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Mitigation and the geoengineering threat

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ABSTRACT

Recent scientific advances have introduced the possibility of engineering the climate system to lower ambient temperatures without lowering greenhouse gas concentrations. This possibility has created an intense debate given the ethical, moral and scientific questions it raises. This paper examines the economic issues introduced when geoengineering becomes available in a standard model where strategic interaction leads to suboptimal mitigation. Geoengineering introduces the possibility of technical substitution away from mitigation, but it also affects the strategic interaction across countries: mitigation decisions directly affect geoengineering decisions. With similar countries, I find these strategic effects create greater incentives for free-riding on mitigation, but with asymmetric countries, the prospect of geoengineering can induce inefficiently high levels of mitigation.

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1. Introduction

Climate change is the result of the accumulation of greenhouse gases (GHG) in the atmosphere. Until now, the international community has relied on mitigation strategies to deal with the warming caused by climate change. It is well understood, however, that mitigation suffers from under-provision due to free-riding. In addition, there is also a great deal of uncertainty associated with the response of the climate system to changes in greenhouse gas concentrations. As a result, scientists are exploring new

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technologies designed to quickly lower temperatures without lowering GHG concentrations. These technologies fall under the category of *geoengineering*.

In this paper, I examine the economic issues introduced when geoengineering is made available in a world where strategic interaction leads to under-provision of mitigation due to free-riding. Specifically, I ask: does the presence of geoengineering increase the free-riding effect on mitigation?

To answer this question, I start with a conventional two-country partial equilibrium model. The model has three key features. First, the two countries interact in a two-stage strategic environment where each country minimizes its own costs of managing climate change. Each country chooses mitigation levels in the first stage and geoengineering levels in the second stage. Second, the effects of both mitigation and geoengineering are global. Third, the damages arising from the potential side-effects of geoengineering and climate change may differ across countries.

Using this framework, I decompose each country's best response to a change in the other country's level of mitigation into a *technical substitution effect* and a *strategic effect*. Using this decomposition I show how the impact of introducing geoengineering depends quite delicately on the degree of similarity between countries. First, when the two countries are similar regarding the damages from climate change and damages from geoengineering, I find that when geoengineering is introduced there is a reduction in the levels of mitigation in both countries. Second, when countries differ in their underlying characteristics, they also differ greatly in their chosen solution to the climate change problem. In this case the levels of mitigation can increase, rather than decrease, due to the introduction of geoengineering. In this case mitigation rises. These two results hold when I extend the analysis to include multiple countries. Just as before, the introduction of geoengineering can induce higher levels of mitigation. Moreover, the incentives to increase mitigation are stronger as the number of countries increases. The results also hold when private benefits from geoengineering exist. Furthermore, the incentives to over provide geoengineering and mitigation are stronger as the private marginal benefits from geoengineering increase.

In this paper, I draw on a variety of tools from economics to answer a question most often considered in physics and other natural sciences. The cost minimizing set up with increasing and convex costs and damages is standard for the analysis of climate change policies (Nordhaus, 2008; Goulder and Mathai, 2000). The sequential nature of the model resembles the problems of capacity building and competition on output (Brander and Spencer, 1983; Dixit, 1986), and these types of models are commonly used to study non-cooperative behavior in the context of international environmental problems (Barrett, 1994; Endres, 1997).

To physicists and natural scientists geoengineering is an option to be used only if society fails to reach an agreement to reduce emissions (Crutzen, 2006; MacCracken, 2006). Alternatively, geoengineering has been proposed as part of a portfolio of technologies to deal with catastrophic climate change (Barrett, 2008; Schelling, 2007; Summers et al., 2007). For both of these reasons, scientists agree that research on geoengineering is important because of the advantages this option offers (Keith et al., 2010; Moreno-Cruz and Keith, 2013), but also agree that its implementation should be highly regulated (Barrett, 2008; Victor et al., 2009).

While there is surely good reason for caution, it appears that geoengineering can achieve any given temperature target at a very low financial cost (McClellan et al., 2012). Unfortunately, this technical possibility may delay or eliminate mitigation by altering the strategic interaction among countries. For example, Scott Barrett finds the introduction of geoengineering lowers the provision of mitigation (Barrett, 2008). In addition, given the low costs of geoengineering, unilateral implementation is a real possibility. This introduces governance problems in excess of those already existing for mitigation and creates the possibility of conflict (Schelling, 1996; Victor et al., 2009; Weitzman, 2012).

The rest of the paper proceeds as follows. In Section 2, I show how mitigation and geoengineering interact to determine temperature. In Section 3, I present the main assumptions regarding the costs of mitigation and geoengineering, the damage function and the timing of events. In Section 4, I define the equilibrium concept and analyze the equilibrium levels of mitigation and geoengineering. In Section 5, I extend the results to multiple countries. In Section 6, I introduce private benefits and analyze the free-driver effect. Finally, in Section 7, I summarize the main implications of the paper.

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