"Advancing the estimation of future climate impacts within the United States." *EGUSphere*, Manuscript #2023-114

General comments

This paper presents new estimates of the impacts of climate change on the economy and society of the United States. The authors assess both marginal and non-marginal changes in the climate, and present results that include a comprehensive list of sectors, ranging from human health to infrastructure and labor supply. Climate change impacts are disaggregated into seven regions across the country, with an additional analysis assessing the racial breakdown of total impacts. The framework they utilize – FrEDI – is built to adapt to an evolving scientific literature, such that damage functions can be updated or additional sectors added, as the evidence base improves.

This is an important line of inquiry, both for informing climate change mitigation and adaptation policy and for pushing climate economic research forward. While many climate impacts analyses exist, especially in the US, this appears to be the most comprehensive set of estimates that cover many sectors and are presented in a framework that allows for the calculation of total projected damages *and* marginal damages (i.e., a domestic social cost of carbon).

Unfortunately, the inputs to the FrEDI model, and some of its key features, are well behind best available science, making the findings difficult to trust. For example, adaptation to future climate change is largely assumed away (at least for all empirically derived damages), spatial resolution is exceptionally limited relative to other work, and key dimensions of uncertainty are ignored. While I think the fundamental goals and structure of FrEDI are valuable for research and policy, I do not think the results represent best available evidence on the question at hand.

I detail my specific comments below and provide some technical corrections and smaller questions at the end of my review.

Specific comments

1. Damage functions do not represent best available science

The damage functions that form the building block of FrEDI are outdated and, critically, fail to incorporate empirically-based estimates of adaptation. It is increasingly clear in a growing climate econometrics literature that populations adapt to a gradually changing climate (e.g., Auffhammer, 2018); generating projections that assume people will act in 2090 as if climate change hit them unexpectedly and without warning is unrealistic. This is particularly problematic in this study with respect to health, which completely dominates all projected damages. There is clear evidence that people adapt to temperature-driven mortality (Barreca et al., 2016; Heutel et al., 2021; Carleton et al., 2022), and yet this large literature is ignored and a damage function is used that assumes no adaptation (from Cromar et al., 2022). Based on prior work, damages via temperature-induced mortality are likely far too large in this manuscript due to this implausible assumption.

Other inadequacies with damage functions include:

- Damages are assumed to be proportional to income (as far as I can tell), which fails to account for the fact that future incomes are likely to dramatically lower sensitivity to climate extremes (e.g., Rode et al., 2021)
- Electricity demand is included but consumption of other energy sources, such as natural gas, are excluded. This, by construction, leads to an inflated projection of damages, as electricity is largely used for cooling while other energy sources are used for heating, demand for which will fall under a warming climate (Deschenes and Greenstone, 2011; Wenz et al., 2017; Rode et al., 2021)
- Uncertainty in damage functions appears to be ignored (e.g., see line 260), although it has been shown to play a critical role in overall uncertainty in prior work (Hsiang et al., 2017; Carleton et al., 2022)

2. Other features of FrEDI that fail to integrate best available science

There are two other features of FrEDI that fail to meet current literature standards.

- As far as I can tell, uncertainty in climate conditional on emissions is ignored (if this is not the case, it should be made much clearer how this is being handled). This uncertainty is large but also easily quantifiable using FaIR.
- Spatial heterogeneity in warming rates across the United States, as well as uncertainty in this spatial heterogeneity, are also ignored. This is unrealistic and easily remediable using available climate models.
- The spatial resolution of FrEDI, at just 7 regions across the U.S., fails to generate insights that can be used by local adaptation planners or policymakers, and fails to capture important local heterogeneities in exposure and vulnerability (which are particularly important in key sectors like health where damage functions are highly nonlinear in temperature).

3. Motivation is unclear

I am slightly confused by multiple claims made in the introduction regarding how this paper improves upon prior work. First, what exactly is meant by the "temperature binning approach" and why is it beneficial? If the authors intend to refer to the approach of reporting climate change impacts by warming levels (e.g., 2C by end of century), as opposed to reporting impacts by emission scenario (e.g., RCP4.5), this doesn't appear to be what is done throughout the paper. Moreover, such an approach doesn't "improve comparability between models" (line 59), it just hides this lack of comparability the background, as different scenarios and models will arrive at a given warming level under very different sets of assumptions.

Second, the authors claim that studies relying on the RCPs and SSPs are not run under "different future trajectories" (line 57), but this is not true. Most of these studies report impacts across the full ensemble of feasible RCPxSSP combinations; these are not probabilistic runs, but they are also not singular scenarios.

4. FrEDI faces key challenges as a "dynamic" framework

The authors describe FrEDI as a dynamic framework that can be updated over time as science evolves. However, this bottom-up framework that adds independently constructed sectors cumulatively to build estimates of a total impact of climate change will increasingly face two key challenges, both of which are left unaddressed by the authors. First, as more sectors are added, "double counting" of sectoral impacts becomes an increasing concern. This is likely already a problem in the current manuscript – labor hours lost and temperature-induced mortality likely overlap; labor supply and recreation likely overlap; flooding related traffic delays and damages associated with rail and roads likely overlap; etc. The authors should present a plan for addressing this issue both within this paper and in future applications of FrEDI, once more sectors are added.

Similarly, impacts in these sectors link to one another, but such interlinkages are ignored. For example, changes in the labor market will likely lead to population reallocations that shift health risks through demographically differentiated migration. Many other examples of interlinkages exist, and the importance of such links will only grow as more sectors are added to FrEDI. As with double counting, I think this issue should be addressed in this paper.

Technical corrections/questions

- Why avoid social cost of carbon (SCC) language when computing the net present value of a marginal ton? The authors are computing what the literature calls a "domestic SCC" – why not use this term to ensure consistency and clarity?
- Line 87 suggests socioeconomic and emissions scenarios are randomly and independently sampled, but my understanding of the RFF scenarios was that there is a joint distribution and that draws should therefore be jointly sampled.
- Line 243 – what figure is being referred to?
- It is very unclear how the racial breakdown was done – are these populations modeled as differentially vulnerable to the same physical hazards? Or are the authors simply calculating how these populations are distributed across the 7 regions? More detail on what these estimates do and do not include is needed.
- The Burke et al. (2015) citation on line 55 appears to be misplaced.
- Is it a feature or a bug that FrEDI can combine any socioeconomics with any warming scenario? Should these things be linked so as to ensure feasibility/plausibility? Lines 65-68)

References

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