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Multiple adaptation types with mitigation: A framework for policy analysis

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ABSTRACT

Effective climate policy will consist of mitigation and adaptation implemented simultaneously in a policy portfolio to reduce the risks of climate change. Previous studies of the tradeoffs between mitigation and adaptation have implicitly framed the problem deterministically, choosing the optimal paths for all time. Because climate change is a long-term problem with significant uncertainties and opportunities to learn and revise, critical tradeoffs between mitigation and adaptation in the near-term have not been considered. We propose a new framework for considering the portfolio of mitigation and adaptation that explicitly treats the problem as a multi-stage decision under uncertainty. In this context, there are additional benefits to near-term investments if they reduce uncertainty and lead to improved future decisions. Two particular features are fundamental to understanding the relevant tradeoffs between mitigation and adaptation: (1) strategy dynamics over time in reducing climate damages, and (2) strategy dynamics under uncertainty and potential for learning. Our framework strengthens the argument for disaggregating adaption as has been proposed by others. We present three stylized classes of adaptation investment types as a conceptual framework: short-lived “flow” spending, committed “stock” investment, and lower capacity “option” stock with the capability of future upgrading. In the context of sequential decision under uncertainty, these subtypes of adaptation have important tradeoffs among them and with mitigation. We argue that given the large policy uncertainty that we face currently, explicitly considering adaptation “option” investments is a valuable component of a near-term policy response that can balance between the flexible flow and committed stock approaches, as it allows for the delay of costly stock investments while at the same time allowing for lower-cost risk management of future damages.

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1. Introduction

Effective global climate policy that reduces net societal welfare loss will consist of investments allocated across a policy portfolio of simultaneously implemented mitigation and adaptation strategies, where the alternative is damages or “suffering” (Holdren, 2008; Parry, 2009; Tulkens and Steenberghe, 2009). Mitigation is the reduction in the rise of atmospheric greenhouse gas (GHG) concentrations via emissions abatement or carbon sequestration. Adaptation is “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (Parry et al., 2007). An area of increasing policy concern and research effort has been how to balance mitigation and adaptation investments, given limited resources. A number of studies have examined this question, often exploring the question of whether mitigation and adaptation are complements or substitutes (Kane and Shogren, 2000; Shalizi and Lecocq, 2009; Yohe and Strzepek, 2007; Bosello, 2008). While some address uncertainty in the form of scenarios or probability distributions, all of these have framed the decision problem as deterministic, and therefore as implicitly static – a once-and-for-all choice of the optimal portfolio of the two responses over time. Ingham et al. (2005) explore a two-period optimization, but without uncertainty.

Climate change is a long-term problem with multiple uncertainties. Policy decisions and investments need not and will not be chosen now for all time. Rather, near-term decisions about mitigation and adaptation are made under uncertainty, some of that uncertainty may be reduced, and then future decisions are made with the new information available. Importantly for this problem, the reduction in uncertainty may partly depend on the near term investments. In this context, there may be an additional benefit to near-term investment in either approach, if that investment reduces uncertainty and leads to improved decisions.

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We propose an alternative framework for considering the tradeoffs between mitigation and adaptation that is explicitly structured as a sequential decision under uncertainty with learning. Using this decision analytic approach, we argue that analytical emphasis should be given to two key characteristics that most inform the tradeoffs that occur when near-term mitigation and adaptation are considered together. First, the two responses exhibit different dynamics in how they reduce damages over time. Investments in mitigation and adaptation differ in the time until benefits begin accruing, how long the stream of benefits lasts, the dependence of benefits on the absolute level of damages, and the limits of a particular investment at reducing damages. Policy investments in both strategies will be made repeatedly over time, but those for adaptation allow for flexibility on the chosen longevity (and, hence, limits) of the investment's effects, as well as the technology that can be paired with different types of damages. Second, the strategy dynamics of mitigation and adaptation behave differently under uncertainty. Reducing uncertainty about the effectiveness of specific adaptation strategies in the near-term will influence mitigation decisions, but the act of mitigating does not provide timely information relevant for near-term adaptation decisions. These differing strategy characteristics of intertemporal dynamics and dynamics under uncertainty are critical to understanding the tradeoffs over time under uncertainty between mitigation and adaptation, as well as between different specific adaptation investments.

The focus on intertemporal and uncertainty characteristics further justifies disaggregating adaptation activities as others have proposed. Treating adaptation as a single homogenous response does not allow the identification of critical tradeoffs to inform investment and implementation choices of a portfolio of mitigation and adaptation. Disaggregation of adaptation has been examined by several authors with (1) flexible and short-lived ''flow'' spending, and (2) committed and long-lived ''stock'' investments (Lecocq and Shalizi, 2008; Bosello et al., 2010, 2009; Yohe et al., 2011; Agrawala et al., 2011; de Bruin, 2011; Hall et al., 2012). A third subtype is ''option stock'' – explored by Nordvik and Lisø (2004), Hertzler (2007), Linquiti and Vonortas (2011), and in several papers by Dobes, e.g. (2008, 2010) – which has a low initial capacity and cost but which can be expanded later as needed. These previous studies did not consider the tradeoffs between these subtypes of adaptation and mitigation in the context of decisions under uncertainty. Our analytical framework explores the implications of near-term investment in mitigation and the three adaptation subtypes of flow, stock, and option stock when there is uncertainty, learning, and future investment decisions. In particular, we argue that given the uncertainty, there should be greater emphasis on option stock adaptation in the near-term, and that an optimal hedging strategy will consist of a balanced portfolio with enough adaptation investments to reduce the uncertainty in their effectiveness and some mitigation investment because adaptation may turn out to be less effective or more costly than expected.

The remainder of the paper is organized as follow. In Section 2, we define and clarify the critical dimensions of an adaptation construct for implementing it with mitigation, specifically the differences in dynamics of each strategy as well as the flexibility of each strategy under uncertainty. Based on these key characteristics of adaptation, we develop an illustrative disaggregation of adaptation into flow, stock, and option stock types in Section 3. In Section 4 we present a conceptual decision-analytic framework for choosing portfolios of mitigation and adaptation investments under uncertainty. We conclude in Section 5 with a discussion of the implications for climate policy.

2. Critical dimensions: dynamics and flexibility

2.1. Background

Mitigation and adaptation are complementary tools for climate risk management. Mitigation reduces future risk, the product of the probabilities of all types of damages and the consequences of those damages, and adaptation reduces the negative consequences of realized future damages (Jones, 2003; Yohe and Strzepek, 2007). The two strategies affect each other in implementation (Wilbanks et al., 2003, 2007; Wilbanks and Sathaye, 2007; Buob and Stephan, 2008; Urwin and Jordan, 2008), where the implementation of either response influences the level of benefits received from the other approach. Mitigation and adaptation are budgetary substitutes as well (Klein et al., 2007), where economic scarcity restricts the space of Pareto superior welfare outcomes and any allocation comes with an opportunity cost from foregone alternative uses of the same resources (Friedman, 2002). Over the long term the appropriate mix of policies depends on the magnitude and rate of climate change (Wilbanks and Sathaye, 2007).

A number of integrated assessment models (IAMs) include adaptation to climate change as an explicit decision variable alongside mitigation, such as those based on the DICE model (Nordhaus, 2007) or the DICE approach (Felgenhauer and de Bruin, 2009; Dumas and Ha-Duong, 2008; de Bruin et al., 2009; Bosello and Chen, 2010), summarized in Felgenhauer and Webster (2013). Economic analyses of mitigation and adaptation tradeoffs include Antweiler (2011) and Bréchet et al. (2013). Additionally, Wilbanks et al. (2007) used the CLIR model in a preliminary effort to test how combinations of mitigation and adaptation pathways would behave over time, with adaptation disaggregated across specific climate affected sectors. In the DICE-based analyses, the tradeoffs between mitigation and adaptation occur via zero-sum budgetary competition with each other, where scarce financial resources devoted to one investment strategy will not be available for the other, and thus represent an opportunity cost (Bosello, 2008; Ingham et al., 2005; Tol, 2005). If a policymaker had started with mitigation, adding a new policy option (adaptation) within the existing budget redistributes the portfolio and lowers the use of the original policy (mitigation) (de Bruin et al., 2009; Felgenhauer and de Bruin, 2009). Some of these studies and others have disaggregated adaptation into flow adaptation (with benefits occurring only while the investment is made), and stock adaptation (with benefits continuing into the future after the investment) (Bosello et al., 2010; Felgenhauer and Webster, 2013; Yohe et al., 2011; Agrawala et al., 2011, 2010; de Bruin, 2011; Bosello et al., 2009).

However, all of these previous analyses are deterministic, in which all quantities are assumed known and the optimal mix of mitigation and adaptation over time are solved for. The known quantities include the costs of adaptation and mitigation, the effectiveness of adaptation of lowering damage, and the effectiveness of mitigation in lowering future damage (typically represented by the climate sensitivity and parameters of a climate damage function). Although such models do solve for optimal paths in which the relative proportion of mitigation and adaptation is changing with time, the omission of uncertainty and the ability to revise decisions after uncertainty is reduced hides some of the critical tradeoffs among the strategies. Most studies did examine alternative scenarios as a way to address uncertainty, but the solution of each scenario is still deterministic, and did not model the near-term decision under uncertainty. Lecocq and Shalizi (2008) apply a model with uncertainty and learning on climate damage functions to compare choices on mitigation, proactive adaptation, and reactive adaptation.