Finding Closure for Climate Economy Models

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

At 419 parts per million right now, CO_2 levels have increased by nearly 115% since 2002 (*Understanding our Planet to Benefit Humankind*, n.d.). The Earth's surface temperature has increased by about 1.1°C since pre-industrial times. Each year, 427 billion metric tons of ice are lost from the ice sheets in Antarctica and Greenland. The sea level has increased by 4 inches since 1993 and the ocean's heat energy has increased by 345 zettajoules since 1955. These changes to the Earth's climate have the potential to induce a variety of adverse effects including ecosystem collapse and increasing occurrences of severe weather phenomena (*Climate Change: Frequently Asked Questions, 2018*). Climate change or global warming is mainly caused by the greenhouse effect which is when air pollutants such as carbon dioxide get trapped in the Earth's atmosphere thereby absorbing solar radiation and making the planet hotter (MacMillan & Turrentine, 2021). Human activities like burning fossil fuels are major contributors to these air pollutants (*The Causes of Climate Change*, n.d.).

Many things are being done to mitigate the effects of global warming including enacting environmental policies aimed at creating a more sustainable future. Environmental policy in the US made its debut with the National Environmental Policy Act (NEPA) which was a law signed by President Nixon in 1970 that required all federal agencies to seek approval of any actions that may have a substantial impact on the environment (Boslaugh, 2016). While this legislation was not made in response to global warming, it served as the foundation for future environmental legislation. The 2015 Paris Agreement marked a significant advancement in global environmental cooperation. The Paris Agreement was conceived in 2015 by the 21st Conference of Parties of the UNFCCC (United Nations Framework Convention on Climate Change) and was adopted by 196 parties including the United States (*What Is the History of the Paris Agreement (2015)?*, 2022).

The main goal it wished to achieve was to limit the increase of the average global temperature from pre-industrial levels to less than 2°C, and preferably less than 1.5°C to significantly reduce the impact of climate change (Paris Agreement, n.d.).

In the US, Congress creates broad environmental laws that cover a variety of things such as specifying how much money goes to a specific sector, requiring businesses to report emissions, or limiting the amount of pollution contributed (U.S. Congress, Office of Technology Assessment, 1995). These laws then enable administrative agencies such as the Environmental Protection Agency (EPA) to create and enforce more specific regulations about what is legal and what is not (*The Basics of the Regulatory Process*, 2022). Another important entity to mention is the United Nations Environment Programme (UNEP) which is a leading international environmental authority that supports governments in establishing laws to promote environmental sustainability and aids countries in integrating low-carbon technologies into society (Sundholm, 2018). These entities generally use climate scientists and industry experts to better inform these legislations and regulations, but another tool that has been used is green economy modeling or climate economy modeling (*Green Economy Modelling*, n.d.).

Climate economy modeling "(a) establishes a relationship between policy targets and relevant economic, environmental and social dimensions; (b) projects the impacts of policy measures in advance; (c) analyses the effects of existing policies and; (d) identifies synergies and cross-sectoral impacts among policy choices." (*Green Economy Modelling*, n.d.) Many different models are under development to better inform future environmental legislation. The environmental modeling field was first established in policymaking at the national and even global level after the oil crisis in the 1970s, when the Western world experienced petroleum shortages, and focused mostly on energy security and costs (Felder & Kumar, 2021). These models are now used in broader regard to develop long-term plans to reduce greenhouse gas emissions. For our society to achieve the climate goals outlined in the Paris Agreement, it is necessary to construct "effective" climate economy models. Well-developed climate economy models are an important step in the development of environmental policy by providing a reasonable prediction of the effects of a particular policy.

In this paper, I will argue that there's a disparity between the output of climate economy models and their usage in environmental policy because the models suggest policies that do not have the social and economic considerations needed for policymakers to create a passable bill. In my literature review, I will outline the difficulties in the creation and implementation of environmental policies, the usage of climate economy models in policy, and the limitations and critiques of climate economy models. In my analysis, I will use the social construction of technology (SCOT) to analyze the relationship between model developers, policymakers, and models to understand how the outputs of these models are interpreted and translated into law. I will then discuss how to bridge the discrepancies in this translation process to positively impact the environment.

Literature Review

Plans to decrease carbon emissions, also known as decarbonization plans, are essential to protect the environment for future generations. However, these plans are expensive to implement with the cost estimated to be $11-$21 trillion through 2050 in order to "decarbonize the ammonia, cement, ethylene, and steel sectors," dependent upon the price of zero-carbon electricity (Pee et al., 2021). Environmental laws are notoriously difficult to enforce because environmental institutions are generally "unable to effectively inspect, prosecute, and adjudicate environmental violations," which leads to a community that believes that non-compliance will not be punished

(Nairobi, 2019; Bruch, 2019, p. 31). Additionally, the impact on the economy is almost immediate, while the change in environmental quality is often ambiguous and far removed from the present (Lazarus & Zdeb, 2021). The uncertainty of any decarbonization plans' effects and the high cost of their implementation make it difficult to pass plans through a legislative body.

As such, tools such as environmental models, specifically integrated assessment models, have been under development since the 1970s to better inform future environmental legislation. Integrated assessment models (IAM) are one type of climate economy models that provide quantitative descriptions of the interactions between humans and the environment (United Nations: Climate Change, n.d.). In a publication about the rise of IAMs, Van Beek et al. (2020) divide the evolution of environmental modeling into five phases. The first phase is from 1972-1985 detailing the emergence of global modeling with the roles of these models varying from agenda setting, technical assessments of energy alternatives, and policy advice. Between 1985-1992, early IAMs such as the Regional Acidification Information and Simulation (RAINS), Atmospheric Stabilization Framework (ASF), and Integrated Model to Assess the Global Environment (IMAGE) demonstrated their applications in policy specifically in the formulation of policy regarding acid rain and emission scenarios for the Intergovernmental Panel on Climate Change (IPCC); thereby, proving the usefulness of IAMs and building a foundation of trust. The International Panel on Climate Change provides policymakers with comprehensive assessments of climate change and its implications (*IPCC — Intergovernmental Panel on Climate Change*, n.d.). In the third phase between 1992-1997, the emergence of the climate regime allowed for the rapid expansion of IAMs and adoption by the IPCC because of the ability to evaluate the social and economic aspects of emission scenarios faster than general circulation models and non-model based integrated assessments. These IAMs also played a huge part in the target formulation concerning the Kyoto

Protocol, the precursor to the Paris Agreement that focused on industrialized countries' efforts to reduce greenhouse gas emissions targeting the increased average global temperature from pre-industrial levels to less than 2°C (*What is the Kyoto Protocol?*, n.d). In the fourth and fifth phases between 1997-2015 leading up to the Paris Agreement, the IAM field matured and became officially responsible for IPCC mitigation scenarios as a way to legitimize early actions and temperature goals, compare temperature target solution alternatives, and monitor progress towards temperature target strongly influencing the provisions in the Paris Agreement. As seen, IAMs have established themselves as a huge part in informing policies. Policymakers, in turn, have increased their usage of these models' results as they are regularly incorporated in IPCC assessments (*IAM Helpful or Not?*, 2015). These assessments among other research journals help them understand the likely socio-economic consequences of climate change.

Many scholars, such as Robert Pindyck (2013), an American economist, have argued that "these models have crucial flaws that make them close to useless as tools for policy analysis" (p#?). Global climate models such as the Global Change Assessment Model (GCAM) are already widely available and used by the IPCC, but due to their highly aggregated nature, "Major imperfections in the models prevent proper simulation of important elements of the climate system" (Lupo et al., 2013, p. 10). Oftentimes, there are significant differences between the observations and the model predictions, and in some cases the sign (+/-) of the observed parameters are incorrect. Climate models such as Integrated Assessment Models (IAMs) still largely remain a black box where thousands of lines of code, input assumptions, and data points are not publicly available leaving us to blindly trust that the model works (Vaidyanathan, 2021). Although many of these inputs are arbitrary, they can significantly influence the outcomes that the models produce (Pindyck, 2017).

My research is meant to put these uncertainties into perspective so that these models can be more readily accepted and effectively used.

I framed my STS research through the lens of the social construction of technology (SCOT) framework. SCOT is a response to technological determinism, and advocates argue that the use of technology is understood through its greater social context (Klett, 2018). In an article by Pinch and Bijker (1984), they explain SCOT to have two stages: interpretative flexibility and closure. Interpretive flexibility is when a technology is defined differently by several groups of stakeholders or relevant social groups. This first stage outlines these relevant social groups and their definitions of a technology, which will later be investigated in the second stage. The next step is to examine how a technology reaches stabilization through either rhetorical closure or closure by redefinition of the problem. Even if the issue may not necessarily be solved, rhetorical closure occurs when all relevant social groups perceive the issue as resolved. On the other hand, closure by redefinition of the problem is when a technology was designed to solve one problem, which may not have been viewed by the relevant social groups as a concern, but instead solves a different problem in which all social groups are satisfied. SCOT looks to the social world in order to explain the success or failure of technology. SCOT does not accept a narrow-minded reason such as the technology succeeded because it was "the best," but rather seeks to identify the criteria for being "the best" through the investigation of the involved stakeholders. The SCOT framework was used in my STS research by defining model developers and legislators as the relevant social groups. Then each social groups' criteria for an "effective" climate-economy model was formed and compared to see how or if these models have reached closure. This framework was used to analyze relevant social groups in order to bridge discrepancies in the definitions of "effective" climate-economy models in the most beneficial way for our environment and drive the creation of better models that satisfy the criteria of the relevant social groups.

Methods

Using academic journal databases, I reviewed academic journals and articles to gain an understanding of the history of environmental models and what factors are important for the development of climate economy models. By doing this, I ascertained the values held by engineers and lawmakers. Since my capstone project is in collaboration with the Joint Global Change Research Institute at Pacific Northwest National Laboratory, I asked a senior research scientist questions about the difficulties they've encountered in creating decarbonization models and the impacts their models have had on policy. The Pacific Northwest National Laboratory (PNNL) is a leading center for scientific discovery and innovation in sustainable energy and Earth science and the main contributor to the model known as GCAM. Lastly, I spoke with a legislative correspondent for a Virginia senator to understand how and to what extent climate economy models are used to inform environmental policy and what other considerations are taken into account when creating environmental legislation. Legislative correspondents quote and summarize various reports such as IPCC Assessments to provide legislators with a big-picture view of the possible impacts of their policies or the need for certain policies.

Analysis

The first relevant social group are policymakers who use climate economy models as one of the tools to inform policy decisions. Although policymakers are in a position to create policies that significantly mitigate the effects of climate change based on the plans suggested by these models, they are held back by "political will" and restraints regarding what legislation will be approved and ratified. In my conversation with a former legislative correspondent to Virginia

Senator Mark Warner, we talked extensively about how the energy and climate provisions in the Inflation Reduction Act of 2022 came to be. The Inflation Reduction Act is a federal law that aims to reduce inflation with several provisions to fund and incentivize the use of clean energy to reduce greenhouse gas emissions (*Inflation Reduction Act*, 2023). These provisions include allocations to the US Department of Energy to upgrade energy infrastructure and tax credits for corporations and consumers to invest in clean energy such as electric vehicles, solar panels, and climate projects meant to decrease emissions (*The Inflation Reduction Act: Here's What's in It*, 2022). Although models may call for a large investment in certain sectors, policymakers often cannot promise such investments, as the bill will not be able to be passed. In the case of the Inflation Reduction Act, the original price tag was around $4 trillion, but in order to get passed it was eventually whittled down to $1.75 trillion. For this act in particular, the Senate was highly polarized among party lines as none of the Republicans signed off on the act. Although all 50 Democrats eventually signed on to the act, there was still a spectrum within the party, so the opinions of the most moderate voices had to be considered to create a bill that would succeed. To make specific decisions on investments, policymakers turn to expert modelers to determine where exactly the allocated money can help the US reach emission targets. As the correspondent stated, they often have to "play" with the inputs in hopes of finding an appropriate solution that is within reason. As a result, environmental policies do not generally mirror those suggested by models but rather incorporate facets of a suggested solution that are implementable with the current resources and mindsets held by legislators. The results produced by models are puzzle pieces that legislators must piece together with many other aspects to create legislation.

The other relevant social group are the model developers that create these models to help inform policies. Despite apparent flaws and uncertainties in climate economy models, these models are still used to inform policy because of the ability to represent large scale interactions. These models can help legislators set priorities, and since they are being constantly improved and reviewed models are still viewed as a reliable source of information. A smaller subset of IAMs is focused on detailed processes that output climate change mitigation cost projections. (Weyant, 2017). However, these models are highly sensitive to any assumptions made about the policy regime, so it is difficult for analysts to make very precise projections. Despite this flaw, "these cost projections can help policymakers understand the trade-offs involved in selecting specific elements of any policy regime" (Weyant, 2017). According to a senior research scientist at PNNL, models are often peer-reviewed to avoid poor advice. If ten peer-reviewed models agree on a particular trend or assertion, this then provides a stronger argument for the effectiveness of a policy. The scientist also states that one of the biggest challenges in developing models is collecting the data needed for them, especially in developing countries. While acknowledging the assumptions and uncertainties programmed within these models, the scientist asserted that the numbers can be off by +/-10%, but as long as the model structure consisting of economic equations among other things is solid and logically sound, the numerical precision can be honed through the everlasting quest for accurate data. Additionally, these models are usually open-source so anyone who may question the accuracy of the model can provide their honest critiques or even change the assumptions as they see fit when running the model. For example, one of the models at PNNL set the CO2 capture rate to 90%, but the literature challenged this rate and asserted that the capture rate could exceed 95% cost-effectively, and this assumption was changed within the official model. As seen, the models are constantly being peer-reviewed and improved with critiques being taken in stride. Model results through the lens of model developers are key to informing policy decisions and creating impactful environmental policies.

Conclusion

In conclusion, model developers have an optimistic view on the use of climate models, but policymakers have more things to consider than the science and what the models account for which explains the discrepancies observed between models and legislation. However, all the relevant social groups outlined previously agree that developing these models is a productive step forward in the fight against climate change. Based on this analysis, these models have reached a level a closure in some regards such as use, but still have a long way to go to fully reach rhetorical closure where issues such as the lack of social and economic factors in models and unrealistic outputted policies are fixed in the view of the social groups. Through the interviews, I have learned that having a team of climate scientists, economists, and industry experts is important to help decipher the outputs of these models in a way that is useful for policymakers. I believe that an important facet of creating an "effective" environmental model is for the model developers to document the assumptions made and how they can affect the outcomes. Another important aspect is to engage in peer reviews so that the models can be more readily accepted as valid arguments for or against particular policies. Model inputs are ever-changing, so for policymakers to continue to trust and use these models, data must be constantly collected and vetted to work towards more accurate models. Lastly, models must find a balance between realistic and environmentally beneficial goals and policies by incorporating the aspects that policymakers must consider and narrowing down the scope to find solutions at the regional or local level that could be easier to implement than global or national initiatives.

Another step that must be taken to further advance environmental policy is to shift the mindset of the general public and reluctant legislators to ensure that climate change mitigation is a priority. According to the legislative correspondent, there does seem to be a shift in constituents' views towards climate change being a greater problem due to the increase in extreme weather events and the rising sea level, facts that cannot be disputed. If constituents believe that climate change is an urgent issue, then they can petition for legislation or vote for legislators that will work towards mitigating climate change. As seen in the case of the Inflation Reduction Act, the act was barely able to be passed because none of the Republicans would approve the bill. By changing their perception of the climate change problem, more ambitious and impactful policies can be created and passed. Climate change affects all people in some significant way, so the policy surrounding solutions should not be partisanal but rather bipartisan cooperation for the good of the US and the planet.

These findings should serve as a road map for engineers to create better climate economy models. I hope that this analysis will help model developers better understand the implications of these models. Additionally, policymakers can read this research to better understand how these models are created and how to better utilize these models to their fullest potential without taking their outcomes for granted. I hope that these findings can assuage any concerns that policymakers may have about using these models.

A future researcher should expand upon this research by incorporating more relevant social groups such as the general public, bureaucratic agencies, and advocacy groups. Additionally, continuing to research and investigate these groups as viewpoints are likely to continue to change. Since a partisanal split is apparent in the creation and acceptance of environmental policies, more research could be done to determine what exactly is causing this split and how to reconcile these differences. Future research should investigate models with the successful qualities outlined and see how they have been used or received. Another interesting path in future research would be to look at the ethical problems that arise from using these models.

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