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Accelerating the development and diffusion of new energy technologies: Beyond the "valley of death"

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ABSTRACT

There are at least three motivations for government intervention in GHG mitigation: (1) inducing the private sector to reduce GHG emissions directly by setting a price on emissions, (2) increasing the amount of innovative activity in GHG mitigation technology development, and (3) educating the public regarding GHG-reducing investment opportunities, allowing consumers to make better private decisions. This paper discusses the pros and cons of policy instruments that might be used to respond to these motivations and makes recommendations for an appropriate mix of policy instruments over time given both economic and policital/instituional considerations.

1. Introduction

Recent scientific assessments have heightened concerns about the severity of the climate change impacts from greenhouse gas (GHG) emissions. Despite calls for urgent action, however, international negotiations regarding GHG emissions control policies are moving slowly and may prove totally inadequate over the next several decades.

A large number of analyses, including several in this volume, have shown that the development of lower-cost GHG-free and low-GHG-emitting technologies can significantly reduce the cost of GHG mitigation, reducing the economic losses associated with limiting emissions and making it more likely that policymakers will pursue effective GHG control policies. However, there is a great deal of uncertainty about how an appropriate level of innovation can be achieved and how much progress can be made, how fast, and at what cost.

One approach to stimulating innovation is to rely primarily on use of externality pricing and the market system to induce profit-oriented firms to develop low-carbon technologies. In that framework, innovation is motivated by taxing GHG emissions under conditions where the industries that produce energy and the industries that produce energy-converting and energy-consuming equipment are approximately competitive, and where the requisite "price signal" is politically feasible. Because such externality prices do not currently exist except for a very small fraction of global emissions, and additionally to address sectors not covered by profit-oriented firms, this paper considers non-market-based innovation policies that can complement these market-based policies. Such supplementary policies will be helpful even if markets are perfectly competitive and the price signal is optimally designed.

The power of markets to pull new, cost-competitive products into the economy and to motivate private firms to push technologies that are reasonably close to being competitive through the advanced development and engineering cycles is incredibly strong. Getting the right price signal for GHG emissions should, therefore, be a very high priority for GHG policy. Nonetheless, I believe that complementary, non-market-based technology advancement policies should be an important element of a strategy for GHG abatement. In a nutshell, the benefits of these "nonmarket" policies result from increasing both the stock of new knowledge and the stock of people in the economy who produce and can use new knowledge, beyond the levels that result from the operation of markets even with the appropriate price signals. Public investment in these resources can actually be quite modest, but the leverage and opportunities these investments can provide, in terms of market outcomes and consumer welfare, can be extremely great.

One motivation for nonmarket policies to stimulate innovation is provided by the "valley of death" metaphor,[1] which refers to the fact that many, if not most, ideas developed in research laboratories fail to make it all the way to the marketplace. I believe that the nature of the innovation process probably precludes bridging these

[1] The phrase "valley of death" is likely drawn from either Psalm 23:4 or Alfred Tennyson's 1870 poem "The Charge of the Light Brigade." It has been used in discussions of technology management for a decade or more and has been popularized in the modern management literature by, for example, Mills and Livingston (2005).

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"knowledge gaps" between laboratory and marketplace as they occur, but that a targeted applied research program in GHG-reducing technology could substantially increase the number of new ideas that are tried, and that well-thought-out consumer education programs can increase the rate of diffusion of developed products that should be economically viable but have not yet been widely adopted. In other words, the problem seems to be one of too few births and too many infants who need help breathing, not one of too many deaths.

2. Rationales for government intervention in GHG emissions abatement

There are at least three motivations for government intervention in GHG mitigation: (1) inducing the private sector to reduce GHG emissions directly by setting a price on emissions, (2) increasing the amount of innovative activity in GHG mitigation technology development, and (3) educating the public regarding GHG-reducing investment opportunities, allowing consumers to make better private decisions. In each of these three areas, the degree of intervention should be set so that its marginal cost equals the marginal benefit of the reduction in the externality it induces. The paper by William Nordhaus in this volume presents the case for relying primarily on setting a price on emissions as the central tool for profit-oriented.

There are synergies among the three kinds of interventions. For example, support for more GHG-reducing technology development may lead to a lower socially optimal marginal cost for GHG emissions reductions and thus a lower optimal GHG emissions tax; more education can lead to a reduction in desired support for R&D because lower-GHG-emitting technologies are implemented more efficiently; and more support for technology development may be warranted if the tax on GHG emissions is lower than socially optimal. We ought to eventually get to a place where all three of these margins are equalized and at a value that represents marginal climate damages avoided, but we are far from that point today, and institutional constraints may prevent us from achieving that objective any time soon.

A simple and direct form of government intervention in GHG mitigation would be a tax on GHG emissions that equals the marginal damages those emissions produce. Opinions still differ on the magnitude of those damages, but we know the right number is already significantly greater than zero and may be increasing rapidly as GHG concentrations in the atmosphere continue to rise.[2]

Arrow (1962a,b) recognized that R&D has both a public and a private dimension. Firms innovate because it helps them become more profitable, but they innovate less than would be socially desirable because they know that other firms and consumers will reap some of the benefits. This lack of "appropriability" of the benefits of one's own innovation creates a strong motivation for public support of R&D. Such support augments the extent to which simply increasing the price of clean energy relative to that of dirty energy induces innovation. A number of studies (e.g., Mansfield et al., 1977; Mansfield, 1996; Griliches, 1992) estimate the social rate of return for innovation expenditures at approximately double the rate of return on private R&D expenditures.

Imperfections in the markets for energy-converting and energy-consuming equipment may be impeding the rate of diffusion of new technologies that are already economically competitive and welfare improving. This situation can result from several different types of market failure, including poor or asymmetric information available to purchasers, limits on individuals' ability to make rational decisions because of time or skill constraints, principal-agent incongruities between building owners and building residents, and lack of financing opportunities.

[2] See Nordhaus (2008), for example.

3. Beyond the profit motive

Although profits are an important and pervasive motivation for inventive activity, highly creative individuals can have other important motivations. For example, university (and national) research laboratories are often run by people who are motivated primarily by the desire to help solve societal problems and gain the acclaim of their peers. These individuals may also perceive that they personally can help internalize the GHG damage and GHG innovation market failures by developing less expensive GHG-free technologies, if they believe public policies in these areas are inadequate. Thus, they might be willing to sacrifice personal gain by accepting a return on their innovation that is far less (to themselves and their institution) than the benefits their innovation provides to the world as a whole. To be sure, some of these individuals will expect that down the road a profitable company might be built around the new technology they have developed, but that is not usually a primary motivation. Although it is difficult to measure the payoff from funding these individuals, policy makers should try to get them the resources they need to succeed, through competitive but publicly financed R&D programs. The benefits to society from this type of program are arguably episodic, but potentially immense. Computers, transistors, microprocessors, the Internet, fiber optics, jet engines, and gene sequencing are just a few of the technologies started by people with these motivations. Their original ideas were later improved through large investments by the private sector in pursuit of profits, but the biggest breakthroughs often came out of mission-oriented basic research in key areas. So a simple and not too risky thing that government can do to stimulate innovation is to support basic and applied research in key areas of technology where the resulting advances could reduce the cost of GHG emissions. This not only increases the pool of knowledge the private sector has to innovate with, but also the pool of innovative people who can work in either the public or the private sector. That such research often has broad spillovers to many other areas makes its impact on the allocation of total innovative activity less of a concern.

4. Possible remedies and challenges

One way to stimulate innovation targeted at reducing GHG emissions is to put a price on those emissions. But beyond that, government can try to increase innovative activity in a number of other ways. These include subsidizing R&D by private corporations, sponsoring graduate fellowships in key areas, supporting university and national laboratory research in these areas, strengthening intellectual property protection for firms that invest in R&D, offering innovation prizes to those who achieve specific technical targets (Reichmann et al., 2008), and sponsoring large-scale demonstration projects in promising technologies. Each of these has its strengths but also its weaknesses — not the least of which is that these additional inducements, if poorly designed, can actually impose net costs on the economy.

Ideally, the most efficient way to internalize this externality would be to offer an R&D subsidy across the whole economy, but that would be optimal only if industries are approximately homogeneous across a range of characteristics: the degree to which the benefits from R&D are appropriable, the market structure, firms' ability to classify non-R&D expenses as R&D, and so forth. So although an economy-wide R&D subsidy would be a good way to start capturing the large difference between the public and the private benefits of R&D, a close look at the energy industries and their potential entrants leads to the conclusion that they are industries where appropriability