

RESEARCH BRIEF • NOVEMBER 9, 2021

# The Economic Geography of Global Warming

## Adaptation and the unequal losses from climate change

Based on BFI Working Paper No. 2021-130, "[The Economic Geography of Global Warming](#)," by José-Luis Cruz, Princeton, and Esteban Rossi-Hansberg, University of Chicago

### KEY TAKEAWAYS

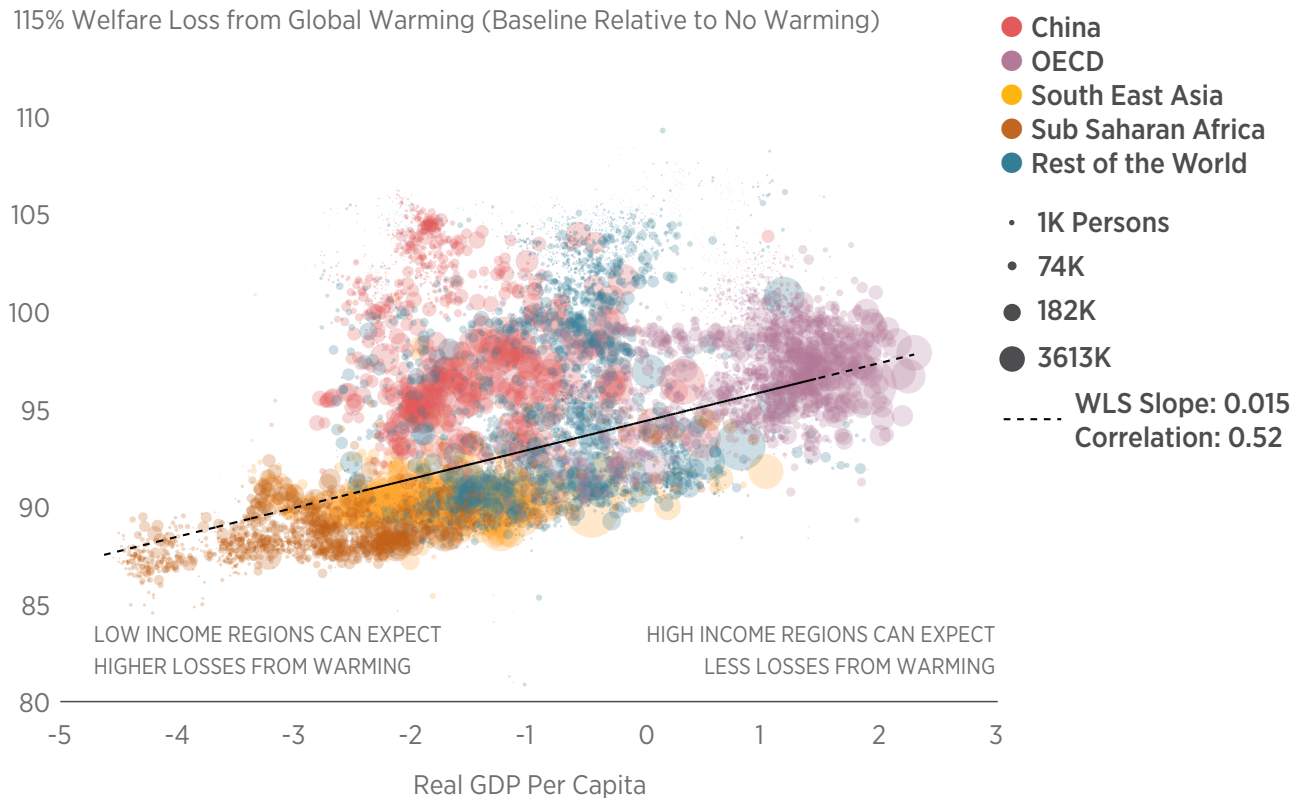
- ✓ Global warming will increase spatial inequality. On average, a country with double the GDP will experience about 1.5 percentage points of additional losses.
- ✓ On average, the world is expected to lose 6% in terms of welfare.
- ✓ Migration and other forms of adaptation are essential and can ameliorate the cost of global warming significantly.
- ✓ As for policy, carbon taxes should be combined with incentives to invent effective abatement technologies.

That unchecked climate change will profoundly affect the world's economy well into the future is almost universally accepted among researchers. But the world is not a homogeneous economy; likewise, climate change will also affect different parts of the world in different ways.

These heterogeneous effects raise important questions: How will different regions experience the impact of carbon emissions and the implied changes in temperatures? How will individuals react to these changes and how are these reactions impacted by their ability to migrate, trade, or invest and develop alternative centers of economic activity? What are the best policies to combat global warming and what are their implications for different regions across the world?

Until now, economists have been hampered in answering these questions by modeling limitations that do not incorporate factors relating to heterogeneous climate effects and decision-making, among other factors. That gap is the focus of "The Economic Geography of Global Warming," a new working paper from Princeton's José-Luis Cruz and UChicago's Esteban Rossi-Hansberg. The authors employ a new modeling technique that allows them to estimate the effects of climate change over long periods of time and across space. They find welfare losses as high as 20 percent in some parts of the world, which will significantly influence migratory patterns within and among countries. Among other important findings, the authors' novel micro-founded spatial modelling approach offers key insights for policymakers into the efficacy of various policy approaches, like carbon taxes and clean energy subsidies.

**Figure 1 • Relationship Between Welfare Losses from Global Warming and Real GDP Per Capita in 2000**



Note: This Figure presents a scatterplot of the welfare losses from global warming and real GDP per capita in the year 2000. The colors indicate different areas of the world, and the size of each dot represents the population of the cell also in 2000. The dashed black line presents the population-weighted linear relationship. The linear slope indicates that, on average, locations with double the level of real GDP exhibit welfare losses from global warming that are roughly 1.5% lower. Hence, the poorest regions of the world, mainly located in Sub Saharan Africa and Southeast Asia, are expected to undergo the highest warming losses. OECD countries, with initially high income, are much less affected. China, with its vast and heterogeneous territory, displays regions with both high and low levels of welfare losses. These results show that global warming will exacerbate the already large spatial inequality in the world.

### Different places, different effects

To begin, let’s broadly review what the authors mean by “micro-founded spatial model.” This technique refers to a dynamic assessment model that measures effects across space, or in different parts of the world, and even in different regions of various countries. The authors describe this approach in detail in their working paper, but broadly speaking their model allows them to incorporate geographic detail where temperatures affect both productivity and living amenities within locations. This assumes that agents in their model (stand-ins for people in the real world) will not sit idly by when their lifestyle and economic opportunities are impacted by climate change. They will act. In this case, such action means migrating to other regions of their home country or to other countries of the world, and/or it means making investment changes to address climate change, among other actions.

The authors’ model also incorporates dynamic changes in the world economy that impact carbon emissions. For example, because global warming is a protracted phenomenon developing over hundreds of years and

happening in a growing economy, their model had to incorporate the implications of this growth on carbon emissions and adaptations over time. In doing so, the model allowed them to study the dynamic implications of this phenomenon across locations.

There is more in this model—much more—including factors relating to trade, migration, innovation, productivity, amenities, mortality, and fertility; in the latter case, in all periods agents at a particular location have a natality rate (birth minus death rate) that depends on their income and the local temperature. This adds local and global population dynamics to the authors’ model. Finally, the authors incorporated the effect of carbon use over time, including projected carbon extraction costs, a factor that depends on the amount of carbon extracted in the past, since the remaining stock is increasingly harder to extract.

Model in hand, the authors then simulate the economy forward over several centuries to evaluate the economic consequences of global warming. They find the following:

- Global warming will increase spatial inequality. On average, a country with double the GDP will experience about 1.5 percentage points of additional losses. The hottest regions in South America, Africa, India, and Australia will experience welfare losses of 20% and the coldest regions in Alaska, Northern Canada, and Siberia undergo welfare gains as high as 11%.
- On average, the world is expected to lose 6% in terms of welfare.
- Importantly, global warming increases inequality across space. Welfare losses across locations are negatively correlated with current real income per capita and welfare. The poorest regions of the world, mainly located in Sub Saharan Africa and Southeast Asia, undergo the highest warming losses.
- By 2200, the average loss in welfare is 10% and in output is 5%; given forecast uncertainties, the model's 95% confidence intervals include losses as high as 20% and 12%, respectively.

Regarding the effects of global warming on amenities or productivity, about half of the average effects come from the impact of temperature rise on productivity. Effects on amenities are particularly important for losses in Africa and gains at the most northern latitudes, while losses in productivity affect almost all regions to the south of latitude 30°.

Key to the authors' evaluation of the effects of global warming are economic adaptation through migration, trade, and endogenous local innovation. For example, if the authors increase migration costs by 25 percent throughout the globe, the average cost of global warming rises by an additional 3 percent by 2200. Higher migration costs make global warming more costly for Africa, but also for northern regions that

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benefit less from the influx of migrants. Increases in migration costs lead to significantly faster population growth as more people stay in poorer areas where they have more children.

There is a smaller impact from increases in trade costs because the evolution of temperature is spatially correlated, and most trade is local.

Regarding innovation, a rise in innovation costs has a large relative effect that benefits the coldest places but hurts the warmest ones significantly. On average, though, less innovation implies that regions in India and China, where global warming will eventually have strong effects, will grow less, meaning the world on average loses less from the rise in temperatures.

### Carbon taxes + abatements = hope

As for policy, the authors are disinclined to offer their own prescription, but they discuss the implications that their work has on three key policy alternatives, namely, subsidies on clean energy, taxes on carbon dioxide, and the importance of abatement technologies that eliminate the pernicious effects of carbon. Briefly:

- Clean energy subsidies have only a modest effect on carbon emissions and global temperatures. Although they generate substitution towards clean energy, subsidies also lead to a reduction in energy prices, which results in more production and ultimately more energy use. These effects tend to cancel each other out.
- Carbon taxes have a larger effect on CO2 emissions and temperatures. The reduction in the use of fossil fuels leads to fewer carbon emissions, which results in lower temperatures that persist for hundreds of years. However, the reduction in carbon use implies that the unexploited carbon will become cheaper to extract over time; thus, carbon taxes primarily delay carbon use rather than decreasing its total use. This has the effect of flattening the temperature curve, with lower temperatures for long periods of time, but with little impact over the very long-run. Hence, the benefits are primarily concentrated in the next 100 years or so.
- As for abatement, if some sort of "moon shot" technologies are forthcoming, then flattening the temperature curve by delaying carbon consumption would have positive effects.

Thus, the authors' results strongly suggest that carbon taxes should be combined with incentives to invent effective abatement technologies.

## Conclusion

Making economic predictions is rife with uncertainty over short periods, let alone over centuries. Those uncertainties are complicated by the additional ambiguities in climate modeling. Taken together, the task of modeling the future may seem overwhelming. Even so, the earth's climate continues to warm, and if policymakers hope to ameliorate future costs, they must do so with the best estimates available. This work builds on existing research to present a novel model of the effect of global warming on economic outcomes and welfare that is based on estimates of migration, trade, and investment across space.

The authors find local effects of global warming on welfare that range from losses of 20 percent to gains of 12 percent, with increases in spatial inequality. However, these forecasts may underestimate effects, as the rise in temperatures has only recently started to affect economic outcomes more severely.

The authors are clear that theirs is not the last or only word on the likely future effects of global warming, but their hope is that this work reinforces the necessity for modern micro-founded economic models that incorporate multiple forms of adaptation and the rich spatial heterogeneity of the world.

## CLOSING TAKEAWAY

Key to the authors' evaluation of the effects of global warming are economic adaptation through migration, trade, and endogenous local innovation. For example, if the authors increase migration costs by 25 percent throughout the globe, the average cost of global warming rises by an additional 3 percent by 2200.

### READ THE WORKING PAPER

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### The Economic Geography of Global Warming

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### ABOUT OUR SCHOLAR



#### **Esteban Rossi-Hansberg**

*Glen A. Lloyd Distinguished Service Professor,  
Kenneth C. Griffin Department of Economics*  
[economics.uchicago.edu/directory/  
esteban-rossi-hansberg](https://economics.uchicago.edu/directory/esteban-rossi-hansberg)



*Written by David Fettig, BFI Senior Writer and Editor*

