Comment on
“Climate Change Uncertainty Spillover in the Macroeconomy”

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Barnett, Brock, and Hansen (BBH, henceforth) build a theoretical and quantitative framework to incorporate concepts of uncertainty and ambiguity aversion to climate policy modeling. Their primary focus is on building a tractable dynamic model that includes uncertainty about carbon dynamics, temperature dynamics, and damage functions in a parsimonious way. Their model features state-of-the-art tools in asset pricing with a continuous-time model, emphasizing specific processes of uncertainty, such as regime changes (jump processes) and misspecified Brownian increments. This model extends the authors’ previous work (Barnett et al., 2020). Climate carbon and temperature dynamics follow scientific inputs that combine various climate models (Joos et al., 2013). The static economic game is simple, focused on investment and consumption choices over time. There are no explicit prices. The use of emissions in production, which are costly from a climate change perspective, largely determines the shadow price of consumption.

The paper presented by BBH is a serious attempt at modeling uncertainty from a mathematical point of view. A comprehensive treatment of uncertainty surrounding climate change, such as the one proposed in this paper, seems warranted. I agree that there are significant uncertainties to be studied, particularly regarding the ability of humanity to adapt and mitigate the change (policy and economic uncertainty) as well as surrounding the possibility of major tipping points (Burke et al., 2015; Lemoine and Traeger, 2016). Indeed, the authors find that uncertainty about climate change damages is the most significant uncertainty influencing optimal policy.

My primary concern is that the analytical and quantitative assumptions built into the exercise minimize the climate change problem and are of limited empirical relevance. Therefore, it is unclear what the broader takeaway from the quantification should be for climate change policy.

1 Assumptions matter

The model in BBH has a novel treatment of uncertainty but it is otherwise highly stylized. A key question emerges: can such a stylized model inform the discussion surrounding uncertainty and optimal climate change policy?

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**Economic assumptions**  In BBH, utility is a function of effective consumption and energy following a Cobb-Douglas specification:

\[ U(C_t, E_t) = \tilde{C}_t^{1-\eta}E_t^\eta, \]

where \( \tilde{C}_t = \frac{C_t}{N_t} \) and \( N_t \) depends on the accumulations of \( E_t \) via increasing temperatures, \( Y_t \). In their empirical specification, \( \eta = 0.032 \). As in BBH, the model has no equilibrium prices. This parameterization implies that cutting emissions by half only reduces utility by 2.2%. More importantly, it implies that cutting emissions by 99% only reduces utility by 13.7%. This assumption has crucial implications for the role of uncertainty. Sharply cutting emissions can avoid adverse outcomes in the model, but the welfare costs from such cut in emissions are, by construction, limited. The model studies relatively extreme outcomes via the damage function but assumes the difficulties of avoiding such events away.

One can make a similar comment about the lack of dynamics in energy use. The social planner can cut emissions instantly as a function of the information set and the temperature levels. However, in practice, the existing capital assets in the fossil fuel industry make the transition extremely difficult and much more costly. In the model, not only can the social planner cut emissions very rapidly today, but it can also quickly update the policy if conditions change. This assumption is unrealistic and very relevant for shaping optimal policy under uncertainty.

**Damage assumptions**  The economic assumptions regarding the production function minimize the welfare impacts from climate change, which enables the social planner to avoid adverse outcomes at a low cost. This assumption is even more concerning considering that, in the model, climate damages only start to matter after temperature increases 1.5 degrees Celsius. According to the model, this event does not occur for several decades. Therefore, the authors not only assume that it is cheap to control emissions via the economic assumptions but also that it is feasible to cut those emissions sharply and avoid any climate damages altogether via the delay in the climate damage functions.\(^1\)

**Uncertainty assumptions**  As I just explained, significant damages in the model only occur very far out in time. Additionally, once damages start happening, the social planner already knows the extent of the gravity, and uncertainty is immediately resolved. The authors interpret early news as “bad news,” given that, in expectation, damages are more significant the sooner they start occurring. However, early damages also resolve all uncertainty surrounding climate change. This assumption minimizes to a great extent the uncertainty problem with climate change. It can lead to an increase in emissions after learning that the climate change problem is minor or, at least, not extreme. I am not aware of any scientific or economic evidence that suggests that we will achieve such certainty, given all the potential nonlinearities in damages and the high degree of uncertainty regarding how humanity will fare in front of such a grave problem (Burke et al., 2015).

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\(^1\)See, for example, Figure 7 in BHH. It shows that the threshold after which climate damages are relevant is only achieved in over 50 years. Under many realizations, significant climate damages only occur after more than 80 years.
2 Re-examining the discussion with a very-simple cake-eating problem

I present a stylized model to highlight some of the tensions expressed above. The model serves as an illustration, and it is not intended to offer a comprehensive assessment. The very simple cake-eating problem is inspired by the model in BBH, but in an extremely parsimonious form. There is no growth or investment, available capital is constant, and the only decision that the social planner needs to make is the speed at which emissions are released into the atmosphere. Damages permanently accumulate, as in BBH.

Three equations govern the variables in the model:

\[
\begin{align*}
\text{[Utility]} & \quad U(C_t, E_t) = \left(\frac{C}{N_t}\right)^{1-\eta} E_t^\eta, \\
\text{[Temperature]} & \quad Y_{t+1} = Y_t + \zeta_t E_t, \\
\text{[Damages]} & \quad \log(N_t) = \gamma_1 Y_t + \gamma_2 Y_t^2 / 2.0 + \gamma_3,t(Y_t - Y_0)^2,
\end{align*}
\]

in which \(E_t\) represents emissions at time \(t\), \(Y_t\) temperature, and \(N_t\) damages to consumption. The social planner maximizes the net present value of utility \(U\), discounted at rate \(\beta\). As fossil-fuels are being used, temperature increases and so do economic damages. All variables are determined in equilibrium by the chosen emissions path and the uncertainty draws. \(\zeta_t\) is a shock to the temperature process described by scientific models. There is also uncertainty regarding \(\gamma_3,t\), as in BBH, which affects the convexity of damages as temperature increases.

I implement this simple model using a discrete-time finite-horizon formulation that allows for limited uncertainty in the form of a tree. Each period represents ten years. I simulate the model for 200 years. Temperature increases, and damages evolve as a function of emissions, with some stochasticity. Uncertainty about \(\zeta_t\) is modeled as a random draw from the scientific distribution of temperature used in BBH. Uncertainty about \(\gamma_3,t\) is modeled with probabilities surrounding alternative scenarios. To mimic the assumptions in BHH coarsely, I also consider simulations in which there is growing certainty about the relevant damage
uncertainty about climate damages is not revealed along the tree. There are equal probabilities of a benign, medium, and extreme scenario, whose damages are shown in Figure 1a. These damages are in the spirit of what is covered by BBH, but I simplify the mathematical formula and remove the unknown structural break.\(^2\) As in BBH, this treatment of climate damages leads to substantial abatement when compared to a business-as-usual (BAU) scenario in which there is limited action to reduce emissions (case 1), as shown in Figure 1b. The figure also highlights that the recommended optimal paths are aggressive, reducing emissions by about two-thirds already in 2020.

Given that climate damages are most important, I consider two situations to highlight that the uncertainty treatment in BBH does not necessarily make the planner conservative. First, I consider one mimicking ambiguity aversion in which the planner effectively puts more weight on the most extreme scenarios. Naturally, as shown in Figure 2a, this makes the planner more conservative. Second, I consider a case in which climate damages become known after a specific date. This assumption has the opposite effect on the social planner, who becomes less conservative, as shown in Figure 2b. Once the uncertainty is resolved, emissions can even increase on average. This issue highlights that the assumptions behind the treatment of uncertainty can affect the robustness (in a conservative sense) of the policy recommendations.

3 On the broader role of uncertainty and climate change policy

Taking a step back, I have some concerns about where the profession should place its efforts when informing the fight against climate change. Annual world emissions show no signs of decline despite the drastic reductions most integrated assessment models (IAMs) recommend. Therefore, it seems worthwhile to investigate climate policy under much more inefficient second-best environments. In particular, the feasible scenario along a particular branch of the tree.

For the baseline simulation, the tree structure is only focused on the temperature increases $\zeta_t$. The uncertainty about climate damages is not revealed along the tree. There are equal probabilities of a benign, medium, and extreme scenario, whose damages are shown in Figure 1a. These damages are in the spirit of what is covered by BBH, but I simplify the mathematical formula and remove the unknown structural break.\(^2\) As in BBH, this treatment of climate damages leads to substantial abatement when compared to a business-as-usual (BAU) scenario in which there is limited action to reduce emissions (case 1), as shown in Figure 1b. The figure also highlights that the recommended optimal paths are aggressive, reducing emissions by about two-thirds already in 2020.

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Figure 3: Likely constraints in policy limit the impact of uncertainty

(a) Decrease constraints (40% per decade)  
(b) Decrease constraints + 15 Gt Carbon leakage

Constrained policy is very likely to fall short of any of the recommended policies derived in these simulations. We should aim at incorporating some of the political economy constraints that policymakers and societies face, as also recently emphasized by several IAM experts (Peng et al., 2021).

Uncertainty about our future is high, but it seems unlikely that there is a risk of fighting “too hard” against climate change. To support such a statement, I introduce two constraints to the simple model above. First, the emissions can only decrease by 40% each decade. Second, I introduce a leak of about 4 Gt of carbon that cannot be prevented by the social planner, e.g., because some nations do not comply or because technological barriers hinder further decarbonization. Figure 3 shows the optimal policy recommendations under the medium and extreme scenarios. Under such very different uncertainty scenarios, the constraints are binding, and the recommended optimal paths are the same. The recommendation, in line with what the scientific community is demanding, is to reduce emissions swiftly in the next two decades (Figure 3a), and go to zero emissions if there are remaining leaks (Figure 3b).

One could conclude, a bit provocatively, that we are so late to act against climate change that uncertainty modeling does not matter. Instead, expanding the feasible set of climate action is crucial. That said, the quantification of uncertainty could still be essential precisely on this front. Correctly modeling extreme events and their economic and uneven consequences can help shift global preferences towards coordinated action. Current events—such as persistent high temperatures near the Arctic, destructive fires of unseen virulence, or deadly floodings even in nations with robust infrastructure—are already telling us quite a different story than what our economic models have been assuming: we are vastly unprepared for the times ahead. My informed assessment is that we are undoubtedly falling short of stepping up to the challenge: the uncertainty lies in the by how much, why, and what to do about it.

3For example, the International Energy Agency recently recommended stopping new fossil fuel developments (IEA, 2020), a policy that seems entirely outside the feasible set.
4Each period is a decade, 2020 should be interpreted as emissions in the 2020’s, 2030 as emissions in the 2030’s, etc.
References


