Combining the Carrot and the Stick: The Best Policy Approach to Reducing Greenhouse Gas Emissions

By Robert Lempert, Mark Bernstein and David Robalino

Introduction

Governments worldwide are pursuing many different types of policies designed to reduce emissions of greenhouse gases. In particular, the Clinton Administration has proposed a phased approach to meeting U.S. commitments under the Kyoto treaty, by first using R&D spending, tax incentives and voluntary actions, followed by emissions trading. The R&D spending and tax incentives are intended as "carrots" to encourage the development and use of new, greenhouse-gas-emissions-reducing technologies. Emissions trading provides a "stick" designed to reduce emissions by increasing the price of using high emitting energy technologies.

Such a combined approach of carrots and sticks seems to have a compelling logic. New technologies will likely be critical to any significant reduction of greenhouse gas emissions during the 21st century and "carrots" such as technology incentive programs may speed their development. In addition, such incentives may be politically more attractive than emissions trading because the latter raises costs for many industries and other stakeholders. On the other hand, economic theory implies that policy-makers should employ only "sticks" such as tradable emissions permits or carbon taxes, which, in the absence of market failures, are the most efficient policies for fostering both technological innovation and reducing emissions. By comparison, technology incentives may distort the market by diverting resources from more to less productive investments**.** Finally, technology incentive programs have had a mixed record of achieving practical success independent of their relative efficiency.

Using an innovative new approach to computer simulation under conditions of extreme uncertainty, our recent RAND Science and Technology Policy Institute study[1] finds that technology incentives are likely to be an important part of a cost-effective climate change strategy. We find that if decision-makers hold even modest expectations that market failures are likely to inhibit new, emissions-reducing technologies or that the impacts of climate change will turn out to be serious then technology incentive programs are a promising hedge against the threat of climate change.

Approach

In the past, it has been difficult to systematically compare such "carrot" and "stick" policies because of the extreme uncertainty involved with technology forecasts and because of difficulty representing mathematically many of the market failures that might suggest a role for a technology incentives. We employ two new analytic innovations to assess the conditions under which technology incentives are an important building block for effective and feasible climate change policies. First, we use what is known as an "agent-based" model of technology diffusion. Agent-based models provide a convenient framework for representing several important features of technology diffusion, including information exchange among economic actors and the heterogeneity among different actors, which are often missed in analytic studies of climate change policy.

Second, we employ a new method of decisionmaking under extreme uncertainty — exploratory modeling[2] — that allows us to compare alternative policies without requiring predictions of the future cost and performance of new technologies. Rather than calculate the expected value of various policies as a function of projected costs and performance, we simulate the performance of alternative policies against a wide range of potential climate change scenarios. We then use search and visualization tools to examine the resulting outcomes to address questions of interest to policymakers. In particular, we can search for strategies that are robust across a wide range of expectations about the future.

In the analysis, we compare a strategy that only uses only "sticks" such as tradable permits[3] to limit emissions of carbon dioxide, which we call the *Limits-Only Strategy*, to a strategy that combines such mechanisms with "carrots" such as technology subsidies, which we call the *Combined Strategy*.

Both sets are adaptive-decision strategies,[4] that is, they evolve over time in response to observations of the emerging economic and environmental conditions in our simulation model. Using the exploratory modeling approach, we conducted a computer search through a huge number of plausible scenarios generated by the agent-based model, looking for those that distinguish one policy choice from another.

Figure 1, a typical result of such comparisons, shows the relative performance of these two strategies as a function of the heterogeneity of economic actors, one of the key, uncertain factors describing the future state of the world. The figure shows that the Limits-Only Strategy (green dashed line) performs better than the Combined Strategy (blue solid line) in a world where there are no potential early adopters.

As the number of potential early adopters increases, the Combined Strategy quickly becomes more attractive. More diversity favors the Combined Strategy, because it creates a number of potential early adopters that are well disposed to use the new, low-emitting technology. The incentives encourage many of these agents to adopt, thus generating learning and cost reductions above and beyond the social benefit gained by any individual adopting agent.

Findings

We considered a large number of results such as those in Figure 1, and find that under three plausible conditions, a strategy of technology incentives combined with tradable permits, or even carbon taxes, is a more effective approach to climate-change policy than an approach based on "getting the prices right" alone. These three conditions are:

- The existence of at least modest expectations among policy-makers that the diffusion of new, emissions-reducing technology will significantly reduce the future costs of emissions abatement. Such technologies might include some combination of fuel cells, hydrogen, solar, wind, biomass, or even new nuclear. Numerous studies suggest that the emissions reduction potential of these technologies may in fact be large.
- Some economic actors must be more willing to adopt such technologies than others. While such heterogeneity of

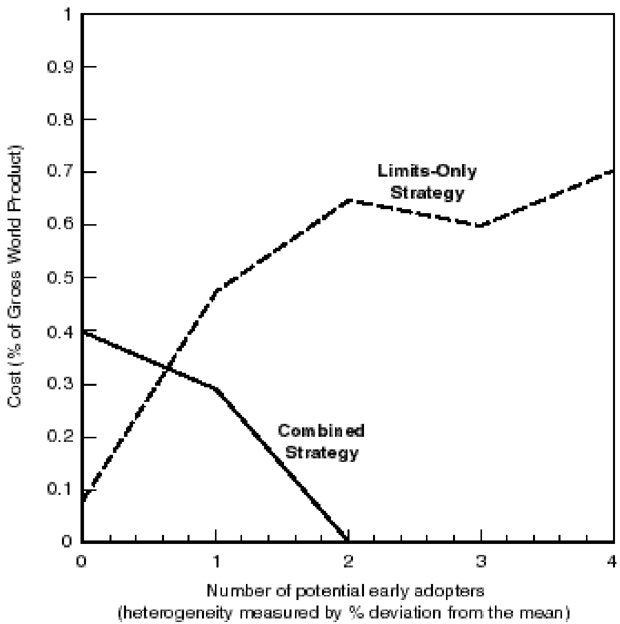
* Robert Lempert, Mark Bernstein and David Robalino and with Rand Corporation, Santa Monica, CA.

[1] See footnotes at end of text.

preferences is clearly the case in practice, it is often neglected in quantitative policy studies of climate change. Recently proposed early credit programs may encourage early adopters.

- Finally, there must be broad social benefits to the early adoption of such technologies by a small number of early users. Such benefits can arise from several sources, including cost reductions due to increasing returns to scale and improvements in the information available to economic actors about the performance of new technologies.

Figure 1

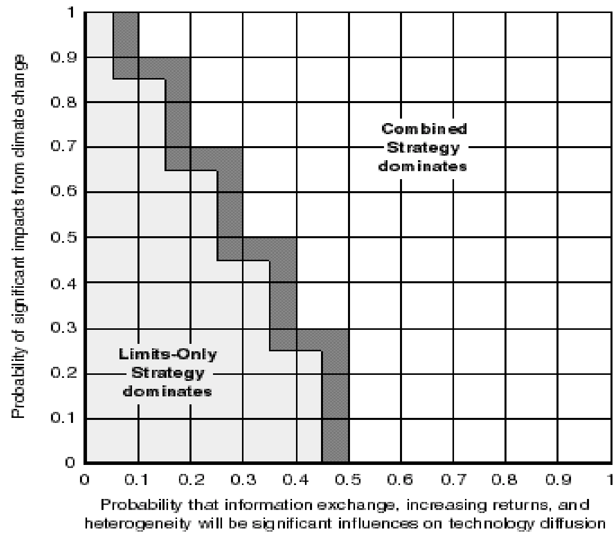


If these conditions are met, and it is likely that they are in practice, then technology incentives are an important component of an integrated climate change strategy.

These results are summarized in Figure 2. The figure shows the expectations about the future that should cause a decision-maker to prefer the Limits-Only strategy to the Combined Strategy. The horizontal axis represents the range of expectations a decision-maker might have for how likely it is — from very unlikely on the left to very likely on the right — that factors such as the potential number of early adopters and the amount of increasing returns to scale will significantly influence the diffusion of new technologies. The vertical axis represents the range of expectations a decision-maker might have that there will be significant impacts due to climate change (greater than 0.3% of the global economic product). The figure shows that the Combined Strategy dominates even if decision-makers have only modest expectations that impacts from climate change will be significant and that information exchange and heterogeneity among economic actors will be important to the diffusion of new, emissions-reducing technologies.

It is important to note that our analysis does not justify technology incentives as a substitute to a perfect market. Rather, we find that technology incentives are a complement to, not a substitute for, flexible mechanisms designed to limit emissions. An effective response to climate change will often require both. However, our work suggests that policymakers may not need to implement both at the same time and that a combined strategy of technology incentives and tradable permits may in fact provide considerable flexibility in choosing when to introduce each type of policy.

Figure 2



Future Work

Significant research steps remain, however, before the innovative methods and models used in this study can be translated into more specific policy recommendations. For instance, our treatment of learning about new technologies among economic agents neglects the institutional networks that help transmit information among economic actors. In addition, our treatment of new technologies is sufficiently aggregate so that it is difficult to relate our technology incentives to specific recommendations for spending levels. Thus, while we argue that technology incentives are likely to be an important part of any climate change strategy, we have not answered the question as to whether the subsidies currently in place and proposed by governments are sufficient or too much or too little. We believe, however, that the methods laid out in this paper provide a powerful framework for addressing such questions.

Footnotes

[1] David A. Robalino and Robert J. Lempert, "Carrots and Sticks for New Technology: Crafting Greenhouse Gas Reduction Policies for a Heterogeneous and Uncertain World," forthcoming.

[2] Steven C. Bankes, "Exploratory Modeling for Policy Analysis," Operations Research, 41, 3, May-June 1993.

[3] Since the impact of permits will be higher energy costs, in this study we use the cost of carbon or carbon taxes as a proxy for tradable permits.

[4] Robert J. Lempert, Michael E. Schlesinger, and Steve Bankes, "When We Don't Know the Costs or the Benefits: Adaptive Strategies for Abating Climate Change", 33, 235-274, Climactic Change, 1996.

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