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Joseph E. Aldy†

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† Harvard Kennedy School; Resources for the Future; National Bureau of Economic Research; Center for Strategic and International Studies. Contact info: E: joseph_aldy@hks.harvard.edu, V: 617-496-7213, M: Mailbox 114, 79 JFK Street, Harvard Kennedy School, Cambridge, MA 02138. Ken Norris and Blake Barr performed excellent research assistance for this project. Thanks to workshop participants at Case Western Reserve University, Harvard University, and Resources for the Future for feedback on earlier versions of this work. Financial support has been provided by the Alfred P. Sloan Foundation and the Smith Richardson Foundation.

Introduction

A well-functioning environmental regulatory program makes the American people better off by protecting the air we breathe, water we drink, and food we eat. If markets work well in allocating resources, then government regulation is unnecessary. Indeed, government intervention in well-functioning markets will likely make society worse off by imposing costs that exceed their benefits. If markets do not work well, as evidenced by negative externalities such as pollution, then government regulation has the potential to remedy the market failure and make people better off. But such regulatory success is not guaranteed. A poorly designed regulation, even if motivated by a market failure, could result in costs that exceed its benefits and may exacerbate the welfare losses. A well-designed regulation, however, can improve the welfare of affected people and attempt to deliver what the market would if it were not suffering from negative externalities.

Identifying the need for environmental regulation and crafting effective interventions has relied on assessments of regulatory impacts dating back to the Carter Administration.[1] Since 1981, the Environmental Protection Agency (EPA) has assessed the benefits and costs of its major regulatory actions.[2] These assessments typically include monetized, quantified but not monetized, and qualitative characteristics of the expected benefits and costs, which can address the fundamental economic question of regulatory policy: does the regulation

1. *See* Exec. Order No. 12,044, 43 Fed. Reg. 12,661 (Mar. 24, 1978) (creating a cost-effectiveness standard for new government regulations); Exec. Order No. 12,291, 3 C.F.R. p. 127 (1981) (repealing Executive Order 12,044 and establishing the norm for the use of cost–benefit analysis as an input to regulatory decision-making); Exec. Order No. 12,866, 58 Fed. Reg. 51,735 (Oct. 4, 1993) (superseding Executive Order 12,291). Since 1993, Republican and Democratic Administrations have used Executive Order 12,866 to guide their analysis and review of executive-branch agency regulations. *See, e.g.*, Susan E. Dudley, *Happy Birthday, Executive Order 12,866!*, Forbes (Sept. 24, 2018, 8:57 AM), https://www.forbes.com/sites/susandudley/2018/09/24/happy-birthday-executive-order-12866/#1bff51cf3eef (discussing presidential reliance on Executive Order 12,866 over the past twenty-five years) [https://perma.cc/ZBV8-KENB].

2. *See* Exec. Order No. 12,291, 3 C.F.R. p. 127 (1981) (defining a "major" rule as one with "[a]n annual effect on the economy of $100 million or more"); Exec. Order 12,866, at § 3(f)(1), 58 Fed. Reg. 51,735 (Oct. 4, 1993) (defining a "significant regulatory action" as one with "an annual effect on the economy of $100 million or more"); Congressional Review Act, 5 U.S.C. § 804(2)(A) (2018) (defining a "major" rule as one with "an annual effect on the economy of $100,000,000 or more"). In each of these three cases, there are also qualitative criteria for classifying a rule as "major" or "significant." Exec. Order No. 12,291, at § 1(b)(2)–(3), 3 C.F.R. p. 127 (1981); Exec. Order 12,866, at § 3(f)(2)–(4), 58 Fed. Reg. 51,735 (Oct. 4, 1993); Congressional Review Act § 804(2)(B)–(C). Throughout this Article, I will use interchangeably "major," "significant," and "economically significant."

increase social welfare? Of course, the EPA promulgates rules under a variety of statutory authorities,[3] and a regulatory impact analysis can illustrate how a given regulatory action delivers on a statutory objective. In conducting analysis at the regulatory development stage, the EPA and stakeholders—through public comment on proposed rules—can identify less costly ways of achieving a societal goal. The evaluation of regulatory impacts, as well as prompt guidance from the external Science Advisory Board, can also inform the EPA's research agenda so that the EPA, and, in turn, the public, can better understand the environmental and public-health benefits and costs to firms subject to agency regulations.

EPA regulations may fall short of maximizing net social benefits, even if the Agency's major rules typically produce monetized benefits greater than their monetized costs.[4] The EPA promulgates regulations subject to its statutory authority, which in many cases places constraints on how it can design its regulation. A statute may prohibit an explicit consideration of benefits and costs in the design of reg–ulations.[5] Alternatively, a statute may prescribe the regulatory intervention and provide little discretion to the EPA.[6] As a result, some regulations may fail to deliver a socially efficient level of environmental protection but nonetheless result in net social benefits.

There may also be cases in which the social costs exceed the social benefits. In that case, regulatory impact analysis can highlight

3. *See, e.g.*, Clean Air Act, 42 U.S.C. § 7401 (2018) (permitting the EPA to regulate air pollutants); Clean Water Act, 33 U.S.C. § 1251 (2018) (permitting the EPA to regulate water pollutants); Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. § 9601 (2018) (permitting the EPA to regulate hazardous waste sites); Safe Drinking Water Act, 42 U.S.C. § 300g (2018) (permitting the EPA to regulate public water systems); Toxic Substances Control Act, 15 U.S.C. § 2601 (2018) (permitting the EPA to regulate chemical substances and mixtures); Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. § 136 (2018) (permitting the EPA to regulate the use and manufacture of pesticides); Resource Conservation and Recovery Act, 42 U.S.C. §§ 6901–02 (2018) (permitting the EPA to regulate waste disposal).

4. *See, e.g.*, Office of Mgmt. & Budget, Exec. Office of the President, 2017 Report to Congress on the Benefits and Costs of Federal Regulations and Agency Compliance with the Unfunded Mandates Reform Act 7 tbl.1-1 (2019) (summarizing the monetized benefits and costs of EPA's major rules).

5. *See, e.g.*, Whitman v. Am. Trucking Ass'ns, Inc., 531 U.S. 457, 464–71 (2001) (finding that the text of the Clean Air Act precluded the EPA from considering costs when the Agency sets national ambient-air-quality standards).

6. *See e.g.*, Nicholas Z. Muller & Robert Mendelsohn, *Efficient Pollution Regulation: Getting the Prices Right*, 99 Am. Econ. Rev. 1714, 1732–37 (2009) (explaining that, while the EPA has no discretion over the sulfur dioxide emission caps set under Title IV of the Clean Air Act, more stringent emission caps could have significantly increased social welfare).

opportunities for legislative reform. The EPA's regulatory impact analyses of proposed rules typically provide rigorous evidence addressing key policy questions: Do regulations deliver on the nation's environmental goals established in statute? Do they maximize net social benefits? Do they achieve their goals at the lowest possible cost? While the EPA has an impressive track record in undertaking prospective analyses of proposed regulations, the Agency, like many federal regulators, has a significantly weaker record in evaluating the per–formance of existing rules.[7] Every administration dating back to President Carter's in 1978 has implemented some form of retrospective review of regulations; yet there is little doubt that the EPA dedicates less attention to retrospective review than it does to prospective review.[8]

This is a critical issue in the context of environmental regulations. The EPA—or, in the case of carbon-dioxide-tailpipe and fuel-economy standards, the EPA and the Department of Transportation—has issued nearly one-third of all major federal regulations between 2007 and 2016.[9] These rules represent an even larger fraction of the monetized benefits and costs of federal regulatory actions. At least 80% of the prospective benefits and at least 66% of the prospective costs of federal regulations result from the EPA's regulatory actions to improve the environment.[10]

In addition, some environmental statutes authorize periodic review and updating, which could benefit from rigorous examination of the performance of the regulation in practice. For example, the Clean Air Act authorizes the EPA to review and revise, when necessary, the national ambient-air-quality standards for criteria pollutants, such as fine particulate matter and ozone, every five years.[11]

To illustrates ways of rigorously evaluating the performance of environmental regulations, in this Article I focus on the lessons from

7. *See generally* Joseph E. Aldy, Learning from Experience: An Assessment of the Retrospective Reviews of Agency Rules and the Evidence for Improving the Design and Implementation of Regulatory Policy (2014) (evaluating the retrospective review processes under the Obama Administration and previous administrations, and recommending certain improvements).

8. *But see* Clean Air Act Amendments of 1990, Pub. L. No. 101-549, 104 Stat. 2399 (codified at 42 U.S.C. § 7612 (2018)) (amending the Clean Air Act to require what are now known as Section 812 reports regarding the impact of the Act on the "public health, economy and environment of the United States"); EPA, EPA-410-R-97-002, Benefits and Costs of the Clean Air Act, 1970 to 1990: Retrospective Study, at ES-1–10 (providing an assessment of the cumulative benefits and costs of the Clean Air Act from 1970 to 1990, but offering little information on the performance of specific Clean Air Act regulations).

9. *See* Office of Mgmt. & Budget, *supra* note 4.

10. *See id.*

11. 42 U.S.C. § 7409(d) (2018).

the policy innovation of pollution markets under the Clean Air Act. While the EPA began experimenting with some more flexible approaches to air-quality-regulation compliance in the 1970s—such as the "netting" of emissions across new and existing sources within a facility and the opportunity for new emissions sources in non-attai–nment areas to "offset" their emissions by reducing emissions at existing sources[12]—they were only mildly successful.[13] The EPA expanded the role of market-based instruments in the 1980s, and cap-and-trade and tradable performance standards have played important roles in implementing ambitious reductions of lead in gasoline and sulfur dioxide and nitrogen oxides at power plants.[14]

The ex post evaluations of the EPA's air-pollution markets in the academic literature provide rigorous evidence about the environmental, public-health, and economic impacts of these rules. These studies inform regulators, legislators, stakeholders, and the public on the performance of one of the most significant policy innovations of the EPA's first fifty years. Moreover, this research highlights credible approaches for estimating the causal impacts of environmental regulations that can inform how the EPA can plan for and design retrospective evaluations in future regulatory actions.

The next Part synthesizes the academic literature on the performance of Clean Air Act pollution markets. Part II draws lessons for the design of pollution markets and Part III draws lessons for institutionalizing retrospective analysis in future regulatory develop–ments.

I. Performance of Clean Air Act Pollution Markets

A. Types of Pollution Markets

The two most common approaches to creating pollution markets under the Clean Air Act have been tradable performance standards and cap-and-trade programs.[15] Tradable performance standards establish a rate-based standard—such as grams of a pollutant per gallon of gasoline or pounds of a pollutant per megawatt-hour of electricity—that serves

12. *See* Robert W. Hahn, *Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders*, 3 J. Econ. Pers. 95, 99 (1989).

13. *See* Richard Schmalensee & Robert N. Stavins, *Policy Evolution under the Clean Air Act*, 33 J. Econ. Pers. 27, 34–35 (2019) (discussing initial experiments with emissions trading in the 1970s, and the more successful efforts starting with the leaded gasoline phase-down in the 1980s).

14. *See id.* at 35–40.

15. *Id.* at 29–30*; See also* Nathaniel O. Keohane & Sheila M. Olmstead, Markets and the Environment (2007).

as the benchmark for trading.[16] If a firm produces pollution at a rate below this standard, then it can generate credits that can be sold to other firms who may produce pollution at a rate above this standard. For compliance purposes, firms must demonstrate that a combination of their own performance and purchased credits satisfy the standard.[17] A secondary market for credits can arise in which the credit prices signal to firms opportunities for reducing pollution at lower cost. The quantity of credits generated and sold thus depends on the technological capacity of and economic incentive for firms to reduce their pollution and sell credits to other firms.

A cap-and-trade program limits the aggregate emissions of regulated firms by establishing a fixed number of tradable emission allowances—equal to the program's overall cap—which are typically allocated to firms either as a function of their historic emissions or via an auction.[18] Firms may buy and sell allowances, but they must surrender allowances to the government to cover their emissions in order to comply with the program. The cap creates scarcity in the right to pollute, which drives the allowances' prices on the secondary market where firms buy and sell the allowances.

These pollution-market approaches may appeal to policymakers and regulators for a variety of reasons. First, pollution markets circumvent a fundamental information problem confronting the regulator. The firms responsible for air pollution typically have much better private information about their opportunities for abating pollution than the EPA does. They also lack an incentive to share this private, firm-specific information with the regulatory agency. As a result, the EPA cannot effectively target and tailor pollution abatement obligations on a firm-by-firm basis. Instead, the Agency typically imposes a one-size-fits-all technology or performance standard, which risks a high cost per unit of pollution abated.[19] In pollution markets, the EPA avoids needing to learn information on a firm-specific basis because it recasts the task in order to deliver firm-specific incentives for reducing pollution. By pricing pollution implicitly through these markets, the EPA leverages the firm's profit motive in a way that encourages the firm to collect information on pollution-abatement strategies and implement them.

Second, in pricing pollution, these markets deliver strong incentives for firms to cost-effectively reduce their emissions. A firm may identify pollution-abatement opportunities that cost less than the going price in the allowance market and decide to reduce its emissions in order to profit from the sale of the allowances it no longer needs for compliance

16. Schmalensee & Stavins, *supra* note 13, at 31.

17. *Id.* at 33.

18. *Id.*

19. *Id.* at 28–29.

purposes. A firm with high abatement costs would find that buying the allowances from this low-cost firm minimizes its compliance costs. Regardless of the initial allowance distribution, trading can result in emission allowances being put to their highest valued use: covering those emissions that are the costliest to abate, and spurring firms to undertake the least costly reductions.[20]

Third, pollution markets promote innovation in new abatement technology that can both lower costs and increase the efficacy of reducing emissions. Under a technology standard, a firm has weak incentives for innovation once it has installed the mandated technology. Under a performance standard, a firm has some incentive to innovate to reduce costs, but little incentive to reduce emissions below the rate set by the standard. In contrast, pollution markets reward innovation because it can lower emissions that free up allowances for sale to other firms or lower costs that can likewise enable a firm to pursue additional abatement for less than the going price of allowances in the market.

Finally, the political economy of the free allocation of allowances under cap-and-trade and the setting of the rate benchmark in a tradable performance standard may appeal to some policymakers.[21] Emission allowances have value regardless of whether they are auctioned or given away for free, and regulated entities that may otherwise oppose a new regulatory approach could instead support one in which they receive these valuable allowances as a function of their historic emissions.

B. Why Focus on the Clean Air Act's Pollution Markets?

The experience of pollution markets in reducing emissions of air pollutants holds important lessons about the record of the Clean Air Act over five decades as well as insights for future policy design. The experimentation with various approaches to trading under the Clean Air Act—with some early successes (e.g., the phase-down of lead in gasoline) and some failures (e.g., the rarely used project-specific trading for new sources in non-attainment areas)[22]—led to more extensive policy innovation. The emergence of pollution markets served as a counter to criticisms that Clean Air Act regulations were imposing excessive costs on American businesses. They also altered the political economy of long-simmering policy disputes, such as how to address the problem of acid rain, and created a path forward for more ambitious environmental goals.

These lessons about effective policy design and implementation facilitated replication of pollution markets in many other contexts.

20. See generally Robert W. Hahn & Robert N. Stavins, *The Effect of Allowance Allocations on Cap-and-Trade System Performance*, 54 J. Law Econ. S267 (2011).

21. *See* Nathaniel O. Keohane et al., *The Choice of Regulatory Instruments in Environmental Policy*, 22 Harv. Envtl. L. Rev. 313, 317–18 (1998).

22. *See* Schmalensee & Stavins, *supra* note 13; *see also* Hahn, *supra* note 12.

Indeed, one of the major legacies of the EPA's implementation of the Clean Air Act is the testing of, learning about, and exporting the idea of leveraging pollution markets to deliver on environmental and energy goals. Policymakers at federal and state levels, as well as in governments around the world, have learned from these experiences with EPA pollution markets and they have implemented those lessons in the design of their policies. Tradable performance standards have become a common instrument for implementing U.S. energy policies, including corporate average fuel-economy standards,[23] state renewable portfolio standards,[24] and the California Low Carbon Fuel Standard.[25] Cap-and-trade programs have helped to implement carbon dioxide emission goals in California,[26] in the northeast and mid-Atlantic states participating in the Regional Greenhouse Gas Initiative,[27] in the E.U. through the Emission Trading System,[28] and in China.[29] In 2019, the World Bank estimated that about 15% of global carbon dioxide emissions were covered by cap-and-trade programs or tradable performance standards.[30] It's virtually impossible for a person anywhere in America to flip a light switch or fuel a car that has not been subject to a pollution market or market-based clean-energy policy.[31]

23. *See* Benjamin Leard & Virginia McConnell, *Emerging Evidence on the CAFE Credit Trading Program*, Resources (Feb. 5, 2016), https://www.resourcesmag.org/common-resources/emerging-evidence-on-the-cafe-credit-trading-program/ [https://perma.cc/LZV9-NC7J].

24. *See* Galen Barbose, Lawrence Berkeley Nat'l Lab., U.S. Renewables Portfolio Standards 7 (2019).

25. *See Low Carbon Fuel Standard*, Ca. Air Resources Board, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard [https://perma.cc/DG9N-B86Y] (last visited June 25, 2020).

26. *See Cap-and-Trade Program*, Ca. Air Resources Board, https://ww3.arb.ca.gov/cc/capandtrade/guidance/cap_trade_overview.pdf [https://perma.cc/UD2F-KBZR] (last visited June 25, 2020).

27. *See Elements of RGGI*, Regional Greenhouse Gas Initiative https://www.rggi.org/program-overview-and-design/elements [https://perma.cc/PFG6-ACQP] (last visited June 25, 2020).

28. *See EU Emissions Trading System (EU ETS)*, European Commission https://ec.europa.eu/clima/policies/ets_en [https://perma.cc/YZ7W-GQGL] (last visited June 25, 2020).

29. *See* William A. Pizer & Xiliang Zhang, *China's New National Carbon Market*, 108 Am. Econ. Ass'n Papers & Proc. 463, 463, 465 (2018).

30. *See* Céline Ramstein et al., WBG, State and Trends of Carbon Pricing 2019, at 14 (2019).

31. *See* Joseph E. Aldy, *Pricing Pollution through Market-based Instruments, in* Handbook of U.S. Environmental Policy 202, 202 (David Konisky ed., 2020).

Pollution markets can serve as a key element of implementing a durable, long-term U.S. climate policy.[32] While federal legislation has failed to deliver major carbon-dioxide-mitigation policy, Presidents Clinton,[33] Bush (George W.),[34] and Obama[35] each advocated for carbon dioxide cap-and-trade as a cornerstone of their climate-change policy programs, either on the campaign trail or once in office. In his second term, President Obama advocated for, and the EPA promulgated, the Clean Power Plan to reduce power-sector carbon emissions by approximately one-third by 2030.[36] This regulatory approach would have enabled states to implement their power-sector carbon goals through either a mass-based cap-and-trade program or a rate-based tradable performance standard.

Finally, the extensive academic literature on the performance of pollution markets can provide lessons for other policies, as well as lessons for how the EPA can conduct retrospective analyses of future regulations. The research questions, empirical methods, and data collection in the peer-reviewed research literature highlight ways that the EPA can plan for and design ex post regulatory evaluations. The basic insight from the academic literature reflects an understanding that an appropriate research design could effectively mimic a randomized control trial. Since EPA cannot implement regulations as real-world randomized experiments with "treatment" groups and "control" groups, alternative quasi-experimental approaches can estimate the causal impacts of a regulation. The research literature employs an array of causal inference methods—difference-in-differences, matching estimators, regression discontinuity, instrumental variables models, synthetic control models, etc.—to distinguish between statistical correlations and causal impacts of regulations.[37]

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32. *See* Ann Carlson & Dallas Burtraw, *Conclusion* to Lessons from The Clean Air Act 225, 231 (Ann Carlson & Dallas Burtraw eds., 2019).

33. *See* Joseph E. Aldy, *Saving the Planet Cost-Effectively: The Role of Economic Analysis in Climate Change Mitigation Policy*, *in* Painting the White House Green, 89, 94 (Randall Lutter & Jason F. Shogren eds., 2004).

34. *Id.* at 109.

35. *See* Office of Mgmt. & Budget, Exec. Office of the President, A New Era of Responsibility: Renewing America's Promise 21 (2009) (implementing a climate change and energy plan through a cap-and-trade system).

36. Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Generating Units, 80 Fed. Reg. 64,662, 64,665 (Oct. 23, 2015) (to be codified at 40 C.F.R. pt. 60).

37. *See* Aldy, *supra* note 7, at 17 for a further discussion and illustration of causal inference methods in the academic literature on retrospective analysis of regulations. *See also generally* John DiNardo & David S. Lee, *Program Evaluation & Research Designs*, *in* 4A Handbook of Labor Economics 463–536 (2011); Joseph S. Wholey, Harry P. Hatry, &

For example, difference-in-differences, the most common approach in the literature discussed below, focuses on two differences: the difference before and after the timing of a regulation and the difference between regulated (the "treatment") group and an unregulated (the "control") group. This latter group should be similar to the former group, except for the regulation. The first difference accounts for possible time trends that could bias the estimated impact of a regulation (e.g., technological innovation or economic growth) and would be common across the treatment and control groups. After taking this first difference, the second difference -- comparing the treatment group's change over time with the control group's change over time -- then isolates the impact of the regulation on outcomes of interest.

In the discussion that follows, I first illustrate what has been learned about the environmental, public-health, and economic impacts of pollution markets. Then I review how these studies' approaches to rigorously estimating impacts can inform future government efforts to assess regulatory performance. In drawing these insights, I focus on papers from the academic literature that employ causal-inference statistical models—i.e., analyses that enable a credible conclusion about the causal impacts, as opposed to associations with outcomes, of these pollution markets.

C. Lead Credit Trading Program

Since 1980, the ambient concentration of airborne lead in the United States has fallen by 99%.[38] Given the significant adverse health impacts of lead exposure,[39] this represents one of the greatest public health success stories of modern environmental law. The initial efforts to reduce lead in gasoline, however, were not primarily motivated by an understanding of lead's public-health risks; rather the goal was to enable catalytic converters on light-duty vehicles to reduce tailpipe-pollutant emissions.[40] The EPA set limits on the lead content of gasoline through several regulations in the 1970s and early 1980s. In 1983, the EPA undertook a benefit–cost analysis that illustrated how more

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Kathryn E. Newcomer, Handbook of Practical Program Evaluation (3d ed. 2010).

38. *See Lead Trends*, EPA, https://www.epa.gov/air-trends/lead-trends [https://perma.cc/JB6G-3LW5] (showing the decline of airborne lead) (last updated June 8, 2020).

39. *See Health Effects of Lead Exposure*, Ctrs. for Disease Control, https://www.cdc.gov/nceh/lead/prevention/health-effects.htm [https://perma.cc/Q7A5-LPVD] (last updated Jan. 7, 2020).

40. *See* Albert L. Nichols, *Lead in Gasoline*, *in* Economic Analyses at EPA: Assessing Regulatory Impact 49 (Richard D. Morgenstern ed. 1997); Suzi Kerr & Richard G. Newell, *Policy-Induced Technology Adoption: Evidence from the U.S. Lead Phasedown*. 51 J. Indust. Econ. 317, 320–24 (2003).

stringent lead standards could increase net social benefits.[41] The resulting rule-making accelerated the phase-down of lead and imple–mented these more ambitious goals through a tradable credit program.[42]

The so-called averaging, banking, and trading program for lead represented the first real-world illustration of how market-based environmental policy can deliver on environmental objectives at lower costs.[43] The EPA set a performance standard—measured as the mass of lead per volume of gasoline—that ratcheted down the permissible lead content over time.[44] Initially set at 1.1 grams of lead per gallon, the EPA reduced the lead content limit to 0.5 grams of lead per gallon in 1985, and then down to 0.1 gram of lead per gallon in 1986.[45] Lead as a fuel additive was banned as of January 1, 1996.[46] If a refiner reduced the lead in its gasoline to an amount below that year's EPA standard, then it could generate tradable credits based on the product of its total gasoline production and the difference in its gasoline's average lead content and that of the standard.[47] The refiner could then sell those credits to another refiner whose gasoline's lead content exceeded the EPA standard.[48] Accounting for both the refiner's own lead content and its net credit position served as the basis for demonstrating compliance with the standard. Refiners could also bank, or save, credits for use in a future compliance year, and some refiners did this in anticipation of higher compliance costs as the standards ratcheted down over time.[49]

The tradable credit program for lead delivered substantial cost savings and incentives for technological innovation.[50] As refiners removed lead from their gasolines, they had considerably diverse opportunities to modify their fuel specifications in order to ensure performance. That opportunity created an opening to exploit those gains from trade through a pollution market. It also enabled the EPA to eliminate a previous distinction in regulatory stringency between small and large refiners, because the typically higher-compliance-cost small refiners could now avail themselves of the tradable-credit market to avoid the high costs of satisfying the standard. The tradable-credit

41. Nichols, *supra* note 40.

42. *Id.*

43. Richard Newell & Kristian Rogers, *The Market-Based Lead Phasedown*, *in* Moving to Markets in Environmental Regulation 171 (Judy Freeman & Charles Kolstad eds., 2007).

44. *Id.* at 172.

45. *Id.* at 173.

46. *Id.*

47. Kerr & Newell, *supra* note 40, at 321–22.

48. *Id.* at 322.

49. *Id.*

50. *Id.* at 340–41.

program likely saved refiners several hundred million dollars over several years.[51]

The public-health benefits of accelerating the phase-down of lead through the tradable-credit program are likely much larger than originally anticipated by the EPA. In its 1983 benefit–cost analysis, the EPA estimated the value of public-health benefits ranged from two to eight billion dollars per year from 1985–1988.[52] In 1997, the EPA concluded that "airborne lead emissions from all sectors were virtually eliminated by 1990,"[53] and more than 94% of these emission reductions occurred because lead was eliminated from gasoline.[54] With improved epidemiological research on lead since the 1980s, especially with respect to the neurologic and cardiovascular risks posed by lead exposure, the EPA estimated that the monetized benefits of reducing airborne lead concentrations exceeded $1.8 trillion from 1970–1990.[55] More than two-thirds of these benefits reflect reduced premature mortality, while higher IQs deliver about $400 billion, and reduced hypertensions yields about $100 billion in benefits.[56]

D. Sulfur Dioxide Cap-and-Trade Program

Since 1990, power plant emissions of sulfur dioxide (SO2) have fallen by 92%.[57] A variety of market factors have played a role in this decline. Low natural gas prices, increased deployment of renewable sources, and slow demand growth have caused coal-fired power plant retirements and lower dispatch from operating coal units.[58] To a lesser extent, environmental regulations such as the Cross-State Air Pollution Rule have played a modest role in reducing SO2 emissions over the past decade.[59] From 1990–2010, however, the major reduction in power plant

51. Robert W. Hahn & Gordon L. Hester, *Marketable Permits: Lessons for Theory and Practice*, 16 Ecology L.Q. 361, 387 (1989).

52. Nichols, *supra* note 40, at 74.

53. EPA, The Benefits and Costs of the Clean Air Act 17 (1997).

54. *Id.*

55. *Id.* at 52 (expressing benefit estimates in 1990 dollars).

56. *Id.*

57. *See EPA Releases 2018 Power Plant Emissions Demonstrating Continued Progress*, EPA (Feb. 20, 2019), https://epa.gov/newsreleases/epa-releases-2018-power-plant-emissions-demonstrating-continued-progress [https://perma.cc/3CRB-3V77].

58. *See* Joshua Linn & Kristen McCormack, *The Roles of Energy Markets and Environmental Regulation in Reducing Coal-fired Plant Profits and Electricity Sector Emissions*, 50 RAND J. Econ. 733, 753–55 (2019); John Coglianese et al., *The Effects of Fuel Prices, Environmental Regulations, and Other Factors on U.S. Coal Production, 2008–2016*, 41 Energy J. 55, 55 (2019).

59. Coglianese et al., *supra* note 58, at 56–57.

SO2 emissions is due to the cap-and-trade program established in the Clean Air Act Amendments of 1990.

To address the risks posed by acid rain, the 1990 Amendments set the goal of cutting SO2 emissions from fossil fuel power plants to one-half their 1980 levels.[60] The law established a two-phase approach to achieving this goal. Phase I would start in 1995 and would cover the largest 263 electricity generating units with the highest SO2 emissions; and phase II would start in 2000 and would expand coverage to virtually all utility-scale fossil fuel power plants in the country.[61] More than 100 phase II units took advantage of the opportunity to voluntarily opt into phase I.[62] Each unit participating in phase I received emission allowances granting the holder the right to emit one ton of SO2, based on the product of that unit's average heat input from 1985–1987 (measured in millions of British thermal units (MMBTUs)) and an SO2 emission rate of 2.5 pounds per MMBTU.[63] Aggregating all units participating in phase I yielded the annual emissions cap. A similar allowance allocation occurred during phase II, but with a lower SO2 emission rate of 1.2 pounds per MMBTU.[64]

A secondary market for emission allowances emerged as power plants bought and sold allowances. A plant could observe the going price for SO2 allowances to determine if it would be economical to further reduce a unit's emissions—if doing so cost less than the allowance price, which would create an additional profit opportunity by selling unused allowances—or to purchase allowances from another plant (if doing so cost less than abating its own emissions).

During a three-month "true-up" period at the end of each year, a regulated unit surrendered emission allowances equal to its SO2 emissions, as measured through so-called continuous emission monitors.[65] If a regulated unit held more allowances than emissions, it could bank an allowance for use in a future compliance period.[66] During the

60. Linn & McCormack, *supra* note 58, at 737.

61. *See* Richard Schmalensee & Robert N. Stavins, *The SO2 Allowance Trading System: The Ironic History of a Grand Policy Experiment*, 27 J. Econ. Persp. 103, 105 (2013).

62. *See* Juan-Pablo Montero, *Voluntary Compliance with Market-Based Environmental Policy: Evidence from the U.S. Acid Rain Program*, 107 J. Pol. Econ. 998, 1006 (1999); Envtl. Def. Fund, From Obstacle to Opportunity: How Acid Rain Emissions Trading is Delivering Cleaner Air 5 (2000).

63. A. Denny Ellerman et al., Markets for Clean Air: The U.S. Acid Rain Program 6–7 (2000).

64. *1990 Clean Air Act Amendment Summary: Title IV*, EPA, https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary-title-iv [https://perma.cc/Z9SR-H9D6] (last updated January 4, 2017).

65. *See* Schmalensee & Stavins, *supra* note 61, at 105.

66. *Id.*

initial phase of the program, power plants reduced emissions below the annual caps, thereby building a large bank of allowances for use in the more stringently regulated second phase. Starting in 2003, the prospect of new air-quality regulations as well as a series of federal court decisions delivered a several-year period of high and volatile allowance prices. As new, more stringent regulations affected power plant SO2 emissions, and provided less compliance flexibility than under the Acid Rain Program, the SO2 cap-and-trade program ceased to be binding on power plants.[67] The Clean Air Interstate Rule, implemented in 2009,[68] and the subsequent Cross-State Air Pollution Rule, issued in 2011,[69] placed state- and source-specific limits on SO2 emissions; and by 2012, allowances prices were below one dollar per ton, having fallen from prices in excess of $1,000 per ton in the mid-2000s.[70]

The SO2 cap-and-trade program represented a significant departure from conventional regulatory approaches, such as the mandate to install smokestack scrubbers on coal-fired power plants built after 1977 and traditional performance standards.[71] Providing power plants the flexibility to explore and exploit the lowest-cost ways of reducing SO2 emissions timed well with the deregulation of freight railroads, which enabled many midwestern power plants to burn low-sulfur coal from Wyoming.[72] Gaining access to low-sulfur coal likely reduced by half the marginal abatement costs for phase I power plants, and, taking full advantage of the gains from trade, delivered about $800 million in annual cost savings relative to a command-and-control performance standard that would have delivered the same aggregate emissions.[73] In practice, however, the novelty of trading and the potential adjustment costs, as power plants transitioned to cap-and-trade from conventional regulations, meant that electricity generating units failed to take full advantage of trading in the early years of the program. For example, analysis of the cost-savings during phase II of the program indicates

67. *Id.* at 113.

68. EPA, The Clean Air Interstate Rule: 2009 Emission, Compliance and Market Analyses 1 (2010), *available at* https://www.epa.gov/sites/production/files/2015-08/documents/cair09_ecm_analyses.pdf.

69. *Cross-State Air Pollution Final and Proposed Rules*, EPA, https://www.epa.gov/csapr/cross-state-air-pollution-final-and-proposed-rules [https://perma.cc/N6VB-RZY5] (last updated July 10, 2017).

70. *See* Schmalensee & Stavins, *supra* note 61, at 114.

71. *See* Curtis Carlson et al., *Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade?*, 108 J. Pol. Econ. 1292, 1293, 1296 (2000).

72. *See* Meghan R. Busse & Nathaniel O. Keohane, *Market Effects of Environmental Regulation: Coal, Railroads, and the 1990 Clean Air Act*, 38 RAND J. Econ. 1159, 1178 (2007).

73. *See* Carlson et al., *supra* note 71, at 1293.

that cap-and-trade reduced compliance costs by several hundred million dollars per year relative to a conventional performance standard.[74]

In addition to lowering costs relative to command-and-control regulation, the SO2 cap-and-trade program delivered substantial public health benefits. Indeed, like the experience with the lead credit trading program, advances in epidemiological research contributed to a better understanding of the program's public-health benefits, especially in terms of reducing fine particulate matter concentrations that contribute to premature mortality. The annual benefits associated with reducing premature mortality could be as great as $100 billion, dwarfing by two orders of magnitude the ecosystem benefits associated with lower rates of acidification that initially motivated the program's development.[75]

E. NOX Budget Trading Program

Since 1990, power plant emissions of nitrogen oxides (NOX) have fallen by 84%.[76] Just as in the case of SO2, market forces have played a role in reducing NOX from coal-fired power plants, but the NOX Budget Trading Program drove significant NOX emission reductions. This program evolved from the 1990 Clean Air Act Amendments' creation of the Ozone Transport Commission (OTC), which aimed to address ozone pollution through a regional strategy focused on the Northeast and Mid-Atlantic states.[77] In 1999, the OTC's twelve states and the District of Columbia launched the NOX cap-and-trade program, which covered NOX emissions during the May-to-September "ozone" season.[78] The program allocated allowances for free to large stationary sources and the cap was set at about 25% below a forecast, counterfactual emissions level.[79]

Given the advances in scientific research and atmospheric modeling, the EPA worked with the states to expand the NOX cap-and-trade program to cover nineteen states in the eastern half of the United States through what became known as the NOX Budget Trading Program. Under full implementation in 2004, the program covered approximately "2,500 electricity generating units and industrial boilers, though the 700 coal-fired" power plants in the program represented 95% percent of the

74. *See* H. Ron Chan et al., *The Impact of Trading on the Costs and Benefits of the Acid Rain Program*, 88 J. Envtl. Econ. & Mgmt. 180, 199 (2018).

75. *See* Schmalensee & Stavins, *supra* note 61, at 109–10.

76. *EPA Releases 2018 Power Plant Emissions Demonstrating Continued Progress*, *supra* note 57.

77. 42 U.S.C. § 7511c(a) (2018).

78. *See* Joshua Linn, *Technological Modifications in the Nitrogen Oxides Tradable Permit Program*, 29 Energy J. 153, 157 (2008).

79. *Id.*

pollution market's NOX emissions.[80] The NOX Budget Trading Program reduced power plant NOX emissions in the covered states by about 40%, resulting in a 6% reduction in mean ozone concentrations, and a 35% reduction in the number of high-ozone summer days.[81] Like the OTC program, the NOX Budget Program capped emissions during the summer ozone season, and allowed regulated firms to buy, sell, and bank allowances.[82] The program ceased in 2009, when the EPA replaced it with the Clean Air Interstate Rule.[83]

The dramatic reductions in emissions and ozone concentrations contributed to substantial public health benefits. The NOX Budget Trading Program reduced premature mortalities in the participating states by about 1,975 deaths per summer,[84] which, when evaluated at the EPA's preferred statistical value of life, translates into nearly $18 billion in benefits.[85] By improving air quality, the program also reduces the need for individuals to undertake defensive efforts and expend resources on health care and pharmaceuticals to mitigate the risk posed by air pollution. Under this program, cleaner air resulted in an $800 million-per-year reduction in such defensive expenditures.[86]

F. RECLAIM Cap-and-Trade Program

The 1990 Clean Air Act Amendments required those areas classified as "extreme" non-attainment for ambient ozone concentrations to implement "economic incentive programs" to reduce emissions of ozone precursors, such as NOX.[87] Given the extreme non-attainment status for Los Angeles, the South Coast Air Quality Management District designed the Regional Clean Air Incentives Market, commonly referred to as RECLAIM, a cap-and-trade program covering NOX emissions at

80. Olivier Deschênes et al., *Defensive Investments and the Demand for Air Quality: Evidence from the NOx Budget Program*, 107 Am. Econ. Rev. 2958, 2963 (2017).

81. *Id.* at 2959.

82. *See id.* at 2963.

83. *See id.* at 2963 n.7.

84. *Id.* at 2960.

85. The EPA uses a value of statistical life of $7.4 million in 2006's dollars. *Mortality Risk Valuation*, EPA, https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatvalue [https://perma.cc/9ET4-P562] (last updated Feb 8, 2018). This is equivalent to roughly $9.19 million in 2018's dollars. *CPI Inflation Calculator*, U.S. Bureau Lab. Stat., https://data.bls.gov/cgi-bin/cpicalc.pl?cost1=7400000&year1=200606&year2=201806 [https://perma.cc/5BPL-WXMS] (last visited June 25, 2020).

86. Deschênes et al., *supra* note 80, at 2958.

87. 42 U.S.C. § 7511a(g)(5) (2018).

392 facilities in the greater Los Angeles area.[88] The program covered all private entities with at least four tons of annual emissions (public facilities, such as police and fire stations, were excluded). These RECLAIM facilities represented about two-thirds of the area's NOX emissions from stationary sources, and the non-RECLAIM sources of NOX emissions operated under command-and-control regulation.[89]

Starting in 1994, the RECLAIM cap-and-trade program aimed to reduce NOX emissions at these regulated facilities by 75% by 2003, and to continue that limit through 2010.[90] Each facility received free emission allowances as a function of their historic fuel consumption and technology characteristics. Regulated facilities could buy and sell emission allowances, but they could not bank them for use in a future year.[91] In addition, RECLAIM established two zones—coastal and inland—and prohibited the sale of allowances from the inland zone to the coastal zone.[92]

The early years of the program witnessed allowance allocations that did not bind the regulated firms, perhaps reflecting the political economy of easing regulated firms into a new program. As a result, the lax emissions cap resulted in low allowance prices before 1999. Allowance prices spiked during the 2000–2001 California electricity crisis, as power generation within the RECLAIM region increased well above past levels: an allowance that traded for about $2,000 per ton in January 2000 traded for more than $120,000 per ton in March 2001. Fourteen power producers exited RECLAIM in 2001, agreeing to pay a non-compliance fee and to adopt best available control technologies on existing generating units by 2004. These units rejoined RECLAIM in 2007.[93]

The RECLAIM program delivered significant reductions in NOX emissions. Meredith Fowlie, Stephen Holland, and Erin Mansur evaluated the performance of the RECLAIM program by matching RECLAIM-covered sources with similar facilities in nearby non-

88. *See* Meredith Fowlie et al., *What Do Emissions Markets Deliver and to Whom? Evidence from Southern California's NOx Trading Program*, 102 Amer. Econ. Rev. 965, 968–69 (2012). The RECLAIM market also covered sulfur dioxide emissions at forty-one facilities. EPA, An Evaluation of the South Coast Air Quality Management District's Regional Clean Air Incentives Market—Lessons in Environmental Markets and Innovation 11 (2002). Most RECLAIM research has focused on the much larger NOX cap-and-trade RECLAIM program. *See* Fowlie et al., *supra*, at 968 n.10.

89. *See* Fowlie et al., *supra* note 88.

90. EPA, An Overview of the Regional Clean Air Incentives Market (RECLAIM) 2 (2006).

91. Fowlie et al., *supra* note 88, at 969.

92. *Id.* at 972 n.22.

93. *Id.* at 969–70.

attainment areas in the state and examining the change in emissions over time.[94] While both RECLAIM and non-RECLAIM sources in their sample experienced falling emissions, they estimate RECLAIM facilities emissions fell about 20% percent relative to their match group over the first decade of the RECLAIM program.[95] The spike in allowance prices during the California electricity crisis also suggests that emissions would have increased, potentially significantly, in the absence of the emission cap.

The authors also explore whether hot spots arise in dispro–portionately low-income and minority communities—a key concern for the environmental justice implications of market-based instruments. Exploiting census-block-level socio-demographic data and facility-level emissions data, they find no evidence of so-called "hot spots" or lower relative-emission reductions in areas near RECLAIM facilities.[96] By exploring the spatial distribution of abatement activity under a cap-and-trade program, such an analysis can complement the findings regarding how efficient the regulatory instrument is in reducing emissions by also illustrating the distribution of its benefits.

G. Renewable Fuel Standard

The Renewable Fuel Standard (RFS) represents the first legislative action to create a regulatory authority under the Clean Air Act that explicitly targets carbon dioxide emissions.[97] The RFS reflects both an initial effort to establish a national biofuels mandate (in the Energy Policy Act of 2005[98]) and a subsequent effort (the Energy Independence and Security Act of 2007[99]) that increases the volumetric goals while limiting the carbon intensity of biofuels. The 2007 revision of RFS included quite ambitious goals, with total biofuels ramping up to thirty-six billion gallons by 2022, and several low-carbon goals that may comprise this total biofuel goal, including sixteen billion gallons of cellulosic ethanol, twenty-one billion gallons of advanced biofuels (which may include celluslosic ethanol), and biodiesel (with goals after 2012 to be set through EPA rule-makings).[100] Qualifying cellulosic ethanol must have at least 60% fewer carbon emissions per volume than

94. *Id.* at 972–73 (explaining the authors' empirical framework).

95. *Id.* at 991.

96. *Id.* at 989–90.

97. *See* Joseph E. Aldy, *Promoting Environmental Quality through Fuels Regulations: Lessons for a Durable Energy and Climate Policy*, *in* Lessons from the Clean Air Act, *supra* note 32, at 159, 160.

98. Pub. L. No. 109-58, 119 Stat. 594.

99. *See* 42 U.S.C. § 7545 (2018).

100. *See id.* § 7545(o)(2)(B)(i).

conventional petroleum-based gasoline.[101] To put these ambitious goals in context, U.S. gasoline consumption in 2018 amounted to about 143 billion gallons.[102] While this program intended to drive technological innovation and large-scale commercialization of low-carbon biofuels, including cellulosic ethanol, the RFS has failed to deliver: EPA has promulgated rules setting cellulosic ethanol volumes below their annual statutory goals for every year since 2010.[103]

Under the RFS, the EPA assigns a renewable volume obligation (RVO) to each gasoline refiner, blender, and importer based on the product of each entities' annual gasoline production and the applicable percentage of renewable fuels that the EPA sets each year (the EPA converts the national volumetric goals in the statute into entity-specific compliance quantities).[104] To satisfy its RVO, an entity can buy credits (referred to as "RINs," based on the unique Renewable Identification Number associated with each unit of biofuel) from biofuel suppliers or others who may have purchased such credits from biofuel suppliers, and annually surrender to the EPA RINs equal to their RVO.[105] When an obligated entity blends a gallon of renewable fuel with conventional gasoline or diesel, the RIN is separated from the biofuel and it may be traded, banked, or surrendered to the government to demonstrate compliance.[106]

The RIN market differed from previous Clean Air Act pollution markets along several important dimensions. First, the RIN market was characterized by a "buyer beware" approach that placed liability on all regulated parties with RVOs for acquiring or transferring fraudulently generated RINs.[107] This reflected the fact that virtually none of the compliance entities—primarily petroleum refineries—generated any renewable fuels on their own, and the source of renewable fuel credits—biorefineries—were not subject to the RVOs. In 2011, the EPA began to identify fraudulently generated RINs and it prosecuted several firms responsible for doing so.[108] The emergence of such fraud, coupled with

101. *See id.* § 7545(o)(1)(E).

102. *See Gasoline Explained*, U.S. Energy Info. Admin., https://www.eia.gov/energyexplained/gasoline/use-of-gasoline.php [https://perma.cc/QM99-HSAD] (last updated May 4, 2020).

103. *See* 85 C.F.R. § 7016, 7020 (2020).

104. *See* 42 U.S.C. § 7545(o)(3)(B)(ii)(I); 40 C.F.R. § 80.1407 (2019).

105. *See* 40 C.F.R. §§ 80.1425, 80.1430.

106. *See id.* §§ 80.1427, 80.1429.

107. Renewable Fuel Standard Renewable Identification Number (RIN) Quality Assurance Program, 79 Fed. Reg. 42,078, 42,079 (July 18, 2014) (to be codified at 40 C.F.R. pt. 80).

108. *Id.* at 42111; Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 Fed. Reg. 14,670, 14,731 (Mar. 26, 2010) (to

the buyer liability in the program, had a chilling effect on the market, reducing liquidity.[109] To remedy this problem, the EPA promulgated a new rule that created a Quality Assurance Program to enhance confidence and liquidity in legitimate RINs.[110] This program provided independent verification of RINs and absolved refiners and other compliance entities of any liability associated with the program-verified RINs they purchase for compliance obligations.[111] In effect, the Quality Assurance Program converted the RFS into a seller-liability scheme, akin to the SO2 and NOX cap-and-trade programs described above.

Second, in contrast to cap-and-trade programs that set clear annual emission targets, the cellulosic ethanol goals under the RFS have been characterized by persistent uncertainty. Under the 2005 and 2007 energy bills authorizing the RPS, the EPA has the discretion to waive RFS goals on an annual and possibly recurring basis if it determines that there is inadequate domestic supply.[112] Given the absence of meaningful cellulosic ethanol production, the EPA has waived every annual RFS goal for cellulosic ethanol and promulgated regulations setting new, annual targets. In the early 2010s, the EPA began setting significantly lower cellulosic ethanol targets at one-twentieth to one-hundredth of the statutory goals.[113] Thus, an annual rule-making process that makes consequential changes to what was a fifteen-year schedule of targets under the statute created significant uncertainty for both firms with compliance obligations and entrepreneurs considering investing in low-carbon biorefineries. In some cases, regulated entities do not learn of their RVOs until after the compliance year has ended. For example, in 2012, cellulosic biofuel production in the United States fell short of the EPA-revised goal. In response to a ruling by the U.S. Court of Appeals for the D.C. Circuit that EPA had exceeded its statutory authority in setting a 2012 target inconsistent with what the

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be codified at 40 C.F.R. pt. 80). By December 2013, the EPA had identified at least 173.5 million fraudulent RINs. Tait Militana, *New Challenges for EPA Renewable Fuels Program*, CONG. Q. ROLL CALL, Dec. 18, 2013, 2013 WL 6672955.

109. Renewable Fuel Standard Renewable Identification Number (RIN) Quality Assurance Program, 79 Fed. Reg. at 42078.

110. *Id.* at 42079, 42085.

111. *Id.* at 42078.

112. 42 U.S.C. § 7545(o)(7)(A) (2018).

113. *See* 2011 Renewable Fuel Standards, 75 Fed. Reg. 76,790, 76,793 (Dec. 9, 2010) (to be codified at 40 C.F.R. pt. 80); 2012 Renewable Fuel Standards, 77 Fed. Reg. 1320, 1323–24 (Jan 9, 2012) (to be codified at 40 C.F.R. pt. 80); 2014 Renewable Fuel Standards, 78 Fed. Reg. 71,732, 71,738 (Nov. 29, 2013) (to be codified at 40 C.F.R. pt. 80); 2013 Cellulosic Biofuel Standards, 79 Fed. Reg. 25,025, 25,027 (May 2, 2014) (to be codified at 40 C.F.R. pt. 80); *see also* 42 U.S.C. § 7545(o)(2)(B)(ii)(III).

market could feasibly supply, the EPA reduced the requirements to the actual level of production for that year.[114]

Third, the RFS includes a "safety valve" by giving firms the opportunity to purchase EPA-issued credits at a pre-determined price in lieu of buying RINs from a biofuel supplier.[115] This effectively converts the RIN market from a quantity-based pollution market to a hybrid quantity-tax instrument through which regulated entities can effectively pay a tax (purchase the EPA-issued credits) in lieu of satisfying their RVO's quantity requirement. This contrasts with, for example, the SO2 cap-and-trade program in which a regulated entity failing to have sufficient emission allowances to cover its emissions must pay a financial penalty ($2,000 per ton—a higher price by a factor of ten than allowance prices for most of the first decade of the program's operation) and retire emission allowances to offset its excess emissions in the subsequent year.[116]

While economists have long argued that hybrid price-quantity approaches to pollution markets can increase social welfare compared to quantity-only approaches,[117] the design of the RFS's safety valve failed to deliver much certainty to regulated firms. In any year that the EPA waives the statutory cellulosic ethanol requirements—i.e., sets new annual goals through regulation—the Agency must also make available for purchase cellulosic biofuel waiver credits to regulated entities.[118] The statute directs the EPA to set waiver-credit prices as a function of wholesale gasoline prices,[119] which vary significantly over time, thus resulting in significant variation in credit prices over time. For example, from 2010–2018, annual waiver prices ranged from $0.42 to $2.00 per gallon.[120] By conditioning waiver prices on volatile gasoline prices, the waiver-credit approach does not deliver much certainty or predictability to either the entities with compliance obligations or the

114. Timothy A. Slating & Jay P. Kesan, *The Renewable Fuel Standard 3.0?: Moving Forward with the Federal Biofuel Mandate*, 20 N.Y.U. Envtl. L.J. 374, 431–33 (2014).

115. *See* Aldy, *supra* note 97, at 181, 187.

116. 42 U.S.C. § 7651(j)(a)–(b).

117. *See generally* Martin L. Weitzman, *Optimal Rewards for Economic Regulation*, 68 Am. Econ. Rev. 683 (1978); Marc J. Roberts & Michael Spence, *Effluent Charges and Licenses Under Uncertainty*, 5 J. Pub. Econ. 193 (1976); Lawrence H. Goulder & Ian W.H. Parry, *Instrument Choice in Environmental Policy*, 2 Rev. Envtl. Econ. & Pol'y 152 (2008).

118. 42 U.S.C. § 7545(o)(7)(D)(ii).

119. *Id.*

120. *See Annual Compliance Data for Obligated Parties and Renewable Fuel Exporters under the Renewable Fuel Standard (RFS) Program*, EPA, https://www.epa.gov/fuels-registration-reporting-and-compliance-help/annual-compliance-data-obligated-parties-and [https://perma.cc/4NZ9-SNQP] (last updated May 21, 2020).

entrepreneurs who may invest in new cellulosic ethanol refining capacity.

The RFS cellulosic ethanol market presents a cautionary tale about the potential for pollution markets to reduce emissions from other sources, for instance, from carbon dioxide associated with the com–bustion of transportation fuels. From 2010–2018, cumulative production of cellulosic ethanol used for compliance with the RFS totaled less than 4% of the statutory volume goals set in the Energy Independence and Security Act of 2007.[121]

II. Learning from Pollution Markets' Experiences

The rigorous ex post evaluations of the experience in implementing pollution markets for fuels, power plants, and large stationary sources under the Clean Air Act address a number of environmental, economic, and political economy questions. The following sub-parts pose many of these important questions and synthesize the key insights from the relevant literature. In drawing these lessons, this Part also highlights how the relevant studies employed causal-inference methods to credibly estimate the impacts of the pollution markets. This sets the stage for Part III, which describes how the academic literature can inform the design and implementation of ex post regulatory performance evaluation at the EPA.

A. Do pollution markets minimize compliance costs?

The standard theory of market-based instruments, such as cap-and-trade and related pollution markets, notes that profit-maximizing firms have the discretion and flexibility to seek out and exploit the least costly ways of reducing emissions.[122] If all firms operating under a cap-and-trade program do just that, then marginal abatement costs are equated with allowance prices for all covered sources. This characterizes the cost-effective potential of a market-based approach to pollution control and has motivated the interest in pollution markets as alternatives to traditional command-and-control regulation.

In practice, pollution markets have lowered compliance costs compared to conventional regulation but they have failed to deliver on the cost-effective ideal. In a variety of contexts, firms have failed to implement cost-minimizing compliance strategies. In their analysis of the initial phase of the SO2 program, Curtis Carlson, Dallas Burtraw, Maureen Cropper, and Karen Palmer found that about one-quarter of their observations deviated from least-cost compliance strategies.[123]

121. *See id.*; *see also* 42 U.S.C. § 7545(o)(2)(A)(i).

122. *See* Joseph E. Aldy and Robert N. Stavins, *Using the Market to Address Climate Change: Insights from Theory and Experience*, 141 Daedalus 45, 51 (2012).

123. *See* Carlson et al., *supra* note 71, at 1304, 1319.

They found that actual compliance in the SO2 market resulted in about $300 million more in costs than they estimated in their least-cost compliance scenario, which was based on their estimated marginal abatement cost functions.[124] Likewise, under the NOX Budget Trading Program, some power plants' investment in NOX-pollution-control equipment deviated from the least-cost abatement strategies.[125]

Such deviations may reflect additional regulatory constraints, the nature of economic competition (more on this below), and political and legal uncertainties. For example, overlapping state-specific performance standards for SO2, as a part of states' implementation plans, played a significant role in scrubber investments by power plants that were covered by the SO2 cap-and-trade program.[126] The constraint imposed by the states' requirements effectively precluded these power plants from exploiting the flexibility intrinsic to the cap-and-trade program. In effect, the resulting allowance price represents the residual demand for, and supply of, allowances conditional on the states' regulatory requirements.

B. How Much Have Pollution Markets Reduced Pollution?

Pollution markets have played substantial roles in reducing pollution in many but not all applications. In the RECLAIM program, Meredith Fowlie, Stephen Holland, and Erin Mansur showed that emissions at facilities covered by the pollution market fell 20% compared to facilities that were otherwise similar except that they were regulated by conventional command-and-control regulations.[127] In their analysis, they employ a difference-in-difference empirical strategy that looks at changes in emissions before and after the start of the RECLAIM program for both RECLAIM-covered sources and nearby sources that were covered by emission performance standards and then compares those changes. This approach can ensure that the estimated impacts are not confounded by some unobserved factors that evolve over time (e.g., economic activity, electricity demand, etc.) or unobserved, source-specific factors (e.g., better plant management).

Olivier Deschênes, Michael Greenstone, and Joseph Shapiro exploited the timing, seasonality, and geographic coverage of the NOX Budget Trading Program to estimate significant 40% reductions in NOX emissions.[128] Their empirical strategy effectively compared the

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124. *Id.* at 1318.

125. Meredith Fowlie, *Emissions Trading, Electricity Restructuring, and Investment in Pollution Abatement*, 100 Am. Econ. Rev. 837, 842 (2010).

126. *See* Elaine F. Frey, *Technology Diffusion and Environmental Regulation: The Adoption of Scrubbers by Coal-Fired Power Plants*, 34 Energy J. 177, 178, 180 (2013).

127. *See* Fowlie et al., *supra* note 88, at 991.

128. *See* Deschênes et al., *supra* note 80, at 2959.

change in emissions at power plants across seasons (ozone season, when the program is in effect, versus non-ozone season), time (pre- versus post-2003 emissions), and geography (plants in the states covered by the program versus those that were not).[129] This so-called "triple-differencing," an extension of difference-in-differences, enables a credible estimation of the causal impacts of the policy.

In contrast, the RFS delivered only a very small fraction of the statutory goals for cellulosic ethanol, the low-carbon alternative.[130] In addition, it is important to recognize the potential role that market forces can play in driving down emissions. In recent years, low natural gas prices, lower-than-expected electricity demand, and investment in wind and solar power, have all contributed to coal-fired power plant retirements and lower capacity utilization rates.[131] The net result is significantly lower SO2 and NOX emissions over the past decade, with environmental regulations contributing much less than market forces to these changes.

C. Do Cost-Effective Emission Reductions Potentially Increase Damages?

Several of the most prominent pollution markets, including the SO2 cap-and-trade program and the NOX 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, Meredith Fowlie found that, under the NOX Budget Trading 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.[132]

In the context of the SO2 cap-and-trade program, Nicholas Muller and Robert Mendelsohn employed an integrated assessment model that accounts for the location of emissions, atmospheric chemistry, pollution transport, and the economic value of public-health impacts to show dramatic discrepancies—in some cases, by several orders of mag–nitude—in the premature mortality damages caused by one ton of SO2

129. *Id.* at 2969.

130. *See supra* text accompanying note 121.

131. *See generally* Linn & McCormack, *supra* note 58 (modeling how market shocks and emissions regulations affect emissions levels, profits, and coal-fired plant retirement); Coglianese et al., *supra* note 58 (finding that the most significant contributor towards declining coal production was the relative decline in natural-gas prices compared to coal prices).

132. *See* Fowlie, *supra* note 125, at 861, 863.

emissions.[133] Ron Chan, Andrew Chupp, Maureen Cropper, and Nicholas Muller evaluated the economic, environmental, and public-health impacts of phase II of the SO2 cap-and-trade program.[134] They also compared the performance of the program to two policy counterfactuals: (1) a uniform performance standard, and (2) a variant of the SO2 cap-and-trade program in which plants receive SO2-program-type allowances, but they could not sell their allowances.[135] They found that the uniform performance standard resulted in the highest public-health damages of the three policies.[136] Since trading under the SO2 cap-and-trade program tended to shift emissions toward more densely-populated areas, the no-trade counterfactual resulted in lower public-health damages than the SO2 program.

Muller and Mendelsohn suggest that a way to address the concern that emissions trading could increase public-health damages would be to institute trading ratios between any pair of sources based on the relative damages associated with one ton of emissions at these sources.[137] They estimated that such trading ratios could improve social welfare by nearly $1 billion per year compared to the ton-for-ton trading in the SO2 cap-and-trade program.[138] Such differentiation in cap-and-trade implementations raises questions, however, about administrative feasibility and accuracy in estimating ratios, especially in the presence of a complicated atmospheric chemistry.[139]

D. How do Imperfectly Competitive Markets Influence Pollution-Market Performance?

The nature of market competition can influence how regulated firms respond to air-quality regulations. Accounting for this potential interaction is important for retrospective analysis, especially consid–ering that most of the EPA's prospective analyses of regulatory compliance costs rely on cost studies that abstract from market structure and market competition. And it is of particular importance given the frequency that the EPA has designed pollution markets that cover entities that operate in imperfectly competitive markets. Some power plants have local monopolies subject to economic regulation by state public utility commissions. Firms in some pollution-intensive industries, such as petroleum refining, can exercise local market power

133. *See* Muller & Mendelsohn, *supra* note 6, at 1727.

134. *See* H. Ron Chan et al., *supra* note 74, at 181–82.

135. *Id.*

136. *Id.* at 183.

137. *See* Muller & Mendelsohn, *supra* note 6, at 1727–28.

138. *Id.* at 1734.

139. For a discussion of these potential limitations, see Art Fraas & Randall Lutter, Commentary on *Efficient Pollution Regulation: Getting the Prices Right*, 102 AM. ECON. REV. 602, 605–06 (2012).

in part due to the high costs of entry. And 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 both for the impacts of regulations and for their evaluation. For example, Meredith Fowlie showed how power plants in restructured power markets responded differently to the NOX Budget Program than those that were subject to economic regulation.[140] She finds that the power plants in the latter category were more likely to invest in more costly and more efficacious pollution-control equipment.[141] As a result, power plants in competitive electricity markets tended to emit more NOX, and potentially expose more people to higher ozone concentrations, given the positive relation–ship between deregulated markets and population density (as noted above). This bias toward capital-intensive environmental compliance by economically regulated power plants is an illustration of the Averch Johnson effect.[142] In an assessment of coal-fired power plants' com–pliance under the SO2 cap-and-trade program, Steve Cicala finds that the power plants in economically regulated markets were also more likely to adopt scrubbers instead of less capital-intensive compliance strategies, such as switching to low-sulfur coal.[143]

The interaction of market power and air-quality regulations can influence the economic incidence of pollution markets. Consider the case of the SO2 cap-and-trade program. One of the key factors in driving the low-cost compliance with the SO2 caps was the availability of low-sulfur coal from Wyoming. With the deregulation of rail shipping, the Powder River Basin's low-sulfur coal became an appealing compliance strategy for many midwestern coal-fired power plants. As Meghan Busse and Nathaniel Keohane showed, the freight rail duopoly that emerged over this time period was able to engage in price discrimination on the basis of environmental regulation and geographic location and to secure some of the economic rents created by the cap-and-trade program.[144] To investigate this, the authors employed a difference-in-differences empirical strategy that exploited the variation in regulatory status in the 1990s. They compared phase I plants covered by the cap-

140. Fowlie, *supra* note 125, at 863.

141. *Id.*

142. *See The Averch Johnson Effect*, Pa. State. Univ. e-Educ., https://www.e-education.psu.edu/ebf483/node/681 [https://perma.cc/SHC4-2UCV] (last visited June 25, 2020).

143. *See* Steve Cicala, *When Does Regulation Distort Costs? Lessons from Fuel Procurement in US Electricity Generation*, 105 Am. Econ. Rev. 411, 440–41 (2015).

144. *See* Busse & Keohane, *supra* note 72, at 1160.

and-trade program starting in 1995 with a set of control plants that were subject to conventional command-and-control regulations during the entire 1990–1999 study period.[145] The ability of a railroad to raise prices depends on the extent of competition it faces in delivering coal to any given power plant. In general, a railroad faces less competition for nearby power plants and more competition for more distant plants. Their analysis accounts for the nature of competitive pressures by examining pricing of coal deliveries as a function of shipping distances from coal mines to power plants.

While overall coal prices fell during the latter half of the 1990s, Busse and Keohane found that delivered prices rose for plants covered by phase I of the SO2 cap-and-trade program relative to those still operating under command-and-control regulation; and prices rose more at plants near a low-sulfur coal source.[146] Overall, they estimate that railroads enjoyed an increase in producer surplus of more than $40 million, which represented about 15% of the economic surplus created by the cap-and-trade program.[147]

While market competition may influence firm compliance behavior with an air-quality regulation, there may be additional interactions with welfare implications. In their evaluation of firm behavior in the southern California RECLAIM market, Jonathan Kolstad and Frank Wolak showed that some firms traded allowances in order to exploit market power in the California electricity market.[148] They examined how the firms that own power plants both inside and outside the scope of the RECLAIM program paid more for NOX allowances during the 2000–2001 California electricity crisis in order to justify higher power bids. As a result, higher electricity prices cleared in the wholesale power market, increasing the revenues for all electricity the firm generated (by RECLAIM- and non-RECLAIM-regulated units). Thus, the NOX cap-and-trade market served as a leverage point for market power in the associated market for electricity.

E. What Happens to Pollution Markets Subject to Shocks?

Pollution markets have been subject to considerable allowance-price volatility. For example, SO2 and NOX allowance prices were more

145. *Id.* at 1161–62.

146. *Id.* at 1174.

147. *Id.* at 1176.

148. *See* Jonathan T. Kolstad & Frank A. Wolak, *Using Environmental Emissions Permit Prices to Raise Electricity Prices: Evidence from the California Electricity Market* 15 (Univ. of Cal. Energy Inst. Ctr. for the Study of Energy Mkts., Working Paper No. 113, 2003), https://www.escholarship.org/content/qt6br429mf/qt6br429mf.pdf [https://perma.cc/EXU4-CDLK].

volatile than crude oil prices over comparable time periods.[149] During the mid-2000s, SO2 allowances increased nearly ten-fold before collap–sing, as power plant managers responded to a variety of regulatory proposals and court rulings.[150] In the RECLAIM market, the price of allowances increased by 100-fold from 2000–2001 during the California electricity crisis, which increased demand for power from pollution-intensive electricity generating units.[151]

Such uncertainty may influence a firm's behavior, as it waits to learn more information before undertaking major, long-lived pollution-control-equipment investments.[152] The intrinsic uncertainty in quantity-based pollution markets, including cap-and-trade and tradable credit programs, may result in higher compliance costs than a policy approach that provides greater cost certainty. Indeed, the evidence of cost-effectiveness anomalies in a wide array of pollution markets is consistent with this adverse effect of uncertain allowance prices.[153] The standard policy remedy advanced by economists is to modify the pollution market so that it operates like a hybrid instrument that converts to a tax—i.e., it provides price certainty—when allowance prices are unexpectedly high.[154] The RFS program, however, shows how the implementation of such an approach is critical. Without sufficient lead time and predictability, firms may not benefit from hybrid price-quantity approaches to pollution markets.

F. What Are the Labor Market Impacts of Pollution Markets?

While labor market impacts typically receive little attention in prospective analyses of regulations, the potential for a regulation to increase or decrease employment is politically salient.[155] Several studies have explored the employment impacts of pollution markets and found that the direct impacts on regulated electric utilities may be modest, but the effects on energy-intensive manufacturing industries that consume power regulated by pollution markets may be more signi–

149. *See* Joseph E. Aldy & W. Kip Viscusi, *Environmental Risk and Uncertainty*, *in* 1 Handbook of the Economics of Risk and Uncertainty 601, 629 (Mark J. Machina & W. Kip Viscusi eds., 2014).

150. *See* Schmalensee & Stavins, *supra* note 61, at 114.

151. *See* Fowlie et al., *supra* note 88, at 969–70.

152. *See* Aldy & Viscusi, *supra* note 149, at 628.

153. *See* Joseph E. Aldy & Sarah Armitage, *The Cost-Effectiveness Implications of Carbon Price Certainty*, 110 Am. Econ. Ass'n Papers & Proc. 113, 115 (2020).

154. *See generally* Goulder & Parry, *supra* note 117.

155. *See generally* Does regulation kill jobs? (Cary Coglianese et al. eds., reprt. ed. 2015).

ficant.[156] These labor-market impacts should also be considered in the context of adverse employment outcomes associated with conventional command-and-control regulations under the Clean Air Act.[157]

Ann Ferris, Ron Shadbegian, and Ann Wolverton studied the employment impacts of the SO2 cap-and-trade program on power plants covered by phase I of the program.[158] The authors employ a difference-in-differences empirical strategy that exploits variation over time and in regulatory coverage. In effect, the authors compare the labor-market outcomes of plants "treated" in phase I with a set of phase II plants that are otherwise similar to serve as "control" observations.[159] The authors find no statistical evidence of changes in employment under the program.[160] Likewise, they find no employment impacts when focusing on various, specific compliance strategies.[161] These results are consistent with the labor demands of pollution-control compliance offsetting the effect compliance has on labor through productivity or output effects.

Mark Curtis focused his analysis on the labor market impacts of the NOX Budget Trading Program.[162] He likewise exploits variation across states and over time, but he also accounts for variation in the energy intensity of manufacturing industries, given the larger com–pliance costs associated with the more energy-intensive (and hence, pollution-intensive) industries.[163] He finds that the states covered by the NOX Budget Trading Program, after the cap-and-trade program began, witnessed a 1.3% decline in manufacturing employment (a loss of about

156. *Compare* Rolf Färe et al., *Environmental Regulatory Rigidity and Employment in the Electric Power Sector*, *in* Does Regulation Kill Jobs?, *supra* note 155, at 89, 101, *with* Joseph E. Aldy & William A. Pizer, *The Employment and Competitiveness Impacts of Power-Sector Regulations*, *in* Does Regulation Kill Jobs?, *supra* note 155, at 70, 84.

157. *See generally* Michael Greenstone, *The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures*, 110 J. Pol. Econ. 1175 (2002); W. Reed Walker, *The Transitional Costs of Sectoral Reallocation: Evidence from the Clean Air Act and the Workforce*, 128 Q.J. Econ. 1787 (2013).

158. Ann E. Ferris et al., *The Effect of Environmental Regulation on Power Sector Employment: Phase I of the Title IV SO2 Trading Program*, 1 J. Ass'n Envtl. & Resource Economists 521, 521 (2014).

159. *See id.* at 521.

160. *Id.* at 550–51.

161. *Id.*

162. E. Mark Curtis, *Who Loses Under Cap-and-Trade Programs? The Labor Market Effects of the NO_X Budget Trading Program*, 100 Rev. Econ. & Stat. 151, 151 (2018).

163. *See id.*

110,000 jobs) with larger employment reductions, of nearly 5% percent, in the most energy-intensive industries. In examining labor market flows, Curtis shows that the reductions in employment fell dispro–portionately on younger workers, with falling hiring rates contributing more to the employment impacts than increasing separation rates.[164]

G. How Have Pollution Markets Adapted to New Information?

The Clean Air Act has endured over fifty years in part because it is designed to adapt to new information about pollution, health risks, and the technological options for mitigating pollution-related health risks.[165] For example, the EPA used its discretionary authority to accelerate the phase-down of leaded gasoline in the 1980s through a tradable credit program. Adapting to emerging knowledge about the adverse impacts of lead exposure in the epidemiological literature, the EPA delivered significant public-health benefits through these discretionary rule-makings.

In contrast, the Clean Air Act prescribed a specific approach to setting emission caps under the SO2 cap-and-trade program, limiting the EPA from adjusting the emission caps over time. Since the 1990 Amendments, a significant improvement in epidemiological research has highlighted how reducing power plants' sulfur emissions contributes to lower fine particulate matter concentrations and lower rates of premature mortality.[166] Indeed, retrospective analyses of the SO2 cap-and-trade program indicate that the EPA could have delivered larger public-health benefits and increased social welfare by tightening the program's emissions caps.[167]

The opportunities for learning and adapting policies to new evidence about the efficacy, effectiveness, distributional, and related impacts of air-quality regulations have improved with advances in research methods and data collection. As described above, innovations in statistical methods have enabled rigorous estimation of the causal impacts, as opposed to associations, of pollution markets. Integrating information on pollution-market design and implementation with high-frequency, geographically specific data on pollution, health outcomes, individual behavior, firm behavior, and other information can produce the assessments that can inform regulators, key stakeholders, and the public about ways to improve air-quality policy over time.

164. *Id.*

165. *See* Ann Carlson & Dallas Burtraw, *Introduction* to Lessons From The Clean Air Act, *supra* note 32, at 1, 3.

166. *See* Schmalensee & Stavins, *supra* note 61, at 109–10.

167. *Id.* at 110; Muller & Mendelsohn, *supra* note 6, at 1735.

III. Institutionalizing Retrospective Analysis

The extensive academic literature on the Clean Air Act's pollution markets, and in particular the causal inference research that credibly estimates the impacts of these policies, provide some important insights for how the EPA might design and implement retrospective analysis of its regulatory program. Before illustrating how to institutionalize retrospective analysis as a critical component of regulatory performance evaluation, the next sub-part makes the case for why such evaluations are needed.

A. The Need for Retrospective Analysis

Policymakers, stakeholders, and the public can each benefit from a credible and rigorous evaluation of regulatory performance. Indeed, this has motivated the EPA's longstanding approach to subjecting its guidance for economic analysis to external peer review by its Science Advisory Board.[168] Likewise, the Office of Management and Budget (OMB) has pushed for the best, most up-to-date peer-reviewed science to inform agency actions.[169] Designing a framework for evaluating regulations in line with three key principles can help ensure its credibility. First, a regulatory evaluation system should be *transparent.* This is consistent with soliciting public comments on proposed regulations and regulatory impact assessments.[170] Providing access to analyses and communicating their impacts to the public and policymakers in a non-technical manner can enhance confidence that regulatory actions are delivering on statutory goals and improving social welfare. Or, in those cases where regulations fall short of regulatory objectives, these retrospective analyses can help identify new ways of delivering on these objectives.

Second, a regulatory evaluation system's framework should be *rigorous.* The best peer-reviewed empirical methods—including causal inference techniques in the program evaluation literature—should serve as a high, default standard for regulatory evaluation.[171] Such quasi-experimental methods can establish statistically appropriate

168. For example, the EPA has solicited a review of its latest revision to its *Guidelines for Preparing Economic Analyses. See* Sci. Advisory Bd., EPA, Guidelines for Preparing Economic Analyses (2020).

169. *See* Office of Mgmt. & Budget, Exec. Office of the President, OMB Bull. No. M–05–03, Final Information Quality Bulletin for Peer Review (2004).

170. *See* Exec. Order No. 12,866, at § 6(a)(3)(E), 58 Fed. Reg. 51,735 (Sept. 30, 1993).

171. *See generally* Joseph E. Aldy et al., *Looking Back at 50 Years of the Clean Air Act* (Resources for the Future, Working Paper No. 20-01, 2020) (evaluating retrospective Clean Air Act literature), https://scholar.harvard.edu/files/jaldy/files/wp_20-01_looking_back_at_fifty_years_of_the_clean_air_act_v2_1.pdf.

counterfactuals, which may enable analysts and consumers of analysis to distinguish the outcomes caused by regulations from those that may be associated with regulations. There may be regulatory contexts that are not amenable to quasi-experimental approaches. In such cases, structural industrial-organization models may serve as an alternative evaluative framework.[172] There may also be value in estimating empirically key parameters that a regulator would use to update its model of a regulatory context.

Finally, an evaluation scheme should be *replicable*. The analytic frameworks and statistical methods should be sufficiently transparent, and the necessary data made publicly available, so that interested scholars, stakeholders, and others may replicate the agency's analyses.[173]

It may not be feasible to undertake ex post evaluations of every current rule because agencies have scarce resources for evaluating regulations.[174] Evaluations should be prioritized by the cases in which the societal returns are expected to be the greatest. For example, economically significant regulations with large prospective benefits or cost estimates may make better targets for performance evaluation than smaller, economically insignificant rules. Some rules may be subject to periodic review and updates under their statutory authorities and thus a retrospective analysis would naturally inform the next iteration of regulatory standards. There may also be cases in which a regulatory evaluation yields significant knowledge that spills over to related regulatory contexts; the lessons from one rule could inform the evaluation and potential design of others. Finally, large changes in economic conditions, the evolution of social norms, or technological change may influence the performance of a regulation, thus meriting a rigorous review.

The political nature of retrospective analysis—reflected in the calls by Presidents over the past four decades to review existing regulations—suggests that regulatory performance evaluations can address important political economy considerations as well. For example, during the Obama Administration, the OMB highlighted the following objectives for implementing retrospective review at regulatory agencies:

> When implementing their retrospective review plans, agencies should give high priority to those reforms that will promote economic growth, innovation, competitiveness, and/or job creation. These high-priority reforms should include those with the greatest potential to produce significant quantifiable cost

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172. *Id.* at 2.

173. Admin. Conf. of the United States, Administrative Conference Recommendation 2014-5: Retrospective Review of Agency Rules 12 (2014).

174. *See id.* at 1.

> savings and significant quantifiable reductions in paperwork burdens. Agencies should give special consideration to reforms that would reduce, simplify, or harmonize regulatory or reporting requirements imposed on small businesses.[175]

This guidance focuses on reducing costs and related regulatory burdens as opposed to increasing net social benefits, and addresses specific distributional consequences, such as the impacts on small businesses. Accounting for such political-economy considerations may enhance the political salience of and support for retrospective review, which may be necessary to ensure its durability. The checkered track record of past retrospective review initiatives illustrates the need to leverage political interest to sustain a rigorous approach to regulatory performance evaluation.

B. Planning for Ex Post Analysis of Regulations

The EPA could establish at the rule-writing stage a framework for retrospective analysis of a regulation. This would include the development of a research plan that could be incorporated into a final rule's preamble, which would highlight for the public and affected stakeholders the importance of the review and the Agency's intent to undertake the review in the future. The research plan would explicitly identify the intended objectives and outcomes of the regulation that would serve as the measures to be evaluated. The plan would also describe the evaluative methods the Agency expects to employ, with an emphasis on data-driven experimental or quasi-experimental designs, where feasible. The EPA may also identify the key assumptions underlying the expected analyses, as well as how they map onto the prospective analyses. The timeframe of and the opportunities for public engagement on the retrospective analysis could also be elaborated in the research plan.

The Agency should develop a data-collection protocol consistent with the data needs of the research plan. It is quite common for the EPA, like other regulators, to collect information only on regulated entities without considering necessary information about unregulated entities or populations that could serve as credible counterfactual controls in the empirical evaluation. The data-collection protocol could also establish ways to cleanly match data collected by the Agency with relevant data collected by other federal agencies, such as the Department of Energy, the National Center for Health Statistics, and the Bureau of the Census.

The design of the research plans for ex post, regulatory performance evaluation should incorporate the causal-inference methods presented above. Such quasi-experimental methods may require creativity on the

175. Office of Mgmt. & Budget, Exec. Office of the President, Memorandum for the Heads of Executive Departments and Agencies (Oct. 26, 2011).

part of both analysts and rule-writers to ensure that the implementation occurs in a manner than can enable a credible identification of the regulation's impacts. As reflected in scholarly work, and in the parlance of an experiment, Clean Air Act regulations often create "treatment" groups (regulated entities, populations in non-attainment areas, etc.) that are similar to "control" groups except for their regulatory status.[176] These distinctions can serve as the basis for a research plan.

To be more explicit, the EPA should consider designing regulations in ways that facilitate rigorous ex post evaluation. Variations in regulatory coverage by geography, industry, season, year, or the regulated entity's size each create plausible opportunities for statistically identifying the impacts of a regulation. Granting flexibility in state and local implementation of a federal rule—which occurs in a variety of environmental statutes implemented by the EPA—may create quasi-natural experiments for rule evaluation as well.

Finally, the data collected for the retrospective analyses should be made available for research and analysis by researchers, stakeholders, and members of the general public. This would enable the replication of the Agency's work, enhancing its credibility. Such public disse–mination would also extend the analysis—through leveraging extra-governmental skills and expertise—in directions that could illuminate more efficient and effective approaches the regulator could pursue in the future.

C. Targeting Rules for Retrospective Analysis

Given the scarce resources and bureaucratic barriers to institution–alizing retrospective analysis, the EPA could consider targeting for retrospective analysis those rules for which regulatory performance evaluation would yield the greatest social benefits. This would be conceptually similar to the standard that a full regulatory impact analysis should be undertaken for proposed rules with at least $100 million in economic impacts.[177] The following four illustrations could help to identify priority rules for retrospective analysis.

First, ex post evaluation of a given regulation may create positive learning spillovers for other rules. For example, the extensive use of cap-and-trade policies for a variety of air pollutants in the United States and around the world reflects, to some degree, the positive evaluations of SO2 cap-and-trade program's performance. The lessons from those evaluations then reflects a fixed cost that can be spread over multiple policy contexts.

Second, a rule with large or uncertain benefits and costs in the prospective regulatory impact analysis may warrant rigorous

176. *See supra* Part I.B.

177. *See* Exec. Order No. 12,866, at § 6(a)(3)(C)(i), 58 Fed. Reg. 51,735 (Sept. 30, 1993).

performance evaluation. Resolving uncertainties may help ensure public support for a regulation with positive net social benefits, or it may signal that a rule should be revised if it has significant, negative net social benefits. In such a case, the value of information could be considerably greater than the cost of producing it. For example, a rigorous assessment of the cellulosic ethanol component of the RFS would show that it yields virtually zero carbon dioxide emission-reduction benefits and that it merits a significant revision, if not by the EPA—given the constraints under current law—then by Congress.

Third, the EPA could focus retrospective analysis on rules subject to, or related to, periodic review and updates under the Clean Air Act. For example, the Agency regularly reviews the national ambient air-quality standards (NAAQS) for criteria air pollutants. While such reviews typically focus on the latest public-health research, they could be expanded to include institutionalized retrospective analysis to assess the impacts, especially in terms of the public-health benefits, of the current NAAQS. This information could improve the quality of the regulatory impact analysis for the NAAQS rule-making, as well as subsequent regulations that implement the NAAQS. For example, the NOX Budget Trading Program and the RECLAIM pollution markets were each developed to address ozone non-attainment.

Finally, rigorous performance evaluation may be quite informative when the EPA employs a novel policy approach. It may be quite instructive to plan for and implement a retrospective analysis of this initial experimental effort to determine whether it should be used in additional contexts.

Conclusion

Pollution markets represent one of the most important, novel, and effective ways the EPA has improved the nation's air quality over the past fifty years. The EPA and state and local governments have used Clean Air Act pollution markets to dramatically reduce airborne lead concentrations, emissions of SO2, and emissions of ozone precursors. The positive experiences with cap-and-trade and tradable credit programs have contributed to the proliferation of markets to reduce pollution, promote renewable energy, and increase energy efficiency across the United States and around the world.

The expanded use of pollution markets reflects, in part, the analyses of their performance conducted by independent researchers. Such research provided the evidence from which policy entrepreneurs could draw when applying pollution markets to new pollution problems. The substantial improvement in the rigor of scholarly research on regulatory performance—through the integration of causal-inference techniques—can also inform the institutionalization of regulatory performance evaluations in the EPA. Designing and implementing rules to enable retrospective analyses can produce information about the realized environmental outcomes, public-health impacts, benefits, costs, labor-market impacts, and other factors. The academic literature provides a roadmap for the design of evaluation and data-collection frameworks.

Understanding whether pollution markets and environmental regulations deliver on their stated goals, do so cost-effectively, and increase social welfare can lead to improvements in environmental policy. In cases where regulations are delivering on their objectives in a low-cost manner, such analyses can demonstrate to the public that environmental regulations are bettering people's lives. In cases where regulations fall short, the insights from the retrospective analysis can drive new rule-makings or highlight opportunities for Congress to revise environmental laws to enhance their effectiveness.