Development of a Computable General Equilibrium Model to Understand the Effects of Decarbonization Plans at a State Level

(Technical Report)

Finding Closure for Climate Economy Models

(STS Research Paper)

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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

Climate change is becoming more and more prevalent. The surface temperature has been steadily increasing since 1977 as seen in a global time series plot created by the National Centers for Environmental Information (NCEI) (*Climate at a Glance: Global Time Series*, 2022). This rise in temperature has the potential to induce a variety of adverse effects including rising sea levels, ecosystem collapse, and more severe weather phenomena (*Climate Change: Frequently Asked Questions, 2018*). 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). 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.).

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). Firms in the US also spend an estimated $200 billion per year to comply with environmental laws (*The Benefits and Costs of US Environmental Laws*, n.d.). Environmental laws are also 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, environmental 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, where 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.

In my technical project, my team members and I will develop a regional computable general equilibrium (CGE) model which will predict the economic effects of an environmental policy at a state level. As for my STS research, I seek to uncover how engineers, legislators, and environmental advocacy groups define an "effective" climate model in hopes of discovering a way to stabilize and support the use of said models towards the creation of environmental policy.

Technical Topic

My technical project is within the realm of climate-economy models, which are models that generally consist of five modules: economy, energy, climate, damage/impact, and intervention (Ortiz & Markandya, 2009, p. 16). In research conducted by Nikas et al. (2018), they classify six types of climate-economy models, two of which, optimal growth integrated assessment models (IAMs) and computable general equilibrium (CGE) models, have been relevant to my technical project (2018). An optimal growth IAM represents the economy as a single sector, and attempts to determine a policy that maximizes welfare while considering emission abatement levels. A CGE model provides a more detailed representation of the economy by disaggregating economic sectors, and then projects the impacts of a specific policy.

The goal of my technical project is to develop a model to determine the economic impacts of decarbonization policies at a regional level. Global climate models such as the Global Change Assessment Model (GCAM) are already widely available and used by the International Panel on Climate Change (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., n.d., p. 10). Often times, there are significant differences between the observations and the model predictions, and in some cases the sign (+/-) of the observed parameters are incorrect. Additionally, global climate models require a tremendous amount of computing power, especially with the resolution of models increasing, that sometimes leads to models being left unresolved unlike regional models which have relatively affordable computing costs (Lupo et al., n.d., p. 10; Giorgi, 2019).

Regional models offer information on at a smaller scale, which is more suited for studying regional phenomena and performing vulnerability, impact, and adaptation (VIA) assessments. According to Gutowski et al., regional models are "developed to understand processes affecting climate that are not resolved well by global models, particularly those that may be important for climate change in regions" (2020). There is already a GCAM model with greater spatial detail in the USA region, GCAM-USA, and even a North American Regional Climate Change Assessment Program (NARCCAP), which is a program that produces high resolution climate change simulations that gives insight on uncertainties in regional scale projections, but these models do not give detailed insight on regional economic impacts, which is where we would like to fill in the gap (*GCAM V6 Documentation: GCAM-USA*, n.d.; *About NARCCAP*, n.d.). Although we could develop another version of GCAM with a smaller, but more detailed scope than GCAM-USA, this path would not give as much economic insight as our proposed solution.

Our proposed solution is to create a regional CGE model for the US based off the CHEER CGE model which is geared towards examining the employment impacts of renewable energy policies in China (Mu et al., 2018). Due to the great amount of economic insight provided in the model, the proposed model can be used to inform policymaking. This proposed model relates to the STS problem because we have to consider the definitions of "success" by different social groups before the model can be of use.

STS Topic

Climate-economy models have a huge impact on humans and the society, as they are often used by the IPCC to create global initiatives for combatting climate change. The problems that engineers face in the development of environmental models include how beneficial environmental impact is traded for lower mitigation costs on the economy and government finances. In a world with unlimited resources, engineers could make a model that simply finds an optimized plan to reach net-zero emissions. However, there is no such thing as unlimited resources and unlimited time; therefore, engineers must also account for plausibility, implementation costs, time constraints, and negative economic impact. In doing this, models may suggest pathways that satisfy lawmakers but displeases environmental advocacy groups because the plan does not do enough to remedy humanity's negative impact on the environment. The overarching STS idea that will be addressed is that "technical things have political qualities" (Winner 1980). Climate-economy models are inherently political because they are used to inform legislative policies. These models generally support a more authoritative government because they generally articulate that in order to reach specific climate goals, high carbon emitting sectors, especially the industrial sector, must be highly regulated.

I will be framing 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 justify 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 will be used in my STS research by defining engineers, legislators, and environmental advocacy groups as the relevant social groups. Then each social groups' criteria for an "effective" climate-economy model will be formed and compared to see how or if these models have reached closure.

Research Question and Methods

The research question I would like to pursue is "How does the definition of "effective" climate-economy models differ between engineers, legislators, and environmental advocacy groups? Using academic journal databases provided by UVA and the internet, academic journals and articles will be reviewed to gain an understanding of the history of environmental models, legislation, and advocacy groups. By doing this, I hope to ascertain the values held by engineers, lawmakers, and advocacy groups. I would also interview my capstone advisor, Andres Clarens, who is a professor of Engineering Systems and Environment and has written academic material about carbon management including a proposal for a state-level decarbonization model. Since my capstone project is in collaboration with the Joint Global Change Research Institute at Pacific Northwest National Laboratory, I would ask them questions about the difficulties they've encountered in creating decarbonization models. If possible, I would like to contact a few environmental advocacy groups such as Greenpeace, the Environmental Defense Fund, Global Footprint Network, and the Earth Institute Center for Environmental Research and Conservation about their thoughts on decarbonization models and what their organizations do to impact legislation. Lastly, I would attempt to contact United States Representative for Virginia's Second

Congressional District, Elaine Luria, about what resources she uses to inform her environmental legislation such as the Chesapeake Bay Program Reauthorization Act. In pursuing this research question, I hope to develop a deeper understanding of the current state of decarbonization models and the trade-offs programmed within them.

Conclusion

The overarching problem addressed in this paper is that "effective" climate-economy models must be developed to inform policymaking that will allow our society to meet climate goals outlined in the Paris Agreement. The pursued technical topic plays a part in solving this problem through the development of high-resolution regional climate-economy model, which will be used to inform regional environmental policies. By performing a SCOT analysis of climate-economy models, we can discover how 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. In pursuing these topics, I hope to develop a deeper understanding of the current state of decarbonization models and the trade-offs programmed within them, and in turn, create a state-level decarbonization model that effectively compromises the sentiments of stakeholders and will be used to actively inform legislation.

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