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Toward Sustainable Technology

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We should not think of environmental policy as an exercise in minimizing the short-term costs of environmental protection. Instead, we should think of it as a means of stimulating sustainable technology, the sorts of technologies that will enable us to meaningfully address global warming while achieving other environmental and societal goals. We must fundamentally change how we think about instrument choice in order to create a positive economic dynamic taking us where we need to go in the long-term.

This chapter will first explain why relentless pursuit of short-term efficiency through broad environmental benefit trading is in tension with the goal of maximizing investment in our long-term future and explore briefly one of the many options for improving trading's design. It will then put forward two alternatives to Kyoto style trading to show how a goal of creating a positive long-term economic dynamic can lead to more imaginative use of economic incentives. The first alternative, a Dirty Input Limit, stimulates fundamental change by limiting the use of fossil fuel. The second alternative, an Environmental Competition Statute, uses competition to stimulate a race to develop the best possible technologies to limit greenhouse gas emissions. Together, they illustrate that adoption of an economic dynamic leading to sustainable development can productively and creatively improve environmental law, even in the instrument choice realm, where efficiency-based thinking has made useful contributions.

I. Environmental Benefit Trading: Short-Term Efficiency and Long-Term Environmental Goals

Measures maximizing short-term efficiency do not necessarily maximize long-term welfare, because lower short-term costs do not stimulate higher long-term benefits.[1] Economists implicitly recognize that short-term cost savings do not aid technological innovation in their modeling of pollution taxes. These models assume that an increase in the tax rate increases innovation rates.[2] This makes sense. Innovation is often costly and almost always uncertain. To develop something new, one must invest in investigating an idea that has not been proven, which means that it might not work out. Therefore, people tend to choose to innovate when not innovating is costly enough to make innovation seem worthwhile.[3] This idea that high costs motivate innovation is consistent with the induced innovation hypothesis that economists often employ in analyzing innovation generally—not just in the environmental context.[4] The induced innovation hypothesis holds that producers tend to innovate in response to scarcity, and scarcity raises costs. To put it more simply, necessity is the mother of invention.[5]

Economists' assumption that high costs stimulate innovation is at war with the assumption that broad emissions trading stimulates innovation more effectively than a traditional performance standard of identical scope and stringency. Emissions trading lowers the cost of employing conventional control techniques by permitting polluters to reallocate their reduction responsibilities to minimize costs, as we have seen. It follows that emissions trading reduces innovation levels below what would occur with the same regulatory limits in place without trading.[6]

As a corollary, a broad emissions trading design, which increases the number of sources potentially generating credits, provides less of an incentive for innovation than a narrow design.[7] A broad design maximizes cost savings, permitting a wide variety of conventional techniques to generate credits. A narrow design limits the number of conventional technological options that can reduce emissions, thereby increasing pressures for innovation. The California Air Resources Board recognized this corollary explicitly when it established its carbon dioxide standards for new vehicles. It refused to permit offset credits from outside the transportation sector to count toward meeting its standard. It justified this refusal by pointing to the desirability of encouraging technological innovation in vehicle design. It recognized that allowing manufacturers to offset rather than actually reduce vehicle emissions would cause the manufacturers to avoid innovative vehicle design in favor of paying for credits reflecting cheaper and more conventional techniques for realizing emission reductions.[8] It did, however, employ a narrower form of trading to increase flexibility and lower cost, allowing vehicle manufacturers to comply with the carbon dioxide standard on a fleet-wide average basis, rather than requiring each and every vehicle to meet the standard.

This idea that short-term efficiency and long-term technological development can conflict is not new to economics. For some time a debate has raged among economists about whether a perfectly competitive market, which would maximize short-term efficiency, maximizes long-term economic growth.[9] The controversy arises because a very competitive market—*i.e.* an efficient market— cuts profits, delivering low prices to consumers. But firms may need profits to make investments in new technologies. Without these investments, firms may be efficient in the short-term, but may be quite static, failing to make the investments needed for long-term technological advancement and growth. Thus, perfect competition, while a precondition for maximizing efficiency, may discourage innovation.

The idea that emissions trading encourages more innovation than traditional regulation comes from a woefully incomplete evaluation of economic incentives. Trading proponents love to point out that trading creates an incentive to go beyond compliance.[10] Of course, this is correct, but only with respect to sellers of credits. Trading creates an incentive for about half of the pollution sources, the ones with the lowest marginal control costs, to go beyond compliance. It follows that trading provides superior incentives for those that already have low marginal control costs to innovate.

Unfortunately, trading also creates an incentive going in the opposite direction. It encourages half of the polluters to stop short of compliance—to emit more than they would have under a performance standard regime. Trading decreases innovation incentives for about half of the polluters, the undercomplying buyers, to innovate.

One cannot analyze trading's effect on innovation by focusing only on the sources that overcomply, any more than one could analyze it by focusing only on those that undercomply. Polluters that do not reduce emissions locally buy credits to make up the shortfall. In a trading program, undercompliance by some finances overcompliance by others. The Economist David Malueg pointed out that trading reduces innovation incentives for half the sources almost two decades ago.[11] But trading proponents often neglect this point.

Since trading decreases innovation rates for about half the sources and increases them for another half of the sources, the right question is: What is the net effect of trades shifting reductions from high cost to low cost sources?

Most importantly, trading decreases the net incentive for high cost innovation, relative to the incentives that a traditional performance standard of identical scope and stringency would provide. Under a traditional performance standard the polluters facing the highest marginal control cost would have incentives to adopt any innovation costing less than their high marginal cost. Under trading, they have no incentive to adopt such innovations. Instead, they will pay polluters with low marginal control costs to make reductions in their stead. The only innovations that will prove worthwhile in a trading program are those lower than the equilibrium price for abatement established by the permit market. And that price will be lower than the marginal control costs of polluters facing high costs under a traditional regulation, substantially lower in many cases. Trading eliminates all incentives to make innovations costing more than the relatively low cost of conventional pollution reductions established by the trading market.

This destruction of incentives for relatively high cost innovation matters, because development of technologies that can significantly increase our capacity to address a major problem like global warming will tend to cost a lot, at least initially. It's not an accident that broad environmental benefit trading programs have done little to promote renewable energy and nothing to promote nuclear power. Development of nuclear power or renewable energy will likely prove more costly than the cheapest conventional approaches for reducing emissions. By referring to nuclear, I do not mean to express any view on its desirability in light of concerns about nuclear accidents and radioactive waste disposal. But some people believe that we will need to deploy nuclear power to adequately address global warming and that the risks are manageable. If governments wish to develop and improve nuclear power to address global warming, they will have to do more than just allow it to generate credits in emissions trading schemes. For an emissions trading scheme gives priority to low cost abatement and therefore provides an inadequate means for securing investment in high cost abatement with huge carbon dioxide reduction potential.

Many technological innovations that have significantly improved our lives involved costly investments that ultimately delivered significant welfare benefits at lowered cost. Manufacturers introduced automobiles as luxury goods commanding a high price. Mass production to lower vehicles' price sufficiently to make their use for personal transportation common came later, and built on the investments previously made in high-cost motoring. Similarly, personal computers followed investment in fiendishly expensive supercomputers, which only large institutions could afford. In these cases, and many others, high cost investment ultimately led to lower cost and significant improvements in our lives.

Investments that make it possible to address global climate change will likely follow a similar pattern. In the short run, many investments that help create technologies that can eventually provide cost effective substitutes for fossil fuels will likely prove costly. These investments, however, will lower prices and improve the effectiveness of the technologies involved. Indeed, this has happened with just about all forms of renewable energy, because of policies put in place specifically to stimulate these costly investments.[12] We desperately need these investments on a massive scale if we hope to cope with the challenge global warming poses.

Emissions trading, however, will usually only stimulate such expensive innovations only when all other cheaper options have been exhausted. Private actors in emissions trading markets tend to purse the least cost abatement options.

They will typically not consider the positive spillovers from investments in new approaches that make them desirable for society at large. For positive spillovers, by definition, are advantages that do not benefit the party investing in the technology generating the positive spillover. For example, an investment in new solar technology can produce ancillary benefits for society that justify its high cost. Such an investment may build knowledge that will allow other producers to make additional advances that reduce solar energy's price or increase its utility (for example, making it more viable in cloudier climates). Since market actors cannot predict these positive spillovers in advance and some of these spillovers may benefit competitors, rather than the company making the investment, project developers will tend to underinvest in this sort of innovation. This idea, that markets often produce an underinvestment in innovation, because the investor cannot capture the positive spillovers and innovation is an uncertain process, is well recognized in the economics of innovation generally.[13] But curiously, analysts of emissions trading have generally failed to consider the implications of these fairly standard lessons in the economics of innovation for emissions trading markets. At a minimum, these lessons suggest that emissions trading markets, like markets generally, will prove suboptimal in stimulating valuable innovation.

Faith in emissions trading's capacity to encourage innovation stems, in part, from the myth that emissions trading provides continuous incentives for innovation, something that traditional regulation does not do. In fact, to the extent emissions trading encourages innovation, the duration of that incentive precisely matches that provided by a traditional performance standard. Both traditional regulation and emissions trading's innovation incentive continues until the compliance deadline arrives and then subsides. The incentive to reduce emissions in a trading program comes from government commands to reduce emissions by a set amount by a date certain. Polluters are willing to pay for emission reductions, because they must purchase them in order to comply by the deadline, unless they reduce locally by the deadline. Some polluters will overcomply, because polluters with high compliance costs will pay for a limited amount of credits, the amount necessary for them to avoid local compliance, and no more. It follows that rational credit sellers will only pay to produce enough credits to meet this limited demand, as no substantial market exists for credits not needed for compliance purposes. Once a polluter has met its compliance obligation, either by purchasing credits or complying locally, no incentive exists to continue reducing emissions.

Trading programs, of course, can lengthen the duration of incentives for innovation by lengthening the compliance period. But a traditional regulation can do the same. While the compliance period can be short or long, the compliance deadline extinguishes incentives for innovation in both cases.

Of course, if regulators could be counted on to continually and predictably tighten their regulatory limits, then a continuous incentive to reduce emissions and innovate might exist. But this would be true whether or not regulators use emissions trading as the mechanism to meet these continually revised limits. In practice, however, polluters frequently lobby and/or litigate to delay or weaken limits, including limits to be met through emissions trading. And regulators often find it difficult to tighten limits for a variety of reasons.

The limits of my claim about trading and innovation require some emphasis. I am not saying that trading never encourages innovation. I am merely pointing out that trading produces less powerful incentives for valuable high cost innovation than traditional regulation of *identical scope and stringency*. I am also claiming that emissions trading does not produce optimal innovation, but it shares this flaw with markets generally.

One can address trading's weakness in stimulating innovation by increasing the cap's stringency. A trading program reducing pollution by X tons encourages expensive innovation less well than a performance standard providing for X tons of reduction. But if one establishes an innovation premium in the cap, call it P, such that the cap requires X + P tons of reduction, the trading program would stimulate more innovation, presumably, than a trading program under a cap of X tons. In order for a trading program achieving a reduction of X + P to produce as much high cost innovation as a performance standard requiring X tons of reduction, however, X + P must raise marginal control costs so that they equal the marginal control costs of achieving X through performance standards. Since trading significantly lowers marginal control costs, the innovation premium (P) necessary to meet this condition will usually prove quite high.

It is unlikely that the political economy advantages of trading will make it feasible to adopt a cap with an innovation premium sufficient to offset the innovation losses from trading (for expensive innovation). The increased stringency deprives polluters of the cost savings that trading would otherwise provide. Moreover, since polluters will likely have little or no information about the marginal cost of reductions at others' facilities that they might purchase, they may evaluate a proposed cap of X + P in terms of the cost of making all of the reductions at their own facilities, attributing little or no cost reduction to the market. Their own abatement costs (not taking into account cost savings from trade) will be much higher for limit X+P than for limit X. And vigorous industry opposition to a more stringent cap decreases the likelihood of government compensating for innovation lost through increased stringency. An innovation premium is a good idea, but it may be difficult to obtain a sufficiently ambitious premium.

Even if this can be done, market actors will not provide optimal investment in innovation, because they cannot capture the positive spillovers from the innovation. With an innovation premium, however, emissions trading should do just as well (or just as badly) as traditional regulation in producing innovation.

In keeping with the prevailing practice in the literature, I've framed this discussion as a comparison between traditional regulation and environmental benefit trading. This approach simplifies my effort to analyze the central tendencies of neoliberal instrument choice and to reorient our thinking. But in truth, there's little evidence that either trading or traditional regulation does a great job of stimulating innovation. A serious effort to address climate change may require more creative use of economic incentives to produce an economic dynamic favoring sustainable development. To do this, however, we must not assume that desirable innovation is an inevitable byproduct of mechanisms designed to maximize short-term efficiency.

Instead, we must design instruments specifically to encourage the innovations that will make it possible to phase out fossil fuels. We have seen that carbon dioxide constitutes about 80 per cent of global warming potential weighted greenhouse gases currently emitted.[14] For that reason, when scientists analyze the question of how one would technically avoid dangerous climate change, they focus almost entirely on analyzing the capacity of various alternative fuel sources and energy efficiency improvements to displace fossil fuels.[15] Furthermore, absent a phase-out of these fuels by the end of this century, scientists expect global warming to be very dangerous.[16] Mid-range predictions include sufficient sea level rise to inundate Florida, Manhattan, and other areas, significant water shortages in the already arid west, the spread of infectious diseases, and an increase in the ferocity of violent weather events, like hurricane Katrina.[17] And global warming could trigger feedback loops soon that will make things even worse.[18] Accordingly, scientists have been accompanying calls for a phase-out by the end of this century with a call for a 50 per cent cut below 1990 levels by 2050.[19] Because developing countries will not cut emissions unless developed countries show good faith and provide technological leadership by going first, developed countries probably need cuts in the order of 80 per cent by 2050 as a prelude to a complete phaseout.[20] Yet, perhaps because of a psychological aversion to squarely confronting the need for such a significant change, most of the instrument choice debate focuses upon abstract "carbon abatement" policies, like emissions trading, which only address the idea of a gradual fossil fuel phase-out obliquely.[21]

We will stop using fossil fuels eventually, no matter what we decide. Oil will run out at some point, and eventually, so will coal. These are non-renewable resources in limited supply. The only question really is whether we will phase these substances out before or after absolute scarcity forces enormous price increases and then makes them simply unavailable for any purpose. Replacing fossil fuels as soon as possible will yield enormous benefits. Every year we continue burning fossil fuels we add carbon dioxide to the atmosphere, which accumulates and remains there for more than a century, committing us to more future warming. Fossil fuels also lie at the root of most of our most serious conventional pollution problems. Phasing out fossil fuels would lessen or eliminate particulate pollution (associated with tens of thousands of annual deaths in the United States), ozone (associated with asthma and other lung disease), hazardous air pollution (associated with cancer, birth defects, and neurological defects), oil spills, non-point source pollution, and destruction of land and water from coal mining. We do not know how quickly oil prices will rise or how quickly the price of renewables will fall. But we do know that the right direction for society is to phase out fossil fuels over time. The economic dynamic theory emphasizes that we should move in the right direction even when the costs and benefits of doing so cannot predicted with reasonable accuracy.

II. Dirty Input Limits

We saw in chapter 7 that environmental benefit trading under the Kyoto Protocol has tended to encourage end-of-the-pipe solutions. This is not surprising, because emissions trading focuses on end-of-the-pipe control. It limits a particular pollution output. In this respect, it follows the prevailing model of traditional regulation, which also focuses on end-of-the-pipe limits, albeit without the trading possibility. This section explores the idea of limiting the inputs that cause global warming instead of the pollution outputs that constitute the symptoms. We refer to laws that limit the use or production of an input generating pollution as a Dirty Input Limit, or DIL.[22]

The climate change regime's focus on end-of-the-pipe solutions is in tension with the teachings of the pollution prevention literature. This literature points out that often pollution prevention—reducing or eliminating undesirable inputs into polluting processes—can reduce multiple pollutants at once, often in several different media. By contrast, end-of-the-pipe control can transfer pollution from one medium to another. For example, carbon capture and storage, an end-of-the-pipe approach under consideration to address climate change—poses some risks of groundwater contamination, because it involves transfer of carbon dioxide from air to land. Methods that avoid generation of carbon dioxide in the first place, however, prevent pollution and contaminate neither medium. The literature also points out that pollution prevention is often cheap.

Pollution prevention tends to involve fairly fundamental technological changes. A focus on pollution prevention challenges firms to change their processes—to change how they produce goods and services valued by society.

Firms tend to like output-based regulation, because end-of-the-pipe control does not require creative changes in fundamental processes.

We can require pollution prevention by imposing limits on the inputs that create pollution, rather than the resulting pollution output. In particular, we could limit the carbon content of all fuels, which would stimulate a move away from fossil fuels with high carbon content like coal and oil. Or we could simply limit the amount of oil and coal that the United States uses. Furthermore, we could create allowances to use or produce these inputs, and make the allowances tradable, thereby reducing cost and improving flexibility.

While this may seem radical, we have used DILs in the past. Indeed, they figure prominently in our most well known environmental success stories, the reduction and eventual phase-outs of lead and of key ozone depleting substances. In the case of lead, EPA first created DILs reducing gasoline's lead content and then gradually phased lead out. This phaseout produced a public health triumph, as lead from gasoline played a large role in elevating blood lead levels and associated neurological problems. Ozone depleting chemicals threatened to deplete the stratosopheric ozone layer, which shields us from ultraviolet radiation. This would allow ultraviolet radiation to increase skin cancers, disorder our immune systems, and wreak ecological havoc. The United States led the world to an agreement to limit the production of key ozone depleting chemicals under the Montreal Protocol on Ozone Depleting Substances. A few years later, the world agreed to phase out key ozone depleters entirely. The United States, and the rest of the world, used DILs to accomplish this phaseout. While a hole opened up in the ozone layer before the world had acted, these DILs were very successful and scientists now expect the ozone layer to heal.

These DILs unleashed significant technological changes, causing the reformulation of gasoline and vast changes in a variety of processes using ozone depleting substances. Thus, many analysts credit these DILs with effectively stimulating innovation.

While the Montreal Protocol provided some authority to trade, no trades actually occurred.[23] The later phases of the lead phaseout, however, involved a quite active trading and banking program, using tradable DILs, rather than tradable emission output allowances. EPA authorized small refiners phasing out lead to bank credits if they phased lead out more quickly than required and to purchase allowances authorizing increased lead content from those who overcomplied. While this arrangement delayed the phaseout somewhat,[24] it lowered the small refiners' costs and increased flexibility.

DILs unleash technological innovation and therefore may produce significant cost savings, because they focus producers on changing fundamental inputs into production processes. Indeed, the ozone DILs unleashed so much cost saving innovation that in hindsight we think of the phaseouts of key ozone depleters as easy accomplishments. But when the United States started to address ozone depleting chemicals, they were used ubiquitously as solvents, refrigerants, propellants, foams, and pesticides, and experts believed that finding substitutes was either expensive or simply impossible.[25] Moreover, the DILs spurred significant technological advances even before the phaseouts came into effect.[26] So, a DIL can catalyze innovation even if they do not involve a phaseout.

Of course, as Professor McGarity's chapter suggests, regulators cannot accurately predict the magnitude of cost savings from technological innovation in advance. The cost of a DIL depends on costs for substitutes performing the same economic functions as the substance being limited or phased out. The experience with ozone depleting chemicals suggests that once firms focus their energies on finding appropriate substitutes, costs can fall to nothing—*i.e.* users find alternatives that cost less than the substance that the DIL targets. This is very different from the experience with output-based measures, such as performance standards and emissions trading.

Most analysts will tend to assume that a DIL phasing out fossil fuels, however, will prove outlandishly expensive, because currently few cheap substitutes for fossil fuels exist. The United States, however, need not phase out fossil fuels in the near term. It could modestly cut their overall use or just permit no further increases in their use. This approach would send a powerful signal that industry needed to innovate to find alternative fuels. It would likely provoke some innovation and might therefore prove less costly than expected. Moreover, regulators could then, following Professor McGarity's suggestion, use the cost experience from implementing a modest DIL to evaluate how much further we could go.

The advantages of a fossil fuel DIL are most acute in the transportation sector. Because output-based limits are so difficult to administer, output-based trading schemes arising under the Kyoto Protocol to date have focused exclusively imposing limits on power plants and large industrial pollution sources. In the United States, however, transportation accounts for about 1/3 of greenhouse gas emissions. Both in the United States and in many other countries these emissions have risen rapidly, because of increased driving. Since greenhouse gases accumulate in the atmosphere, capping rapidly growing transportation emissions—*i.e.* limiting the total mass of transport emissions in a country (and ultimately in the world) is extremely important. Yet, output-based cap and trade for transport is not feasible, because we cannot track each driver's carbon dioxide output in order to set up a tradable allowance system focused on outputs. Nor can vehicle manufacturers or fuel providers comply with a cap on the mass of vehicle emissions actually released into the environment. A combination of fuel characteristics, vehicle design, and driving habits determined vehicle emissions, and no one party controls all of these variables. Only a driver can limit the total mass of emissions released, and the driver can't readily change the practices of fuel providers or vehicle manufacturers; a driver could stay within a cap by driving less, taking the carbon dioxide per mile from her vehicle as a given. As a result, trading schemes have not included transport emissions, and this sector's emissions remain uncapped.

A DIL would permit capping fossil fuel use in the transport sector, guaranteeing a reduction in the total mass of emissions within the polity employing the DIL. For example, EPA could calculate the total carbon content burned in the United States in a recent year. It could then auction off allowances reflecting 90 per cent of the total carbon content of fuel emitted to refiners and fuel importers.

This DIL, like all DILs, would create a ripple effect beyond the sector possessing allowances. Because a DIL constricts output that forms part of a production stream, it limits production and use of the limited input at every stage from material extraction to end use. Fuel manufacturers would have to change fuels in order to stay within the DIL's limits and still supply the drivers with sufficient fuel. The gasoline scarcity this creates would cause vehicle manufacturers to innovate as well, as fuel efficiency and flex fuel vehicles would become a necessity. If the innovation this unleashed contains costs sufficiently (vehicle efficiency improvements, in particular, would likely have that impact), then consumers would not be affected. If costs rose, this would put pressure on drivers to use public transport, ride a bike, or live closer to work and would therefore put pressure on governments to fund mass transit.

Because producers of pollution inputs are usually less numerous than end users, DILs usually will prove much easier to administer than output-based programs. In the United States, a program limiting the carbon content of transportation fuels could be administered by auctioning tradable permits to refiners, owners of natural gas pipelines, and fuel importers. This is a smaller group of entities than those successfully regulated under the acid rain trading program. Expanding the program to include coal processors, allowing rather comprehensive regulation of fossil fuels would only produce about 2,000 regulated entities.[27] Such a program is a lot simpler than the output-based trading mechanisms under Kyoto, which could, in principle, reach not just the handful of suppliers of dirty inputs, but all of the downstream users of those inputs where pollution outputs are released. And it would be far easier to administer than the piecemeal program of output-based measures that have struggled to address the transportation sector's emissions in the past.

A fossil fuel DIL would provide a wide variety of benefits, going beyond climate protection. Limits on fossil fuel production or use would ameliorate environmental damage throughout the production stream. Oil extraction, transportation, and refining damage land, water, and pollute the air. More air and water pollution occur when the fuel is added to gasoline tanks and then burned. Similarly, coal mining destroys water and land. When the coal is burned, the power plants emit many more harmful pollutants than just carbon dioxide. The U.S. regulatory system has struggled for many years to separately regulate all of the pollution outputs stemming from fossil fuel use on a piecemeal basis. It would be far more efficient to simply limit fossil fuel production at the source, thereby simultaneously addressing all of these problems.

Adoption of a DIL will require a change in our thinking. If one's only goal is to reduce private polluters control costs for a single pollutant, than an output-based trading approach makes sense. After all, polluters generally have the option of using a pollution prevention approach if it meets their output-based limit. For example, under an output-based approach, power plant operators complying with a limit on their carbon dioxide emissions could choose to switch to natural gas—*i.e.* to change inputs. But operators of coal plants will prefer to have the option of employing carbon capture and storage—an end-of-the-pipe control—if it proves cheaper (regardless of whether it's safe and effective). If one accepts the prevailing quick fix mentality, then the polity should clearly permit this choice, and DILs would not be applied in this sector. But even in this case, DILs may prove worthwhile. Carbon capture and storage will not reduce the impacts of coal mining on land and water, which have been devastating; coal mining firms have removed whole mountaintops to get at coal. Carbon capture and storage only addresses global warming, not the particulate, nitrogen oxide, and mercury emissions emanating from coal-fired power plants. By addressing each of these problems piecemeal we complicate long-term planning for industry and strain the capacity of regulators. And carbon capture will not prepare us for the day, admittedly long in the future, when coal will run out.

DILs make sense if your goals include sustainable development, long-term technological development, and efficient use of government resources devoted to addressing serious environmental problems, not just achieving a single environmental goal at the lowest possible short-term costs. They offer a far more positive economic dynamic than output-based trading, as they are far more likely to stimulate fundamental technological change than an output-based system, which accommodates, rather than fights, technological lock-in.

DILs' capacity to challenge the status quo, however, may create political obstacles to their enactment. Leaders determined to seriously address climate change, however, may overcome these challenges. Some states, such as

California, may find such a reform congenial, because they see themselves as environmental leaders. And if more Katrina-like disasters unfold, the political climate may come to favor the most effective solutions, even on the federal level. Finally, effective political leaders may find that some firms, those with substantial investments in alternatives to fossil fuels, can become their allies in seeking to effectively change the status quo. The major petroleum companies certainly have the resources to become big players in a move to alternative fuels. It's not inconceivable that even one of them could play the role DuPont is reputed to have played in the ozone controversy, as a firm interested in change because it can benefit from it.

Yet, government timidity in demanding changes that may require substantial innovation has limited our achievements under a host of environmental instruments, and this problem may well impose some limit on the scope and effectiveness of DILs as well.

The next section addresses an approach specifically designed to allow private sector initiative in environmental innovation to prosper even in the face of government timidity in setting limits.

III. An Environmental Competition Statute

We have achieved a number of advances in material welfare because entrepreneurs seek to get rich by developing and introducing innovations. Examples include the cellular phone, the personal computer, and various uses of the internet. Innovators' ability to gain market share through productive change is limited only by their imagination and capabilities in meeting potential demand. Unfortunately, the free market rarely encourages innovations improving the environment, because they usually benefit the public as a whole, rather than particular consumers paying for favorable environmental changes.

An Environmental Competition Statute aims to stimulate a race to the top, a competition to develop and deploy environmentally superior technology. In order to stimulate this race, an Environmental Competition Statute authorizes those producing products or services with relatively low carbon emissions to collect two fees from competitors with higher emissions. The law would require that the first fee fully compensate the lower emitting facility owner for the full cost of using and developing an environmentally superior approach. The second fee would provide a guaranteed profit for these investments. The government would establish the rate of profit in the statute, by setting a premium above the cost of achieving lower emissions. This premium would assure a reasonable profit to any producer who achieved lower emissions than a competitor on top of the basic costs recouped from that competitor. For example, if the government set a 10 per cent premium and a coal fired power plant spent a million dollars on carbon capture and storage, the owner of that plant could demand that the owner of a power plant with higher carbon dioxide emissions pay her $1,100,000, the cost incurred in lowering emissions plus the premium.

For climate change purposes, the legislature should make this obligation apply to targeted industries producing greenhouse gas emissions. For example, Congress (or a state legislature) could authorize all power producers with low emissions to recoup the costs they incurred in achieving these low emissions from any power plant they choose that has higher emissions, along with the government set premium. The legislature should require that emissions measurement on a tons per kilowatt hour produced per year basis. Normalizing emissions by production volume will avoid a perverse problem that might otherwise arise. A small very dirty coal-fired power plant might have lower total emissions than a clean, but very large, natural gas power plant serving many more customers if a simple mass-based metric were employed. By normalizing emissions according to production, the scheme would make sure that dirtier operators paid cleaner operators, not visa-versa. This scheme implies that a solar power plant owner, which would have zero emissions, could collect her construction costs from a coal-fired power plant with high emissions.

We could apply the same approach to the automotive industry. Manufacturers achieving low carbon dioxide emissions per vehicle per mile for the entire passenger car lineup could collect a fee reflecting the full costs of improving their carbon emissions performance from whichever competitor they'd like to target.

In order to maximize the performance of an environmental competition statute, the term "competitor" should enjoy as wide a definition as is fairly plausible. For example, manufacturers who make a lot of Sports Utility Vehicles (SUVs) will argue that their SUV emissions should be measured against other manufacturers' SUV emissions. In other words, they will try to argue that the relevant market involves competition among SUV manufacturers for SUV sales. Lawmaking bodies should reject this claim. Individual car owners choose between SUVs and sedans in meeting their personal and family transportation needs. Therefore, the market should be defined broadly, to include all vehicles that provide family transportation. This broad definition would encourage manufacturers to either make fewer SUVs or drastically improve their environmental performance (or both). On the other hand, it would be reasonable to leave cement mixer trucks out of this market, as manufacturers of cement mixers presumably serve a different market, as cement mixers do not work as a family passenger vehicle. Cement truck makers ought not have to compensate passenger vehicle manufacturers if the passenger vehicles happen to have lower carbon dioxide emissions (or visa versa).

An Environmental Competition Statute has the potential to encourage contests to improve environmental quality comparable to the ongoing competition to realize other sorts of improvements. It aims to allow the capabilities of innovators free reign in improving environmental quality. It makes it possible for anybody reducing pollution to realize a profit from doing so. It seeks to emulate the economic dynamics of competitive markets, instead of the efficiency posited in economic modeling exercises.

The statute also creates risks for those who fail to advance and innovate, comparable to the risks faced by non-innovators in competitive markets for non-environmental goods and services. Just as makers of mainframe computers must adapt to the threat posed by PCs, or risk losing market share, those who fail to adopt the latest environmental technology should lose money to faster moving competition. This statute allows environmental innovators to prosper at the expense of environmental laggards, thereby allowing environmental markets to function like other competitive markets. In short, an Environmental Competition Statute encourages competition to improve the environment.

Absent government regulation, free markets permit polluters to externalize the costs pollution create. Exxon, for example, will not bear the full costs of global warming that its gasoline caused. The rising seas will inundate Bangladesh and, closer to home, Florida, and homeowners there will pay the costs, if they live. While Exxon externalizes its pollution costs, it must internalize (pay) all costs incurred to limit carbon emissions. Therefore, if Exxon wished to devote most its resources to developing alternative fuels, it would bear these costs itself. No wonder that markets by themselves have failed to produce significant progress on global warming, even though some companies have voluntarily improved energy efficiency—a move that usually has no net costs. An Environmental Competition Statute permits facilities to systematically externalize pollution control costs, even significant costs, just as they now systematically externalize pollution costs—*i.e.* the environmental and public health harms that pollution causes.

Most existing law allows the timidity of government officials to limit our environmental achievements. The law authorizes federal and state officials to limit the amount of pollution polluting facilities can emit. The officials administering these laws usually must take the costs environmental law might impose upon our most antiquated facility owners into account in thinking about mandating environmental change. They rarely, however, actively consider the economic benefits those with newer technologies might realize from substantial positive environmental change when establishing new standards. As a result, even when modernization would generate new jobs and greatly improve the environment, government regulations only rarely demand significant changes in approach.

Government officials often feel obliged when setting standards for an entire industry to make sure that every company in an industry can meet the standards it sets. While the law authorizes and sometimes requires regulations based on the achievements of the best performers, government officials tend to avoid aggressive regulation because of the political and legal problems that tough standards might create. While in other areas competition tends to make the best performers the trend setters, in environmental law, laggards have a big influence on the quality of environmental performance.

This feeling of obligation and pressure from the judiciary leads to standards not reflecting the full capabilities industry possesses to improve environmental performance. Government officials often base their regulations on the technical capabilities of pollution control technology. Government officials often, however, have limited knowledge of industry capabilities to improve environmental performance. As a result, they tend to demand relatively modest improvement based on well-understood technology. This has been the case, to some degree, even under statutory provisions designed to force technology.

Many policy-makers associate this problem of government regulation failing to encourage substantial innovation with command-and-control regulation. But this timidity problem also limits emissions trading programs' achievements. Emissions trading programs require, as we have seen, that government officials limit the amount of pollution that regulated facilities emit. Government officials develop these limits with the costs to old established industry of making changes very much in mind. They therefore usually make demands that do not require basic technological changes significantly improving societal welfare. So, trading has not functioned to produce the kind of wide open competition that has enriched people with new ideas providing material benefits to consumers.

The same problem of government timidity would limit the efficacy of pollution taxes. If the traditional U.S. antipathy toward taxes abated sufficiently to allow them to be passed at all, government officials would have to choose the tax rates to apply to pollution. They would probably find it politically difficult to set rates sufficiently high to stimulate significant innovation in environmentally friendly technologies. A tax program would provide a continuous incentive to innovate, but only for a limited class of innovations, those with marginal costs less than the marginal tax rate. Taxes would not provide good incentives for important cutting edge technologies that would require significant investments putting their marginal costs above marginal tax rates, even if such investments would lower costs and improve environmental quality in the long run.

The legislation should also forbid communication about how firms plan to respond to the Environmental Competition Statute among competitors. Otherwise, they might agree to do nothing, thereby eliminating the incentives to compete. Violation of these provisions should carry very heavy penalties, including jail terms for individuals committing deliberate violations. Such communication should be regarded as proof of a conspiracy to prevent environmental competition in violation of anti-trust principles. Absent such conspiracies, some companies with advanced environmental capabilities will likely seize the opportunity to extract payments from competitors, thereby starting the race to the top. Firms who do not view themselves as environmentally advanced may start beefing up their emission reducing activities out of fear of becoming a target.

The legislation should also seek to minimize litigation by providing a dispute settlement mechanism, perhaps through mandatory arbitration. Disputes may arise about who is a competitor and who has the lowest emissions. A dispute settlement mechanism can prevent these quarrels from becoming too distracting, even though actions taken to reduce pollution in order to get transfer payments or to avoid becoming a payer of one can prove productive even if final settlement is delayed.

This approach can either address greenhouse gas emissions neglected by other schemes or supplement them. It's possible, for example, to use DILs to require as much movement away from fossil fuels as government regulators feel comfortable in requiring, while using an Environmental Competition Statute to accelerate the innovation process to produce the newer, better, cheaper, technology that would make stricter DILs than would otherwise be possible plausible in the near future. Or, for that matter, one could continue with the current output-based approach, and use an Environmental Competition Statute to pave the way for stricter future limits.

Those who think that environmental law should above all make sure that we do not spend too much on pollution control will not find the Environmental Competition Statute very congenial. It gives free reign to entrepreneurial effort to reduce emissions, but apparently does little to constrain costs. In practice, however, some cost restraint would exist. In order to be a competitor in one of these markets with a legal right to demand payment, the entrepreneur reducing emissions would also have to continue to make and sell a product. If the firm spends so much reducing carbon that it goes bankrupt or has no customers, it's not a competitor and can't collect a fee. So, a polluter cannot spend infinite amounts of money on carbon reduction under this scheme, only as much as is feasible while meeting society's needs for the goods or services produced.

Yet, this approach, by design, contains less *a priori* cost constraints than typical government-led regulation provides. The relative lack of restraint helps this mechanism generate the rapid improvement in environmental technology that we will need to address the daunting challenge of global warming. We are not in any eminent danger of doing too much to avoid dangerous climate change. We desperately need mechanisms that can move us beyond the slow plodding limits of government decision-making through cumbersome and oft-litigated administrative law proceedings.[28]

IV. Some Concluding Thoughts About Instrument Choice

Allegiance to the neoliberal economic efficiency ideal has proven neither efficient nor efficacious. We ought not to assume that measures designed to maximize short-term efficiency will maximize long-term welfare with climate change looming on the horizon. Since we have locked-in infrastructure that destabilizes the climate, the most cost effective moves from this decidedly inefficient baseline will tend to perpetuate the lock-in. We should instead aim to create an economic dynamic that moves us away from fossil fuels to a future of much cleaner technology. Recognition of the tension between relentless pursuit of short-term cost effectiveness and mechanisms that will produce the needed investments and experiments to produce a more sustainable future should inform American climate change law, as we finally move to meet the challenge we have so long neglected.

The mechanisms introduced here—the DILs and Environmental Competition Statutes—present some fruits of the more creative thinking that a focus on positive economic dynamics can produce. Adopting these approaches can greatly aid our effort to make up for lost time. But these mechanisms are not flawless and other mechanisms also have value. Renewable portfolio standards, for example, have encouraged more use of renewable energy. And other mechanisms no doubt will be put forth and adopted. We hope that future policymakers focus hard on the question that this chapter puts front and center—what are the best mechanisms for speeding a shift away from fossil fuel use? Policy-makers should employ an economic dynamic framework in answering this question and seriously consider the proposals advanced in this chapter as part of the answer. They should ask how they can create incentives for rapid technological innovation and deployment, taking into account the full range of incentives and institutional considerations that this chapter and this book highlight.

[1] See generally David M. Driesen, *The Economic Dynamics of Environmental Law* (Cambridge, MA: MIT Press, 2003), 4; F.M. Sherer, "Schumpeter and Plausible Capitalism" in *Economics of Technical Change,* ed. Edwin Mansfield and Elizabeth Mansfield (Brookfield, VT: Elgar, 1993), 183.

[2] See, e.g., Francesco Ricci, "Environmental Policy and Growth When Inputs Are Differentiated in Pollution Intensity," *Environmental and Resource Economics* 38 (2007): 297-98.

[3] Margaret R. Taylor, Edward L. Rubin, and David A. Hounshell, "Regulation as the Mother of Invention: The Case of SO_2 Control," *Law and Policy* 27 (2005): 348-378.

[4] Patrick Matschoss and Heinz Welsch, "International Emissions Trading and Induced Carbon-Saving Technological Change: Effects of Restricting the Trade in Carbon Rights," *Environmental and Resource Economics* 33 (2006): 172; Richard G. Newell, Adam B. Jaffe, and Robert N. Stavins, "The Induced Innovation Hypothesis and Energy Saving Technological Change," *Quarterly Journal of Economics* 114 (1999): 941-975.

[5] Taylor, Rubin, and Hounshell, "Regulation as the Mother of Invention."

[6] See Taylor, Rubin, and Hounshell, "Regulation as the Mother of Invention"; David M. Driesen, "Is Emissions Trading an Economic Incentive Program: Beyond the Command and Control/Economic Incentive Dichotomy," *Washington and Lee Law Review* 55 (1998): 289-350; David M. Driesen, "Does Emissions Trading Encourage Innovation?" *Environmental Law Reporter* 33 (2003): 10106; Timothy F. Malloy, "Regulation by Incentives: Myths, Models, and Micromarkets," *Texas Law Review* 80 (2002): 541; David Wallace, *Environmental Policy and Industrial Innovation: Strategies in Europe, the USA and Japan* (London: Royal Institute of International Affairs, Energy and Environmental Programme, 1995), 20.

[7] See David M. Driesen, "Sustainable Development and Market Liberalism's Shotgun Wedding: Emissions Trading Under the Kyoto Protocol," *Indiana Law Journal* 83 (forthcoming).

[8] California Environmental Protection Agency, Air Resources Board, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles* (2004), vii (prohibiting use of credits from non-vehicle measures or for measures outside of California to avoid diluting carbon reduction regulations' technology forcing effect).

[9] See John Kenneth Galbraith, *American Capitalism: The Concept of Countervailing Power* (Boston: Houghton Mifflin, 1952); Joseph Alois Schumpeter, *Capitalism, Socialism, and Democracy* (New York: Harper, 1947); John Stuart Mill, *Principles of*

Political Economy, Book 4, Ch. VII, (London: John W. Parker, 1852), 352; John B. Clark, *Essentials of Economic Theory* (New York: MacMillan, 1907), 374.

[10] See, e.g., Adam B. Jaffe et al., "Environmental Policy and Technological Change," *Environment and Resource Economics* 22 (2002): 51.

[11] David A. Malueg, "Emissions Credit Trading and the Incentive to Adopt New Pollution Abatement Technology," *Journal of Environmental Economics and Management* 16 (1987): 52-57.

[12] Axel Michaelowa and Sonja Butzengeiger, "EU Emissions Trading: Navigating Between Scylla and Charybdis," *Climate Policy* 5 (2005): 3; Jeffrey Greenblatt et al., "Baseload Wind Energy: Modeling the Competition Between Gas Turbines and Compressed Air Energy Storage for Supplemental Generation," *Energy Policy* 35 (2007): 1474 (attributing a thirty percent annual increase in installed wind capacity to a "twofold drop in capital costs between 1992 and 2001" and "government initiatives"); Commission of the European Communities, *The Share of Renewable Energy in the EU: Commission Report in Accordance with Article 3 of Directive 2001/77/EC, Evaluation of the Effect of Legislative Instruments and Other Community Policies on the Development of the Contribution of Renewable Energy Resources in the EU and Proposals for Concrete Actions* (Brussels: 2004), 12; see, e.g., "Sunlit Uplands: Wind and Solar Power Are Flourishing, Thanks to Subsidies," *Economist*, June 2, 2007.

[13] Brett M. Frischman and Mark A. Lemley, "Spillovers," *Columbia Law Review* 107 (2007): 257-301, 258-61; Gregory N. Mandel, "Promoting Environmental Innovation and Intellectual Property Innovation: A New Basis for Patent Rewards," *Temple Journal of Science, Technology and Environmental Law* 24 (2005): 51-69, 56 (explaining that if a person "builds a better mousetrap," others may copy it); Richard A. Posner, *Catastrophe: Risk and Response* (New York: Oxford University Press, 2004), 123-24.

[14] Daniel A. Lashof and Dilip R. Ahuja, "Relative Contributions of Greenhouse Gas Emissions to Global Warming," *Nature* 344 (5 April 1990): 529-531; and see H.-Holger Rogner et al., "Introduction," in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Bert Metz et al. (Cambridge: Cambridge University Press, 2007), 102-3.

[15] See, e.g., Bert Metz and Detlef van Vuuren, "How, and at What Costs, Can Low-Level Stabilization be Achieved?—An Overview," in *Avoiding Dangerous Climate Change,* ed. Hans Joachim Schellnhuber (Cambridge: Cambridge University Press, 2006), 337-45; see Ken Caldeira, Atul K. Jain, and Martin I. Hoffert, "Climate Sensitivity Uncertainty and the Need for Energy Without CO_2

Emission," *Science* 299 (28 March 2003): 2052-54; Daniel P. Schrag, "Confronting the Climate-Energy Challenge," *Elements* 3 (June 2007): 171-78.

[16] See Schrag, "Confronting the Climate Energy Challenge;" James Hansen et al., "Dangerous Human-Made Interference with Climate: A GISS ModelE Study," *Atmospheric Chemistry and Physics* 7 (2007): 2287-2312; Martin I. Hoffert et al., "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet," *Science* 298 (1 November 2002): 981-87.

[17] Richard A. Kerr, "Global Warming is Changing the World," *Science* 316 (13 April 2007): 188-90; Cynthia Rosenzweig and William D. Solecki, eds., *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change* (Columbia Earth Institute, 2001); Edward R. Cook et al., "Long-Term Aridity Changes in the Western United States," *Science* 306 (5 November 2004): 1015-18; J. A. Patz et al., "Climate Change and Infectious Disease," in *Climate Change and Human Health: Risks and Responses*, ed. A. J. McMichael et al. (Geneva: World Health Organization, 2003), 103-32; James Hansen et al., "Global Temperature Change," *Proceedings of the National Academy of Sciences of the United State of America* 103, no. 39 (2006): 14288-293; Thomas R. Karl and Kevin E. Trenberth, "Modern Global Climate Change," *Science* 302 (5 December 2003): 1719-23.

[18] Hansen, "Global Temperature Change," 14288-93; Peter M. Cox, et al., "Acceleration of Global Warming Due to Carbon-Cycle Feedbacks in a Coupled Climate Model," *Nature* 408 (9 November 2000): 184-87; Karl and Trenberth, "Modern Global Climate Change," 1719-23.

[19] Michel den Elzen and Malte Meinshausen, "Multi-Gas Emission Pathways for Meeting the EU 2°C Climate Target," in *Avoiding Dangerous Climate Change*, 299-309.

[20] Ibid.

[21] See, e.g., Robert R. Nordhaus and Kyle W. Danish, "Assessing the Options for Designing a Mandatory U.S. Greenhouse Gas Reduction Program," *Boston College Environmental Affairs Law Review* 32 (2005): 97-163; Robert N. Stavins, *Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?* (Washington, DC: Resources for the Future, January 1997).

[22] See David Driesen and Amy Sinden, "The Missing Instrument: Dirty Input Limits", Harvard Environmental Law Review, 22:__- __ (forthcoming 2008).

[23] Ibid.

[24] *See* Driesen, "Is Emissions Trading an Economic Incentive Program?: Replacing the Command and Control/Economic Incentive Dichotomy," Washington & Lee Law Review 55 (1998): 289-350, 316-17 & n. 131.

[25] Edward A. Parson, Protecting the Ozone Layer: Science and Strategy (Oxford: Oxford University Press: 2003), 9.
[26] Ibid., 40, 183-191.
[27] Center for Clean Air Policy, "U.S. Carbon Emissions Trading: Description of an Upstream Approach" (1998), available at http://www.ccap.org, 6.
[28] *See generally* Thomas O. McGarity, "Some Thoughts on 'Deossifying' the Rule-making Process," Duke Law Journal 41 (1992): 1385-1462.