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Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis

EPRG Working Paper **1925**
Cambridge-INET Working Paper Series **2019/13**
Cambridge Working Paper in Economics **1965**

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Global temperatures have increased significantly in the past half century and extreme weather events are becoming more frequent and severe. Climate change is not only affecting low-income countries, but also advanced economies—in September 2017 while Los Angeles experienced the largest fire in its history, Hurricanes Harvey and Irma caused major destruction in Texas and Florida, respectively. A persistent rise in temperature, changes in precipitation patterns and/or more volatile weather events can have long-term macroeconomic effects by adversely affecting labour productivity, slowing investment and damaging human health; something that is usually overlooked in the literature owing to the focus of existing studies on short-term growth effects.

We investigate the long-term macroeconomic effects of climate change across 174 countries over the period 1960 to 2014. We link deviations of climate variables (temperature and precipitation) from their historical norms to changes in real output per capita. We estimate the size of income effects across countries; assess whether the effects are temporary or permanent; allow for human activity to also affect climate change; investigate the relative importance of climate change for poor (hot) economies versus rich (cold) countries; and study the channels of impact and the sectors that are affected the most. Also, by using deviations of climate variables from their respective historical norms, while allowing for nonlinearity, we avoid the econometric pitfalls associated with the use of trended variables, such as temperature, in output growth equations in previous studies.

Our results suggest that a persistent change in climate has a long-term negative effect on per capita GDP growth. Specifically, we show that if temperature rises (falls) above (below) its historical norm by 0.01°C annually, per capita income growth will be lower by about 0.05 percentage points per year. Furthermore, we show that our empirical findings apply equally to poor or rich, and hot or cold countries. This is contrary to most of the literature which finds that temperature increases have uneven macroeconomic effects, with adverse consequences in countries with hot climates.

We perform several counterfactual exercises to investigate the cumulative income effects of annual increases in temperatures over the period 2015-2100 (when compared to a baseline scenario under which temperature in each country increases according to its historical trend of 1960-2014). We show that an increase in average global temperatures of 0.04°C per year (assuming high greenhouse gas emissions and no additional measures to combat climate change) reduces world's real GDP per capita by around 7 percent by 2100, albeit with varied effects across countries. Keeping the increase in the global average

temperature to below 2 degrees Celsius above pre-industrial levels as agreed by 190 parties in Paris in December 2015, will reduce the damage to only 1 percent by 2100.

Moreover, our results suggest that all regions (cold or hot, and rich or poor) would experience a relatively large fall in GDP per capita by 2100 in the absence of climate change policies. The size of these income effects varies significantly across countries depending on the speed with which temperatures increase above their norms; for instance, for the United States the losses are relatively large at around 10 percent without mitigation/adaptation efforts by 2100 (reflecting a sharp increase in above-norm average temperatures), but the loss would be limited to 2% under the Paris Agreement. Moreover, the speed with which the historical norms change, that is how fast countries adapt to climate change, affects the size of income losses (e.g., more adaptation means less damage).

We also examine the robustness of our findings and the channels of impact, using panel data sets of different economic indicators across 48 U.S. states over the period 1963 to 2016. While cross-country studies are informative, they also have drawbacks. Averaging temperature and precipitation data at the country level leads to a loss of information, especially in geographically diverse countries such as Brazil, China, India, Russia and the United States. The within-country geographic heterogeneity of the United States enables us to compare whether economic activity in `hot' or `wet' states responds to a temperature increase in the same way as economic activity does in `cold' or `dry' states. The richness of the U.S. data also allows for a more disaggregated study of the climate change-growth relationship and enables us to test whether the country at the aggregate level, parts of the country, or sectors of the economy have been more successful in their adaptation/mitigation efforts. To do so, we conduct a case study of the U.S. using various state-specific economic performance indicators at the aggregate and sectoral levels.

Our within-country results provide evidence for the damage that climate change causes in the United States using various economic indicators at the state level: growth rates of Gross State Product (GSP), GSP per capita, labour productivity, and employment as well as output in different sectors (e.g., agriculture, manufacturing, services, retail and wholesale trade). We estimate that if temperature increases by 0.01°C annually above its historical norm across U.S. states, average per-capita real GSP growth will be lower by about 0.03 percentage points per year–a number that is smaller than those obtained in our cross-country regressions. We show that while certain sectors in the U.S. economy might have adapted to higher temperatures, economic activity in the U.S. overall and at the sectoral level continues to be sensitive to deviations of temperature and precipitation from their historical norms. Moreover, in contrast to our cross-country results, the within United States estimates tend to be asymmetrical with respect to deviations of climate variables from their historical norms (in the positive and negative directions).

Our findings call for a more forceful policy response to the threat of climate change, including more ambitious mitigation and adaptation efforts.

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Publication July 2019
Financial Support Keynes Fund, University of Cambridge