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The Costs and Consequences of Clean Air Act Regulation of CO_2 from Power Plants†

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The Clean Air Act (CAA) provides the regulatory framework for climate policy in the United States. In 2011, the US Environmental Protection Agency (EPA) enacted regulations for light-duty vehicles that require a 5 percent improvement in fuel economy per year and implemented preconstruction permitting for greenhouse gas emissions. The next major category to be regulated is stationary sources, beginning with electricity generators, which are responsible for nearly 40 percent of the nation's carbon dioxide (CO_2) emissions.

Most observers perceive the failure to adopt comprehensive legislation (i.e., the Waxman-Markey bill, HR 2454) in the 111th Congress as a major undoing for US climate policy. However, the United States remains positioned to achieve domestic emissions reductions in 2020 as great as would have been achieved under that legislation (Burtraw and Woerman 2013). This could enable the United States to achieve President Obama's pledge of a 17 percent reduction from 2005 emissions levels by 2020 for CO_2. Achieving the pledge hinges on the stringency and nature of regulations for the power sector.

The form of the regulations will determine their cost effectiveness. In 2013, President Obama directed EPA to move forward with regulations that, "to the greatest extent possible," allow the use of regulatory flexibility—perhaps including market-based approaches.[1]

This paper surveys the major policy approaches EPA and the states are likely to consider if markets are to be harnessed to achieve a cost-effective outcome. Each approach differs in the way it creates and allocates asset values, and this difference has important distributional and efficiency consequences. Using a simulation model of the US electricity system, we compare policies that would reduce emissions sufficiently to take the nation near the 17 percent goal for 2020. Two innovations make this modeling valuable: the model includes the first econometric estimates of the costs of improving emissions rates at existing coal boilers, and investments in energy efficiency are paid for with emissions allowance auction revenues, endogenously affecting electricity prices, investment, and system operation, and yielding dynamic demand reductions.

The policies we consider create valuable assets, and they direct those asset values to four alternative groups or uses: government, owners of fossil-fired generators, electricity consumers, and end-use energy efficiency.

We compare a cap-and-trade policy that directs auction revenue to government, and may in fact be implemented by states rather than the federal government, with a tradable performance standard that distributes the value to fossil-fuel-fired electricity generators. The standard sets a uniform emissions rate and allows generators that outperform the standard to sell credits to those that do not meet it. We compare these with two other options, following the two existing state-level cap-and-trade programs, which may serve as templates for state implementation plans. One would direct auction

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[1] http://www.whitehouse.gov/the-press-office/2013/06/25/presidential-memorandum-power-sector-carbon-pollution-standards.

revenue to electricity consumers through their local electricity distribution companies (LDCs), the regulated retail providers of electricity, and the other would direct it to investments in efficient end-use technologies.

A key result is that the approaches that distribute asset values to fossil-fuel producers or consumers lead to very small changes in average electricity prices compared with one that allocates value to government. Under the tradable performance standard, all of the asset value is concentrated as a production subsidy to fossil-fuel generators. These generators almost always provide the marginal generation that determines the electricity price, and the production subsidy lowers the variable cost of fossil production; the electricity price increase is less than one-tenth of the change under cap and trade with auction. Alternatively, assets may be given to LDCs which we assume would reduce consumers' bills, and electricity prices rise by only one-quarter as much as under cap and trade with auction.

The small change in electricity price may have a political advantage, but it has an economic disadvantage compared with a revenue-raising auction because lower electricity prices create less incentive for reducing electricity consumption or improving end-use energy efficiency. In every case, the sum of producer and consumer surplus within the electricity sector is substantially greater if the asset value stays in the industry than if it leaves the sector and goes to government. However, because of the lower electricity prices, emissions reductions must come from electricity supply at incrementally greater cost, or investments in energy efficiency.

I. Clean Air Act

Considerable uncertainty surrounds the structure of regulations for existing power plants under the CAA, but it is possible that a market-based and reasonably cost-effective approach will emerge. In *Massachusetts vs. EPA* (2007) the Supreme Court affirmed EPA's authority to regulate greenhouse gases. The agency subsequently reached a formal finding of harm from these gases, which compelled it to act to mitigate this harm. Regulation of existing stationary sources will unfold as standards of performance under Section 111(d) of the CAA. EPA is developing guidelines that states must address with state implementation plans. The president called for final guidelines by June 2015 and for states to submit plans by June 2016. Legal challenges typically follow major new regulations, but the courts usually let EPA continue to implement air regulations while they are under judicial review.

Performance standards do not require emitters to install a particular technology, but traditionally their stringency is based on measures that can be taken at individual facilities. The standards must reflect "the degree of emission limitation achievable through the application of the best system of emission reduction which … the Administrator determines has been adequately demonstrated." The phrase "best system of emission reduction" is understood to mean not a technology but a regulatory system, opening the way for flexible and market-based approaches (Wannier et al. 2011).

One approach, a tradable performance standard, would allow emissions rate averaging across sources. This approach would not be new; it was a key feature of the phaseout of lead in gasoline in the 1980s (Newell and Rogers 2003). A disadvantage of emissions rate averaging is that it does not inherently provide incentives for emissions reductions beyond the "fence line" of regulated sources, such as transmission line upgrades, increased use of nonemitting technologies, or end-use energy efficiency.

In contrast, an emissions cap-and-trade program could provide incentives for any action that reduces emissions. EPA or states might use modeling to predict electricity production (MWh), which can be multiplied by a performance standard (tons/MWh) to calculate an emissions budget (tons) for each state, and this would accommodate trading. This approach also would not be new; it was the approach used to launch the regional nitrogen oxides (NO_x) trading program among Eastern states in 2003. States could auction the tradable emissions allowances.

Determination of stringency will be a central issue. EPA initiated the rulemaking in 2008–2009 by identifying cost-effective engineering opportunities for emissions rate improvements at existing coal plants. States, however, must consider multiple criteria in identifying the best system, including emissions reductions and costs, which together imply cost effectiveness.[2]

[2] The statute also cites other environmental outcomes and gives states the discretion to consider the remaining useful life of facilities.

EPA could use cost effectiveness as the basis for determining stringency by directing states to identify all abatement options that could be taken by all fossil generators at or below some marginal abatement cost. Alternatively, to determine stringency, EPA might cite the recently revised interagency estimate of the social cost of carbon as justification for determining the stringency of emissions reductions (Interagency Working Group on Social Cost of Carbon 2013).

II. Model

We use the Haiku partial equilibrium electricity market simulation model to characterize the response of the electricity system to climate policies that might unfold under the Clean Air Act (Paul, Burtraw, and Palmer 2009). Existing coal-fired facilities make endogenous investments to improve their efficiency based on unit-specific econometric estimates of abatement costs (Linn, Mastrangelo, and Burtraw forthcoming) that are similar to estimates from the engineering case studies (Sargent and Lundy 2009).

Baseline.—The baseline reflects all major environmental policies, including allowance trading for SO_2 under Title IV of the CAA, the Regional Greenhouse Gas Initiative and California's CO_2 cap-and-trade programs, the federal renewable energy production and investment tax credits, and all of the state renewable portfolio standards and renewable tax credit programs. The baseline includes the Mercury and Air Toxics Standards, which have been finalized by EPA and fully take effect in 2016 in our model, and the Clean Air Interstate Rule for SO_2 and NO_x in the eastern United States. Demand and input prices are calibrated to Annual Energy Outlook (AEO) 2012 forecasts, with the exception of natural gas prices, which are benchmarked to the updated AEO 2013 forecasts for both level and supply elasticity (US Energy Information Administration 2012, 2013).

III. Policy Scenarios

We analyze policy scenarios that are calibrated to achieve the same CO_2 emissions trajectory in the electricity sector. The constraint achieves a reduction of 367 million short tons in 2018 from the baseline, escalating linearly to 400 in 2020 and 650 in 2035. These targets would result in emissions reductions close to President Obama's 17 percent reduction pledge. There is no banking nor borrowing across years. We compare four scenarios that differ according to whether asset values are granted to government, fossil-fuel generators, or electricity consumers or are invested in end-use energy efficiency.

Emissions Cap and Trade with Revenue-Raising Auction.—A national emissions cap-and-trade policy is implemented with auction revenues accruing to the government. Although EPA could not introduce a revenue-raising policy, such an approach might be implemented by states.

Tradable Emissions Rate Performance Standard.—Each source is assigned a compliance obligation, which we refer to as its benchmark emissions rate, denominated in tons of CO_2 per megawatt hour of generation. Generators earn credits equal to the benchmark emissions rate multiplied by their annual generation. The crediting constitutes a production subsidy compared with the cap and trade with auction scenario. Generators surrender credits equal to their actual emissions rate multiplied by their annual generation, which mimics the imposition of an emissions price like that present in the cap and trade with auction scenario. The net compliance obligation stems from the difference between the benchmark and actual emissions rates. We implement a uniform national emissions rate benchmark for all fossil-fired generators sufficient to achieve the emissions target.

Emissions Cap and Trade with Allocation to Local Distribution Companies.—California's existing cap-and-trade policy for the electricity sector and the Waxman-Markey proposal (HR 2454) both include cap and trade with the allowance value allocated to LDCs. In this scenario, auction revenue is distributed to LDCs in proportion to their share of consumption. Even if the value is used to offset only the fixed portion of the bill, consumers are assumed to respond to the overall bill (Ito 2014). Consequently, in this scenario, consumers behave as if electricity is less expensive than when auction revenues go to the government.

Emissions Cap and Trade with Allocation to LDCs and Energy Efficiency.—The second existing cap-and-trade program, which includes nine Northeastern states (RGGI), involves an auction with the major portion of revenue (63 percent in 2011) directed to investments in end-use energy efficiency and a smaller portion (21 percent) returned to LDCs to benefit consumers (Burtraw and Sekar 2014). In this scenario, we model national emissions cap and trade with emissions allowances distributed to LDCs, with half of the revenue to investments in end-use energy efficiency and the remainder to consumers. About 22 percent of the lifetime energy savings associated with an investment in efficiency is realized in the first year. We assume first-year cost of energy savings of \$180/MWh, with reductions persisting and decaying yielding lifetime undiscounted cost of \$40/MWh. In comparison, Arimura et al. (2012) find a lifetime undiscounted cost under previous utility-sponsored programs of \$32/MWh. (All values are in 2010\$.)[3]

IV. Results

Table 1 compares scenarios for 2020, when emissions reductions of 400 million short tons are achieved compared with emissions of 2,073 million short tons in the baseline.

Under the cap-and-trade policy with a revenue-raising auction, the national average electricity price increases by 9 percent. Under the other policies, the change in electricity price is not more than 2 percent. Under the tradable performance standard, the asset value subsidizes production. In particular, the benchmark emissions rate is above the observed emissions rate for most natural gas units, providing a valuable net subsidy to production. Given the relatively greater level of electricity production due to the subsidy, the marginal abatement cost is about 50 percent greater than under cap and trade with auction. Because production is greater, the carbon intensity of electricity generation must be less. This is achieved primarily by greater substitution from coal to gas.

When the asset value is returned to the power sector, not retained by government, producers fare better if the value is directed to consumers through their LDCs rather than directly to them. Consumers fare better when the asset value is directed to fossil generators because this has the greatest effect on the variable cost of the marginal electricity generator, which is typically gas fired, leading to a lower electricity price.

When half of the auction revenue is directed to investments in energy efficiency, however, electricity consumption and generation are reduced more substantially. This enables the emissions intensity to be greatest across the scenarios we examine, because in this case, less generation emits the same amount of CO_2.

Total social cost is measured in a partial equilibrium framework and includes changes in producer and consumer surplus within the electricity sector plus changes in government revenue. The total social cost is least under cap and trade with auction, which results in \$28 billion in auction revenue. The cost is more than doubled under the tradable performance standard and the auction with allocation to LDCs. Producers and consumers combined are worst off under cap and trade with a revenue-raising auction and best off when the asset value stays within the sector. It is noteworthy, however, that the change in natural gas use would raise gas prices outside the electricity sector.

These costs are strongly dominated by benefits that roughly equal ten times the size of costs. In the cap and trade with auction scenario, benefits come almost equally from CO_2 reductions valued at the medium case value (\$42 per short ton) of the social cost of carbon (Interagency Working Group on Social Cost of Carbon 2013) and from reductions in SO_2 (EPA 2011).[4] CO_2 benefits are the same across the policy scenarios; however, coal generation varies, so SO_2 emissions do also.

V. Conclusion

Much of the economics literature has approached the policy challenge of addressing climate change as a problem of designing an efficient system, often not recognizing the institutional constraints and political economy that affect the outcome. In the US domestic policy arena, policy is taking shape through the existing institution of the Clean Air Act with a

[3] Further detail on model scenarios and results are available in Burtraw et al. (2014).

[4] In the eastern United States, the value is \$30,492 per short ton of SO_2, and in the West, it is \$8,741 (2010\$).

TABLE 1—KEY RESULTS FOR YEAR 2020 (2010$)

Recipient of asset value:	Baseline	Cap and trade: auction (government)	Tradable perform. (producers)	Cap and trade: LDC (consumers)	Cap and trade: LDC + EE (consumers)
Marginal abatement cost ($/ton)	—	18	27	21	12
Electricity price ($/MWh)	98	107	99	100	100
Emissions rate at fossil units (lbs./MWh)	1,637	1,415	1,332	1,345	1,466
Total consumption (TWh)	3,821	3,631	3,764	3,753	3,545
Delivered natural gas price ($/mmBtu)	4.3	5.0	5.5	5.3	4.6
Total welfare change: cost (B$)	—	–3	–7	–7	n/a
Producer surplus	—	2	–4	0	—
Consumer surplus	—	–33	–2	–8	—
Government revenues	—	28	–1	0	—
Total welfare change: benefits (B$)	—	34	38	37	34
CO_2 benefits	—	16	16	16	16
SO_2 benefits	—	17	22	21	17

Notes: n/a: The cost for the scenario with investment in energy efficiency leads to a large shift in the demand curve. Consequently, the partial equilibrium welfare changes we measure are not well defined and not reported.

Source: Authors' calculations.

process that involves many stakeholders at the federal and state levels.

In simulation modeling, we found producers and consumers together fare much better when the value of assets created by introducing a (shadow) price on carbon is kept within the electricity sector than if the value accrues to government, even though the latter approach would have lower social cost. However, in every scenario we examined, the net benefits of regulation are positive and large. Moreover, net benefits are similar across the policies because the approaches with greater social cost serendipitously yield greater ancillary reductions in SO_2 emissions. The most inefficient policy outcome among those we compared would be no policy; in contrast, regulation under the Clean Air Act appears hugely beneficial.

A regulatory approach threatens additional inefficiency because of inconsistency of marginal abatement costs across sectors (Metcalf 2009). One way regulation might address this is by aligning stringency according to a common metric such as the interagency estimate of the social cost of carbon. One important result in this paper is that the observed marginal abatement cost can vary substantially depending on the form of the regulation, and efforts to coordinate the stringency of regulation across sectors should take this into account.

Another form of inefficiency may stem from the coordination problem among states. In this analysis, we examined alternative forms of a uniform policy implemented by all states. However, if states retain a great degree of discretion, they may not all choose the same approach. Failure to coordinate may create perverse outcomes because of the interaction of state policies and regional power markets.

On the other hand, if conflicts are avoided, state actions can capture a major share of the potential cost effectiveness of first-best policy instruments, and states may build coalitions and institutional infrastructure to enable greater emissions mitigation. Economists have a huge opportunity to influence the outcome by suggesting that the regulations create proper incentives for abatement and by helping develop a program design that anticipates and avoids strategic behavior in the decisions of state governments.

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