Pricing Pollution through Market-based Instruments

Joseph E. Aldy is Professor of the Practice of Public Policy at the Harvard Kennedy School, Cambridge, MA, USA.

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Abstract

Market-based instruments – including cap-and-trade programs, pollution taxes, and tradable credit programs – have emerged as common instruments for federal, state, and local policy-makers in addressing environmental challenges. This chapter describes the key characteristics that define these instruments and illustrates their environmental and economic impacts through a series of brief case studies on the lead phase-down, the sulfur dioxide and nitrogen oxides cap-and-trade programs, waste charges and bag fees, and the renewable fuel standard. These experiences provide a foundation for drawing out key lessons in the design and implementation of market-based instruments. The chapter concludes with a discussion of their potential application to climate change and highlights opportunities for future research on pricing pollution through market-based instruments.

Keywords: cap-and-trade, pollution taxes, instrument choice, overlapping instruments, environmental justice, climate change

<a> Pricing Pollution through Market-based Instruments

<b> Introduction

It is virtually impossible for an American to fill up her car or turn on his lights and consume energy that is not produced subject to some kind of market-based instrument. Cap-and-trade programs for carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_X) have covered power sector emissions. About two-thirds of the country consumes electricity subject to state renewable portfolio mandates. And transportation fuels are subject to credit trading under the renewable fuel standard and fuel content standards, such as benzene and sulfur.

Market-based instruments implement environmental policy through market signals instead of prescribing specific technologies or mandating specific performance levels common to command-and-control regulation. By "harnessing market forces," these approaches can align firms' profit-maximization objectives with societal environmental protection goals (Stavins 2003). In unregulated private markets, firms bear no costs for their pollution. If a firm paid to emit air and water pollutants like it pays for materials, workers, and equipment, then it would have a strong incentive to reduce pollution. Market-based instruments deliver that incentive by pricing pollution.

The two most common market-based instruments are cap-and-trade programs and taxes. A cap-and-trade program starts with the objective of limiting the aggregate quantity of emissions, which is represented by the cap. The government divides this aggregate cap into emission allowances, which it typically allocates either through an auction or on a free basis to firms covered by the program. The covered firms must report their emissions and surrender allowances equal to those emissions to the government. Firms may buy and sell allowances in a secondary market, where an allowance price emerges that creates a profit incentive for firms to reduce pollution.

A pollution tax directly prices the pollution on a per unit basis. For example, a tax could be placed on every ton of emissions. Or a fee could be collected for every pound of residential waste a family sets out for pick up (Miranda and Aldy 1998). Or a charge could be set on disposable bags at grocery stores. A tax could be imposed on the emissions of CO_2 and other greenhouse gases contributing to climate change (Morris 2013; Aldy 2016; Metcalf 2019).

Several policy derivatives have emerged in energy and environmental policy in the form of tradable credit programs and tradable performance standards. These approaches typically establish a performance target that applies to covered emission sources. These sources can generate tradable credits if they emit less than the standard and sell them to firms exceeding the standard. In air quality policy, tradable credit programs have evolved from performance standards, especially in the context of lead, sulfur, and benzene fuel content regulations. In addition, several energy policies with climate change benefits, such as state renewable power mandates, fuel economy standards, and renewable fuel standards, are implemented through tradable credit programs.

Three related rationales motivate interest in market-based instruments. First, the government faces a fundamental information problem when considering whether to regulate a pollutant. The firms responsible for the pollution have more information about their emission-reduction opportunities than does the government, but they have little incentive to share this knowledge with the regulator. Employing conventional command-and-control approaches – such as by mandating technology standards – then risks setting the regulatory bar too high for some firms and too low for others. A market-based instrument does not require the government to solve this information problem. Instead, it sends a price signal that creates the incentive for firms to solve the information problem on their own.

Second, by sending a price signal, market-based instruments can deliver cost-effective pollution abatement. Regardless of whether pollution is priced through a tax or tradable allowances, firms have a strong incentive to abate pollution if the cost of doing so is less than the price, and to pay the tax or purchase allowances if their abatement opportunities are more expensive than the pollution price. Firms optimizing on these pollution price signals minimize the aggregate societal costs of achieving any emission goal. From an economic standpoint, this would increase social welfare and from a political economy perspective, this would mitigate cost concerns among regulated firms.

Third, pricing pollution directly creates a strong, technology-neutral incentive for innovation. In contrast to regulations that prescribe specific technologies, a market-based instrument delivers a constant motivation to develop more effective, lower-cost abatement technologies. Any technology or process that reduces emissions is rewarded under a market-based approach. This can create a positive dynamic in which today's pollution price enables more emission abatement at a given cost in the future.

This chapter surveys the implementation of market-based instruments in U.S. environmental policy by reviewing their environmental and economic impacts through five case studies. These experiences provide the foundation for drawing lessons about the design of market-based instruments. The chapter concludes with a brief discussion of how these lessons may inform future U.S. climate change policy and motivate future research.

<b> Environmental and Economic Impacts of Market-based Instruments

The increasing interest and application of market-based instruments in U.S. environmental and energy policy reflects a number of early policy experiments that demonstrated significant pollution abatement and public health benefits at low costs. This section reviews the record in phasing down lead in gasoline, reducing power plant SO_2 emissions, cutting NO_X emissions at power plants and manufacturing facilities, taxing disposable bags, and promoting renewable fuels.

<c> Lead Phase-down

In the early 1980s, the Environmental Protection Agency (EPA) undertook a benefit-cost analysis of options for more stringent regulation of lead in gasoline (Nichols 1997). In light of the growing research on the adverse health impacts of lead exposure, this analysis illustrated large net social benefits of phasing down lead. The EPA moved quickly in promulgating an accelerated phase-down schedule for lead in gasoline. Initially set at 1.1 grams of lead per gallon, the standard ratcheted the permissible lead content down over time to 0.1 gram of lead per gallon starting in 1986 (Newell and Rogers 2006).

The lead phase-down program – which served to implement the more ambitious lead goals over 1982–87 – incorporated the first widespread use of an averaging, banking, and trading program in environmental regulation (Nichols 1997). If a refiner reduced lead below the standard, then it could generate tradable credits. The refiner could then use these credits at another one of its facilities or sell them to another refiner that has not removed lead down to the standard. In addition, refiners could bank credits for use in a future year, when the lead targets are more stringent and more costly.

The phase-down of lead from gasoline represents one of the most significant public health successes of the Clean Air Act (Aldy 2019). The Clean Air Act eliminated virtually all airborne emissions of lead, with the phase-down of lead in gasoline responsible for more than 94 percent of these reductions. The monetized benefits over 1970–90 of reducing lead concentrations exceeded $1.8 trillion (1990 dollars), accounting for more than $1.3 trillion in reduced premature mortality, nearly $400 billion in higher IQs and about $100 billion in reduced hypertension (EPA 1997).

The EPA's analysis of the lead phase-down suggested that it would cost $500 to $600 million per year (in 1983 dollars) and increase gasoline prices by about 2 cents per gallon (Nichols 1997). The opportunity for banking lead reduction credits produced cost savings on the order of $200 million. Implementing the lead phase-down through a tradable credit system created strong incentives for advanced technology adoption (Kerr and Newell 2003).

<c> Sulfur Dioxide Cap-and-Trade Program

To address acid rain, the Clean Air Act Amendments of 1990 authorized a nationwide SO_2 cap-and-trade program with the goal of cutting power plant SO_2 emissions to one-half their 1980 levels (Schmalensee and Stavins 2013; Chan et al 2018). The EPA implemented the program in two phases, with phase I covering the largest generating units over 1995-1999 and an expansion in phase II, starting in 2000, covering virtually all fossil fuel generating units in the country. A Phase II unit could voluntarily opt into phase I, and more than 100 units did so. Each covered unit received free emission allowances – granting the holder the right to emit one ton of SO_2 – as a function of that unit's historical heat input (efficiency in converting coal into electricity). The Environmental Protection Agency (EPA) also auctioned off a small fraction of allowances each year to facilitate price discovery in this emerging market. A unit covered by the SO_2 cap-and-trade program installed continuous emission monitors, which enabled high-frequency reporting to the EPA. At the end of each year, a regulated unit surrendered emission allowances equal to its reported SO_2 emissions.

A secondary market for emission allowances emerged, primarily brokered by a small set of firms. Several of these brokerages reported monthly average allowance prices to inform trading and compliance activity by regulated units. In phase I, the regulated units built a large allowance bank – saving a current vintage's allowances for use in a future compliance period – reflecting expectations about future allowance prices under the more stringent second phase of the program. Over the course of the program, nearly perfect compliance resulted in a dramatic reduction in power plant SO_2 emissions. During its first phase, the program resulted in costs about $250 million lower than what an environmentally-equivalent performance standard would have cost (Carlson et al. 2000). In its second phase, the SO_2 cap-and-trade program reduced compliance costs by about $200 million (1995$) relative to a performance standard (Chan et al. 2018). The monetized benefits of the sulfur dioxide cap-and-trade program are on the order of $50 to $100 billion per year, primarily due to reduction in premature mortality (Schmalensee and Stavins 2013).

Starting in 2003, the prospect of new air quality regulations as well as a series of Federal court decisions delivered a period of high and volatile allowance prices (Schmalensee and Stavins 2013). As new, more stringent regulations affected power plant SO_2 emissions and provided less compliance flexibility than under the Acid Rain Program, the SO_2 cap-and-trade program ceased to bind on power plants. The Clean Air Interstate Rule, implemented in 2009, and the subsequent Cross-State Air Pollution Rule, issued in 2011, placed state- and source-specific limits on SO_2 emissions and, by 2012 the auction prices for SO_2 allowances fell below $1 per ton, well below the $1,000+ per ton allowance prices of the mid-2000s.

<c> Nitrogen Oxide Budget Program

The Clean Air Act Amendments of 1990 created the Ozone Transport Commission (OTC) – comprised of state governments from Maine south to the metropolitan Washington DC area – with the task of addressing ozone pollution at the regional level. In 1999, these twelve states and the District of Columbia launched the OTC NO_X emissions cap-and-trade program for the May-to-September "ozone" season. Given improved understanding about ozone transport over the 1990s, the NO_X Budget Program evolved to cover nineteen states in the eastern half of the country.

The NO_X Budget Program began full implementation in 2004 and covered about 2,500 electricity generating units and industrial boilers. Like the OTC program, the NO_X Budget Program capped emissions during the summer ozone season, allowed regulated firms to buy and sell allowances, as well as bank allowances for future use. The program ceased after 2008, when EPA replaced it with the Clean Air Interstate Rule.

This program reduced summertime NO_X emissions by about 40 percent, resulting in a 6 percent reduction in mean ozone concentrations and a 35 percent reduction in the number of high-ozone days. The significant reductions in emissions and ozone concentrations contributed to substantial public health benefits: 2,000 fewer premature deaths annually and $800 million less in pharmaceutical spending per year (Deschênes et al 2017).

Realizing these substantial benefits came at a cost, in terms of capital investment and worker displacement (Fowlie 2010; Curtis 2018). After 2004, the states covered by the NO_X

Budget Program witnessed a 1.3 percent decline in manufacturing employment – a loss of about 110,000 jobs in total – relative to states outside the program. The most energy-intensive industries experienced reductions in employment of nearly 5 percent. Younger workers disproportionately bore these impacts, with falling hiring rates contributing more to the employment impacts than increasing separation rates (Curtis 2018).

<c> Waste Charges and Bag Fees

Local governments have employed price instruments to promote waste reduction since the 1970s. Unit-based pricing of solid waste collection – through pay per bag, pay per can, and pay per pound schemes – have been employed by more than 1,000 municipalities across the United States (Miranda and Aldy 1998). In recent years, local governments have imposed fees for disposable bags at retail establishments to encourage the use of reusable bags (Taylor and Villas-Boas 2016).

Pricing residential waste generation creates incentives both to reduce total waste generation and to divert waste to recycling. Pricing waste on a per bag basis resulted in about a one-third decline in residential waste set out on the curb, and increased the probability that a household participated in a recycling program in a Marietta, Georgia program (Van Houtven and Morris 1999). An evaluation of approximately 1,000 local waste collection programs – with more than 100 using unit-based pricing – showed that a $1 per bag fee reduced garbage production by 44 percent, with about 7 percent of the reduction diverted to recycling (Kinnaman and Fullerton 2000).

Modest fees on disposable bags – such as bags traditionally used by grocers – have also resulted in significant reductions in their use. For example, Washington DC implemented 5 cents per bag fees in 2010, which led to a 40 percent decline in grocery store disposable bag use (Homonoff 2018). This reflected a 46 percent increase in the share of customers who bring reusable bags to the grocery (Taylor and Villas-Boas 2016).

<c> Renewable Fuel Standard

In 2007, Congress amended and expanded the Renewable Fuel Standard (RFS), which mandated ambitious biofuel targets with explicit carbon intensity goals for the transportation fuels market. The RFS set a goal of 36 billion gallons of biofuels by 2022 implemented through a multi-tiered system wherein obligated parties (e.g., petroleum refiners) must comply with volume requirements for cellulosic biofuels and other advanced biofuels (defined as having lifecycle greenhouse gas emissions half those of petroleum-based fuels) as part of a total renewable fuel requirement.

Trading plays a central role in RFS compliance. Under the program, refiners, blenders and importers are assigned a Renewable Volume Obligation (RVO). To comply with its RVO, these firms must purchase renewable fuel credits, which represent a gallon of renewable fuel, and they must do so for each of the biofuels categories set out in the law. When an obligated party blends a gallon of renewable fuel into conventional fuel, the credit is separated from the biofuel and it may be traded, banked or surrendered for compliance purposes.

The tradable biofuel credit program embodies a “buyer beware” ethos, placing liability on all regulated parties for acquiring or transferring fraudulently generated credits. Starting in 2011, the EPA began identifying and criminally prosecuting biorefiners who generated credits without generating a corresponding gallon of biofuel. Because purchasers are liable for using fraudulently generated credits to satisfy their RVO, these cases of fraud reduced liquidity in the credit market. In July 2014, the EPA introduced the voluntary Quality Assurance Program to promote credit market confidence and liquidity in the credit market. This program provides independent auditing and verification of credits and creates an affirmative defense for purchasers who bought government-verified credits.

A fundamental problem with RFS lies with how its ambitious targets for cellulosic biofuel have dramatically outpaced technological innovation (Aldy 2019). For example, the statute set a 2017 cellulosic ethanol target of 5.5 billion gallons, but actual production that year was approximately 10 million gallons. EPA has the authority to waive the cellulosic biofuel requirement and it has done so every year of the program. In waiving the statutory goal, EPA must set a new quantity goal and make available waiver credits, a de facto tax in lieu of holding sufficient credits to demonstrate compliance. Uncertainty about a given year's goal – in some cases set in regulation after the year ended – and in waiver credit prices (which are based on a complicated formula and may vary with crude oil price volatility) have had a chilling effect on investment in new technologies as well as frustrated regulated entities as they develop their compliance strategies (Aldy 2019).

<b> Lessons about the Experience with Market-based Instruments

<c> Fit for Purpose

While market-based instruments hold tremendous promise in driving large environmental gains cost-effectively, they may not work well in all environmental contexts. The very limited and generally unsuccessful experiences with water pollution trading reflect several challenges. First, the difficulty in monitoring some pollution sources (e.g., farms) reduces market size and potential trading opportunities. Second, the localized nature of water pollution necessarily limits the scope of the market. Trading or pollution charges could result in localized hot spots with high pollution levels. This phenomenon is not unique to water pollution. Pollutant emissions that contribute to especially localized health impacts – such as air toxics – may not be amenable to market-based instruments out of concerns for the emergence of hot spots.

Several of the most prominent cap-and-trade programs, including the SO_2 cap-and-trade program and the NO_X Budget Program, cover pollutants that do not mix uniformly across their regulatory jurisdictions. As a result, two sources could trade emission allowances – with the seller emitting one ton less and the buyer emitting one ton more – and in doing so the public health benefits may change. If the buyer is in a densely populated area but the seller is in a sparsely populated area, then the trade could reduce the benefits of the policy. For example in the NO_X Budget Program, the emission sources that made pollution abatement investments tended to be farther away from major population centers than the emission sources that tended to purchase allowances (Fowlie 2010).

One approach to addressing this concern would be to differentiate the value of emission allowances based on the relative damages associated with a ton of emissions among any pair of sources that may trade allowances. Analysis with an integrated assessment model that accounts for the location of emissions, atmospheric chemistry, pollution transport, and the economic value of public health impacts suggest that establishing trading ratios as a function of relative monetized public health damages would increase social welfare of the SO_2 cap-and-trade program by $1 billion per year (Muller and Mendelsohn 2009).

<c> Environmental Justice

By design, market-based instruments provide covered firms with discretion on how to comply with the policy. Some may invest in pollution abatement equipment while others may purchase allowances or pay a pollution tax. Since the government does not prescribe specific actions to individual pollution sources, emissions will vary from source to source. If a group of co-located pollution sources decides to purchase more allowances (under cap-and-trade) or pay more in taxes (under a tax), then pollution in this location may be higher than it would have been under a command-and-control regulatory approach.

The prospect of such hot spots has raised concerns that market-based instruments could disproportionately harm low-income and/or minority populations living downwind of these sources. Hot spots in disadvantaged communities are not an intrinsic characteristic of market-based instruments (Farber 2012), but could arise just as they have in the past under alternative regulatory approaches. This adverse distributional consequence can weaken political support for market-based policies and illustrate inefficiencies in the program.

In California, environmental justice issues have played an important role in cap-and-trade policy debates dating to the 1990s when southern California implemented the RECLAIM cap-and-trade program to reduce NO_X and SO_2 emission. Analysis of emission levels, however, shows that RECLAIM-covered facilities reduced their emissions 20% relative to similar non-RECLAIM facilities covered by command-and-control regulations and that these pollution reductions were equally distributed across neighborhoods with different socio-economic characteristics (Fowlie et al. 2012).

Analysis of the early years of California's carbon dioxide cap-and-trade program indicate that greenhouse gas emissions increased for about half of the covered emission sources with similar increases in associated particulate matter, NO_X, and air toxics. The communities near these sources with higher greenhouse gas emissions were more likely to have higher proportions of residents of color and higher rates of poverty (Cushing et al. 2018). In contrast, evaluations of the SO_2 cap-and-trade program do not find any concentrations of SO_2 emissions in black or Hispanic communities (Ringquist 2011).

<c> Instrument Choice and Design

If the characteristics of an environmental problem are amenable to a market-based approach, the question then becomes one of choosing and designing the instrument. The choice of cap-and-trade or an emission tax reflects a trade-off between emissions quantity certainty and emissions price certainty. The former may be appealing in terms of assuring attainment of an environmental goal and explains why environmental stakeholders have traditionally supported cap-and-trade over tax instruments (Keohane et al. 1998). SO_2, NO_X, and biofuels markets, however, have each been subject to significant price volatility, which could weaken investment and innovation incentives (Aldy and Viscusi 2014).

While a long economics literature has examined the cases when cap-and-trade or a tax would maximize social welfare (based on Weitzman 1974), policy practice has drawn from elements of both approaches. These hybrid instruments can address concerns over cost and emissions uncertainty. For example, a cap-and-trade program can be designed to ensure allowance prices stay within a prescribed range, or so-called price collar. Setting an auction reserve price can serve as a price floor in cap-and-trade programs with allowance auctions. The California CO_2 cap-and-trade program and the Regional Greenhouse Gas Initiative (RGGI) – a power sector CO_2 cap-and-trade program for Mid-Atlantic and Northeast states – each have established reserve prices in their allowance auctions.

If the government stands prepared to sell additional allowances at a pre-determined price, then this serves as a ceiling on allowance prices. Both the California and RGGI programs have implemented "cost containment" reserves that would introduce additional allowances into the market to prevent allowance prices from exceeding a specified level. As a result, the policy operates as a cap-and-trade program when allowance prices fall within the range set by price floors and ceilings, but it operates like a pollution tax if the price floor or ceiling is binding.

Several tradable credit programs also have effective credit price ceilings to prevent high compliance costs. About thirty states have renewable portfolio standards that require utilities to demonstrate that a specified share of their power comes from renewable sources. In some state programs, utilities can comply by either (1) producing renewable power; (2) buying credits from a qualified renewable power source; or (3) make "alternative compliance payments" to the state based on a pre-determined price. These alternative compliance payments serve as a ceiling on the compliance cost for a utility.

<c> The Use of Economic Value

A cap-and-trade program creates the scarce right to emit in the form of an allowance, which can have significant value to a firm, either as a low-cost alternative to abating pollution or as a revenue source if it sells the allowance. The government can capture this value if it auctions the allowances, but it conveys the value to the firm if it gives away allowances for free. An emission tax would also enable the government to capture the value associated with the right to emit through tax collection. The choice and design of instruments can have substantial distributional consequences for covered firms as well as the potential beneficiaries of the use of any revenues raised. Such decisions may significantly influence the political economy and stakeholder support for a given market-based instrument design.

<c> Adapting to New Information

A well-designed environmental policy – and one that can secure durable political support – should adapt to new information (Carlson and Burtraw 2019). EPA's use of discretionary authority to phase down lead in gasoline through a tradable credit program serves as an excellent example of such adaptable policy. Just as epidemiological research highlighted opportunities to improve public health by reducing exposure to lead pollution in the 1980s, a growing epidemiological literature on the adverse health impacts of fine particulate matter motivated regulatory action starting in the late 1990s including regulations to reduce the sulfur content of gasoline and diesel fuels implemented through tradable credit programs.

In contrast, Congress established the emission caps in the SO_2 program, but provided the EPA with no discretion to adjust these caps over time. Retrospective evaluations of the SO_2 cap-and-trade program suggest that a much more stringent cap would pass a benefit-cost test and deliver large public health improvements (Muller and Mendelsohn 2009; Schmalensee and Stavins 2013).

The methods and data for evaluating regulatory performance, including for market-based approaches, have improved considerably over the past several decades. Innovations in statistical methods have enabled rigorous estimation of the causal impacts, as opposed to associations, of cap-and-trade programs. The recent increase of the scale, frequency, and quality of data on firm behavior, pollution, health outcomes, and other relevant measures will facilitate more extensive, rigorous evaluations of market-based instruments in the future.

<c> Innovations in Monitoring Pollution

Innovation in monitoring technology has facilitated the use of market-based approaches. For example, the development of SO_2 continuous emission monitors enhanced the credibility of the SO_2 allowance market. More recent technological advances have lowered the cost and increased access to satellite and drone-based monitoring capacity that could lay the foundation for further application of market-based instruments. For example, satellite measurements of biomass and associated carbon could expand the role of land use-based carbon sequestration as emission offsets for use in CO_2 cap-and-trade programs. High-frequency, location-specific measurements of methane from oil and gas extraction may enable an expanded coverage of a carbon tax to include such emissions. The combination of better monitoring and modeling techniques could facilitate the use of cap-and-trade to address non-point sources of water pollution, such as farm run-off. These technological advances also prompt questions about the political economy of expanding the scope of pollution pricing policy instruments to a broader set of traditionally less-regulated industries.

<c> Overlapping Policies

A market-based instrument may serve as one of multiple policies that a covered firm may operate under, with potentially important economic and political economy implications. Consider two examples focused on CO_2 emissions, each of which applies in California and the northeast states. In the power sector, a utility may be subject to a state CO_2 cap-and-trade program, a state renewable power mandate, a federal CO_2 emission performance standard, federal subsidies for wind and solar power as well as fossil fuel power with carbon capture and storage through the tax code, and local solar power subsidies. In the transportation sector, federal policies mandate fuel economy and tailpipe CO_2 emissions, state policies mandate a fraction of vehicles must be zero-emission vehicles, federal policies subsidize electric vehicles and mandate a fraction of fuels must come from various types of biofuels, and a cap-and-trade program covers the embodied carbon in gasoline sold to the market.

The emergence of a complicated, overlapping policy landscape reflects several phenomena. First, states and the federal government may simultaneously address the same problem, e.g., CO_2 emissions. Second, in both the power sector – with renewable power – and the transportation sector – with biofuels – effective lobbying has long delivered policies to promote deployment of their favored technologies. These stakeholders may find it easier to secure agreement on a number of "small" policies targeting their preferred technologies – especially at various levels of government and in both the regulatory agencies and Congressional tax committees – than on one comprehensive, transparent policy. Once the government begins implementing a given policy, vested interests will advocate for sustaining it.

The key economic implication of a patchwork of policies overlapping market-based instruments is that it increases the costs of delivering emission reductions. In the case of cap-and-trade, if the emission cap is binding then implementing additional policies will have no impact on aggregate emissions. State mandates and federal subsidies for renewable power in California do not reduce emissions given a binding CO_2 emission cap that covers the California power market. Using tax credits to subsidize electric vehicles sold by manufacturers that must meet a fuel economy standard likewise only reshuffles the effort in complying with the standard without affecting aggregate emissions. These overlapping policies constrain the market-based instruments and the cap-and-trade program represents only the residual emission reductions necessary for compliance with the cap.

Under a pollution tax, the overlapping policies again will increase aggregate costs. The overlapping policies may drive investment in pollution-reducing technologies that would not have occurred under the tax. This increases total pollution abatement, but undermines cost-effectiveness by promoting high-cost abatement in lieu of alternative abatement technologies that cost more than the tax but less than the favored technology under the overlapping policies.

<c> Imperfect Competition

The nature of market competition can influence how firms respond to a market-based instrument. Some power plants have local monopolies subject to economic regulation by public utility commissions. Firms in some pollution-intensive industries, such as petroleum refining, can exercise local market power in part due to the high costs of entry. Compliance strategies may draw on inputs subject to market power, such as the rail shipping duopoly associated with moving low-sulfur coal from the Powder River Basin to Midwestern power plants.

The evolution of the power plant regulatory landscape over the late 1990s and early 2000s had important implications for cap-and-trade programs. Power plants in deregulated power markets responded differently to the NO_X Budget Program than the power plants subject to economic regulation (Fowlie 2010). The power plants in the latter category were more likely to undertake investment in higher-cost and more efficacious pollution control equipment, in contrast to the former. As a result, power plants in competitive electricity markets tended to emit more NO_X and purchase more allowances from power plants in regulated markets, and potentially expose more people to higher ozone concentrations given the positive relationship between deregulated markets and population density. A similar phenomenon emerged in the SO_2 cap-and-trade program, where power plants subject to economic regulation made capital-intensive abatement investments more than power plants in deregulated markets (Cicala 2015).

The interaction of market power and environmental regulations can influence the economic incidence of the rule. In the SO_2 cap-and-trade program, railroads shipping low-sulfur coal from the Powder River Basin to Midwestern power plants exploited their market power. While railroad deregulation caused coal shipping rates to fall overall during this period, the two major freight railroad companies charged relatively higher rates to those power plants with few alternatives relative compared to those with greater options for lowering their sulfur emissions. This effectively transferred value created under the program to the railroad companies, with the increase in their producer surplus equal to about 15 percent of the entire surplus created by the cap-and-trade market (Busse and Keohane 2007).

<c> Vintage Differentiated Regulation

Applying market-based instruments to all pollution sources ensures a level playing field in the market and delivers on cost-effective attainment of the environmental goal. For example, the SO_2 cap-and-trade program covers all power plant sources of SO_2 emissions and each of these plants must surrender allowances to cover their emissions.

In contrast, technology standards have been subject to effective lobbying that results in vintage-differentiated regulation. For example, the 1977 Clean Air Act Amendments mandated sulfur scrubbers on new coal-fired power plants, but not on existing facilities (Yandle 1999). Such vintage-differentiated regulation reflects the greater political voice that incumbents operating existing facilities have relative to operators of facilities built in the future (Stavins

2005). In practice, vintage-differentiated regulation imposes more costly rules on new facilities that can undermine cost-effectiveness, slow the retirement of high-polluting incumbents, and result in higher levels of pollution than under a uniformly applied policy (e.g., Gruenspecht 1981).

The design details of a market-based instrument, however, may still convey benefits to incumbents relative to new entrants in a market. The 2007 law creating the RFS credit market established carbon intensity benchmarks to ensure climate change benefits through the promotion of biofuels. A biofuel would have to achieve at least a 20 percent reduction in lifecycle greenhouse gas emissions compared to petroleum fuel baseline to generate a credit under the RFS, unless it was produced at a facility built before 19 December 2007. Thus, the more carbon-intensive corn-based ethanol refineries operating at the time the bill was signed into law were guaranteed the opportunity to sell credits in the biofuels market (Aldy 2019).

<c> The Politics of Pricing Pollution

While the conventional economic argument for market-based instruments has focused on their cost-effectiveness, stakeholders' and policymakers' interests in the distribution of gains and losses under market-based approaches also influence their design. In some cases, environmentalists championing a significant policy goal may partner in the legislative and regulatory processes with the business community, which would concentrate its efforts on developing a favorable approach to implementing the goal (Yandle 1999). This potential demand from stakeholders interacts with the prospect that policymakers have the incentives and institutional discretion to supply a public policy responsive to this demand (Keohane et al. 1998).

The evolution over time in the design of cap-and-trade programs may illustrate a shift in the politics of pollution markets. Cap-and-trade programs developed over the 1980s and 1990s, including the SO_2 and NO_X markets, gave away nearly all emission allowances to regulated entities (Keohane et al. 1998). The free allocation of allowances under the SO_2 cap-and-trade program reflected some rent-seeking behavior – where utilities in some of the most emission-intensive states received significant allowance allocations during the program's initial phase – but states with political clout (influential members of Congress in key roles during the legislative process) fared better than major coal-consuming and coal-producing states during the second phase of the program (Joskow and Schmalensee 1998).

More recently, state-level CO_2 cap-and-trade programs have distributed allowances primarily through auction mechanisms. The durability of public support for the California and RGGI cap-and-trade programs draws, in part, from the use of allowance auction revenues for the public benefit, primarily to finance clean energy and climate-related projects. In contrast to the SO_2 experience, the extremely complicated scheme to allocate free allowances in the American Clean Energy and Security Act of 2009 – attempting to target key constituencies and secure votes in the legislative process – may have undermined broader support for national legislation on CO_2 cap-and-trade in 2009 and 2010 (Rabe 2016).

<b> Conclusions

Since the 1980s, market-based instruments have played a significant role in improving environmental quality cost-effectively in the United States. Cap-and-trade programs have reduced air pollution, fees and charges have reduced waste generation, and tradable performance standards have emerged in recent energy policies – such as state renewable power mandates and fuel economy standards – that have important implications for climate change. In some cases, the characteristics of environmental pollution make for a poor fit for market-based instruments. And in other cases, such as the renewable fuel standard, market-based instruments have not delivered much environmental progress.

The positive environmental and economic experiences with market-based instruments have motivated interest in applying them to CO_2 and potentially other greenhouse gas emissions. Indeed, CO_2 cap-and-trade policies implemented by California and a group of Mid-Atlantic and Northeast states illustrate some progress on this front. Nonetheless, adequately combating the risks posed by climate change will require emission mitigation policies covering the full scope of carbon pollution in the United States.

A key environmental characteristic of carbon pollution – that it imposes global damages – makes it especially attractive for a market-based instrument, since CO_2 hot spots would not arise. The design of a CO_2 market-based instrument may be a hybrid of cap-and-trade and tax. The state programs are implemented as cap-and-trade programs, but can function as taxes if the auction reserve price binds (as has happened in numerous RGGI auctions) or if a cost-containment mechanism is triggered in the future. One could also design a carbon tax that adjusts in order to attain emission goals or respond to new information about the environmental benefits of reducing such emissions (e.g., Aldy et al. 2017).

The use of the economic value of a greenhouse gas market-based instrument – likely to be on the order of at least $100 billion annually – could be a key determinant of the political acceptability and durability of the policy. The value could be used to target vulnerable populations and stakeholders, such as low-income households that may disproportionately harmed by rising energy prices, coal communities, energy-intensive manufacturing facilities, etc., returned to the economy by cutting taxes, or distributed as a regular per capita dividend payment (Goulder et al. 2019). A final key question in the future of U.S. climate policy is how a market-based instrument would fit within the existing complicated set of overlapping energy and climate policies at the federal, state, and local levels. Policy design that addresses the overlapping policy landscape will likely influence the economic costs, environmental benefits, and political economy of a market-based carbon instrument.

Future research on market-based instruments can improve understanding of their design, applicability, impacts, and political economy. Successful cap-and-trade programs have relied on administratively simple designs that have promoted high rates of compliance and low transaction costs. Such designs, however, have typically focused on an output – such as emissions – as opposed to an outcome – such as pollutant concentrations or public health damages (e.g., Muller and Mendelsohn 2009). How could future designs incorporate the insights from atmospheric chemistry, epidemiology, and economics to better target the harm caused by pollution, and do so in ways that do not substantially undermine the cost-effectiveness rationale for market-based instruments?

Layering a market-based instrument on top of existing regulations, subsidies, and other public policies raise important questions about efficacy, efficiency, distributional, and political economy implications. In some contexts, consumers may suffer from behavioral anomalies that may weaken the effect of a pricing pollution on their behavior (e.g., Houde and Aldy 2017). How could market-based instruments and policies based on behavioral insights work in tandem?

Evaluating the performance of market-based instruments can enhance their legitimacy with the public and stakeholders and help identify socially beneficial reforms (e.g., Aldy 2014).

How can such policies be designed – in terms of their structure, implementation, and data collection – to enable rigorous, ex post assessment of their impacts?

Finally, the political durability of any market-based instrument will likely depend on how its design ensures a broad, lasting political coalition supporting it (e.g., Carlson and Burtraw 2019). What are the key design elements, and combination of elements, necessary to ensure durable market-based policies to address the most pressing environmental problems of the 21st century?

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