Global non-linear effect of temperature on economic production

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Overview

Main results

Burke, Hsiang, and Miguel find that overall macroeconomic productivity is **non-linear**, **smooth**, and **concave** as a function of average temperature

This is a contrast to leading reports that productivity is either unresponsive to or linear with temperature

There are a few consequences:

- Productivity increases slowly with temperature until a critical point, then decreases very rapidly
- Countries in tropical regions will have much more severe costs, since their temperatures are higher on average

Empirical basis for the paper

The study arises from an observation that microeconomic (industry) productivity tends to be highly non-linear in temperature, whereas macroeconomic productivity is reported to be linear or non-responsive

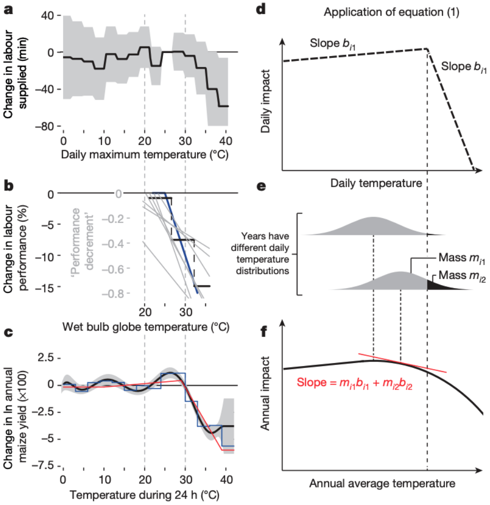
This is problematic because aggregate production is a sum of industry production:

$$Y(\overline{T}) = \sum_i \int_{-\infty}^{\infty} f_i(T) g_i(T - \overline{T}) dT$$

(where f_i is production of industry i as a function of temperature, and g_i is weighting based on unit-hours across temperature)

$\rightarrow$ **Hypothesis:** This kind of aggregation should lead to smooth, non-linear, and concave production (the literature from the time suggested otherwise)

This diagram shows what they mean



- Microeconomic features are well approximated by a non-linear function with a single kink (subfigure **d**)
- Aggregating these approximations makes for a smooth, non-linear, and concave aggregate production (subfigure **f**)
- Increase in average annual temperature will result in more frequent ocurrences of high temperature and lower aggregate production

An experiment

To test the hypothesis, Burke, Hsiang, and Miguel performed an experiment:

1. Use economic data from 1960-2010 in 166 countries and compare production between warm years and cold years
2. Only compare data from a country with data from the *same* country (different years) to avoid confounding with country-specific differences
3. Plot GDP per capita against average temperature and observe its shape

Let's see about what they found

Effect of annual average temperature on economic production

The authors decompose economic growth to account for:

1. All constant differences between countries, for example, culture or history;
2. All common contemporaneous shocks, for example, global price changes or technological innovations;
3. Country-specific quadratic trends in growth rates (which may arise, for example, from changing political institutions or economic policies);
4. The possibly non-linear effects of annual average temperature and rainfall.

$\longrightarrow$ Basically, the authors analyse whether country-specific deviations from growth trends are non-linearly related to country-specific deviations from temperature and precipitation trends, after accounting for any shocks common to all countries.

Effect of annual average temperature on economic production

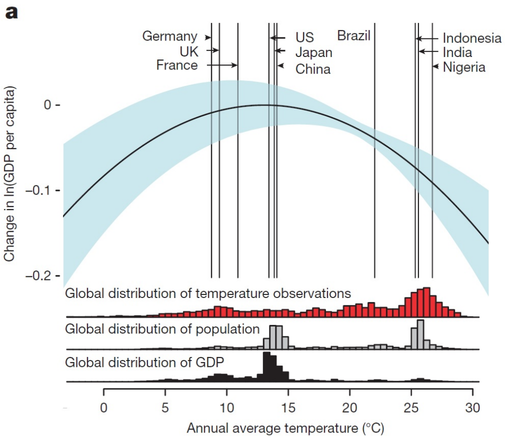


Figure 1: Global non-linear relationship between annual average temperature and change in log gross domestic product (GDP) per capita.

- Country-level economic production is smooth, non-linear, and concave in temperature, with a maximum at 13 C^0 (below the threshold recovered in micro-level analyses)
- Cold-country productivity increases as annual temperature increases, until the optimum.
- Productivity declines gradually with further warming, and this decline accelerates at higher temperatures.
- Much of global economic production is clustered near the estimated temperature optimum.

Effect of annual average temperature on economic production

- **Fig. (2 - b)** - Poor tropical countries exhibit larger responses mainly because they are hotter on average, not because they are poorer.
- **Fig. (2 - c)** - Technological advances or the accumulation of wealth and experience since 1960 has not fundamentally altered the relationship between productivity and temperature.
- **Fig. (2 - d and e)** - Consistent with micro-level findings, the authors find that agricultural and non-agricultural aggregate productions are non-linear in average annual temperature for both rich and poor countries.

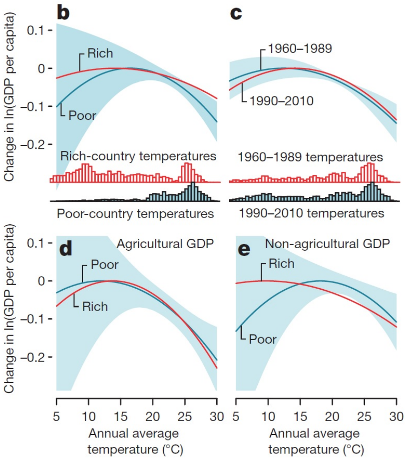


Figure 1: Histograms show global distribution of temperature exposure (red), population (grey), and income **(black)**.

Country-level income projections

The authors quantify the potential impact of warming on national and global incomes by combining the estimated non-linear response function with "business as usual" scenarios (RCP 8.5) of future warming.

- This approach assumes future economies respond to temperature changes similarly to today's economies.
- In 2100,they estimate that unmitigated climate change will make 77% of countries poorer in per capita terms than they would be without. climate change.
- Climate change may make some countries poorer in the future than they are today, depending on what secular growth rates are assumed.

Country-level income projections

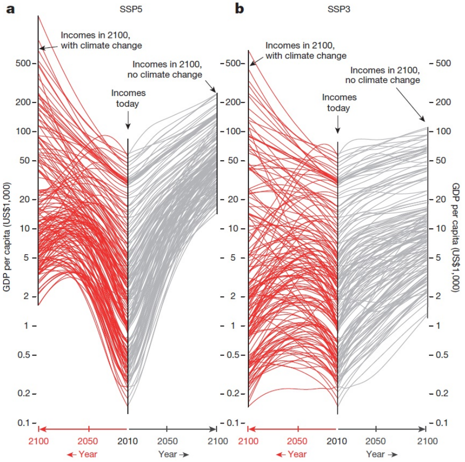
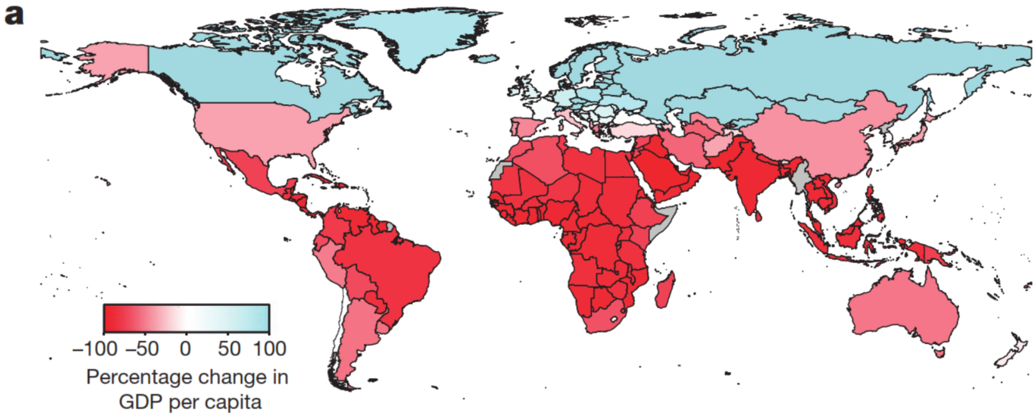


Figure 2: Country-level income projections with and without temperature effects of climate change.

- **Fig. (3 - a)** - Assumes high baseline growth and fast income convergence.
- With high baseline growth and unmitigated climate change, the authors project that 5% of countries are poorer in 2100 than today.
- **Fig. (3 - b)** - Assumes low baseline growth and slow convergence.
- With low baseline growth and unmitigated climate change, 43% of countries will be poorer in 2100 than today.

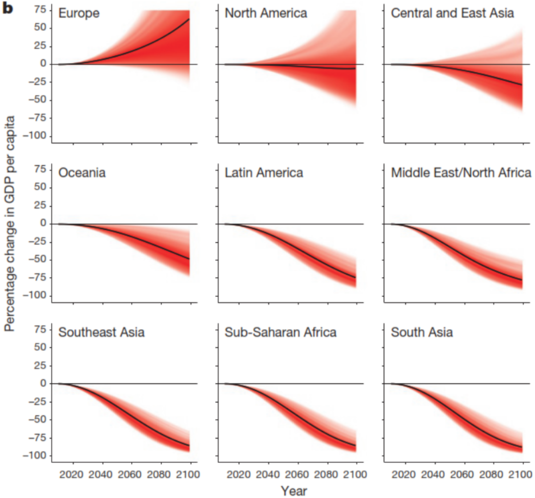
Effect of Temperature Changes by Region

Climate change reduces projected global output by 23% in 2100 (best estimate, SSP5) relative to a world without climate change.



Effect of Temperature Changes by Region

Colder Countries are better off, Poor countries, which are also hotter, are worse off



Effects of Temperature on Future Income Projections

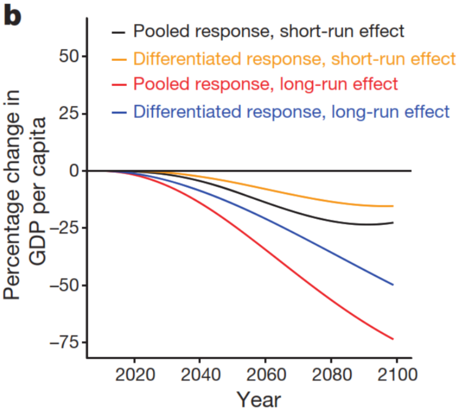


Figure 5: Global Damage Estimates - comparing approaches to estimating temperature effects (pooled/differentiated; short run/long run: effects account for 1 or 5 years of temperature, respectively;

- If the relationship between temperature and income is linear, then there is no significant effect of temperature on the future income. Countries adapt to temperature effectively as they become richer.
- If the relationship is non-linear, rich and poor countries behave alike at similar temperatures, ie, Rich countries do not adapt.
- The impact of additional warming worsens over time as countries becomes warmer. As a result, projections using linear and non-linear approaches diverge substantially—by roughly 50–200% in 2100

Global Damage Estimates

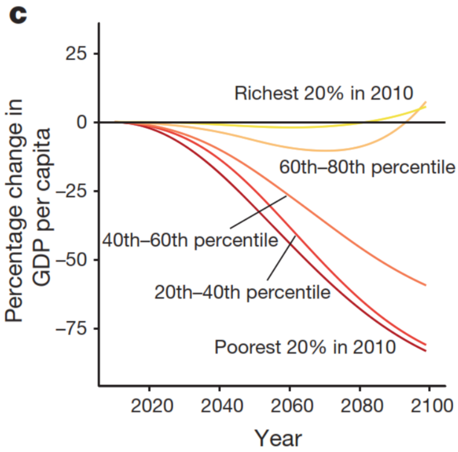


Figure 6: Global Damage Estimates - Mean impacts by 2010 income quintile

- Strong negative correlation between baseline income and baseline temperature indicates that warming may amplify global inequality because hot, poor countries will probably suffer the largest reduction in growth.
- In the benchmark estimate, average income in the poorest 40% of countries declines 75% by 2100 relative to a world without climate change, while the richest 20% experience slight gains,since they are generally cooler.

Comparison with other IAMs

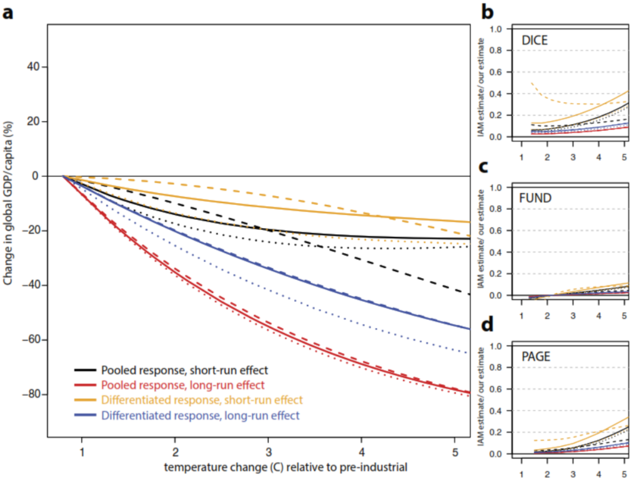


Figure 7: Estimated damages at different levels of temperature increase by socioeconomic scenario and assumed response function, and comparison of these results to damage functions in IAMs.

Conclusion

Overall macroeconomic productivity is **non-linear**, **smooth**, and **concave** as a function of average temperature.

Consequences:

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- Countries in tropical regions will have much more severe costs, since their temperatures are higher on average