crucially determine the strength of each economic force at work in the model. For example, an important parameter governs the extent to which consumers around the world are willing to substitute one crop for another, or one country's version of a particular crop for another country's version, in their consumption choices. If climate change were to (in some region) make wheat scarce, how willing would consumers there be to substitute imported wheat, or rice, instead? A similarly important phenomenon concerns farmers' ability to substitute their production of one crop for that of another crop. Finally, an essential unknown is the extent to which international trade appears to be impeded by trade barriers, since this will govern, all else equal, the geographical reach of any given country's trade.

We use publicly available data, again from the FAO, on international trade, production, and prices in 2009 to estimate the unknown parameters of our model. As is always the case, estimation of demand-side substitution patterns is challenging due to the fact that prices paid and quantities consumed in the data move in a correlated manner due to both unobserved supply- and demand-side variation. We overcome this well-known problem by using the GAEZ predictions about exogenous determinants of local productivity as a source of supply-side variation that allows us to arrive at unbiased estimates of the true demand-side parameters. After applying a similar procedure to estimate the other model parameters, we find that the within-sample fit of our model for output levels, land use, and trade flows is strong, and this is especially reassuring when it concerns aspects of the data that were not directly used in our estimation procedure.

Armed with estimates of the crucial economic parameters at work, as well as with detailed knowledge of how scientific experts expect the pattern of comparative advantage (across fields and crops) to change around the world, we then simulate the impact of climate change. To do so, we solve for the economic equilibrium that we would expect to occur once yields for each crop and location around the world change from their current (or "pre-climate change") levels to the agronomists' predicted post-climate change levels. This is clearly a crude, discrete approximation to the continuous (slowly evolving over a matter of many decades) dynamics of actual climate change. But we believe that it nevertheless cuts to the heart of the matter and provides a useful approximation to reality.

In our first climate change scenario we imagine that countries are free to trade (subject to trade frictions consistent with our estimates of these parameters) and that farmers face no barriers to changing their output decisions in the face of new yields or prices. Under this scenario, we find very heterogeneous effects across countries, with some countries like Malawi (a major agricultural producer and consumer, whose location puts it at the front lines of climate change) experiencing dramatic welfare losses. Overall, climate change is predicted, following our estimates, to amount to only a 0.26 percent decrease in world GDP. But this relatively low number merely reflects that fact that agriculture is a relatively small share of global output: The value of output in the crops in our study (the world's most important 10 crops) is equal to just 1.8 percent of world GDP. This implies that the predicted impact of climate change is about one-sixth of total crop value, a relatively large impact within agriculture itself.

As discussed above, a potential source of adjustment to climate change will be the ability of farmers to produce different crops. To shed light on this mechanism, we consider a second counterfactual scenario in which countries can trade, but farmers cannot reallocate production within each field. Under this scenario, we find that the adverse welfare consequences of climate change are significantly larger than in the previous scenario. For the world as a whole, the loss would be three times as large: 0.78 percent of GDP, or two-thirds of total crop value. This illustrates how farmers' abilities to substitute crop production in response to changes in their comparative advantage—which our micro-level dataset gives us a unique opportunity to study—will play an essential role in our ability to mitigate the negative effects of climate change.

Another potential source of adjustment, at the macro-level, is the ability of countries to change what they trade with the rest of the world. To explore the quantitative importance of this economic channel, we consider a final counterfactual scenario in which export patterns—that is, shares of crop output exported to the rest of the world—are held fixed before and after climate change (however, unlike in the previous counterfactual scenario, farmers can reallocate production here). In contrast to the previous counterfactual scenario, the welfare consequences of climate change in this case, a 0.27 percent loss in world GDP, remain very similar to those obtained under full adjustment. That is, imposing a hypothetical constraint that prevents countries from changing what they trade has little bearing on the overall consequences of climate change. This is in strong contrast to the hypothetical constraint on farmer's abilities to change what they grow, a constraint that would (as discussed above) prove detrimental. Putting together these two findings tells us that international trade is likely to play only a minor role in alleviating the consequences of climate change. However, intra-national trade (trade across farmers, and between farmers and consumers, within countries) appears to be crucial. This is not surprising given the nature of the damage that scientists expect climate change to cause: strongly heterogeneous across crops and locations, even within countries that occupy a relatively small land area.

There is, of course, a great deal of uncertainty—and even controversy—about future climate change and how it will affect crop yields at various locations around the world. We therefore have devoted significant effort to an exploration of how our results change as we consider different assumptions about future climatic conditions as well as the contemporary growing conditions used in the GAEZ data. (Naturally, we also document that our results are robust to the use of alternative assumptions about farming technology, consumer preferences, and trade barriers.) Not surprisingly, the large uncertainty about future crop yields leads to large uncertainty over the welfare consequences of climate change. Interestingly, however, the relative importance of production adjustments relative to trade adjustments remains of similar magnitude across all of the tens of scenarios that we explore. So while the overall impact is uncertain, the central lesson about mitigation strategies that emerges from our research appears to hold regardless of the extent of climate change uncertainty.

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