

# **Climate Change Policy Choices and Technical Innovation**

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Carolyn Fischer

“Concern for man himself and his fate must always form the chief interest of all technical endeavors ... in order that the creations of our mind shall be a blessing and not a curse to mankind.”

—Albert Einstein, address at the California Institute of Technology, 1931

## Introduction

Climate change is a public policy issue because it may impose costs on society, including adverse human health impacts, productivity losses, and degradation of valued natural resources. On the other hand, policies to reduce greenhouse gases can have serious economic consequences, such as higher costs of production and increased energy expenses for households. This tradeoff is the classic problem for policymakers trying to strike a balance between costs and benefits of environmental regulation.

The political balancing act would become much easier if policy can generate a “win-win” scenario with both environmental and economic benefits. Thus, much attention has been given to the “Porter hypothesis” that environmental regulation can actually increase the profits of firms, chiefly by encouraging them to look for more efficient production technologies that ultimately lower their costs (see the paper by Porter and van der Linde in Further Readings). Economists traditionally doubt the concept of a free lunch: if such gains in efficiency were worthwhile in the first place, why would firms not take advantage of them without regulation? What appears to be cost savings due to regulation can often be negated by proper accounting of management time and other human resource costs, for example (see the paper by Palmer, Oates and Portney in Further Readings). While some theories have developed to explain how “win-win” situations might arise, it is still unclear how widespread these opportunities would be (see the paper by Sinclair-Desgagné in Further Readings).

Technology is increasingly being touted as the answer to the economy-environment tradeoff. If technological progress is the engine of growth, then “green” technologies could be the engine of sustainable, “climate-friendly” growth. But beyond just looking for low-cost greenhouse gas abatement policies, some advocates propose that we can use clean technologies to take care of the environment without economic costs and without imposing environmental regulations. The search for such “win-win-win” scenarios is illustrated by a recent press release, in which President Clinton looks to promote bio-based energy technologies to “help grow the economy, enhance U.S. energy security, and meet environmental challenges like global warming” (see the White House press release in Further Readings).

Can technology really allow us to have our free lunch and eat it too? Unfortunately, if it sounds too good to be true, it probably is. Good incentives for developing climate-friendly technologies depend critically on whether good climate policies are in place. Furthermore, the usefulness of public investment in green technology also depends on the incentives created by climate policies. Thus, while cases can be made for both greenhouse gas regulation and promotion of innovation, pursuit of these goals will involve hard

choices and real resource costs, not the least of which is the opportunity cost of research and development expenditures.

In this issue brief, we present some of the economics of innovation as it relates to climate policy and explain how the two are fundamentally linked. We then discuss the appropriate role of the government in promoting research and development (R&D) and greenhouse gas abatement. These same arguments apply to environmental policy generally, but our focus here is on climate change policies.

### **Why would firms want to develop cleaner technologies themselves?**

Economists note that the driving force behind the development of new and improved technologies is the profit motive. Firms realize greater profits if they can produce more and better products for the same cost, or if they can make the same products with less. Thus, they are willing to spend resources on research and development if the results will be lower costs and higher productivity.

Even without any explicit climate policies, this drive for more, better, and cheaper can lead to lower-emitting techniques. Energy is costly, so firms will want production processes that use less energy. For the same reason, consumers will demand products that use energy more efficiently as well. However, market forces will provide insufficient incentives to develop climate-friendly technologies if the market prices of energy inputs do not fully reflect their social cost (inclusive of environmental consequences). This incentive problem is magnified if energy prices do not even cover the costs of production (see the Issues Brief by Fischer and Toman in Further Readings).

Even if energy prices reflect all production costs, without an explicit greenhouse gas policy firms have no incentive to reduce their greenhouse gas emissions per se beyond the motivation to economize on energy costs. For example, a utility would happily find a way to generate the same amount of electricity with less fuel, but without a policy that makes carbon dioxide emissions costly, it would not care specifically about the carbon content of its fuel mix in choosing between, say, coal and natural gas. For firms to have the desire to innovate cheaper and better ways to reduce emissions (and not merely inputs), they must bear additional financial costs for emissions.

### **How do greenhouse gas abatement policies compare in creating incentives for innovation?**

Policies designed to abate greenhouse gases also can have significant impacts on incentives for innovation. However, the incentives can differ greatly across the range of possible measures.

**Command-and-control** policies that dictate what specific technologies or processes a firm must use by design give firms little leeway. As a result, the firm has little or no incentive to employ a more cost-effective way to achieve the same emissions reduction, since it is not allowed to deviate from the specified technology. A policy mandating the “**best available technology**” might allow the firm to update or retrofit its production process with a more cost-effective technology. However, the firm would not want to develop a better technology that would achieve more abatement if that switch entailed higher total costs—even if from a social standpoint the extra reductions in pollution would justify the added costs.

The *threat* of future regulation can indeed induce innovation to develop the technology necessary for compliance; however, that threat must be credible. To the extent that governments express a second industrial policy goal, such as a preference for domestic technology, their credibility for implementing the

environmental regulation is compromised, and the development of such a technology becomes less likely. (See the paper by Cadot and Sinclair-Desgagné in Further Readings.)

**Performance standards**, which dictate a certain level of abatement but leave the methods up to the firm, give the firm an incentive to develop a cheaper method of attaining the standard. A problem with performance standards, however, is that firms have no incentive to perform beyond the standard, even if lower abatement costs make more abatement desirable from a social perspective.

**Market-based instruments**, such as emissions taxes or permits, create a price for emissions. Firms then reduce their emissions as long as the cost of an additional amount of abatement is less than the tax (or permit) cost of additional emissions. For the remainder of their emissions, they pay the tax, buy permits, or use permits that they could otherwise sell. This system ensures that marginal abatement costs are equalized across firms, meaning that total abatement costs cannot be lowered by shifting some abatement from one firm to another (see the seminal work by Kneese and Schultz in Further Readings). By developing a more cost-effective way to reduce pollution, an innovating firm can then save in two ways: on its costs for achieving its current level of abatement, and on its tax or emissions permit payments by performing additional abatement at the new, lower cost.

Thus far, the incentives discussed here are restricted to the firm's own gains from lower pollution abatement costs. Looking at this single-firm context, earlier analyses of environmental policy and innovation showed that emissions taxes and emissions permits generally provide more incentives for technological innovation than command-and-control policies like technology mandates and performance standards (see such papers as those by Downing and White, Magat and Zerbe in Further Readings). However, new technologies or processes may be useful for more than just the one firm performing the R&D. When innovations are more widely applicable, other incentives come into play and further differences arise among environmental policies.

### **What if one firm's research is also applicable to other firms?**

A technology developed to reduce one firm's costs of abating emissions may also help other firms do the same. As a result, the social gain from this technology consists of the cost reductions to all firms (and potentially gains from additional abatement once it is less costly to implement). Furthermore, if adopting the new technology helps these other firms' bottom lines, they will be willing to pay to license it. Thus, with a well-functioning patent protection system, for example, the innovator can sell the fruits of its R&D to the potential adopters and reap the full social gains from the invention.

However, reaping those gains may be difficult. New knowledge can create "spillover benefits" for other parties for which the innovator is not compensated. Not every advance may receive a patent: basic research may not have specific, patentable applications. Still, broadening the overall knowledge base can make future valuable applications possible. Even if a new technology or process does receive a patent or copyright, it may be hard to enforce. For example, other firms may also have the opportunity to imitate the innovation despite the patent, such as through reverse-engineering. Studies for commercial (or non-environmental) innovations suggest that appropriation rates vary considerably over different types of innovations, with an average rate of around 50% (see the papers by Griliches and Nadiri in Further Readings). The easier it is for other firms to imitate the innovation on their own, the less they will be willing to pay for a license, and the lower the gains the original innovator will be able to appropriate. As

a result, the innovator will have less incentive to conduct R&D than would be best from a societal perspective.

On the other hand, the market for R&D might also encourage too much research. For example, several innovating firms competing for the rewards of a patent can collectively spend too much on redundant research. Thus, these “patent races” can lead to too much R&D. The consensus view, however, is that the private rate of return to R&D is well below the social rate of return (see the papers by Mansfield, Bernstein and Nadiri, and Griliches in Further Readings). Thus, positive spillover effects prevail, and markets will tend to provide too little R&D.

### How do environmental policies compare when other firms may adopt a new technology?

When we take into account interactions among innovating firms and other firms potentially adopting the new technology (at a price), the analysis of how different abatement policies affect innovation becomes more complex and ambiguous. Table 1 summarizes the various incentives for innovation and gives an idea of their relative importance.

**Table 1: Incentives for Innovation Created by Environmental Policies**

| <i>POLICY</i>   | <i>Direct gains to innovating firm</i>                                 | <i>Potential rents from adoption</i>                             |
|---|--|--|
| Command-and-Control                                     | none   | none   |
| Best-Available Technology                               | –<br>new standard raises overall compliance costs                      | + + +<br>tighter standard raises incentive to adopt              |
| Performance Standards                                   | + +<br>limited to existing abatement costs                             | + +<br>limited to existing abatement costs                       |
| Emission Tax  | + + +<br>lowers abatement costs and taxed emissions                    | + + +<br>lowers abatement costs and taxed emissions              |
| Auctioned Emission Permits                              | + + + + +<br>lowers abatement costs and costs of all permits purchased | +<br>buying permits becomes cheaper alternative                  |
| Grandfathered Emission Permits                          | + +<br>lowers abatement costs  | +<br>buying permits becomes cheaper alternative                  |
| Tradable Performance Standards/Output-Allocated Permits | + +<br>initial abatement costs higher but lowers output subsidy        | + +<br>initial abatement costs higher but permits become cheaper |

**Command-and-control** policies that specify a technology allow other adopters no more leeway than the innovator. Therefore, little or no incentive remains to employ more cost-effective pollution reduction techniques. However, a policy mandating the “**best available technology**” offers the possibility that the innovator’s new technology would be made the standard. Then the other firms in the industry would have to pay to adopt it, if they could not come up with their own equivalent technology. Therefore, although the innovating firm’s own pollution reduction costs could rise due to the new, stricter technology standard, the gains from other firms licensing the technology could be large.

Under **performance standards**, adopting firms receive the same gains from abatement cost reduction as the innovator. They are willing to pay for a cheaper way to abate their emissions up to the standard, but they will not want to push reductions beyond the standard.

With **market-based mechanisms**, the development and industry-wide adoption of an innovation can affect not only individual firms’ costs, but also the prices and quantities prevailing in the industry’s market. Because different market-based mechanisms allow for different changes in prices and quantities of emissions, they have different implications for innovation (see the paper by Fischer, Parry, and Pizer in Further Readings for the full treatment of this analysis). Taxes set the price of emissions, allowing total abatement to vary, while permits set the total amount of emissions, allowing the marginal cost of abatement to vary. Therefore, while one can choose a tax and an emissions cap that would generate the same outcome before innovation, product and technology markets will adjust differently after innovation, depending on the policy.

Under an **emissions tax**, as innovation makes abatement cheaper, the total amount of abatement will rise because it will be less expensive to reduce emissions some more than to pay taxes on all current emissions. With **emissions permits**, on the other hand, firms as a group will not abate more after the innovation, since that total amount is set by the cap. Therefore, the total abatement cost savings are less than under the tax, where more abatement was performed after innovation. Furthermore, as innovation lowers abatement costs, the price of emissions permits will fall.

From the point of view of the adopting firms, their individual decision of whether to license the technology does not affect the permit price; however, they will attempt to anticipate the fall in the permit price caused by collective adoption of the innovation. The lower permit price means that they now have a less costly option of foregoing the new technology and buying cheaper permits instead. Thus, adopting firms will not be willing to pay as much for the innovation under permits as under the tax. This “adoption price effect” lowers the maximum royalty the innovating firm can charge to license the technology.

However, the price fall can benefit the innovator directly, if permits are auctioned. Then, a lower permit price means the innovator will not have to pay as much for the rest of its emissions. This “emissions payment effect” raises the gains to innovation. If permits are freely distributed, on the other hand, the price fall lowers the value of the innovator’s allocated permits, which counteracts the emissions payment effect. Thus, free permits give less incentive to innovate than auctioned permits and less than taxes due to the smaller abatement cost savings and the adoption price effect.

It is harder to say whether auctioned permits or taxes generate more innovation, since the incentives depend critically on the adopting firms’ ability to imitate the innovation. In general, with little imitation, unless the emissions payment effect is very large, taxes provide more innovation incentive. However, if imitation is substantial, preventing the innovator from recouping most gains, if any, from the adopters, auctioned permits provide more incentive.

With respect to climate policy, the more compartmentalized the emission permit programs, the larger will be the impact of a single innovation on permit prices. If a major fuel-saving invention is adopted by the trucking industry, it might have a small effect on permit prices in a broad-based cap-and-trade program, but it would have a large effect on a permit program limited to the trucking sector. Thus, in a broad-based carbon trading program, innovation incentives in a specific sector are going to resemble more closely those of a carbon tax.

Finally, it is worth mentioning another permit regime, **output-allocated permits**, which are very similar to **tradable performance standards**. Examples of the latter in other contexts include the phasedown of lead from gasoline and Corporate Average Fuel Economy (CAFE) standards; related policies have been proposed for dealing with greenhouse gases. These two types of market-based mechanisms require firms to hold permits to cover their emissions, while they are allocated permits according to their output times an average emissions rate. Thus, above-average emitters must buy permits, while below-average emitters can sell them. This permit allocation method creates an implicit subsidy for output, since the more a firm produces, the more permits it gets.

This implicit subsidy affects innovation incentives in a number of ways that are not so obvious. First, it discourages firms from cutting back output, placing more of the abatement burden on lowering emission rates. As a result, for a given target level, total abatement costs are actually higher (see the paper by Fischer in Further Readings). This inefficiency then raises the potential gains to innovation, although in a costly way. Second, while it may seem that an innovator would want to push costs even lower in order to gain market share and more subsidies, widespread adoption eliminates any such market share advantage. Furthermore, the subsidy lowers output prices across the industry compared to the other permit or tax schemes, meaning that the extra subsidy gains from expanding market share are largely negated by lower revenue gains. Thus, the output subsidy seems more likely to reduce innovation incentives.

Of course, it is important to look beyond which environmental policy generates the most R&D and think about overall impacts on societal well-being. R&D spillovers and global warming pollution are two separate problems. To correct for both ideally requires two separate policy tools. However, when R&D shortfalls cannot be ameliorated directly by available policies, such as research grants or tax credits, abatement policy is then forced to balance its impacts on the two problems. Some environmental policies may help offset imperfections in the market for innovation. But the cost may be wasted expenses on abatement (such as with a high tax) or wasted opportunities for abatement once costs fall (such as with auctioned permits). As with any good thing, one can have too much of innovation or of abatement, since those resources could be used elsewhere. Therefore, an overly strict environmental policy to stimulate for shortcomings in R&D gives rise to its own costs; likewise, an overly generous R&D subsidy to make up for inadequately low emissions pricing can be wasteful.

### **How do innovation and environmental policy interact over time?**

As we have seen, greenhouse gas abatement policies not only determine the price signals (or regulatory requirements) for emission abatement, but also the signals for innovation. However, just as the amount of innovation depends on those price signals, getting the right price signals depends on the amount of innovation.

For “stock” pollutants like greenhouse gases, which build up over time, current and future costs and benefits are dynamically linked. Future innovation can have a significant impact on the emissions rate,

both now and in the future. To the extent that innovation reduces future abatement costs, it makes sense to postpone some emissions reductions until the future. (See the discussion paper by Toman, Morgenstern and Anderson in Further Readings)

Ideally, policy would take into account future innovation and the evolving costs and benefits of regulation in setting current and future emissions taxes or quotas. Of course, in reality the results of R&D investments are highly uncertain, and predicting such a path may be difficult. Furthermore, adjusting policies frequently may be difficult and involve significant administrative costs. In this case, policymakers need to weigh the benefits and costs of inducing more or less innovation against too much or too little abatement.

A fixed tax policy does not allow emission prices to adjust, thus creating a risk of too much abatement if costs fall (assuming the tax starts out reflecting the initial damage costs of emissions, which then decline as emissions fall). However, taxes do allow the amount of abatement to fluctuate according to cost conditions. On the other hand, a permit policy does not allow an adjustment of the quantity of abatement, meaning that too little will be done if costs fall (and too much effort will be put into abatement if costs rise). In the case of greenhouse gas emissions, their potential damage is relatively insensitive to the rate of emissions at any particular time (although the total cost likely will rise as greenhouse gases accumulate in the atmosphere). Thus, the presence of uncertainty in abatement costs due to unpredictable innovation favors a tax-based approach over a quantity-based permits approach. The reason is that in these circumstances uncertainty about the volume of abatement imposes less of a burden on society than does abatement cost uncertainty (see the paper by Pizer in Further Readings for details).

### **Should diffusion be aided?**

The incentives to adopt a cleaner technology mirror those for creating it for oneself, namely the cost savings. Higher energy prices raise the returns to adopting energy efficient technologies and thus encourage their diffusion. (For more discussion and empirical evidence regarding diffusion of energy-saving products, see the paper by Jaffe, Newell and Stavins in Further Readings.)

However, even when potential cost savings are substantial, a technological advance is not often adopted completely and immediately. Diffusion may lag because of adjustment costs (such as training personnel in a new production process that reduces energy use), information costs (like educating consumers about energy efficiency), or irreversible investments (like building a whole new plant with new generation technology), or because an even better technology might be on the way, making the wait worthwhile. As these cases all represent real resource costs for the firm, avoiding or postponing adoption can be quite rational. Furthermore, in the absence of market failures or important returns to scale, delay or non-adoption can also be an appropriate allocation of resources from the point of view of society.

On the other hand, the innovator may choose to limit diffusion. A patent is essentially a temporary monopoly, and unless the innovator can charge higher prices to firms valuing the technology more (i.e., price discriminate), royalties may be maximized by restricting licenses. A tension can then exist between the gains from spreading new technology today and those from promoting future innovation. Society would benefit most from the widest worthwhile diffusion of an existing innovation. For example, to convert as many vehicles on the road as possible, one might want to distribute freely the design of an engine modification that cost-effectively raises fuel-efficiency. However, if automobile companies expected that to happen, they would have had little motivation to develop the modification in the first

place. Therefore, when society values more immediate and complete distribution, such a policy must be done in a way that maintains the proper incentives for future innovation. In other words, the policy precedent should involve compensation (e.g., buying the patent rights) rather than expropriation or forced distribution (see also the Climate Brief by Blackman in Further Readings for discussion of international diffusion policies).

In many cases, however, government can aid diffusion without compromising R&D incentives. Support for high-spillover advances, such as in basic knowledge from fundamental research, offers such an opportunity. Reducing adjustment costs can aid diffusion as well as incentives for innovation. Public institutions, with their existing infrastructure of regulatory expertise and contacts, can take advantage of returns to scale in gathering and distributing information. Public policy toward the environment could include the dissemination of best business practices and the subsidization of training in environmental management, thus helping firms to take advantage of any “win-win” opportunities that might otherwise be ignored (see the papers by Sinclair-Desgagné, Decanio, and Decanio and Watkins in Further Readings). However, the need for such subsidies depends on the extent to which there are internal management failures in firms, and on the extent to which these problems can be distinguished from the pursuit of unnecessary subsidies by firms. These issues remain controversial. Similarly, investment subsidies can reduce the barriers created by capital market problems (like impediments to borrowing), but they do come at the cost of scarce public funds and offer windfalls to those who would adopt anyway.

A policy mandating the best available technology is a type of forced diffusion. How the policy is designed greatly affects the payoffs to innovation. Requiring all firms to buy the new technology puts few limits on what the innovator can charge, possibly resulting in too much incentive to innovate. If costs are a consideration in imposing a new standard, some limit will be put on such opportunities. If other firms can use alternative means to achieve the new standard, then payoffs will be more in line with actual net benefits, unless imitation is an option. Finally, if the innovator is required to disseminate freely the advance, little incentive will exist for innovation. Thus, in situations where market-based instruments are not feasible and technology standards are used, policy design must also take innovation incentives into account.

### **What is the role of government?**

“Societies will, of course, wish to exercise prudence in deciding which technologies—that is, which applications of science—are to be pursued and which not. But without funding basic research, without supporting the acquisition of knowledge for its own sake, our options become dangerously limited.”

—Carl Sagan

Economists generally agree that the main role of the government is to stick to the basics: first, to create the proper private incentives for environmental protection and for innovation; second, to supplement the socially useful R&D that the private sector does not tend to provide sufficiently.

For the first part, the government can provide institutions like a strong system of patents and copyrights to ensure inventors can reap the fruits of their efforts. To aid diffusion, the government can take cost-effective measures to lessen informational costs and other barriers that create transaction costs. If fast, low-cost distribution of new research and technologies is a priority, its implementation should remain consistent with preserving the long-run incentives for R&D, as discussed above.

With respect to climate change, the government should ensure producers face financial costs for their emissions which bear some resemblance to the expected future environmental costs, however inadequately these costs currently are measured. Market-based instruments not only promote cost-effective pollution reduction but also provide the most efficient incentives for investing in the development of environmentally friendly technologies.

Even with strong patents and emissions pricing, private firms may not invest in the right kinds or the right amounts of R&D. Basic research is a good example: one can rarely foresee all the useful applications that may arise from the expansion of the general knowledge base. Therefore, government has a central role in funding high-spillover research. One way to achieve this goal in a decentralized manner is through a system of competitive grants.

With respect to R&D for specific applications (such as particular manufacturing technologies or electricity generation), governments are notoriously bad at picking winners. (An example involving a breeder reactor is provided in Cohen and Noll in Further Readings.) The selection of these projects is best left to private markets, while the government ensures those markets face the socially correct price signals. One exception may be specific technologies that would aid in the implementation of more efficient greenhouse gas policies; for example, better emissions monitoring devices could reduce compliance and enforcement costs and enable the transition to market-based mechanisms for emissions control. In this case, in a sense, the government is the relevant market for the innovation. But for most cases, to the extent that markets still tend to provide insufficient R&D, broad rather than project-specific R&D subsidies are in order. (The paper by Wright in Further Readings discusses the efficiency of alternative research policy instruments in the context of stimulating commercial (i.e. non-environmental) innovation.)

Above all, policymakers concerned about climate change must recognize that incentives for abatement and innovation are inexorably linked. If failures in the market for R&D exist, and available policies cannot correct them, the choice of climate policy will then be affected. If innovation incentives are lacking, the best climate policy response is likely to be looser regulation, reflecting the higher expected abatement costs, not stricter regulation to promote innovation. Similarly, if emissions are underpriced and too little abatement is performed, less investment in R&D may actually be warranted, since the new climate-friendly technologies will not be sufficiently exploited. Since greenhouse gases accumulate over time, incentives for their abatement and innovation are further intertwined, since current and future abatement can depend on each other as well as innovation, which in turn depends on abatement.

Thus, a technology policy is no substitute for environmental policy. **The primary gains to environmental protection always come from reducing environmental damages** in the most cost-effective manner, regardless of innovation. Innovation then has the potential to increase those gains, but the benefits of emissions-reducing innovations are by definition limited to the potential environmental gains (see the paper by Parry, Pizer, and Fischer in Further Readings).

More than other policy instruments, market-based mechanisms offer the incentives both to protect the environment efficiently and to develop better methods of protection. Put simply, rather than look for a free lunch, perhaps we should make a nutritious lunch.

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