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The effect of near-term policy choices on long-term greenhouse gas transformation pathways

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ABSTRACT

To successfully limit climate change, today's greenhouse gas mitigation policies should encourage reductions that will continue for decades. History suggests, however, that some policy reforms lead to societal changes that persist over the long-term while others fade without long-term effect. Current climate policy literature provides little guidance on how today's policy choices can successfully shape long-term emission reduction paths. To address such questions, this paper introduces a new agent-based, game theoretic model designed to compare how near-term choices regarding alternative policy architectures influence long-term emission reduction trajectories. Drawing on political science literature that identifies the characteristics of policies that persist over time, this simulation for the first time integrates the co-evolution of an industry sector, its technology base, and the shifting political coalitions that influence the future stringency of the government's emission reduction policies—all as influenced by the initial choice of policy architecture. An exploratory modeling analysis that represents deeply uncertain phenomena such as the future potential for innovation and the behavior of future governments draws policy-relevant conclusions from this model. The analysis finds that near-term choices regarding the architecture of a carbon pricing policy may affect long-term decarbonization rates significantly. In particular, such rates are higher if program revenues are returned to firms in proportion to their market share, thus, creating a political constituency for continuing the carbon pricing policy. More generally, the analysis provides a framework for considering how near-term policy choices can affect long-term emission transformation pathways within integrated assessment models.

1. Introduction

Limiting climate change requires large-scale transformation of energy and other socio-economic systems (Clarke et al., 2014). To hold global average temperatures within 2 °C of pre-industrial levels would require sustained decarbonization rates of 3–4 percent per year—quite rapid by historical standards (Guivarch and Hallegatte, 2013). Not surprisingly, there exists a large gap between the policies most governments have put in place and the scale of change many argue is needed (Victor et al., 2014). This study offers a decision-analytic, simulation modeling framework for evaluating how politically actionable, near-term policy choices might affect long-term carbon emission trajectories.

Current literature on integrated assessment modeling (IAM) reflects this distance between action and aspiration. IAM analyses can sketch contours of greenhouse gas transformation pathways produced through future technology mixes and deployments which hold climate change within proscribed bounds (Clarke et al., 2014). Such studies can also suggest policy mechanisms that might help drive such transitions over the long-term such as a steadily rising, globally harmonized carbon tax (Nordhaus, 2008). But such work provides little guidance on what today's policy makers might do to cause such pathways to be followed: What choices today might increase the likelihood that any carbon tax would rise over time? Numerous studies also provide guidance on specific policies – such as investments in efficiency and fuel switching – which may reduce near-term emissions. While the reductions achievable from such polices generally fall short of those required to achieve long-term ambitions, the transformation pathways literature suggests that near-term progress can help catalyze subsequent larger changes by reducing the scale of emissions reductions required in the future and reducing near-term investment in high-emitting capital that could "lock-in" future emissions. Nonetheless, other than the reasonable claim that cost-reducing R&D will encourage future technology adoption and the suggestion that policy uncertainty hinders low carbon investment, the current integrated assessment literature does not satisfactorily grapple with the

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mechanisms by which near-term policies might – or might not – shape long-term emission reduction paths.

This study offers a new perspective on this question by combining several strands of literature. First, it adopts a view of longer-term policy analysis that focuses on the long-term consequences of near-term decisions (Lempert et al., 2003, 2009; Lempert and Light, 2009). That is, rather than predicting or characterizing long-term emissions paths, this study employs decision-analytic methods designed to identify and evaluate near-term policy actions that would reduce 21st century emissions over a wide range of plausible futures (Lempert et al., 2006; Lempert and Collins, 2007). Second, this study draws on the political science literature of policy persistence which identifies the attributes associated with policy reforms that persist over long periods of time (Patashnik, 2003). This literature, along with a game-theoretic model describing how competition among firms and the government can shape policy outcomes (Grossman and Helpman, 1994), suggests mechanisms that decision-makers might exploit in the near-term to affect long-term emission pathways. Third, this study uses agent-based, evolutionary economic formalisms (Dosi et al., 2006; Gerst et al., 2013a) to instantiate in simulation models these mechanisms that might relate near-term actions to long-term emission reductions, along with numerous and deeply uncertain socio-economic factors that also affect this connection between action and consequence.

In particular, this study builds on Patashnik's policy persistence work which reviews historical cases of new legislation put into place in areas such as social protection and deregulation during a brief period of focused public concern and identifies the conditions that lead the policy reform to endure over time after public concern dissipates (2003). New policies are more likely to persist when they create supportive and enduring political constituencies.

Our analysis envisions policy makers in a national government with a brief window of opportunity to implement a greenhouse gas (GHG) reduction policy (e.g., pass legislation) with the ultimate goal of eliminating those emissions. Subsequently, the policy will evolve along paths no longer under the control of those initial policy makers as firms and future governments negotiate over the carbon price. We examine how policy makers might use their policy window to choose a policy architecture that increases the chances that their long-term goal will be achieved, in part by causing societal transformations that will yield future conditions supportive of these goals (Lempert et al., 2003; Lempert, 2007).

This study employs an agent-based evolutionary economics model (Ciarli et al., 2010; Nelson and Winter, 1982; Saviotti and Pyka, 2004; Silverberg and Verspagen, 1994), based on that of Dosi et al. (Dosi et al., 2006, 2010), to evaluate the policy-implications of such dynamics. Previous versions are described in detail in two earlier reports (Isley, 2014; Isley et al., 2013). In particular, we have added a game theoretic component based on the work of Grossman and Helpman (1994) which describes the competition among firms as they attempt to influence the stringency of future GHG regulations. The climate policy literature emphasizes the importance of tracking often complex feedbacks among different components of coupled natural and human systems. This study focuses on a generally neglected, but potentially crucial class of feedbacks relevant to the long-term persistence of emission reduction policies—those among the government and political coalitions that results from the interaction of firms, technology, and evolving market structure.

This agent-based simulation both contains many uncertain parameters and aims to project hard-to-predict phenomena such as innovation and evolving political coalitions. To manage such deep uncertainty, we use an exploratory modelling approach (Bankes, 1993) which seems well-suited to the type of simulation employed here (Lempert, 2002). In particular, exploratory modelling regards simulation models not as predictive engines but as tools for mapping assumptions onto consequences without privileging one set of assumptions over another. This study draws analytic methods and concepts from Robust Decision Making (RDM) (Lempert et al., 2003), an exploratory modelling-based approach, to identify near-term policies that increase emission reduction rates over a range of assumptions regarding the future behaviour of firms and the government, future technological opportunities and future economic conditions.

This study contributes to a growing literature on climate-related transformation (Denton et al., 2014) and sustainability transitions (Voss et al., 2009) suggesting that shifting to a low carbon society would not only require large-scale changes in technology but would also disrupt existing political arrangements and ways of life (O'Brien and Sygna, 2013; O'Brien, 2012). In contrasting such transformation to incremental change, this literature notes that some interests may oppose what others see as the vital societal changes needed for sustainability. Similarly, this literature emphasizes the challenges of lock-in, both at the level of technologies as well as at the level of socio-economic regimes, as well as the potential importance of policy windows that offer an opportunity for significant policy change. This study examines such themes albeit in the narrow context of interactions among firms and the government which might witness the restructuring of a previously high-emitting industry sector. In so doing, this study offers two novel contributions. First, we provide a quantitative analysis of mechanisms that may drive and hinder transformation. Second, we take a decision–actor approach in contrast to a systems view. The latter view extends over time and emphasizes the connections among different societal spheres, such as practical, political, and personal (O'Brien and Sygna, 2013) or technical, market, and behavioral, but does not privilege any particular actor in the system. The former, in focusing on how a particular agent, acting at a particular time, can influence the evolution of the system aims to contribute more directly to the evaluation of policy-relevant decision options.

Overall, this work provides an initial, quantitative, decision-analytic evaluation of how near-term choices about greenhouse gas regulatory architectures can affect the long-term co-evolution of technology, market shares, and political coalitions that affect the stringency of greenhouse gas regulation. This study also suggests how this general decision-analytic framework might prove broadly useful to the study of climate-related transformations and sustainability transitions.

Section 2 describes our integrated assessment model, the following describes the analysis and the final section offers some conclusions.

2. An evolutionary, game-theoretic model of firms and the government

This study employs an "XLRM" framework (Lempert et al., 2003) to help organize the structuring of the decision, the factors considered in the analysis and the subsequent model development and exploration. The letters X, L, R, and M refer to four categories of factors to be explored in RDM-related analyses: **Metrics (M)** are measures of merit used to express policymakers' goals; **Policy levers (L)** are near-term actions that policymakers can take to pursue their goals; **Exogenous uncertainties (X)** are factors outside policy makers' control that may determine if their near-term actions achieve their goals; **Relationships (R)**, represented by the simulation model, describe how the policy levers perform, as measured by the metrics, under the various uncertainties. Table 1 summarizes the factors considered in this analysis. We will now use this XLRM structure to describe our modeling activities.