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A short note on integrated assessment modeling approaches: Rejoinder to the review of “Making or breaking climate targets — The AMPERE study on staged accession scenarios for climate policy”

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A R T I C L E I N F O

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A B S T R A C T

We provide a rejoinder to a review (Rosen, 2015) of our original article “Making or breaking climate targets — the AMPERE study on staged accession scenarios for climate policy” (Kriegler et al., 2015a). We have a substantial disagreement with the content of the review, and feel that it is plagued by a number of misconceptions about the nature of the AMPERE study and the integrated assessment modeling approach employed by it. We therefore see this rejoinder as an opportunity to clarify these misconceptions and advance the debate by providing a clearer understanding of the strengths, weaknesses, and ultimately the value of integrated assessment.

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Critical reviews of published work can foster scientific debates and advance research. In this spirit, we provide a rejoinder to a review (Rosen, 2015) of our original article "Making or breaking climate targets — the AMPERE study on staged accession scenarios for climate policy" (Kriegler et al., 2015a) and the wider results of the AMPERE project.[2] We have a substantial disagreement with the content of the review, and feel that it is plagued by a number of misconceptions about the nature of the AMPERE study and the integrated assessment modeling approach employed by it.

Our rejoinder is organized into five sections, a conclusion and supplementary information. The sections contain a point by point rebuttal of the central points of criticism in the review article, to which we will refer as simply, "the critique". Those central claims are: 1. our study was motivated by the desire to advocate globally fragmented climate policy approaches, 2. the model comparison approach that we are using was not credible, 3. our estimation of mitigation costs was inadequate and misleading, 4. the integrated assessment models (IAMs) used in our study were not well documented and 5. the peer review of our study did not serve its purpose. In our rebuttal, we will clarify 1. the objective of our study, 2. the validity of the model comparison approach, 3. the nature of mitigation cost estimates, 4. the extensive documentation of modeling tools and study design in the publication, and 5. the adequacy of the review process of our study. The supplementary information provides more detailed discussions of relevant points, including further discussion of misconceptions of our approach and specific claims that appear to contradict the content of our publication. We will also point out instances where the critique does not appear to account for the broad coverage of topics by the articles in the special issue and the recent literature on IAM model comparison studies.

1. Objective of the AMPERE study

The AMPERE study aims to assess the implications of the fragmented state of near-term international climate policy action for the attainability of long-term climate targets (Kriegler et al., 2015c). We developed the analysis by comparing scenarios of staged accession to a global climate regime vis-à-vis a benchmark case of global cooperative climate action. The staged accession scenarios allowed better representation of short term climate policy choices and provided new insights on their alignment with long term goals. Their use was motivated by the research question, not by a desire to advocate specific climate policy scenarios.

2. Validity of the model comparison approach

We agree with Rosen (2015) that changing parameters of a model to evaluate their influence on model output is a very valuable exercise to understand model sensitivities to input assumptions. Such studies have been frequently performed with individual integrated assessment models (e.g. Gritsevskyi & Nakicenovic, 2000; Clarke et al., 2008; McJeon et al., 2011; Luderer et al., 2013; Rogelj et al., 2013). However, single model sensitivity analyses are not directly transferable to multi-model comparison studies such as the AMPERE study. Models differ in many input and structural assumptions, and what may be an input parameter to one model could be a constraint or a structural assumption in another model.

Model comparisons undertake controlled variations of, e.g., a set of policy assumptions (such as the AMPERE (Kriegler et al., 2015c) and EMF22 studies (Clarke et al., 2009)), technology assumptions (such as the AMPERE (Riahi et al., 2015) and EMF27 studies (Weyant & Kriegler, 2014)) or socio-economic development assumptions (such as the RoSE study (Kriegler et al., 2013)) to understand robust and sensitive features of energy-emissions pathways along the selected dimensions given the full set of differences between models along the other dimensions. This is an effective way to capture "between model" uncertainty. It also allows us to better understand differences in model behavior due to the iterative process of comparing model output and discussing underlying reasons for output differences among modeling teams. Here the goal is to identify key underlying factors for output differences independently of whether those are input or structural assumptions. Model comparison studies differ in their emphasis placed on capturing the degree of "between model" uncertainty in policy applications vs. diagnosing differences in model results in more stylized experiments. AMPERE has undertaken both types of study: (Kriegler et al., 2015a; Riahi et al., 2015) emphasize application, while (Kriegler et al., 2015b) emphasizes model diagnostics.

The value of model comparisons is underlined by the fact that they are conducted in many modeling communities, including the climate modeling community (CMIP1-5), the climate impact modeling community (ISI-MIP), the agricultural modeling community (AgMIP) and the water modeling community (WaterMIP). The model comparison approaches in these communities do not differ structurally from the approach taken in integrated assessment modeling studies.

3. Nature of mitigation cost estimates

The critique suggests that the mitigation cost estimates in the AMPERE study are flawed. However, we used standard cost-effectiveness analysis to estimate mitigation costs as many other integrated assessment modeling studies have done before. It is long standing practice in climate change economics to differentiate between cost-benefit and cost-effectiveness analysis of climate policy. By definition, cost-effectiveness analysis does not consider the magnitude of climate damages nor the intertemporal trade-off between mitigation costs and climate damages. Cost-effectiveness studies focus on the economics of reaching pre-defined climate goals. The benefit of this approach is to gain a deeper understanding of mitigation dynamics and the direct costs of mitigation policy, inter alia because it allows the use of models with higher sector detail. There is value in research that looks at both the cost and benefit components separately. The IPCC, for example, devotes separate working groups to the assessment of climate impacts and damages (Working Group II) and mitigation costs (Working Group III).

Contrary to what is suggested in the critique, we clearly indicated the nature of mitigation cost estimates in our article, in particular the fact that they do not include the benefits of reduced global warming.[3] Furthermore, we included an entire section (4.4) and a dedicated Figure (Fig. 4) to compare global warming reductions due to mitigation action with mitigation costs. It appears that the critique neither recognized the cost-effectiveness approach that we took in the AMPERE study nor the discussion of mitigation benefits in our article.

The critique places an emphasis on technology cost assumptions which it hypothesizes to be the main driver of mitigation costs. As further discussed in the supplementary information, this is by no means obvious. Mitigation costs are calculated relative to a dynamic baseline as is common practice in integrated assessment modeling. This implies that if a low carbon technology outperformed a fossil fuel technology without any climate policy intervention, it would already be reflected in the baseline. The cost estimates thus capture the additional effort due to climate policy. We discuss the important topic of the choice of baseline and the assessment of the changes between baseline and policy scenario in greater depth in the supplementary information. Contrary to what is claimed in the critique, the AMPERE study accounted for and

[2] Published in a special issue on the economics of climate stabilization in *Technological Forecasting and Social Change* (see supplementary information for a full list of articles in the special issue). In addition to our study on staged accession scenarios, the special issue included studies on the role of delayed mitigation and technology availability (Riahi et al., 2015) and model diagnostics (Kriegler et al., 2015b).

[3] We state in our article: "*Reported values are direct (or gross) mitigation costs that do not include the direct benefits from avoided climate damages, or any co-benefits and adverse side-effects from mitigation action.*" ((Kriegler et al., 2015a), pg. 33).

investigated the climate policy impact on energy efficiency improvements, learning-by-doing of low-carbon technologies and fossil fuel prices.

The critique comes to the general conclusion that mitigation costs over the 21st century are unknowable because technology costs in the far future are unknowable. We agree with Rosen (2015) that no robust prediction of economic outcomes can be made even over much shorter time spans. But no unconditional predictions are attempted. Rather, it is the careful framing of mitigation cost estimates relative to a dynamic baseline that allows a structured exploration of economic impacts conditional on a range of different, and uncertain, scenarios. The integrated assessment modeling community is well aware about the deep uncertainty about long-term technology developments as documented by, e.g., its involvement in research on technological innovation in the energy system (e.g. Wilson et al., 2013; Grübler & Wilson, 2014). It is indeed an important debate how the tension between deep uncertainty in the long run and the need to perform century-scale analysis due to the long-term nature of climate change and mitigation goals can be adequately addressed (e.g. Morgan & Keith, 2008). This debate needs to be informed by the existing research on the topic and should not suffer from misinterpretations of methodological approaches.

4. Extensive documentation of modeling tools

The critique states that the modeling tools and assumptions used in the AMPERE study were not adequately documented. Here we disagree. Our article (Kriegler et al., 2015a) provides a comparative overview of key characteristics of the underlying models both in the main paper and the supplementary information. To this end, the supplement includes a detailed spreadsheet on model characteristics providing harmonized descriptions across models to allow for direct comparisons. In addition, we have provided a 50 page supplementary documentation of the study approach, the scenario setup (including the original study protocol) and the participating models. This documentation includes a summary paragraph on each model with further references to articles and model documentations for the interested reader. Quantitative information on model input assumptions, including cost assumptions, can be found in several of these references.[4]

Moreover, we have published the data of the full set of AMPERE scenarios used in our study, and the two companion studies (Riahi et al., 2015; Kriegler et al., 2015b), in a database hosted by IIASA and referenced in our article (AMPERE Database at http://tntcat.iiasa.ac.at/AMPEREDB/). This database includes, e.g., information about capital costs of electricity generation technologies, fossil fuel prices, socio-economic drivers (GDP and population) and energy demand (which the critique mistakenly claims to have not been disclosed) along with a large set of other key variables characterizing the scenarios. Finally, the special issue contains a companion study (Kriegler et al., 2015b), which is one of the largest integrated assessment model diagnostic studies to date featuring the explicit aim of increasing transparency about the differences in model response patterns. Given this wealth of information, and contrary to what is claimed in the critique, we conclude that modeling tools, study design and scenario results are documented extensively in our publication of the AMPERE study.

5. Adequacy of peer review process

The critique raises concerns about the peer review of our study and the modeling tools. Those concerns are unfounded with regard to the publication of the AMPERE special issue in Technological Forecasting and Social Change. We followed the journal's peer review process rigorously and relied on expert reviewers with deep knowledge about integrated assessment modeling tools and approaches. The AMPERE project itself was supervised by a scientific advisory board throughout its lifetime. Numerous studies based on the models in the AMPERE study have been published in the peer-reviewed literature before. The critique's recommendation to zero-base the review of modeling tools in each study that uses them contradicts the basic notion of the scientific enterprise to build on published work.

The critique makes the broader point of an external review of modeling tools independently from individual applications. We agree with Rosen (2015) that improving comprehensibility and comprehensiveness of model documentations and subjecting them to external review have large benefits for transparency and model evaluation (see also Schwanitz, 2013). To this end, the integrated assessment modeling community is actively working on expanding and harmonizing model documentation standards, e.g. in the ADVANCE project (see http://www.fp7-advance.eu/content/model-documentation). But before claiming a lack of model documentation, the available resources[5] and peer-reviewed literature should be recognized and put into the context of documentation standards for large-scale numerical models in other research areas.

6. Conclusion

Based on the above discussion, we find the central points of the critique of our AMPERE study to be unfounded, and largely based on misinterpretations of its methodological approach. Since this approach is fairly standard in integrated assessment modeling, there is an apparent need for better explanation of integrated assessment modeling practices. To this end, we hope that our rejoinder has been able to clarify a number of items concerning the purpose, scope and role of IAM studies, model comparisons, mitigation cost estimates, and model documentation, and thus will contribute to an improved understanding of the AMPERE approach, and of that involved in many integrated assessment modeling studies more generally.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.techfore.2015.07.011.

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[4] E.g. (Luderer et al., 2011) for the REMIND model and the GCAM Model Website http://www.globalchange.umd.edu/models/gcam providing the entry point to the GCAM wiki at http://wiki.umd.edu/gcam.

[5] For a few examples of web-based documentations of integrated assessment models see the documentation of the GCAM Model developed by the Joint Global Change Research Institute at http://wiki.umd.edu/gcam, of the REMIND model developed by the Potsdam Institute for Climate Impact Research (PIK) at http://pik-potsdam.de/research/sustainable-solutions/models/remind, of the IMAGE model developed by the Netherlands Environmental Assessment Agency (PBL) at http://themasites.pbl.nl/models/image/index.php/Welcome_to_IMAGE_3.0_Documentation, and of the WITCH model developed by the Fondazione Eni Enrico Mattei (FEEM) at www.witchmodel.org.

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