Comment

Supplementary information to:

Climate policy models need to get real about people — here's how

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Supplementary Information for "*Climate policy models need to get real about people – here's how*"

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This appendix includes the following content:

1. An explanation of our deliberation process
2. A full list of eleven politically-relevant model reforms examined in this study (Table S1)
3. Qualitative scores for eleven model reforms (Table S2)
4. Numerical scores for eleven model reforms (Table S3)

An explanation of our deliberation process

We are a team of interdisciplinary scholars deeply immersed in both the worlds of integrated assessment modeling (IAMs) and political economy. We convened —at a distance, thanks to Covid—to answer one question: how could insights from political economy make the IAMs more useful for political decision-making in the real world? The answers depend, of course, on which decision-makers are listening. The IAM community has already made tremendous efforts to engage real-world stakeholders to align model developments with the needs of users.[1–3] Based on the insights gained from the interactions with model users, we decided to focus on three communities of policy-relevant decision-makers as summarized in the main text: a) Analysts interested in emission trajectories: those who want better predictions about what might happen in the world as a whole; b) International policymakers: those who design international agreements; c) National policymakers: those who design policy within countries.

It is easy to imagine many things that decision-makers might want to know and see included in IAMs. In fact, many IAM studies have begun to account for some of these considerations in stylized ways (see more discussions in a few review papers[4–6]). For example, some have examined how political disagreements can delay policy action and hence increase the mitigation cost[7–9]. Some are looking at how variations in the quality of governance affect investment choices[10], and how perceptions of risk and the time horizons influence investment planning[11,12]. That's an important start.

However, some human and political factors are difficult to be included in IAMs. For example, the field of behavioral economics has offered sundry insights[13] into how humans are systematically irrational in how they weigh risks or evaluate inconvenient information such as the need to make costly transformative reductions in emissions. Despite a few examples with oversimplified assumptions[14,15], most of those insights aren't amenable to the structure and coding needed to make them tractable in an IAM. Also potentially useful would be insight into how the political conflicts over decarbonization policy might create social movements that affect (strengthen and weaken) the impetus for strong policy over time. There, too, neither the social science understanding of how political mobilization works nor the ability to represent that in IAM tools make this ripe for advance yet. Indeed, if the ideas we advance here about incorporating political economy get traction then similar exercises might be conducted in other domains of social science aimed at identifying essential intuitions and applying them in IAM-tractable frameworks. In our effort we learned, early on, that these activities require teams of scholars who are deeply anchored in the IAMs (and thus knowledgeable about what's feasible) and also well tethered to the relevant social sciences (and thus aware of what's important).

To help identify the political economy factors of highest priority that might be amenable to inclusion in IAMs, we undertook an exercise of identifying plausible insights from political economy (and related fields in the social sciences) and assessing them for their tractability and insight. We used the existing suite of studies that has already attempted to include more political realism in IAMs as one guide; then, as a group, we filled out the population of plausible insights through a structured process of draft, comment and group discussion. The result reveals that the list of potential improvements is long, and a list of eight items just represents our consensus on the top candidates (see first column in Table S1 and the Box in the main text).

Then we identified 11 specific model representations that could reflect the insight—for example, changes in model code, the addition of new factors and weights in objective functions, computation at different geographical and temporal resolutions, and the inclusion of new data sets. Those "politically relevant model representations", or "reforms" as described in the main text, are our unit of analysis in this study. Put plainly, these representations are things that IAM teams might do with their models.

For each, our team coded along two dimensions: a) Usefulness: how much leverage would the insight offer in making IAMs more useful for decision-makers. And b) Ease of modeling: how tractable would be to include the insight in an IAM.

The usefulness of each reform varies across three types of decision-makers. The ease of modeling also varies mainly due to the availability of data to calibrate the model at different spatial scales. For each reform and each type of decision-maker, we first provide a qualitative score to put it into different categories (e.g., low, medium or high; see Table S2). We then discuss in more detail, especially within each category, to come up with a numerical score (between 1-10; see Table S3). Because we are anchored in the tools of modeling we also looked closely at our confidence, as a group, in our scores for ease of modeling—assessing the extent to which the modeling community of experts really agrees on the tractability of making these different reforms in models (see the last column in Table S2-3).

We show a sample of the results in the main text figure ("How to Improve Models"), with the full results included in Table S2 and S3. Filled circles show the usefulness and ease of modeling for making IAMs better at explaining how the real world might evolve—something useful for analysts interested in the future emissions trajectories. The other two types of circles show how those scores would vary if the audience shifts to international policy makers (open circles) or policy makers who focus on national or subnational action (bullseye circles).

For example, we looked at how IAMs might better represent policy instruments (see Reforms #3 and #4 in Table S1-3). For decades, there has been a debate among analysts about the relative merits of economy-wide policy measures such as carbon taxes and specific policies aimed at particular classes of technologies such as renewable power. Already it is quite tractable to refine how these policies are represented in IAMs, and the usefulness of such refinement will rise as IAMs are focused within countries at national and subnational policy choices. Meanwhile, many real world policy debates are looking at the merits of other economy-wide policies such as what's often called "industrial policy"—active measures to create and redirect whole industries, as revealed for example in the history of energy policy strategies in China and growing interest in green new deals. Modeling this shift can be harder and the skills don't yet exist to offer much improvement in explanatory power of IAMs. Historically, the community has addressed these kinds of broad policy trends through scenarios, such as the Shared Socioeconomic Pathways (SSPs), rather than in specific code within IAMs.[16–18] But if new model representations could be developed, then this approach could be particularly useful for international policy makers who need more realism in setting international goals, such as in the Paris Agreement.

Modeling climate policy in the real world requires grappling with how social agendas shift. Over the same time that climate change has risen on the policy agenda so has concern, in many countries, about rising economic inequality. In these societies, making climate policy politically sustainable requires demonstrating not just that it lowers emissions but also that does not exacerbate—indeed, might mend—inequalities of income, race and other matters of great social importance. Economic analysts already have some tools for such analysis—such as the ability to compute incidence of costs by income group, at least in countries where the data are available (Reform #7 in Table S1-3). But the usefulness of such representation in IAMs might be low for international decision makers because coarse sectoral and spatial coverage in global models remains misaligned with how these political debates are unfolding. Better representation could be particularly helpful for national and subnational policy makers, and fortuitously that approach is also likely to be more tractable than attempting a one-size-fits-all model representation for the whole planet.

Our analysis suggests still other evolutions that might occur in the IAMs. More attention to the quality of government (Reform #11 in Table S1-3), for example, could be important for those interested in future emission trajectories because that affects firms' incentives to make long-term investments and the cost of capital for those investments.[11] Decarbonization, for the most part, is a capital intensive activity, and thus, such factors matter mightily. (A shift to a more capital-intensive energy system may also affect inequality, for the returns to capital tend to accrue to those segments of society already endowed with capital.) Also important in this era of de-globalizations—where institutions such as the World Trade Organization are under threat—is how openness to international trade and investment could affect climate policy (Reform #10 in Table S1-3). Profound technological revolutions, such as in the plummeting cost of solar cells, have benefitted massively from open trade in manufactured goods; if that erodes, what might be the impact on the cost and efficacy of climate policies? In economic research that has endogenized policy into trade movements—the so-called "new new trade theory"[19]. Something similar could evolve in the study of decarbonization, although the algorithms will need a lot of spadework first.

Table S1. A full list of eleven politically-relevant model reforms examined in this study. Model reform NO. 6, 7, 10 and 11 are shown as examples in the main text figure ("How to Improve Models").

Eight plausible insights from political economy	Model representations (or "reforms")	Description	Prior examples
Access to capital	1. Different costs of capital across countries or regions	Representation of variations in costs of capital across regions based on empirical evidence or proxied by institutional quality and other political factors	Iyer 2015[10]; Battiston 2021[12]
	2. Different financing options	Representation of different financing mechanisms such as grants, loans, private finance, which involve different actors and terms	
Design and type of policy instrument	3. Technology-based policy instruments	Representation of the *outcomes* of different sector- and technology-based policy instruments, such as renewable portfolio standards, low-carbon fuel standards, etc.	Hultman 2020[20]; Roelfsema 2020[21]
	4. Economy-wide policy instruments	Representation of the *outcomes* of different economy-wide policy instruments, such as carbon tax and revenue recycling, industrial and innovation policies.	
	5. Policy diffusion across states/countries	Representation of the *processes and outcomes* that policies in one or a few states/countries get emulated or reproduced in other states/countries	
Lock-in and stranding of assets	6. Age structure of existing energy assets (e.g., stranded assets)	Representation of the age structure and operational lifetime of existing energy infrastructure in the electricity, transport and residential sectors.	Cui 2019[22]; Bertram 2015[23]
Incidence of policy costs and benefits	7. Distributional effects of policy across different groups	Representation of the distribution of costs and impacts on different segments of populations with different socioeconomic status (e.g., income and race) and political power	Rausch 2011a[24]; Rausch 2011b[25]
Public opinion	8. Attitudes about the priorities for climate action	Representation of the public support level for overall climate ambition and for different types of climate policies, as well as the resulting impacts on policy implementation	Peng 2021[26] (forthcoming)

Confidence in political institutions	9. Expectation about the policy direction and duration	Representation of trust in institutions about policy consistency and future directions of climate and energy policies	Bosetti and Victor 2011[11]
Trade and investment policies	10. Openness of different sectors to cross-border trade and investment	Representation of current trade linkages in different sectors and future trends of trade and investment activities	Daioglou 2020[27]; Snyder 2020[28]
Competence of government	11. Effect of government quality on the efficacy of decarbonization policy	Representation of the variations in implementation success of climate and energy policies driven by institutional capacity	Iyer 2015[10] Olmstead 2016[29]

Table S2. Qualitative scores for "usefulness" and "ease of modeling". Here the "ease of modeling" scores are assessed based on three metrics: a) whether it requires structural changes given the current model setup, b) data requirement, and c) computational need.

	Usefulness Score			**Ease of Modeling Score**			
Model representations (or "reforms)	**Analysts interested to understand what will happen in the world**	**Designers of national or subnational policies**	**Designers of international policy**	**Analysts interested to understand what will happen in the world**	**Designers of national or subnational policies**	**Designers of international policy**	**Degree of confidence**
1. Different costs of capital across countries or regions	Medium	Low	High	High	High	Medium to High	High
2. Different financing options	Low	High	Medium	Medium	Medium	Medium	Low
3. Technology-based policy instruments	High	High	High	Medium	Medium to High	Low to Medium	Medium
4. Economy-wide policy instruments	High	High	Medium	Medium	Medium	Medium	Medium
5. Policy diffusion across states/countries	Medium	Low	High	Low	Low	Low	Low
6. Age structure of existing energy assets (e.g., stranded assets)	Medium	High	Low	High	High	Medium	High
7. Distributional effects of policy across different groups	Medium	High	Low	Medium	Medium	Low to Medium	High
8. Attitudes about the priorities for climate action	Medium	High	Medium	Low	Low	Low	Low to Medium

9. Expectation about the policy direction and duration	High	High	High	Low	Low	Low	Low
10. Openness of different sectors to cross-border trade and investment	High	High	High	Medium	Low to Medium	Medium	Medium
11. Effect of government quality on the efficacy of decarbonization policy	High	Medium	Low	Low	Low	Low	Low to medium

Table S3. Numerical scores for "usefulness" and "ease of modeling". Based on the qualitative scores in Table S2, we give numerical scores (from 1-10 scale) to show the variations across the low, medium and high groups, as well as possible variations within each group. Note that for each model reform, the cross-audience variations in "ease of modeling" are mainly driven by the data requirement to calibrate the model at different spatial scales.

	Usefulness Score			**Ease of Modeling Score**			
Model representations (or "reforms)	**Analysts interested to understand what will happen in the world**	**Designers of national or subnational policies**	**Designers of international policy**	**Analysts interested to understand what will happen in the world**	**Designers of national or subnational policies**	**Designers of international policy**	**Degree of Confidence**
1. Different costs of capital across countries or regions	7	2	8	8	8.5	7.5	8
2. Different financing options	2	8	5	5.5	6	6.5	2
3. Technology-based policy instruments	8.5	9.5	8	6	7.5	3.5	5
4. Economy-wide policy instruments	8	9	7	5	6	4.5	6
5. Policy diffusion across states/countries	7	2	8	3	3.5	2.5	2
6. Age structure of existing energy assets (e.g., stranded assets)	7	8	3	8	10	7	8
7. Distributional effects of policy across different groups	6	9	3	5	5.5	3.5	8

8. Attitudes about the priorities for climate action	7	9	6	2	2.5	1.5	3.5
9. Expectation about the policy direction and duration	8.5	10	9	2.5	3	2	2
10. Openness of different sectors to cross-border trade and investment	9	10	8	4	3.5	5	4
11. Effect of government quality on the efficacy of decarbonization policy	7.5	5	2	2	3	1	3.5

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