

## Damages and social costs of carbon from tropical cyclones

### Key messages

- Tropical cyclones can have adverse impacts on economic development for more than a decade, and are predicted to intensify under global warming.
- Under a middle-of-the-road scenario, the additional average per-capita damage from tropical cyclones corresponds to about one day of annual income lost for the average household in strongly affected countries such as Taiwan, Japan, the United States, the Philippines or India.
- For each additional ton of CO<sub>2</sub> that is emitted in 2025, the impacts of tropical cyclones increase the total economic burden of climate change (*social cost of carbon, SCC*). The tropical cyclone-induced increase in SCC is most pronounced for strongly affected major greenhouse gas emitters such as Japan (+39.8%), China (+8.1%) or the US (+6.3%).

### Problem

State-of-the-art models weighing the costs of climate change impacts against the costs of adaptation and mitigation measures do not account for the long-term effects caused by extreme weather events such as floods and tropical

cyclones, which may result in a critical lack of ambition in climate action. On the contrary, the intensification of extreme weather events under global warming requires the development of tailored evidence-based adaptation and mitigation strategies to reduce the loss and damage caused by these events. A quantification of climate change-induced damages from tropical cyclones pave the way to adequately account for the impacts of extreme weather events in integrated assessment of remaining climate damages along mitigation and adaptation pathways.

### The effects of extreme weather events on economic development

Already today, tropical cyclones (TCs), floods and droughts cause annual economic losses of US\$ 51.5bn, 37.8bn and 8.5bn averaged over the last decade. TCs alone affect on average 20.4 million people annually. A recent publication of the SLICE project concluded that, historically, TC and flood impacts have reduced economic growth in the affected country for more than a decade [1].

Under global warming, the frequency of the most intense TCs is projected to increase, amplifying long-term growth losses in the absence of additional adaptation measures. Further, there are

substantial differences in the economic vulnerability to TC strikes between countries which cannot be explained by differences in their development level.

A recent study published as part of the CHIPS and the SLICE project quantifies the additional burdens that climate change imposes on national economies and societies through TC impacts using two complementary metrics: the *discounted annual damages* (DAD) and the *social cost of carbon* (SCC) [2].

### The discounted annual damages by tropical cyclones

The discounted annual damages (DAD) by tropical cyclones are computed over the period 2021–2100 as the discounted difference of the national GDP trajectories with and without the change in tropical cyclone activity under additional warming.

Our DAD analysis reveals that differences in income among countries must not be neglected when estimating and comparing the adaptation challenges of countries. In per-capita terms, absolute DADs are highest for strongly exposed high-income countries such as Taiwan, Japan, and the US. However, when DAD is measured relative to average household income, the damages for the small island developing state of Mauritius but also for the lower-middle-income countries of the Philippines and Vietnam become comparably large. For an average household, these correspond to one to about 10 days of income lost per year, largely depending upon assumptions on discounting.

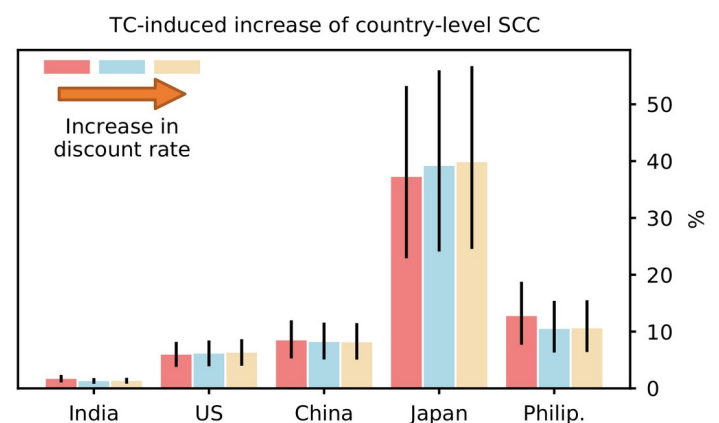
### The social cost of tropical cyclones

Using temperature damage functions derived from tropical cyclone induced damages to economic growth, it is possible to compute the (discounted) costs of an additional ton of CO<sub>2</sub> that is emitted in 2025, the social cost of carbon (SCC). The SCC is a good measure to inform carbon taxation and

climate mitigation efforts. Investing in a policy that avoids a specific amount of CO<sub>2</sub> emissions today can be justified in terms of saved additional costs over the course of the 21<sup>st</sup> century.

Compared to the global cost of carbon emissions, the contribution of tropical cyclones of 2.1% seems moderate. But the burden is almost entirely on only five countries: USA, Japan, China, India, and the Philippines contribute more than 99% of the tropical cyclone-induced SCC. In the case of Japan, the damages from tropical cyclones increase the national SCC by almost 40% (Figure below).

It is critical to keep in mind that these estimates only comprise the contributions of TCs, which affect only a limited set of countries. Other major categories of extreme weather events such as floods and droughts cause direct damages that are comparable to TC damages globally and also reduce the economic growth of the affected countries in the long term.



### References

1. Krichene, H., Geiger, T., Frieler, K., Willner, S.N., Sauer, I., Otto, C. (2021): Long-term impacts of tropical cyclones and fluvial floods on economic growth – Empirical evidence on transmission channels at different levels of development. *World Development* 144: 105475.
2. Krichene, H., Vogt, T., Piontek, F., Geiger, T., Otto, C. (2022): The Social Costs of Tropical Cyclones [under review in *Nat. Commun.*].



Project website (SLICE): <https://climate-impact-economics.org/>

Project website (CHIPS): <https://chips-project.org/>

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