9 Climate Change, Federalism, and Promoting Technological Change

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THIS CHAPTER EXAMINES THE LEVEL OF GOVERNMENT – STATE versus federal – at which an Environmental Competition Statute could be most effectively implemented. After years of inaction, the federal government is now debating legislation to address climate change. On May 21, 2009, the House Energy and Commerce Committee took the unprecedented step of voting for the American Clean Energy and Security Act of 2009, which would establish, among other important policies, a comprehensive cap-and-trade program for controlling emissions of greenhouse gases (GHGs).[1] Recent federal action follows a period of rapid policy development by state and local governments. In the absence of strong federal leadership, a growing number of states have filled the void in climate policy with a broad array of programs, including regulation of GHG emissions from vehicles and power plants, renewable energy mandates, GHG emissions registries, and energy-efficiency initiatives.[2]

The question addressed in this chapter is how state initiatives can operate in conjunction with federal programs to induce the technological change needed to mitigate climate change. I show that promoting innovation is a distinct regulatory end that is subject to a market failure – technology spillovers – unrelated to the negative externalities that have traditionally justified environmental regulation.[3] This distinction is significant because critics of state action have questioned whether anything is left for the states

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once the federal government acts or even whether state initiatives are per se misguided given the global scale inherent in reducing GHG emissions.[4] Indeed, existing rationales for state climate programs reflect these limits insofar as they view them primarily as a means of prompting federal action or policy innovation.[5]

This chapter challenges the view, endorsed most prominently by the George W. Bush administration, that climate change policies should be set at the international level, leaving only secondary roles for federal or state policies.[6] Economists focused on the principle of fully internalizing the costs and benefits of regulations view federal or limited multinational regulation skeptically, and state policies even more so. Critics also point to countervailing market dynamics. They argue that reductions in GHG emissions will be eroded through emissions leakage, which refers to the circumstances in which GHG reductions in regulated jurisdictions are offset by corresponding increases in emissions from unregulated territories as a result of competitive market conditions. The possibility of adopting an Environmental Competition Statute to address GHG emissions would face these same objections.

None of these arguments refutes the capacity of state (or federal) policies, including an Environmental Competition Statute, to promote technological change. Instead, critiques of state policies have focused almost exclusively on their capacity to reduce GHG emissions, ignoring their capacity to achieve the distinct objective of inducing technological change. Thus, although critics have convincingly demonstrated the degree to which state efforts to reduce GHG emissions are undermined or insignificant, their analyses are incomplete.[7]

This one-sided focus is counterproductive given the importance of new technologies to climate change mitigation. It is also out of step with the economic literature on the capacity of government policies to induce technological change. Economists have noted that "[t]he effect of environmental policies on the development and spread of new technologies may, in the long run, be among the most important determinants of success or failure in environmental protection."[8] Nor is this a naive brand of technological optimism; strong evidence exists that widespread adoption of existing technologies on its own could "solve the carbon and climate problem for the next half century."[9] The current debate over federalism and climate change

is therefore not only incomplete, but also overlooks an essential element of climate change policy.

This chapter seeks to refocus attention on the independently valuable objective of inducing technological change through measures like an Environmental Competition Statute. To evaluate the capacity of state and federal legislation to promote technological development, the chapter analyzes the two types of market failure – environmental and technological – relevant to climate change policy. It then explores several avenues for states to induce technological change, whether through technological innovations or adoption of existing technologies. Market dynamics will differ according to whether states adopt policies in the shadow of federal legislation or instead act alone; both scenarios are examined herein. The chapter demonstrates that technology-forcing laws, such as an Environmental Competition Statute, can be effectively implemented by state and federal governments. The chapter concludes with specific recommendations for harmonizing state and federal climate change policies.

Climate Change Market Failures

According to conventional economic theory, environmental regulation is justified when businesses and consumers fail to internalize the negative environmental impacts of their actions. Environmental policy is not limited, however, to deterring or restricting behavior with bad environmental consequences; it also seeks to promote development of new technologies that reduce abatement costs and enable more aggressive action. This latter objective is difficult to meet because it implicates two distinct market failures: traditional negative environmental externalities and the positive externalities associated with uncompensated technology spillovers.

Efforts to regulate climate change are particularly susceptible to these forms of market failure. The negative impacts of GHG-emitting activities are diffused globally, although risks from climate change are by no means distributed uniformly. Similarly, technology spillovers are likely to be large because of the global importance of environmental technologies relevant to mitigating climate change and because of the modest protections for and volatile politics surrounding intellectual property rights in many countries.

The two subsequent sections examine the capacities of federal and state climate change policies to address these externalities. Although state regulation is clearly inferior to national (or coordinated international) regulation in achieving GHG emissions reductions, I show that it has significant potential to complement federal policies and has certain advantages over them in promoting technological change. The third section analyzes how the federal system can accommodate the respective strengths of national and state policies.

Traditional Environmental Externalities

Climate change produces a classic form of pollution externality: industrial producers and consumers alike reap the benefits of activities that generate GHGs while imposing the costs of the emissions on the world as a whole. Because polluters internalize only a fraction of these costs, their incentives to reduce them are only a fraction of what would be economically efficient. Accordingly, traditional economic theory dictates that the global scale of climate change necessitates international regulation.

The dominance of state climate change initiatives in the United States runs contrary to the predictions and principles of classical economic theory. Drawing on this theory, opposition to state programs rests on two primary arguments: (1) state-level programs, by virtue of their small geographic scope, will be too small to have a meaningful impact on global GHG emissions, and (2) state climate regulation is vulnerable to emissions leakage, which involves market responses that can offset emissions reductions in a regulated jurisdiction.

Regulation of GHG emissions from electric power plants illustrates the limited scale of state and regional action. Even when the results of aggressive state programs are aggregated, the volume of emissions reduced constitutes just a small fraction of total emissions in the United States. A useful benchmark here is the group of states committed to or considering involvement in the Regional Greenhouse Gas Initiative (RGGI) – eleven states and the District of Columbia in all.[10] The direct impact of RGGI is minimal because carbon dioxide emissions from power plants (its exclusive focus) in the eight committed states constitute only 2 percent of U.S. emissions from this sector (this rises nominally to 4.5 percent for all eleven states and the District of Columbia).[11] These statistics reveal that state-level standards

would have to be twenty times more stringent than a federal standard to achieve a comparable reduction in GHG emissions.

The vulnerability of state programs to emissions leakage weakens the case for state action further. Even if a state program constituted a significant fraction of national GHG emissions, its emissions reductions could be substantially eroded or nullified by emissions leakage to other jurisdictions. Economists have identified three sources of emissions leakage – the first driven by falling fuel prices, the second by reductions in production levels, and the third by relocation of industries to unregulated jurisdictions.

The first two leakage scenarios follow from standard supply-and-demand economics. The logic is simple: insofar as state regulation diminishes demand for carbon-based fuels, it will trigger a drop in global fuel prices (higher local prices or caps would decrease demand in the regulated jurisdiction) that, in turn, will cause offsetting increases in fuel consumption in unregulated areas. The *degree* to which emissions reductions within a regulated territory are offset will depend on the sensitivity of demand to price in unregulated areas; the more price sensitive it is, the more complete the offsetting emissions will be.

The second scenario is a variation of the first, but it involves reductions in the production of goods within a regulatory territory that are driven by increases in costs of production caused by regulation (i.e., higher energy costs). Similar to the first scenario, a reduction in production levels within a regulated territory will lead to compensating production increases in unregulated areas. Here, reductions in supply lead to increases in product prices, which motivate producers outside a regulated jurisdiction to expand their production levels. Furthermore, if relatively efficient production in a regulated area is replaced by production with higher per-unit GHG emissions, the net result could be greater overall GHG emissions.

The significance of price – and supply-based leakage is dependent on the magnitude of actual reductions and market dynamics. If reductions in carbon fuel demand or product supply are small, the effects will be nominal unless price or supply is extraordinarily sensitive (elastic) to demand or price, respectively. Thus, because leakage rises with impacts on price or supply, the small scale of state programs makes them less susceptible to price and supply leakage.

The third form of leakage arises when production facilities are relocated outside of a regulated area. For industries that are sensitive to energy prices, differentials in energy prices between regulated and unregulated jurisdictions may justify incurring short-term relocation expenses. Consequently, instead of reducing GHG emissions, a regulating state would merely prompt companies to relocate outside of its borders and continue to emit GHGs at similar (or possibly even greater) levels.

Economic modeling studies support claims that leakage can undermine efforts to regulate GHG emissions at the regional (e.g., all Organisation of Economic Co-operation and Development member countries) or national levels. Estimates using standard economic models predict leakage rates ranging from about 5–20 percent, although some investigators have predicted rates as high as 41 percent.[14] The most dramatic results have involved undifferentiated goods (i.e., fungible commodities) and more complex economic models that take into account the potential for companies to migrate to unregulated jurisdictions. Under these circumstances, leakage rates can range as high as 50–130 percent, implying that state or regional efforts to reduce GHGs emissions can cause a net increase in global emissions.[15]

The potential significance of leakage is therefore highly variable. For industries that produce differentiated goods, the threat of leakage is relatively low, whereas for industries that produce undifferentiated commodities, it can wipe out or even overwhelm GHG emissions reductions from regulatory programs. But for industries that are not mobile, whether because of the nature of the good, unique geographic production needs or human capital constraints, the potential magnitude of leakage is unlikely to offset GHG reductions in a regulated territory.

Not all leakage is negative, though. Technology spillovers can cause it to be positive; that is, regulation in one jurisdiction can precipitate reductions of GHG emissions in unregulated areas. Under this scenario, regulation in a jurisdiction promotes diffusion of new technologies that reduce abatement costs. If technologies, for example, increase energy efficiency and the price sensitivity of carbon-based fuels is sufficiently high, it may be profitable for industries in unregulated areas to adopt them, causing a net reduction in GHG emissions both inside and outside a regulated jurisdiction.[16]

The potential for positive technological spillovers demonstrates the counterbalancing effects of technological change on GHG emission levels. It is also important to recognize that state policy makers have strong incentives to promote the spread of effective technologies and policy experience

to other governments precisely because climate change is a global problem. There is already "abundant" evidence of this occurring, with recent studies suggesting that regulatory programs, subsidies, or a combination of the two that induce development and adoption of cost-effective technologies can eliminate leakage.[17] These observations anticipate the important role of technological change for climate change policy discussed in greater detail below.

The preceding discussion highlights several factors that affect the viability of state climate change regulation, including a state Environmental Competition Statute, to mitigate GHG emissions. First, the small scale of state programs severely limits their ability to meaningfully affect global GHG emission levels. Second, leakage may overwhelm regulatory programs, particularly larger ones that involve mobile industries that manufacture undifferentiated goods – the textbook case being reshuffling of electric power generation between existing sources. Third, leakage will be minimal and certainly will not nullify state-level GHG reductions if the regulated industries cannot easily relocate or if they produce differentiated goods. Taken together, these factors indicate that the net effect of leakage will often be neutral or modest, implying that the impacts on GHG emissions will not undermine other grounds for state action. Further, if a federal law, such as a cap-and-trade regime, were promulgated that covered the relevant sources, it would further mitigate, if not eliminate, emissions leakage between states.

Technological Change as a Primary Objective of Climate-Change Policies

Innovation will be an essential element of efforts to mitigate climate change, as well as critical to controlling the costs of climate change policies. Yet technological change continues to be overshadowed by policy makers' and public interest in direct commitments to reducing GHG emissions. This bias is clearly evident in debates over the merits of state programs for mitigating climate change, which have focused on the capacities of cap-and-trade programs and environmental taxes to reduce GHG emissions.[18] In this section, I aim to correct this oversight and to examine the potential for state policies to facilitate the technological transformations that will be essential to mitigating climate change.

Technological change encompasses research and development that produces new technologies and adoption (or diffusion) of existing technologies, which can itself produce innovation through "learning by doing" as experience is gained with the use and production of a technology.[17] This section will highlight the significant potential of technology adoption and learning by doing, both of which an Environmental Competition Statute might spur.

One of the most prominent studies on climate change mitigation identifies a collection of fifteen technology-specific stabilization wedges that can be used to stabilize carbon emissions over the next fifty years. While acknowledging the importance of new, groundbreaking technologies, the authors show that existing technologies are more than adequate for meeting standard stabilization goals through about 2050.[18] These findings provide a strong basis for the importance of promoting technology adoption to climate change mitigation. They also demonstrate that calls for policies to advance technology adoption are not based on mere speculation: many effective technologies already exist.

Learning by doing is derivative of technology adoption. It originates from the observation that the attributes and production of existing technologies improve and evolve as experience is gained with them (the rapid evolution of computer programs following their commercialization is exemplary of this process). Technology assessments, such as the stabilization-wedges analysis, incorporate assumptions about innovation rates from learning by doing. Significant knowledge gaps remain, however, concerning actual rates of innovation from learning by doing. Data for the energy sector, for example, suggest that learning rates are significant and that the corresponding cost savings when integrated over time are in the billions of dollars.[19] As even this example shows, the existing studies are far from comprehensive, though, and often fragmentary.

Predictably, not everyone is convinced by the available data and theories, including some prominent commentators who have challenged the significance of innovation from learning by doing for climate change mitigation.[20] I expect that innovation from learning by doing will be significant for many technologies relevant to mitigating climate change (e.g., solar power, energy-saving technologies), but given the importance that simply adopting existing technologies has for achieving GHG emission reductions, my argument is not dependent on it.

Sources of Technology Market Failure

Economists have long recognized that technological innovation is subject to market failure stemming from investors' inability to appropriate the full social value of their work. This lost value leads to underinvestment in research and development. Technology adoption and the innovation from learning by doing that it promotes are impeded for similar reasons. Early adopters of new technologies, for example, absorb the costs of working through the kinks in early versions of a technology. This learning process produces valuable knowledge and refinements, which firms adopting the technology later benefit from without having to incur any of the costs. These knowledge spillovers, which early adopters cannot fully internalize, cause investment in learning by doing to be socially suboptimal.

Government regulation has the potential to offset technology market failures because "the rate and direction of innovation are likely to respond to changes in relative prices."[21] Under this theory, governments can induce technological change either directly, through subsidies, or indirectly, through increasing potential market payoffs. Accordingly, government policies that increase the costs of polluting activities or improve the economics of innovative work can potentially stimulate innovation that lowers pollution abatement costs and, in doing so, enhance collective capacities to reduce GHG emissions.

An Environmental Competition Statute has attributes of both an indirect enhancement in market payoffs and a traditional environmental tax on GHG emissions. As we will see more fully below, it is the Environmental Competition Statute's effective increase in marginal profits that is most important to stimulating innovation and offsetting technology market failures, although it is also true that the combination of such complementary measures creates important synergies that enhance the effectiveness of the technology and regulatory policies built into an Environmental Competition Statute.

Policies will differ, however, according to whether they are designed to promote adoption of existing technologies or development of new ones. For companies considering whether to invest in developing new technologies, the key factors will be research and development costs, expected revenues, projected market share, and any likely royalties. The latter three factors are all strongly tied to the size of the market, which implies that a national innovation policy will be favored over a limited state-based one. By contrast, adopters of existing technologies will typically focus on factors such as capital and operating costs, product characteristics, and the environmental benefits of a product. Because none of these factors is sensitive to market size, inducing technology adoption can occur at any level of government.

Differences between developing a new technology and adopting an existing technology prove critical to preserving a role for state-level policies. Because companies developing new technologies will often be different from those adopting them, the market factors that affect technology diffusion, as well as learning by doing, will be distinct from those relevant to promoting research and development. Further, although market size will limit the capacity of environmental policies to spur investments in research and development – the larger a regulated market, the larger the effective incentive – it is irrelevant to states' capacities to induce technology adoption.

State-level policies also have certain advantages over their federal counterparts. Although a federal standard can reach a much greater number of potential technology adopters, multiple state-level measures can mitigate problems with tunnel vision, pork-barrel politics, and picking the wrong technology that can compromise technology programs. For instance, the rise in federal support for biofuels, particularly ethanol produced from corn, is a glaring example of interest group politics overtaking sound policy.[22]

State programs can generate a diversity of approaches by virtue of their multiplicity and differing mixes of socioeconomic, environmental, and political factors. For example, in the field of renewable energy, some states require that solar power constitute a specific share of an electricity provider's portfolio, while others emphasize wind or geothermal resources.[23] Similarly, states such as West Virginia and Ohio, both of which have large supplies of coal, are supporting innovation directed at clean coal technology,[24] whereas Texas, with its abundant wind resources, has focused on generating power from wind turbines.[25] Other states, such as New Jersey, have been driven by a mix of the potential threats (e.g., sea-level rise) and economic considerations (e.g., impacts on its large chemical production industry) and adopted a more integrated strategy that does not favor a single technology or approach.[26] The variation in state-level programs thus reflects the diversity of conditions present in the states.

The case for state action on climate is bolstered further by the diseconomies of scale endemic to technological change, whether innovation of new technologies or adoption of existing ones. In particular, whereas meaningful reductions in GHG emissions require coordinated large-scale action, technological change often occurs most readily at small geographic scales. Broad consensus exists that innovation is enhanced in geographic clusters (i.e., the Silicon Valley phenomenon) because spatial concentrations allow inventors and adopters to access knowledge externalities that reduce the costs of research, development, and commercialization.[27]

States clearly have a role to play in promoting technological change. To the extent that market size matters, state programs will be inferior to federal regulation. However, although state-level regulation may provide weaker overall incentives, its compensating virtue is the diversity of approaches and experimentation that are a hallmark of state policies. Moreover, where innovation is subject to substantial uncertainties, diversity is often more important than the coordination and large scale found in federal programs.[28] These competing factors reveal important trade-offs between federal and state programs, particularly as they apply to research and development. By contrast, inducing technology adoption, which is insensitive to the size of the market being regulated, is less constrained by these trade-offs. Finally, states are arguably in a better position to establish geographically concentrated centers of innovation that can boost development of new technologies. A state Environmental Competitiveness Statute, particularly through its enhanced market payoffs, can thus play an important role in promoting technological adoption critical to addressing climate change.

Research and Development: The Temporal Schism in Technology Forcing

Limited empirical support exists for the effectiveness of environmental regulation, at any level of government, inducing research and development. Two recent studies have identified modest correlations between pollution abatement costs and either: (1) patenting rates in related technological areas or (2) levels of research and development.[29] More extensive studies exist for research and development related to energy-efficient technologies. Researchers have, for example, observed "significant amounts of innovation" in response to both increases in energy prices and changes in energy-efficiency standards.[30]

None of these studies provides compelling evidence that environmental regulation offers a powerful means of stimulating research and development. This is not to suggest that regulations can never be effective in this respect. To the contrary, the 1970 Clean Air Act successfully spurred significant research and development.[31] But even this example is subject to qualification, as the extended grace period the statute provided and fortuitous timing of the new technology were critical to the success of the regulations.

The equivocal empirical data may reflect deeper problems. The degree to which environmental regulations can promote technological innovation is hampered by the political economy of the regulatory process itself. This critique turns on the realization that incentives to conduct research and development, because of the long lag time between conducting research and sale of a product, are tied to the stringency of regulations in place when a commercially viable product is produced. Consequently, under this view, it is the credible threat of stringent regulation in the future – not primarily policies currently in place – that is most relevant to spurring investments in research and development.[32]

The extended lag between investment decisions and the relevant regulatory policies creates uncertainties that erode regulatory incentives. These uncertainties stem from the disparities that exist between current and future government policies. In fact, the optimal policy today – permit levels that reflect the costs of adoption *and* invention – will not be the politically expedient or economically optimal policy in the future when regulatory standards matter.[33] The current debate over drug pricing is perhaps the best example of this dynamic. Politicians and consumers want to reduce drug prices to just above the marginal cost of producing them whereas drug companies object that this ignores the high costs of research and development. There are many nuances to this debate, on both sides, but the central tension is the same regardless of the underlying technology. Moreover, the higher the political or moral stakes, typically the greater the pressure for producers to lower their prices. These uncertainties are compounded by those associated with the projected magnitude and timing of climate change and the corresponding societal impacts.

The questionable credibility of government commitments to future levels of regulation diminishes the capacity of environmental regulations to induce companies to invest in long-term research and development. This

temporal paradox has led some observers to conclude that environmental regulation has little or no capacity to induce innovation relevant to mitigating climate change. For them, the benefits of environmental regulations rest solely on their capacity to "minimize the costs of technology adoption for existing technologies" or to stimulate short-term innovation with "immediate implications for cost savings."[34] Insofar as an Environmental Competition Statute relies on policies that provide incentives that accrue in the future, which is true of both its regulatory and subsidy provisions, it is susceptible to this critique.

These arguments expose the pitfalls of ignoring the political (and economic) realities of environmental regulation at any level of government. One must be careful, however, not to take this argument too far. For one, this critique runs contrary to those studies and examples suggesting that environmental regulation can influence research and development. More fundamentally, the critique rests on a narrow conception of economic rationality that does not necessarily match common understanding of political decision-making processes. Little doubt nevertheless exists that the politics of regulation and uncertainties in climate change science diminish the incentives that environmental regulation – whether state or federal – can provide for investment in extended research and development. One admittedly modest way to mitigate these uncertainties is to include phase-in provisions that match the expected time (often decades) for new technologies to be developed. Alternatively, in the case of an Environmental Competition Statute, it could be structured to pull some of the revenue it generates for upfront direct subsidies similar to traditional government research and development programs.

Adoption of Existing Technologies: A More Promising Role for the States

Significant empirical support exists for the benefits of using environmental regulations to induce technology adoption. Examples include studies of prominent regulations under the Clean Air Act and the Clean Water Act.[35] Positive correlations have also been found between energy prices and adoption rates of energy-efficient products.[36] The most compelling evidence is associated with Corporate Average Fuel Economy (CAFE) standards, which have been found to be substantially more effective than increases in fuel prices.[37] Consistent with these findings, researchers have found that "technology adoption decisions are more sensitive to up-front costs than to longer-term operating expenses."[38]

One potential reason for these robust results is the absence of a temporal schism between the timing of regulation and investments in technology adoption. Both technology adoption and learning by doing are responsive to incentives created by current environmental policies. This dramatically reduces the uncertainties that undermine regulatory incentives for innovation, although they are by no means eliminated because the policies themselves are, of course, subject to change by state (or federal) governments. On the other hand, competing companies must comply with a regulation, meaning that no one is at a competitive disadvantage by adopting an underused technology – even if a state later chooses to relax its regulatory standards – and free-rider problems are minimized because learning by doing occurs in parallel.

Paradoxically, the successes in using environmental regulations to promote technology adoption may also owe something to the many barriers that impede it. Many studies have shown that adoption of new technologies is slow even when they are clearly superior to existing technologies with respect to cost and performance. Economists, for example, have calculated implicit discount rates for consumers purchasing energy-efficient technologies that far exceed market interest rates (25 percent and often much higher).[39] As these findings suggest, multiple potential barriers exist including transaction costs, bounded rationality, information deficits, technological and financial risks, and investor-user splits.[40] Unfortunately, the factors that impede adoption of specific technologies are highly variable across different classes of technologies and no unifying theory currently exists to guide policy.[41] Policy makers must therefore be attentive to the specific barriers that may be present (e.g., onerous upfront capital costs) and structure policies accordingly.

Technology adoption and learning by doing has a significant local component that shrinks the scale at which success is measured. Both, as argued previously, are enhanced by knowledge externalities captured only in geographically localized communities. Further, the trajectory of technology adoption typically follows an S-curve – rising gradually at first, then steeply increasing and finally leveling off – such that success is marked by achieving levels of adoption that trigger a shift to rapid diffusion (the steep part of the adoption curve).[42] State-level programs, such as renewable portfolio

standards for electric power generation,[43] thus have distinctive advantages over federal programs insofar as they can be more precisely targeted to meet specific barriers to technology adoption and can sustain a diversity of approaches. State-level Environmental Competition Statutes should therefore focus on promoting technology adoption and learning by doing over innovation.

A Hybrid Approach to Climate Change Policy

One of the great virtues of federal climate change policies, particularly when linked to an international regime, is that they can overcome the eroding, or even perverse, effects of emissions leakage on GHG reductions. I have shown already how, in the absence of a federal program or where gaps in a federal regime may exist, states can adopt technology-oriented policies that circumvent the limited scale of state programs and their vulnerability to emissions leakage. This strategy sidesteps the challenges of achieving meaningful reductions in GHG emissions by focusing on technological change. In this section, I address the circumstances in which states operate under the backdrop of significant federal legislation, such as a multisector cap-and-trade program.

An important potential limitation of this approach is the irreducible uncertainties that may foreclose standard optimization strategies. The efficiency gains, as opposed to benefits alone, of induced technological change have proved difficult to demonstrate. William Nordhaus and other researchers have estimated that "the impact of induced innovation is modest."[44] By contrast, other studies have predicted cost savings from induced innovation of 30 percent,[45] and where cost functions are convex (i.e., the rate of increase rises with required abatement level) and the abatement standard is stringent, another study has found the benefits of induced innovation to be dramatic.[46] These inconsistencies suggest that the best we may be able to achieve is increases in relative efficiency, often referred to as satisficing, as opposed to optimization.

The available studies provide solid grounds for identifying state policies that meet this satisficing principle. A recent set of studies evaluates strategies that combine market-based environmental regulations with technology-push policies. The estimated benefits over either type of approach on its own are impressive. As one might expect, given the long lag times and high costs of research and development, a dual approach is far superior (about a factor of ten less costly) to a straight technology policy.[47] Although not quite as dramatic, dual approaches that combine a carbon tax with direct innovation subsidies can reduce costs by more than one-third over a carbon tax on its own.[48] These studies provide strong support for policies that utilize complementary measures, such as a carbon tax combined with subsidies for innovation and learning by doing. A hybrid approach can also enhance the efficiency of other measures, such as renewable portfolio standards, by implementing them in parallel with, for example, market-based regulations.[49]

By allowing environmental and technology objectives to be decoupled, a hybrid approach circumvents the tensions created by these sometimes-competing goals. In particular, near-term GHG reductions can be pursued efficiently, if focused on technology adoption, because they are not burdened by the perceived need to implement stringent standards to spur investment in costly research and development. At the same time, by recognizing the limitations of using regulations to stimulate research and development, one can leverage technology policies to subsidize research and development. This strategy has the virtue of ensuring that new technologies will be available in the future while limiting abatement costs and encouraging continual improvements in technologies and their production processes over time. A federal cap-and-trade program, for example, aimed at reducing GHG emissions could be combined with state Environmental Competition Statutes aimed at promoting technology adoption and learning by doing.

The efficiencies gained by combining environmental regulatory measures and technology policies is borne out by a recent comparative study of environmental taxes in Europe targeted at reducing carbon dioxide emissions. The author, Monica Prasad, found that environmental taxes in several Scandinavian countries dating back to the early 1990s have had little discernable effect, except in the case of Denmark.[50] Prasad identified several reasons for Denmark's success including, most importantly for our purposes, that "Danish policy makers made huge investments in renewable energy and subsidized environmental innovation."[51] By ensuring that substitute technologies were readily available, the Danish government overcame the risk aversion of firms, countervailing sunk costs, and

network effects that often limit technology adoption. Denmark encouraged technology adoption through direct subsidies, differentially high taxes on coal, and tax benefits to industries that voluntarily agreed to reduce emissions. Prasad concluded that this mix of environmental taxes and technology policies was essential to Denmark's success and ultimately distinguished its system from the failed policies of other European countries.

The existing econometric analyses and Prasad study reveal the benefits of combining traditional environmental regulations with technology policies to address climate change. They also highlight the importance of remaining attentive to the two distinct but related objectives of climate policy – reducing GHG emissions and promoting the technological changes that will be essential to meeting long-term GHG emissions targets.

The preceding sections have explored the strengths and weakness of different regulatory and technology policies in an effort to identify the policies most amenable to state action when a federal regime is in place. This exploration leads to three central conclusions. First, state climate change regulations should not center on reducing GHG emissions. Second, the primary objective of state climate change policies, including any state-level Environmental Competition Statutes, should be to induce technological change, principally through technology adoption and innovation through learning by doing. Third, complementary regulatory and technology policies should be adopted by states, with particular emphasis on market-based regulations, technology portfolio standards, and innovation subsidies, while the federal government retains primary responsibility for direct regulation of GHG emissions.

Recommendations: Environmental Federalism in an Era of Climate Change

A central premise of this chapter is that federal and state climate change policies should be complementary. Federal action is essential to achieving the dramatic GHG emissions reductions that scientists predict will be necessary, and it will play a critical role in promoting technological change as well. The primary role of the states, as I have argued previously, should be fostering technological change, particularly technology adoption and innovation through learning by doing. Federal laws should therefore enhance the ability of states to contribute to climate change mitigation in these ways. With this objective in mind, I propose several recommendations for federal climate change legislation.

State and Regional Cap-and-Trade Programs Should Be Retained but Should Not Be the Focus of State Climate Efforts

Much ink has been spilled analyzing the ways in which a federal cap-and-trade regime could be harmonized with state and regional programs, such as RGGI and California's A.B. 32. As I have shown, once a federal program enacts a legitimate cap-and-trade program, investment of substantial resources in parallel state or regional cap-and-trade programs is unwarranted if the objective is reducing GHG emissions, as opposed to promoting new policy development. These programs, particularly if focused on the short-term, generate little in the way of technology development or adoption, and they achieve only nominal reductions in GHG emissions relative to even a modest federal program.

Federal legislation nonetheless should not entirely preempt state and regional cap-and-trade programs. State and regional GHG emissions reduction programs have the potential to augment emissions reductions over and above those of any federal program that is ultimately adopted. Although the amount will be small, federal programs are unlikely to be optimally stringent and any additional reductions should not be needlessly precluded.

The policy development and institutional capacity building generated by state GHG regulations offer further grounds for preservation. The RGGI and A.B. 32 have already made important contributions to policy development by requiring participants to work through the details of regulatory regime and functioning as a proverbial laboratory of democracy. These contributions will not end on the enactment of federal legislation regime if for no other reason than that federal and state programs differ in many important ways. For instance, although each of the leading climate change bills in Congress allocate most of the GHG allowances without charging a fee,[32] RGGI gives each member state broad discretion in determining whether it will auction off permits.[33] Currently, five states (Maine, Massachusetts, New York, Rhode Island, and Vermont) have pledged to auction off 100 percent of their state's emissions allowances.[34] Preservation

of state programs is particularly important given the complexity of these programs, as it will enable much greater experimentation than a unitary federal system.

Federal and State Climate Change Programs Should Adopt Complementary GHG Emissions-Reducing and Technology-Forcing Measures

The importance of technological development to climate change policy and the distinct advantages of pursuing multiple policies to induce technological change provide a strong basis for a continuing state role in climate policy making, even after the enactment of federal climate legislation. By adopting a complementary approach, states and the federal government leverage synergistic benefits that are greater than either can achieve alone. Under this approach, emissions reductions should be left primarily to federal policy (i.e., cap-and-trade regimes), while states focus on technology change in parallel with the federal government. An Environmental Competition Statute is well suited to this framework, as it has the ability to provide significant incentives for companies to promote technology adoption and learning by doing.

A complementary approach is also consistent with standard principles of federalism. It reflects the understanding that some policies are more effectively pursued by the federal government, while others are better addressed by the states. Beyond their focus on reducing GHG emissions, federal policies can make valuable contributions by establishing minimum technology portfolio standards, regulating sectors that transcend state boundaries (e.g., transportation), and offering subsidies for research and development and technology adoption. The states are well suited to playing a complementary role through measures, particularly Environmental Competition Statutes, that promote adoption of existing technologies or learning by doing or that provide direct subsidies for technological change generally.

NOTES

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2. See generally Pew Ctr. for Global Climate Change, What's Being Done in the States, available at http://www.pewclimate.org/what_s_being_done/in_the_states; Barry G.

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