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The Production Function of Environmental Quality

JONATHAN R. NASH, J.B. RUHL, JAMES SALZMAN[1]

INTRODUCTION

Over the past three decades, Congress has repeatedly sought to restrain the Environmental Protection Agency (EPA) both by legislation and, less directly, by reducing its resources. Consider, for example, a description of Congress' proposed EPA budget for 2015 by the Center for Effective Government:

> In a continuing effort to dismantle the ability of the [EPA] to protect public health and the environment, Congress is poised to adopt a fiscal year 2015 budget that would reduce the agency's funding for the fifth year in a row. The $60 million cut in EPA's budget, which builds on previous reductions, will bring the agency's staffing to its lowest level since 1989. These funding cuts are not surprising, given that anti-regulatory forces in Congress have made clear their intent to use the budget process to block EPA's work.[2]

The Natural Resources Defense Council (NRDC) similarly decried the budget reductions in 2011 as "a contract on America masquerading as a spending bill. It's nothing short of a declaration of war on our most basic health protections. It would do away with fundamental safeguards that keep

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[1] Professor of Law, Emory University School of Law; David Daniels Allen Distinguished Chair in Law, Vanderbilt Law School; Donald Bren Distinguished Professor of Environmental Law, UCLA Law School and the Bren School of the Environment at UC-Santa Barbara.
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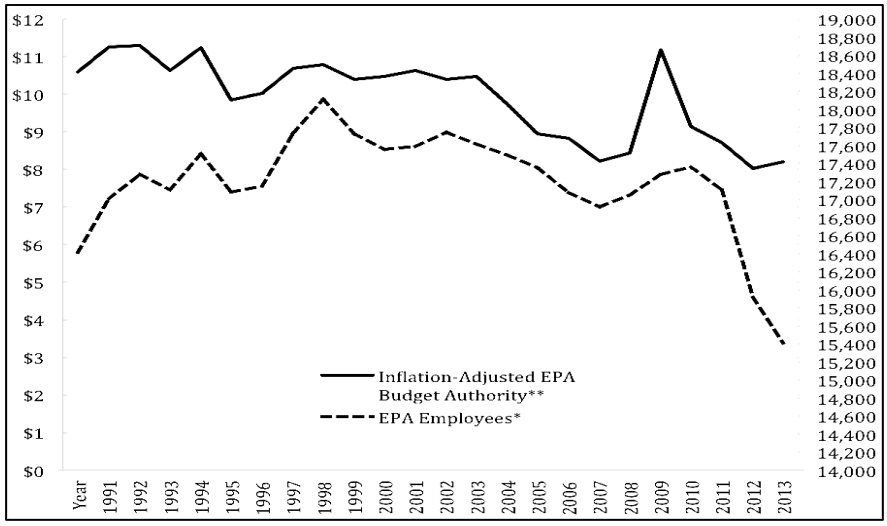
[2] Ronald White, *Congress Slashes EPA Budget Again Despite Strong Public Support for Strengthening Health Protections*, CTR. FOR EFFECTIVE GOV'T (Dec. 12, 2014), http://www.foreffectivegov.org/blog/congress-slashes-epa-budget-again-despite-strong-public-support-strengthening-health-protection, *archived at* http://perma.cc/3WAM-65WK.

our air, water and lands clean."[3] Nor has the pressure to limit EPA's resources only come from Capitol Hill. The Obama administration acquiesced to significant personnel cuts in 2013 and 2014 as part of the broader "sequestration" initiative across government agencies.[4] The trends in EPA personnel and inflation-adjusted budget in Chart 1, below, show a generally static or slightly declining level of total resources.



The charge by the Center for Effective Government and NRDC is straightforward – limiting EPA's resources will make it less effective and, as a result, worsen the pollution of our air, water and lands. The connections are easy to draw – less resources means fewer personnel and inspections for compliance monitoring, less enforcement actions, less deterrent effect, and therefore more violations that harm the environment. It means fewer resources for permitting, drafting new regulations, and revising existing regulations. According to the Center for Effective Government, the EPA's

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[3] Press Release, Natural Resources Defense Council, House Panel's Spending Bill Threatens Public Health Protections (July 6, 2011), *available at* http://www.nrdc.org/media/2011/110706.asp, *archived at* http://perma.cc/D7W8-UDKQ. As Joel Mintz has concluded, "any form of budget cutting in EPA's severely understaffed enforcement program is likely to have an adverse effect on the robustness and effectiveness of the Agency's critical enforcement work." Joel Mintz, *Cutting EPA's Enforcement Budget: What It Might Mean*, CENTER FOR PROGRESSIVE REFORM BLOG (Apr. 12, 2012), http://www.progressivereform.org/CPRBlog.cfm?idBlog=A6A2E941-98B3-8007-9CEEB42458BED78E, *archived at* http://perma.cc/6DSX-6T98.

[4] *See* Andy Amici, *Government Cuts 84,500 Federal Employees in Three Years*, FEDERAL TIMES (Jan. 20, 2015, 2:44 PM), http://www.federaltimes.com/story/government/management/agency/2015/01/20/agencies-cut-feds/22012321/, *archived at* http://perma.cc/M49B-NKC7.

strategic plan to balance its budget in 2014 called for a 40-50% reduction in inspection and enforcement cases.[5] One might call this future one of "Doing less with less."

There is, however, a competing narrative. Terry Anderson, the noted "free market environmentalist," argues that "if lawmakers are looking for an agency in which to cut spending without causing harm to the environment, the EPA is a great place to start."[6] Anderson and others championing budget cuts defend their actions as trimming fat from the bureaucracy. This was one of the central themes behind Congress' haircut strategy of sequestration—cutting equal amounts from all agencies.[7] Increasing agency budgets are far more likely, they imply, to strengthen bureaucracy than environmental quality. This strategy centers on "Doing more with less."

Which narrative is accurate – budget cuts will harm environmental quality or have no impact?

To bolster his argument, Terry Anderson produced Chart 2, below, graphing EPA's inflation-adjusted budget against measures of air quality.[8] Despite a flat or declining budget, air quality shows steady improvement over three decades. This is not what one would expect from the "Doing less with less" dystopia.

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[5] Ronald White, *Congress Slashes EPA Budget Again Despite Strong Public Support for Strengthening Health Protections*, CENTER FOR EFFECTIVE GOV'T (Dec. 12, 2014), http://www.foreffectivegov.org/blog/congress-slashes-epa-budget-again-despite-strong-public-support-strengthening-health-protection, *archived at* http://perma.cc/EF99-BRNJ.

[6] *Ibid.*

[7] Sequestration cite

[8] Terry Anderson, *EPA Budget Cuts: Reducing Bureaucracy, Not Environmental Quality*, THE PERC BLOG, http://perc.org/blog/epa-budget-cuts-reducing-bureaucracy-not-environmental-quality#sthash.vT4i3Ayx.dpuf (last visited Mar. 11, 2015), *archived at* http://perma.cc/8SWW-L4ZQ.

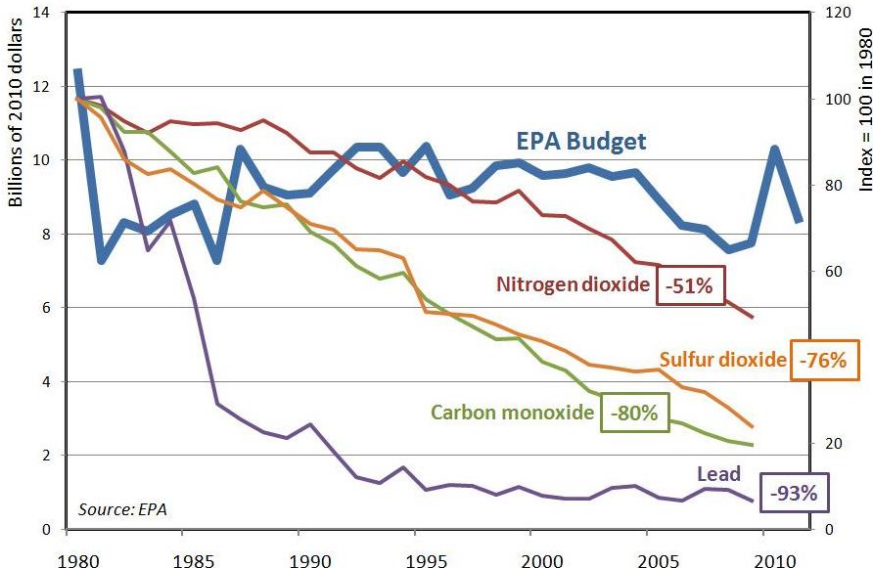

Chart 2 – Air Quality and EPA Budget

Trying to explain this chart – clear and continuous improvements in air quality at a time of steady and declining agency resources – is far from obvious. Indeed, it raises a fundamental question: *What is the relationship between EPA resources and environmental quality?*

The dynamic linkage between funding and outcome represents an important area of study in most fields of social importance. What is the relationship between police funding and crime? How does health care spending influence medical outcomes? What is the significance of school funding on test scores? In all these sectors and many others, researchers devote a great deal of time to examining the relationship between resources and results. Yet virtually no research has considered this relationship in the environmental field. The most basic question linking agency resources and outcomes – are we getting what we pay for? – remains largely anecdotal and limited to political sound bites.

In particular, do greater EPA resources actually lead to greater environmental protection efforts? If so, to what extent do these efforts then lead to improved environmental quality in the field? Is the converse true, with flat or reduced resources leading to poorer environmental quality? Of course, how the resources are spent matters greatly. Which aspects of environmental quality are most at risk from reduced EPA resources and which are less vulnerable to backsliding?

These are empirical questions with important theoretical and practical implications, not just for EPA, but for all regulatory agencies. The leading Republican candidates for president have repeatedly denounced EPA, with Donald Trump calling for dramatic reduction of EPA's budget.[9] Ted Cruz promised to eliminate four cabinet agencies were he to become president.[10]

Even without an avowed enemy of EPA in the White House, the simple math of discretionary spending means that money available for agencies will continue to shrink in the coming decades. Increases in future spending for Social Security and Medicare are built-in.[11] This growing portion of the federal budget necessitates either that federal revenues increase (which would likely require higher taxes), deficits increase, discretionary spending falls, or some combination of these three.[12] Regardless of the exact combination, the likelihood of significant increases in EPA budgets seems low. What does an era of extended agency austerity mean for environmental quality?

Such a challenge deserves serious study, not the current state of sweeping ideological claims from both sides of the debate. But how would one go about addressing these questions?

This article lays the groundwork for the research agenda of a new field of study examining the "production function" of environmental quality and the marginal effects of incremental reductions (or increases) in EPA's budget on environmental quality. While we focus on environmental protection, our findings have important implications across the administrative state on the relationship between agency funding and outcomes for public health, safety, and welfare agencies.

Part I describes relevant scholarship on the broader topic of agency resources and outcomes, with a focus on environmental quality. Using regressions, Part II tests the hypothesis that there is a statistically significant relationship between agency funding and particulate matter pollution. This

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[9] Igor Bobic, *Donald Trump Would Cut Department of Education, EPA,* HUFFINGTON POST, October 18, 2015, http://www.huffingtonpost.com/entry/donald-trump-epa-education_us_56240035e4b02f6a900cc0e7; Oliver Milman, *Republican candidates' calls to scrap EPA met with skepticism by experts,* THE GUARDIAN, February 26, 2016, http://www.theguardian.com/environment/2016/feb/26/republican-candidates-donald-trump-eliminate-epa-law-experts.

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[12] Cite CBO

relationship is examined empirically at the level of EPA budget, EPA Air Office budget, EPA Enforcement Office budget, and state environmental agency budgets. Contrary to the political rhetoric from both ends of the spectrum, we find that none of these regressions provides statistically significant correlations between agency funding levels and particulate matter pollution.

Part III then turns to a set of hypotheses that could explain the lack of correlation between funding and environmental protection. Using the conceptual model of a production function, we examine the possibilities that the improvements in air quality may be due to strict regulations, path dependency from capital investments, increased state and local protection efforts, non-state actors' use of citizen suits, as well as other explanations. Part IV then explores the important research questions that emerge from this analysis.

The relationship between agency resources and environmental quality is of the first importance. It goes to the very heart of environmental protection policy. Yet it is woefully understudied empirically and undertheorized. This article provides the first step in laying an intellectual foundation to address these shortcomings and set out future avenues for research.

I. SCHOLARSHIP EXAMINING THE RELATIONSHIP BETWEEN AGENCY RESOURCES AND OUTCOMES

As discussed in the Introduction, the relationship between public funding and outcomes has long been an active field of research in a wide range of social sciences.

Many scholars have examined the relationship between public spending on education and student academic achievement.[13] They find that increasing educational spending does not, on its own, improve student achievement.[14]

Other research has focused on the relationship between police funding and crime rates. The findings have not been uniform, with some studies showing that crime rates are positively correlated with police funding (suggesting that higher crimes trigger greater funding) and others that increases in police levels tend to reduce crime at the local level.[15]

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[13] *See* ULRICH BOSER, CTR. FOR AM. PROGRESS, RETURN ON EDUCATIONAL INVESTMENT: 2014 (2014), https://cdn.americanprogress.org/wp-content/uploads/2014/07/ROI-report.pdf (comparing academic achievement, as measured by the percentage of students scoring proficiently on state exams, with the educational spending of school districts, while controlling for factors including the cost of living and student poverty); ANDREW J. COULSON, CATO INST., STATE EDUCATION TRENDS: ACADEMIC PERFORMANCE AND SPENDING OVER THE PAST 40 YEARS (2014), http://object.cato.org/sites/cato.org/files/pubs/pdf/pa746.pdf (using a time-series regression approach to adjust state SAT score averages for factors including participation rate and student demographics from 1972 to the present. The study then compares these adjusted SAT scores with the raw SAT scores and inflation-adjusted per pupil spending to examine the link between education funding and outcomes); Rob Greenwald, Larry V. Hedges & Richard D. Laine, *The Effect of School Resources on Student Achievement*, 66 REV. EDUC. RES. 361 (1996) (analyzing a comprehensive collection of sixty school funding and achievement studies that have been performed, and uses combined significance analysis and effect magnitude estimation to determine the relationship between three variables—public expenditures (i.e., per pupil spending), teacher background characteristics (e.g., certification, educational history, and ability), and class/school sizes—and the standardized test scores considered by the surveyed articles; Emiliana Vegas & Chelsea Coffin, *When Education Expenditure Matters: An Empirical Analysis of Recent International Data*, 59 COMP. EDUC. REV. 289 (2015) (comparing per capita GDP, per pupil educational spending, and learning outcomes, as measured by mean scores in mathematics and reading as reported by the Program for International Student Assessment).

[14] Instead of simply increasing aggregate funding, the studies suggest moderate increases in funding on specific resources could greatly improve student achievement (such as reducing class sizes, school sizes, and improving the quality of teachers).

[15] *See* Thomas B. Marvell & Carlisle E. Moody, *Specification Problems, Police Levels, and Crime Rates*, 34 CRIMINOLOGY 609 (1996) (comparing the number of police employees around the country divided by population with crime rates for the seven crime types and finding it makes little difference whether police expenditures are considered in place of police employees because the two factors are strongly correlated and because the bulk of police expenditures are for personnel); Thomas F. Pogue, *Effect of Police Expenditures on Crime Rates: Some Evidence*, 3 PUB. FIN. Q. 14 (1975) (exploring the relationship between public spending on law enforcement and the rate of criminal activity, as measured by the proportion of arrests to crime reported in the FBI's index of serious crime, across metropolitan areas); Ben

Significant research efforts have also addressed the relationship between healthcare spending and health outcomes. These studies tend to show that increasing public spending on healthcare improves quality of life by, for example, reducing infant and childhood mortality. Some studies, though, find that differences between state expenditures on healthcare had little effect on infant mortality rates between different states.[16] Other scholars have also examined the relationship between transportation investments and economic growth.[17]

To be sure, there are important differences between funding police or teachers and funding an agency. Many of the funds spent to ensure

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Vollaard & Joseph Hamed, *Why the Police Have an Effect on Violent Crime After All: Evidence from the British Crime Survey*, 55 J.L. & ECON. 901 (2012) (exploring the relationship between police funding and crime in the UK by, first, assuming that police funding levels are tied to the crime rate, and then considering factors including: police funding, the number of police personnel, crime rates as recorded by the police, and crime rates as deduced by police staffing and police funding levels); Ashish Yadav & Paul D. Berger, *On the Relationship Between Police Funding and Crime Rates*, 2 INT'L J. INNOVATION RES. 1 (2015) (evaluating the link between police funding and crime by comparing the following factors across fifty small cities in the United States: total reported crime, reported violent crime, annual police funding per resident, and educational attainment of residents below and above age 25).

[16] *See* Marwa Farag, A. K. Nandakumar, Stanley Wallack, Dominic Hodgkin, Gary Gaumer & Can Erbil, *Health Expenditures, Health Outcomes and the Role of Good Governance*, 13 INT'L J. HEALTH CARE FIN. & ECON. 33 (2013) (examining the relationship between public health spending and health outcomes, including infant and child mortality, in 133 low- and middle-income countries for the years 1995, 2000, 2005, and 2006); Richard Heijink, Xander Koolman & Gert P. Westert, *Spending More Money, Saving More Lives? The Relationship Between Avoidable Mortality and Healthcare Spending in 14 Countries*, 14 EUR. J. HEALTH ECON. 527 (2013) (comparing the growth of the proportion of healthcare spending to GDP with "avoidable mortality" in fourteen western countries, based on data from 1996 to 2006); David R. Morgan & James T. LaPlant, *The Spending-Service Connection: The Case of Health Care*, 24 POL'Y STUD. J. 215 (1996) (exploring the relationship between public healthcare spending at the state and federal levels, various service measures (e.g., the quantity of hospital beds and full-time equivalent healthcare workers) and several health outcomes, including low infant birthweight, infant mortality, and childhood mortality); John Nixon & Philippe Ulmann, *The Relationship Between Health Care Expenditure and Health Outcomes: Evidence and Caveats for a Causal Link*, 7 EUR. J. HEALTH ECON. 7 (2006) (analyzing the relationship between healthcare expenditures and health outcomes, including life expectancy and infant mortality, for fifteen member-states of the European Union, relying on data from 1980 to 1995).

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environmental quality are spent by regulated parties, not the EPA. That said, as the quotes above made clear, agency resources matter, and not just in the environmental field. The Food and Drug Administration, Occupational Health and Safety Administration, Federal Aviation Administration, Center for Disease Control, and a host of others have strong mandates to protect the public. There have been a few studies examining securities regulation[18] and OSHA regulation of the workplace.[19] But, overall, there has been strikingly little research examining the connection between agency resources and public health, safety, and welfare outcomes. This is most certainly true in the environmental field.

To be sure, EPA provides a great deal of useful data. Annual reports are published on environmental quality indicators for air, water and solid waste,[20] as well as detailed data on inspections, enforcement actions, fines collected, technology mandated, and other sanctions.[21] The Government Performance and Results Act requires EPA and other agencies to submit reports to Congress identifying goals and updates on how well it has achieved

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[18] In a comparative study across nations, Jackson and Roe found that agency resources (budget and staff) are a better predictor of regulatory outcomes than formal elements of regulation, arguing that increased public enforcement is an effective means of obtaining the market outcomes security regulators seek. Howell E. Jackson & Mark J. Roe, *Public and Private Enforcement of Securities Laws: Resource-Based Evidence*, 93 J. FINANCIAL ECON. 207 (2009). *See also*, James D. Cox, Randall S. Thomas & Dana Kiku, *SEC Enforcement Heuristics: An Empirical Inquiry*, 53 DUKE L.J. 737 (2003) (arguing that SEC resource limitations lead to insufficient enforcement); Jason Scott Johnston, *A Game Theoretic Analysis of Alternative Institutions for Regulatory Cost-benefit Analysis*, 150 U. PENN. L.R. 1343 (2002) (asserting that agency budget decreases will reduce regulatory capacity).

[19] McGarity and Shapiro's comprehensive analysis of OSHA inspections and workplace injuries concluded that OSHA inspections have had a greater impact on the injury rates of inspected firms and therefore that greater funding will increase workplace safety. They also cite an OSHA assertion that 15% budget cuts would lead to an additional 50,000 workplace injuries and 50,000 cases of occupational disease. Thomas O. McGarity & Sidney A. Shapiro, *OSHA's Critics and Regulatory Reform*, 31 Wake Forest L. Rev. 587 (1996). *See also*, Sydney Shapiro, Rena Steinzor, and Matthew Shudtz, *Regulatory Dysfunction: How Insufficient Resources, Outdated Laws, and Political Interference Cripple the 'Protector Agencies'*, Center for Progressive Reform White Paper #906 (August 2009) (arguing that the CPSC was responsible for 25% drop in injuries caused by durable goods but following budget cuts in the Reagan years, injury rates leveled off).

[20] http://www3.epa.gov/airtrends/aqtrends.html#comparison

[21] http://www.epa.gov/sites/production/files/2014-12/documents/fy-2014-enforcement-annual-results-charts-12-12-14.pdf

them.[22] While providing an impressive range of data, none of these reports assesses the *relationship* between funding and outcomes.

Nor have academics filled this gap. A small number of publications have addressed aspects of this issue, none directly. At a macro level, the Environmental Kuznets Curve literature has explored the relationship between GDP and common pollutants.[23] Across a wide range of countries, research has shown that as societal wealth increases, there is an inflection point where pollutants decrease. The basic explanation is that environmental quality becomes a priority once more fundamental needs such as food and shelter have been met. This is an important insight as an economy-wide matter but does not provide insight into agency funding.

There has been a small number of more specific articles. Bernauer and Kobi examined the connection between government size and air quality (as measured by sulfur dioxide concentrations) by surveying 42 countries from 1971 to 1996.[24] Islam and Lopez looked at the link between public expenditures for social goods and air pollution levels.[25] Heckman explored the relationship between management quality and air pollution.[26] Woods and co-authors tracked state-level environmental expenditures to public-health outcomes for three years, finding that, all else being equal, states with stronger enforcement and more funding have lower levels of pollution and better public health.[27]

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[22] "Departments and agencies must clearly describe the goals and objectives of their programs, identify resources and actions needed to accomplish these goals and objectives, develop a means of measuring their progress, and regularly report on their achievements." EPA's goals and assessments, though, are quite general.

[23] Grossman and Kruger; John A. List & Craig A. Gallet, *The Environmental Kuznets Curve: Does One Size Fit All?*, 31 ECOLOGICAL ECON. 409 (1999).

[24] Thomas Bernauer & Vally Koubi, *Are Bigger Governments Better Providers of Public Goods? Evidence from Air Pollution*, 156 PUB. CHOICE 593 (2013) (finding an inverse correlation – countries with larger governments suffer from more air pollution).

[25] Asif M. Islam & Ramón E. López, *Government Spending and Air Pollution in the US*, 8 INT'L REV. ENVTL. & RESOURCE ECON. 139 (2014) (finding that shifting public funding from private subsidies to social and public goods at the state level improves air quality but is not true at the federal level.).

[26] Alexander C. Heckman, *Desperately Seeking Management: Understanding Management Quality and Its Impact on Government Performance Outcomes Under the Clean Air Act*, 22 J. PUB. ADMIN. RES. THEORY 473 (2012) (finding a statistically significant but "modest or negligible" impact from spending on environmental outcomes).

[27] Neal D. Woods, David M. Konisky & Ann O'M. Bowman, *You Get What You Pay For: Environmental Policy and Public Health*, 39 PUBLIUS 95 (2009). They measure environmental spending combining all expenditures, including state, deferral and other monies such as fees and fines that pass through the state

The most relevant law review article was by Flatt and Collins. Looking at the state level, they found that an increase in state enforcement funding led to shorter periods of noncompliance under the Clean Air Act.[28] They treated noncompliance as a proxy for environmental quality. While a useful study and the most rigorous examination to date, this does not answer our research question for the simple reason that periods of noncompliance may have little impact on environmental quality. It may well be the case, for example, that the noncompliance has only marginal impacts on air or water quality because the other major emitters are in compliance. To assess the relationship between periods of noncompliance and environmental quality, we would need to know more about which parties were in noncompliance and the resulting environmental impacts.[29]

While helpful in understanding specific aspects of government resources and environmental outcomes, none of these studies has focused on EPA budgeting and environmental quality.

II. EMPIRICAL ANALYSIS

The relationship between agency funding and environmental quality is ultimately an empirical one, albeit complicated. We consider two primary hypotheses that posit how EPA funding affects environmental quality.

> Hypothesis A: An increase in EPA funding results in an increase in environmental quality.
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> Hypothesis B: Over certain ranges of environmental quality, an increase in EPA funding results in an increase in environmental quality; otherwise, an increase in EPA funding results in no change in environmental quality.

In contrast to these hypotheses stands the null hypothesis.

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budgetary process. Their assessment of environmental pollution is a composite measure of 70 environmental conditions.

[28] Victor Flatt and Paul Collins, *Environmental Enforcement in Dire Straits – There is No Protection for Nothing and No Data for Free*, 85 NOTRE DAME L. REV. (2009).

[29] *See also,* Victor B. Flatt, *A Dirty River Runs Through It (the Failure of Enforcement in the Clean Water Act),* 25 B.C. Envtl. Aff. L. Rev. 1 (1997) (arguing that lack of adequate EPA funding has diminished water quality across states).

Null Hypothesis: An increase in EPA funding results in no change in environmental quality.

To explore the hypotheses that higher funding will generally lead to higher environmental quality, at least over some ranges of environmental quality, we regress environmental quality on environmental agency funding. As described above, similar types of analyses have been conducted to determine the correlation between increasing police deployment and decreasing crime rates.[30]

Given the complexity and range of environmental pollutants, we take an intentionally reductionist approach and focus on air quality, specifically levels of particulate matter, as our dependent variable. We select particulate matter for several reasons. First, data on criteria pollutants[31]—including particulate matter—are readily available for a large number of air quality monitoring stations nationwide and over an extended period of years.[32] Second, particulate matter is a heavier pollutant, remaining suspended in the air a shorter time, and therefore travels a shorter distance from its source than do lighter pollutants. This should minimize the challenge of accounting for enforcement efforts in distant jurisdictions (which would be very relevant for pollutants that travel greater distances).[33]

Our analysis will extend from the 1990s through the present. We begin at a time that agency budgets would have reflected the requirement of the Clean Air Act Amendments of 1990, the last major air pollution statute. This also avoids the concern of accounting for initial reductions in pollution emissions that were relatively inexpensive to effect, and thus (under a rational actor model of deterrence), would have required relatively little threat of enforcement to induce compliance.

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[30] *See, e.g.*, Rafael Di Tella & Ernesto Schargrodsky, *Do Police Reduce Crime? Estimates Using the Allocation of Police Forces After a Terrorist Attack*, 94 AM. ECON. REV. 115 (2004) (effect of local deployment of police resulted in decrease in crime only within immediate area of police deployment); Hope Corman & Naci Mocan, *A Time-Series Analysis of Crime and Drug Use in New York City*, 90 AM. ECON. REV. 584 (2000) (finding evidence of police deterrence, either directly, or through arrests, of property-related and assault offenses, but not for murders); Steven D. Levitt, *Using Electoral Cycles in Police Hiring to Estimate the Effect of Police on Crime*, 87 AM. ECON. REV. 270 (1997) (finding that increases in police size have a large deterrent effect on murders, but a small deterrent effect on property crimes).

[31] *See* 42 U.S.C. § 7408 (directing the EPA Administrator to develop national ambient air quality standards for so-called criteria pollutants).

[32] *See* http://aqsdr1.epa.gov/aqsweb/aqstmp/airdata/download_files.html (last visited July 16, 2015).

[33] *See* Jonathan Remy Nash & Richard L. Revesz, *Markets and Geography: Designing Marketable Permit Schemes to Control Local and Regional Pollutants*, 28 ECOLOGY L.Q. 569, 576-78 (2001) (distinguishing among global, regional, and local pollutants).

Our regressions will analyze particulate levels against annual overall EPA funding, funding for the EPA air program, enforcement funding at regional level, and state agency funding. Because the cost of environmental compliance can sometimes vary unpredictably and unforeseeably[34]—which may tend to mask the extent to which enforcement spending spurs environmental quality—we will also control for annual state gross product and for annual state enforcement budgets.

We have chosen to use measures of environmental agency funding for a few reasons. While program-specific funding is more likely to address directly the environmental quality issue on which we are focusing, it is also less likely to remain a consistently reported budget item over time, therefore making time series data sets difficult to compile. Broader agency funding figures will relate less directly to the particular problem but are more amenable to comparisons across periods of time.

To gain some initial traction on the problem, we calculated the percentage annual change in (i) annual mean 2.5-micrometer particulate matter levels,[35] and (ii) annual spending (in 2013 dollars) on federal support for air programs and air quality management ("federal support for AQM"), which represents funding provided by EPA to state, local, and tribal authorities to achieve air quality goals.[36] The results—reported on Chart 4, with percent changes in pollution levels represented by the dotted line and percent changes in spending represented by the solid line—seems suggestive of some correlation.

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[34] *See, e.g.*, Jonathan Remy Nash, *Too Much Market? Conflict Between Tradable Pollution Allowances and the "Polluter Pays" Principle*, 24 HARV. ENVTL. L. REV. 465, 492 (2000) (explaining that market prices for tradable sulfur dioxide emissions allowances in the 1990s decreased as a result of "[r]ailroad deregulation, which decreased freight rates, has supported the use of . . . environmentally friendlier western coal).

[35] We took annual averages of the "annual 2013" measure of $PM_{2.5}$ levels at all receptor points in EPA's database.

[36] The federal support for air quality management program

> includes both EPA Headquarters and Regional Federal support to state, tribal, and local air pollution control agencies for the implementation of evaluation of programs related to the National Ambient Air Quality Standards (NAAQS). The program also includes regular review of any associated national guidance and outreach information for implementation of standards.

http://archive.epa.gov/oig/catalog/web/html/44.html (last visited Jan. 10, 2016).

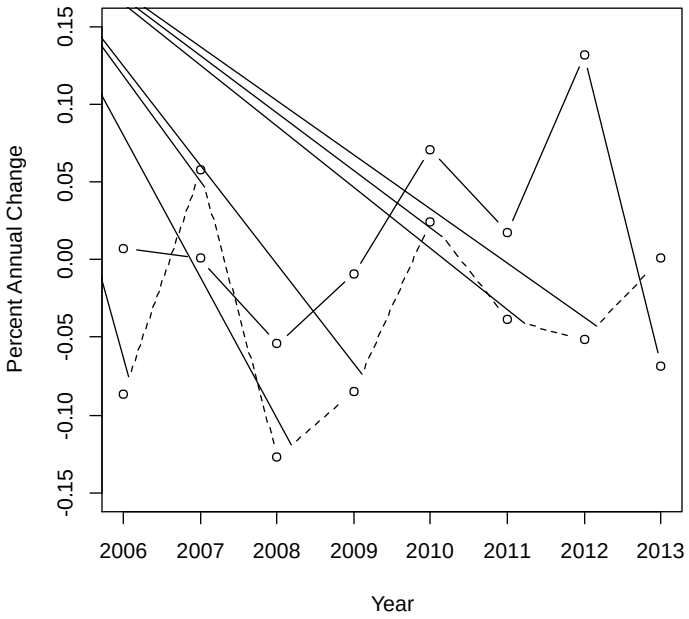

Chart 3 – Changes in Particulate Matter Levels and Federal Support for Air Quality Management

Preliminary regression analysis, however, undercuts this conclusion. In our regressions, particulate matter concentration was our dependent variable. We ran two regressions, each using a different measure of funding. For the first, we used (as in Chart 4) the change in federal support for AQM,[37] data for which we have back to fiscal year 2005. For the second regression, we used the change in the sub-budget for all of EPA,[38] data for which we have back to the fiscal year 2000.[39] We note that, to the extent that a time lag is appropriate, the federal fiscal year runs from Oct. 1 of the previous year through Sept. 30 of the next year; thus, the regressions incorporate a small time lag.

We included two control variables in both regressions. First, insofar as combustion of natural gas contributes to particulate matter pollution, we included the annual change in the national average citygate price for 1000

[37] *See supra* note 17.
[38] This represents EPA's entire budget, before rescission of prior years' funds and pension and benefits accrual.
[39] For both these variables, we initially converted the amounts in the dollars for the same year, and then calculated the percent changes.

cubic feet of natural gas.[40] Second, we included the change in the gross domestic product ("GDP") for the United States as a control variable.

Table 1 reports the results of the first regression (where the key independent variable is change in federal support for AQM). The key independent variable is *not* a statistically significant predictor of change in particulate matter concentration. Notably, despite the very low number of observations, change in GDP is statistically significant at the 10% level. While the number of observations is far too low for us to reject the null hypothesis,[41] the fact that we do find a statistically significant result for GDP and the fact that the *p*-value we find for federal support for AQM is so far from significance[42] strongly suggest to us that, to the extent that funding has any meaningful effect on environmental quality here, it is dwarfed by the impact of the national economy.

TABLE 1.—Results of regression of change in particulate matter concentration (2005-2014).

Variable	**Coefficient**	**Standard Error**	***p*-Value**
Change in federal support for AQM	-0.075	0.364	0.845
Change in natural gas prices	-0.022	0.157	0.893
Change in GDP	2.366	1.144	0.094*
(Intercept)	-0.069		

N = 9. Adjusted-R^2 = 0.172. *** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level.

Table 2 reports the results of the second regression (where the key independent variable is change in the EPA sub-budget). Once again, the key independent variable is *not* a statistically significant predictor of change in particulate matter concentration. And once again, despite a (slightly higher but still) very low number of observations, change in GDP is statistically significant, this time at the 5% level. Once again, the data lend support to the idea that, to whatever extent overall EPA funding has any meaningful effect

[40] As with the other variables, we first converted the amounts to dollars of the same year, and then calculated the annual change. We obtained the data from the U.S. Energy Information Administration.

[41] In the language of statistics, we lack sufficient observations to validate a power analysis.

[42] The *p*-value is 0.845.

on environmental quality here, it is dwarfed by the impact of the national economy.

TABLE 2.—Results of regression of change in particulate matter concentration (2000-2014).

Variable	**Coefficient**	**Standard Error**	***p*-Value**
Change in EPA sub-budget	0.070	0.169	0.690
Change in natural gas prices	-0.007	0.073	0.924
Change in GDP	1.962	0.864	0.047**
(Intercept)	-0.061		

N = 14. Adjusted-R^2 = 0.187. *** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level.

In sum, our empirical analyses offer no support for the notion that reductions in EPA budget have had an effect on environmental quality. We thus find no support for Hypothesis A. The results are not inconsistent with Hypothesis B – which posits that changes in funding will have an effect on environmental quality only over some ranges of initial funding; on the other hand, if Hypothesis B is valid, then the time period over which we conducted our study seems not to have included years during which EPA funding fell within those ranges.

[In the next draft of this article, we intend to augment our empirical analysis in three ways. First, we will use changes in concentrations of conventional air pollutant other than particulate matter as the dependent variable. Second, we intend to use as a key independent variable the change in the funding of other EPA offices—for example, the Office of Enforcement and Compliance Assurance. Third, we intend to incorporate the factor of state funding, by regressing changes in environmental quality (again in the form of changes in pollutant concentration) on changes in state environmental agency funding over time, with changes in regional EPA funding also included as an independent variable. Finally, in order to account for the possibility that funding may have an effect on quality over a more extended time horizon, we intend to run regressions that introduce a time lag between funding and quality (e.g., regressing changes in environmental quality in one year on changes in funding 2 years prior).]

III. EXPLAINING THE PRODUCTION FUNCTION

A. A MACRO MODEL OF HOW ENVIRONMENTAL QUALITY IS PRODUCED

The regressions in Part II found no correlation between EPA funding and particulate matter pollution. Terry Anderson's more macro analysis in Chart 2 found air quality improvements over an extended period of flat to declining budgets. If either of these findings is accurate for other air pollutants, which we believe to be more than plausible, then it poses a key challenge – if agency funding is not driving improvements in air quality, then what is?

We address the relationship between agency resources and environmental quality through the conceptual approach of a production function. Economists use the production function to relate the physical output of a production process, such as the proverbial "widget," to the physical inputs or factors of production, such as labor and raw materials.[43] Other disciplines, such as ecology, have borrowed the concept to help explain the input-output relationship of processes, such as a production function relating nutrient input to vegetation output in an aquatic ecosystem.[44]

Claims about whether decreasing EPA funding will or will not affect environmental protection are at heart claims about the production function of environmental protection. The "doing less with less" position argues that EPA funding has a significant impact on the nation's production of environmental quality, whereas those advocating the "doing more with less" position argue that other factors—their claims do not identify *which* factors—are more important and EPA funding can be decreased without reducing, and perhaps even improving, environmental protection. Indeed, these competing hypotheses dominate today's political rhetoric regarding regulatory agency funding, yet they have not been carefully assessed.

Clearly, much of what determines air quality lies beyond EPA's daily operations. Yet, at the same time, surely agency activity is an important part of the production of environmental quality and it remains surprising to find no correlation to its funding at all, or even an inverse correlation. That certainly would not have been expected from the quotes decrying budget cuts that introduced this article. A deeper understanding is needed of how environmental quality is produced.

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In this Part, we seek to develop a more robust and complete model of the production function of environmental quality. In short, claims that increased or decreased funding for EPA will or will not have an effect on environmental quality account for only the beginning and the end of the production function: funding is a raw input and environmental quality is the final product. Quite obviously, what goes on between those two points also matters.

At the outset, we want to make clear that determining the production function of environmental quality is dauntingly complex. There is a good reason scholars have avoided this topic. As Cliff Rechtschaffen has cautiously observed, "[c]ausality between program activities and outcomes is usually impossible to prove. Outcomes cannot generally be attributed to individual functions of an agency or program. 'Prevention' or deterrence of undesired outcomes is difficult to measure."[45]

Building a comprehensive model is beyond our scope, but building even a rudimentary model will be an improvement over the current "funding = quality" assumption. Our efforts below represent a starting point for hypotheses to explain why EPA funding may have a less influential role in the production of environmental quality than is commonly believed.

Figure 1 below sets out a simplified model of the key factors affecting environmental quality (and also of how the factors interact with one another). In addition to EPA action, these include the actions of Congress, state governments, and non-governmental organizations; technological innovation; and economic activity. In addition, it is likely that some of these factors have an extended effect over time, and indeed may have a *greater* effect only once some time has passed.

[45] Clifford Rechtschaffen, *Deterrence vs. Cooperation and the Evolving Theory of Environmental Enforcement*, 71 S. Cal. L. Rev. 1181, 1272 (1998).

Our point here is not to claim that we have captured exactly how environmental quality is determined—to the contrary, we believe the flowchart certainly oversimplifies matters—but rather to show that it is a complicated dynamic. Further complicating the picture, we assume that while environmental quality remains a goal of EPA, it may not be the sole and sometimes even the most important goal. This may seem an odd statement, for surely EPA is in the business of environmental protection. But given the agency's multiple principals and audiences, it has other concerns, as well.[46]

For example, much attention—in Congress, in the media, and by researchers—is paid to EPA's compliance and enforcement efforts. Compliance and enforcement tend to be easily quantifiable: how many enforcement actions are taken, and how large are the fines? Enforcement actions against large companies, and the imposition of large fines, have tended to draw considerable media coverage. It would hardly be unreasonable for EPA to choose to divert resources to measures that it feels are carefully followed and related to environmental quality.

Nor is there a single measure of air quality. EPA might choose to pursue environmental quality either by seeking to meet uniform nationwide

[46] *See generally,* James Q. Wilson, Bureaucracy (19XX) (discussing how government agencies often focus efforts on those activities that can be observed and counted).

standards (as does the Clean Air Act through its creation of national ambient air quality standards), or by focusing on improving environmental quality in areas where that quality is especially poor.[47]

Since there will always be more than one goal for the agency to pursue, it will need to allocate resources among its goals. The emergence of a new policy concern might cause an agency to have to spread its resources around. For example, the issue of climate change and greenhouse gases has loomed larger and larger over the last decade; budget data for EPA show that the issue has claimed funding from other (mostly air-pollution-related) issues.[48]

The extent to which Congress mandates agency action may affect the agency's decisions. In fact, even so-called "mandatory" actions run a gamut from those that are less, or more, likely actually to be undertaken. An agency might decide not to undertake—or at least not to prioritize—a "mandatory" action if it faces no real risk of reprisal. On the other hand, to the extent that Congress demands action—or empowers, for example, private citizen enforcement suits—the agency's hand might be forced.

Finally, if Congress does not mandate actions and instead vests the agency with some degree of discretion, agency choices may be determined by the extent to which agency outcomes are monitored. One might expect an agency with little oversight to feel free to pursue (i) long-term, as opposed to short-term goals, (ii) goals that are less quantifiable and less readily subject to measure, and (iii) goals that may involve only modest progress in response to spending.

Using the approach of a production function, though, we do not need to determine EPA's internal deliberations. Even if agency policy affects goal quality, so too might other factors. Thus, increasing agency spending might improve goal quality *all else equal*, but the odds are that all else will *not* be equal. For example, expending money to expand the size of a police force might well reduce crime "all else equal," but other factors—such as the state of the economy, the punishments courts are authorized to mete out, and the

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[47] *Cf.* James T. Hamilton & W. Kip Viscusi, *The Magnitude and Policy Implications of Health Risks from Hazardous Waste Sites*, *in* ANALYZING SUPERFUND 55, 76-80 (RICHARD L. REVESZ & RICHARD B. STEWART eds., 1995) (criticizing risk assessment under CERCLA statute as sometimes too stringent, in part as response to public perceptions of risks of hazardous waste sites); Jonathan Remy Nash & Richard L. Revesz, *Markets and Geography: Designing Marketable Permit Schemes to Control Local and Regional Pollutants*, 28 ECOLOGY L.Q. 569, 578-79 (2001) (explaining how the shape of the damage function for a pollutant determines whether the pollutant is better uniformly distributed or concentrated a few points).

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weather—likely will also have an effect on crime. Depending on those other factors, it is possible that an increase in spending might be seen to accompany a *decrease* in goal quality.

Moreover, between raw inputs and final product there are intermediate products important to the production function of the final product. For example, EPA does not use funding to produce environmental quality directly; it first has to produce intermediate products such as regulations, monitoring tools, education programs, and so on. EPA and other institutions then use these intermediate products to continue down the production chain until some actor or action changes conditions that *directly* change environmental quality, such as reducing emissions or restoring a wetland area. For example, an EPA regulation could be enforced by a state agency so as to require an industrial facility to install technology to reduce PM emissions. *That* is when environmental quality changes, not when EPA receives funding.

To translate this into our environmental quality model: (1) there are likely numerous institutions using raw inputs such as funding and producing or using intermediate products like regulations, standards, litigation, and monitoring, that go into the production of environmental quality; (2) the influence each input and intermediate product has on the production function depends on its marginal effects, the substitutability effects of other inputs and intermediate products, and scale effects; and (3) the overall production function can be affected by external forces such as policy instrument innovation, the creation of new institutions, and stochastic natural, market, and political events.

B. EXPLANATORY HYPOTHESES

Below we unpack these three aspects of the production function to generate plausible hypotheses regarding the relationship between EPA funding and environmental quality—in particular, to explain how the improvements in air quality that Terry Anderson demonstrated in Chart 2 occurred during an extended period of agency budget austerity.

1. Institutions and Instruments

This category includes the main components of the production function—the institutions and instruments intended to contribute to improving environmental quality—such as EPA actions, state and local actions, industry efforts, and NGO initiatives. Importantly, in all of these instances, except perhaps that of direct industry emissions, these institutional players are producing intermediate products in the form of policy

instruments. In other words, EPA uses its budget to produce regulations, monitor, sanction, educate, conduct research, etc. The same is true for state and local regulators. Industry groups develop codes of practice, and businesses and NGOs file citizen suits, lobby agency and elected officials, and mobilize at the grassroots. None of these activities *directly* produces improvements in environmental quality. These are all outputs of each institution's particular production function that then go into the larger environmental quality production function.

These intermediate products, though, are much easier to measure and link directly to resource levels, which explains why most studies of how we produce environmental protection have focused on evaluating the role of intermediate products such as enforcement actions, with little attention to their role in the larger production of environmental quality, i.e., which intermediate goods are most influential in the production function (which will likely change depending on the measure of environmental quality and over time). One could hold constant or increase funding of the agency, for example, but not contribute to environmental quality because the agency is producing the wrong intermediate products. Some of the most important of these intermediate products are described below.

a. Regulations

As mentioned above, EPA has adopted a series of regulations aimed at pollution created by coal burning. This, along with other initiatives aimed at mountaintop mining and greenhouse gases, has led some politicians to accuse the Obama Administration of a "War on Coal." Adding a scrubber or other pollution controls to comply with mercury regulations, to take one example, raises the price of operation and has led some facilities to shut down. As an indirect benefit, particulate matter emissions have likewise decreased.

This also appears to be the case for the other conventional air pollutants. Looking back at Chart 2, one can spot large drops in pollution soon after major regulatory enactments. Lead levels dropped dramatically after regulations adopted in the early 1970s and NOx fell after the 1990 Clean Air Act Amendments.

It should not be surprising that promulgation of strict regulations leads to pollution reductions. As a consequence, resources spent on regulatory drafting and implementation will likely have greater direct impacts on environmental quality than other agency expenditures. And these are relatively inexpensive activities. Moreover, agency effectiveness likely depends more on political will to write a strict rule or enforce it than agency resources.

Thus looking at agency budgets potentially misses the point. As a regulatory agency, EPA's costs are relatively minor. The main costs for reducing pollution fall on the regulated community.

Interestingly, measured in terms of the number of rules published in the Federal Register, there has been little or no correlation between regulation and budget. According to the Americans for Competitive Enterprise, a deregulatory think tank, apart from the drop in 2012-2013 that the authors attribute to a decrease in regulatory activity in the run-up to the 2012 election, EPA regulations have not noticeably been declining, as demonstrated in Chart 4 below.[49]

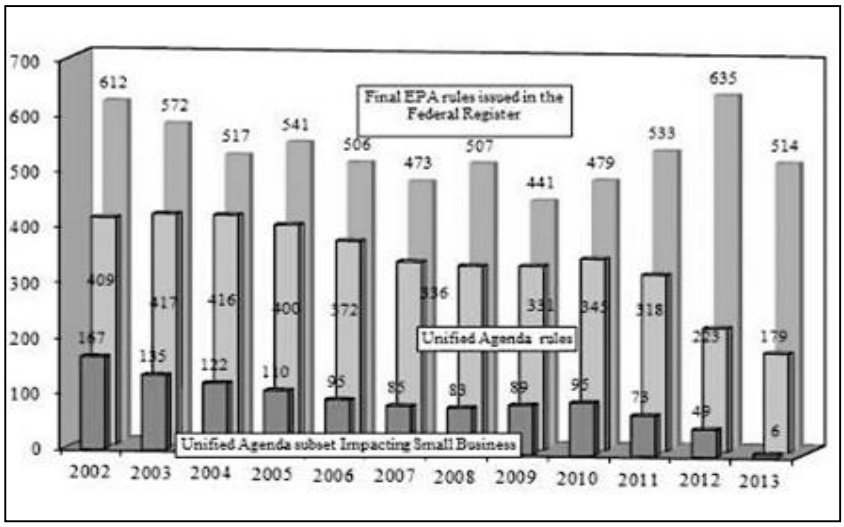

Chart 4 – EPA Regulations Trends

One explanation for this chart might be that the agency shields its regulatory offices when there are budget and personnel cuts, thus protecting their most effective units (perhaps similar to how the body shunts blood to the brain when starved of oxygen).

b. Monitoring and Enforcement

The conventional wisdom is that less agency enforcement will result in worse outcomes in the relevant policy area. As Gary Becker's classic

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[49] *See generally* Clyde Wayne Crews, *Red Tapeworm 2014: Environmental Protection Agency Regulations Declining? Don't Bet on It*, AMERICANS FOR COMPETITIVE ENTERPRISE (Sept. 23, 2014), http://freedomaction.org/2014/09/red-tapeworm-2014-are-environmental-protection-agency-regulations-declining-dont-bet-on-it/, *archived at* http://perma.cc/7LYJ-76X6.

formulation asserted, rational actors will adjust their noncompliant behavior based on the likelihood of detection and the magnitude of sanction.[50] This partly explains the results of the Flatt and Victor research. When state agencies spend less on enforcement, plants spend more time in noncompliance.

There is an equally strong body of literature, however, suggesting that much environmental noncompliance is not the result of bad faith but, rather, lack of capacity.[51] Most regulated parties, this literature suggests, will comply if they knew how. The problem is not inadequate monitoring and sanctions but, instead, lack of capacity.

Put another way, it is possible that significantly less enforcement expenditures would have little impact on environmental quality because most parties would still comply. This is an empirical question and has important implication for EPA's enforcement strategies. If true, it suggests that EPA could shift its enforcement emphasis from specific deterrence (changing the behavior of the individual charged) to general deterrence (a smaller number of enforcement actions intended to influence the larger regulated community).[52]

c. The Importance of State and Local Protection Efforts

The intermediate products of state and local agencies include regulations, inspections, and enforcement as well. If you compare the number of environmental agency personnel at the federal and state levels, state officials far outnumber those at EPA. Indeed, through its cooperative federalism model, EPA has delegated the implementation and enforcement of most of its significant environmental laws to states, writing regulations and retaining an oversight and strategic role. As a result, one would expect that the EPA budget would be less important for environmental quality than state budgets. A key question, therefore, is whether there is a correlation between state environment budgets and environmental quality. The Flatt and Collins study suggests this may be the case, but more direct research is needed. A potential problem with this explanation is that many state environment agency budgets have also been cut over time, some dramatically so.

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d. Industry Codes of Conduct

Linked to the explanation of market forces described above, private standards may serve the purpose of regulation and obviate the need for EPA resources. Michael Vandenberg has provided many examples of private certification systems, for example, effectively acting as regulations through supply chains and enforced by large retailers such as Walmart and Home Depot.[53] The key question, of course, is to what extent such private standards actually influence environmental quality.

e. Non-state Actors' Use of Citizen Suits

One of the unique features of environmental law is the ability of non-state actors to step into the shoes of environmental authorities and litigate against polluters or agencies when they are not carrying out mandatory duties or are acting arbitrarily or capriciously. These citizen suits can be pathbreaking and certainly offer one likely explanation for why environmental quality might not decline, or could even increase, during times of agency austerity. Indeed, the number of citizen suits clearly increased during the Reagan Administration, when enforcement efforts were reduced.

2. Functional Dynamics

As Figure 1 and the previous section made clear, there are many players influencing the production of environmental quality – EPA, Congress, states, regulated parties, etc. – and they are engaged in making and using a variety of intermediate products aimed at furthering the production chain towards the final product of environmental quality. Ultimately, though, what actually *directly* moves the needle for environmental quality? There are two primary ways to do so. One is through direct intervention in the environment, such as through site remediation, ecological restoration, eradication of invasive species, and so on. The other is through inducement of human behavioral change that leads to reduction of harms to the environment.

EPA, for example, produces intermediate products aimed at both avenues of influence—it sues under Superfund to force site remediations and it promulgates regulations to force reduction of PM emissions. Yet these are

53.Michael P. Vandenberg, David Daniels Allen Distinguished Chair of Law, Director, Climate Change Research Network, Vanderbilt Law School, Keynote Address at Pace Environmental Law Review Symposium: Reconceptualizing the Future of Environmental Law (Mar. 20, 2015) (transcript on file with Pace Law School), *available at* http://www.law.pace.edu/symposium-reconceptualizing-future-environmental-law, *archived at* http://perma.cc/YG2E-RH7D.

not the only possible intermediate products EPA can make or use, and EPA is not the only player that can make or use intermediate products. In this section, therefore, we turn to examining how the production system works.

a. Marginal Returns

Each production input that influences environmental quality, from raw inputs like funding to intermediate product inputs like regulations, likely does so with something other than a linear relationship. In all probability, adding marginal increments of an input over time eventually leads to diminishing marginal returns.

For example, let's say EPA initiates a new widget facility inspection program. In year one it inspects 100 facilities and detects 200 violations, which when corrected reduces PM emissions by quantity X. Each year it adds 100 facilities into the program until after five years all 500 widget facilities are being inspected every year. It is highly unlikely that the program will from then forward produce PM reductions of 5X year after year. In all probability each time a facility is first inspected the most egregious violated are detected—the program catches the low hanging fruit with the first inspection. Over time, most violations the program detects are minor except for possible "bad actor" violations, which means the program cannot possibly expect to return the same annual PM reductions over time.

It is also possible that a particular policy instrument has diminishing marginal returns because of physical properties of technology and the environment. It may simply not be possible to produce a widget without some level of PM emissions. Once regulation or other measures have squeezed the widget industry down to that level, adding more of those inputs will yield no returns on the per-widget PM emissions—only reductions in total widget production will produce lower total emissions. This is why many pollution regulation programs take technology into account. Likewise, the environment itself may pose limits on pollution reduction. Arsenic, for example, exists at natural background levels in many groundwater systems, and no amount of regulation of arsenic pollutant emissions will move that needle downward.

This diminishing marginal returns effect could help explain the lack of correlation between EPA funding and PM reductions over our study period. Whatever mix of intermediate products EPA is throwing at PM may have reached a phase of highly diminished marginal returns, in which case decreasing budgets that support those intermediate products will initially, and perhaps for a good while, produce little incremental change in PM.

A consideration of marginal returns also cautions not reading too much into Terry Anderson's graph. No correlation between *marginal* EPA funding changes and air quality measures does not mean no correlation between the EPA *in aggregate* and air quality. While we cannot demonstrate this from our analyses, we think it likely that major cuts in EPA funding eventually would result in significant reductions in environmental quality. How much funding would need to be reduced before the nonlinear production function tips back into the region of high marginal effects is difficult to say, but it is certainly a plausible projection.

b. Input Substitutability

Given the large universe of institutions and instruments at work in the environmental quality production function, it is highly likely that (1) not every input has the same marginal returns curve, and (2) some inputs can substitute for others and improve production efficiency. To put it bluntly, if you had $100 million to spend on environmental quality improvement, would you simply hand it all to EPA and say, here you go, run with it? Certainly not. A prudent investor in environmental quality would investigate which inputs get the most *marginal* bang for the buck. Perhaps financing industry best practices codes is more effective on the margin in reducing PM than adding to EPA's monitoring budget, or perhaps financing NGO citizen suits is more effective than financing industry codes. The substitutability effect could also help explain why EPA funding has no correlation to PM pollution. If the intermediate products EPA is using have low marginal returns and other institutions are using products with higher marginal returns, the other institutions are necessarily going to have more influence on PM. We extend this theme below in Part IV.

c. Path Dependency from Capital Investments

While the relationship between strict regulation and improvements in environmental quality is not surprising, it does beg a question: Why do regulated parties comply initially with the regulations, and then continue to comply over time? For many pollutants, capital investment locks in pollution gains. For those air pollutants that are reduced by pollution control devices, once the control technologies have been installed they should keep pollutant levels down so long as there is not a high cost of operation and maintenance. And even if there are high operating costs, companies may still choose to keep the technologies in place. The implication is that once EPA sets the reductions in motion through regulation, the reductions become locked in place irrespective of later reductions in EPA's budget. While this could

explain initial drops in pollution, it does not explain why the concentrations of many pollutants continued to drop over time.

3. External Forces

A major driver of air quality is unintended, in the sense that there are larger forces determining air quality that are not motivated by environmental concerns. These include market forces, natural stochastic events, and the nonlinear utility curve. This category is important because it could overwhelm actions by EPA, indeed by most of the relevant parties, to influence environmental quality.

a. Institution and Instrument Innovation

Just as a new technology or new product can change the production function of a widget, the creation of new institutions and instruments can strongly affect the production function. The creation of EPA in 1970 changed the production function of environmental quality by providing an institutional framework for the implementation of the new environmental laws.[54] The lead phasedown, Toxic Release Inventory, and SO2 cap-and-trade programs were all new *kinds* of intermediate products that changed the production function. They were not just iterations of traditional regulatory approaches. Some market-based instruments, for example, have greatly reduced the costs of regulations.

b. Market Effects

Market forces act at both the macro and micro levels. At the macro level, economic growth has a major influence on levels of production and therefore levels of pollution. The recent history of China provides clear evidence of that. So, too, in the United States. Recessions tend to reduce pollution while boom periods lead to greatly increased levels of potentially polluting activities.[55] We addressed this dynamic in our regressions by controlling for GDP.

At the micro level, every pollutant tells its own story. In particular, parties may have economic incentives to reduce pollution wholly apart from regulatory compliance. It may just be good business.

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[54] Though see work of Jonathan Adler arguing that environmental quality measures were improving through state action well before the creation of EPA.

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Some of the reductions in particulate matter, for example, can be explained by commodity prices. In particular, fracking has dramatically changed energy markets in recent years. Natural gas, a cleaner fuel than coal, has dropped in price. As a result, there has been a wide-scale shift as coal-fired utilities reduce their coal use and build natural gas fired units. The overall effect is a drop in particulate matter from electricity generating units.[56]

While market forces are clearly part of the story, this cannot be the sole explanation for three reasons. First, particulate matter concentrations were falling before the advent of fracking. Second, other conventional air pollutants also have fallen over time so, at a minimum, researchers would need to understand the role of market forces in their story. And finally, another market reason for fuel switching from coal to natural gas has been the added costs of regulatory compliance from recent Clean Air Act regulations aimed at coal-burning pollution. Regulation is also part of the explanation.

c. Natural Stochastic Events

Parents forever debate the relative contributions of nature and nurture, and environmental protection is no different. While anthropogenic emissions and waste clearly affect environmental quality so, too, does natural variation. Particularly wet seasons will reduce concentrations of water pollutants while droughts will increase them. Wind patterns can disperse of concentrations air pollutants. Periods of clear skies and still air will lead to greater production of smog than windy and overcast periods. Thus our contributions to environmental quality will always be in combination with the changing environmental conditions, themselves.

As a result, even when government resources dwindle or there is little political will for strong enforcement, there exists a potent back-up. Organized interest groups can take on enforcement efforts at times of agency austerity.

IV. FOUNDATIONS FOR RESEARCH

We opened this paper by contrasting the conventional wisdom that reduced EPA funding will impair environmental quality with Terry Anderson's chart purporting to refute that relationship. Neither view, however, relies on more than a superficial black box model of the production function of environmental quality with only one input—EPA funding—and

[56] Craig Oren

no explanation of its functional properties. Part II ran a series of regressions and found no statistically significant correlation between agency budget and measures of air quality. Part III looked inside the box of the production function of environmental quality, setting out competing hypotheses to explain Terry Anderson's graph and why environmental quality seems so unconnected to agency resources.

These hypotheses, as well as others we did not include for the sake of space, are all plausible. The fact that we find no correlation between EPA funding and air quality could be because EPA is producing the wrong intermediate products, or not enough of the important ones compared to the intermediate products other institutions can produce (e.g., the most important drivers during this time period may have been citizen suits or the low price of natural gas). Or, equally, perhaps EPA is producing the right intermediate products and doing so efficiently, such that budget austerity does not hinder the production of environmental quality.

The key points to emphasize are that (1) these alternatives suggest very different realities with very different law and policy implications, (2) we don't know which is accurate, and (3) we don't have an established methodology to figure this out.

Why should we care about developing a more sophisticated understanding of the relationship between agency funding and environmental quality? The obvious answer is that the competing black box models leave policy makers deciding the appropriate size and allocation of EPA's budget, as well as the larger environmental protection budget, with no means to assess their decision apart from the percent increase or decrease compared to previous budgets.

The Republican candidate for President, Donald Trump, stated in a March, 2016, debate that he would dramatically reduce the size of the EPA. As he described, "We're going to have little tidbits left but we're going to get most of it out."[57] When presidential and Congressional candidates call for major budget cuts to agencies, we need to understand better the likely consequences. But this is not a problem only in times of austerity.

Consider, for example, how little basis there would be for knowing how to expend an environmental protection budget wisely and effectively in times of *abundance*. As a thought experiment, if you were given control of an additional $1 billion to spend on environmental protection over the next five years and instructed to maximize the environmental quality

[57] Kyle Feldscher, *Trump says he'd eliminate 'Department of Environment Protection'*, WASHINGTON EXAMINER, March 3, 2016.

improvement return on the dollar, where would you invest? What expenditures would yield the greatest marginal yield of environmental quality? Our production function approach suggests four major questions as you undertake this challenge.

First, since EPA is not the only player in the environmental protection game, you would want to know how to distribute investment *institutionally* – between federal programs, state and local programs, environmental NGOs, private sector industry, and other actors. It may very well be the case that supporting compliance training in private sector industrial facilities would yield a greater return than investing the same amount in EPA's facility inspection program.[58] Investing in urban land trusts to secure ecosystem services such as water filtration and groundwater recharge could be more efficient at producing those benefits than imposing tighter federal regulation of development in wetlands.[59] Or perhaps the low-hanging fruit lies in state programs facing even more austerity than EPA. Dollar for dollar, beefing up state resources might make more of a difference to environmental quality.

There is a great deal of scholarship on these different policy instruments as well as case studies of their application. There is remarkably little to go on, though, for how to allocate *between* the institutional actors undertaking these initiatives. To take a particular example, we have learned a lot about the private certification of forest products and which programs are more effective than others.[60] We still know little, though, about the appropriate balance between private certification programs and public regulation of forests. This is a harder question, to be sure, but of fundamental importance in a world of scarce resources.

Second, once EPA's investment share is allocated, what should you instruct EPA to do with the newfound money to achieve your efficiency mandate? Would restoring programs that experienced the most in terms of budget cuts in the past be the best return on the dollar? Our findings suggest not—those cuts do not appear to have had an effect on environmental quality. So which intermediate products that EPA produces should receive the new money? Maybe it would be most effective for EPA to experiment with producing new intermediate products. Again, there is virtually no empirical foundation on which to base these decisions.

Third, we can think of *resilience* as a special kind of intermediate product meriting its own consideration. We have little understanding of the extent to which past decades of austerity may have deteriorated the resilience

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59 Catskills story

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of EPA and other state and local agencies. Many of the narratives about the drinking water crisis in Flint, Michigan, have pointed the finger at under-funded environmental agencies. This was, they charge, a tragedy waiting to happen. The widescale governmental failure in the Flint drinking water crisis may be a one-off anomaly, or it could be evidence of cracks building in the public governance infrastructure.[61]

Investment in maintaining resilience of infrastructure—whether highway bridges[62] or a metro system[63] or public governance—rarely provides an obvious and immediate return on the dollar, but failing to invest will eventually take its toll. Collapse can be nonlinear, and repair efforts might come too late to avoid a cascade of failure. From this vantage, both the environmental groups decrying budget cuts and Terry Anderson could be correct. It may be the case that reduced agency funding has little correlation to measures of environmental quality but a close correlation to individual pollution disasters.

Are we close to that tipping point with EPA and other federal and state public governance institutions? Does Terry Anderson's chart take a drastic turn for the worse or do the lines keep extrapolating indefinitely? Again, we do not know.

Fourth, how will you measure your success? The regulatory state, and environmental policy in particular, has relied heavily on analysis of aggregate social costs and benefits as a means of evaluating the merits of regulatory initiatives, such as a rule lowering allowable PM emissions. In some cases—for example, where minimum public health standards are mandated—cost-benefit analysis is not allowed;[64] however, in most cases it is required[65] and in some can be the driving factor in determining the legality of a new regulation.[66]

Despite the prevalence of this kind of cost-benefit analysis in agency decisionmaking, it will not be of much use in your budget investment allocation decision because that requires a marginal analysis. Specifically, what is the impact on environmental quality from an incremental investment in a particular institution's budget?

This is not to suggest that aggregate cost-benefit analysis is useless. It provides valuable insights and information about the total social costs and

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64 example

65 Recent SCOTUS case etc.

66 example

benefits flowing from an existing or proposed environmental protection measure, such as a PM emission standard, and in that sense informs the return on investment in the measure. But it is an analysis of the measure's *aggregate* social costs and benefits, not a marginal analysis of what the last institutional budget dollar produced in incremental gains.

Your investment decision, by contrast, turns on comparing the improvement in environmental quality from additional funding for an intermediate product of environmental protection. Will the money go to regulation, enforcement, education, industry training, or a different institution altogether?

Similarly, to analyze budget cutting we would need to assess the impact on environmental quality from a one percent budget cut versus a five percent budget cut. Knowing that the *total* social costs of a program on the chopping block are X and the *total* social benefits are Y will not answer these questions, except in the unlikely case in which the return on budget investment is constant across the entire production function from the first budget dollar to any sized budget.

For example, if an EPA enforcement program were shown to have aggregate social benefits twice those of social costs, this would be a positive sign about the program's overall effectiveness. But this would not necessarily mean that investing more in the agency's enforcement program budget is a good decision. It is entirely possible that most of the environmental quality gains could have been secured with a smaller budget investment in the first place and adding more money yields little additional gain. Conversely, if the program were shown to have costs twice those of benefits, this would not necessarily mean the program's budget should be eliminated, as scaling back to a smaller program budget could continue to produce most of the environmental quality benefits *and* improve its cost-benefit profile.

Put simply, aggregate social cost-benefit analysis of particular initiatives, such as lowering emission standards or mandating employee training, isn't asking the same question we are asking—what's the marginal impact on environmental quality of raising or cutting EPA's or any other institution's budget by some increment? As practiced, cost-benefit analysis in the modern regulatory state is focused on the net social outcome of intermediate products, whereas as our question is focused on how to allocate institutional budget investments or cuts to most efficiently produce environmental quality bang for the buck. In times of austerity and budget cuts, therefore, aggregate cost-benefit analysis alone cannot fully inform decisions about where to cut (or invest) the next budget dollar.

The key point is not that cost-benefit analysis is not an important analytic tool. To the contrary, it can be very informative. That's why the

regulatory state has worked so hard to develop and deploy cost-benefit analysis, with Executive Orders, legislative mandates, and other government apparatus erecting a vast system of cost-benefit analysis to support policy decisions. Marginal return analysis of institutional budgets could be just as informative and valuable. But it, by contrast, is neither required nor conducted prospectively or retrospectively.

To be sure, EPA and many other public and private entities compile reports on environmental quality, but few such studies purport to correlate those improvements with returns on investment in the agency's budget. As important as investment in cost-benefit analysis is to decisionmaking, a similar need exists for a systematic research program to assess agency budget return on the dollar over time.

Viewing environmental quality as a production function thus opens up a whole series of important research questions. More specifically, we propose the following research agenda:

Developing Methods to Measure Budget Yield. Federal and state agencies collect mountains of data on environmental quality and conduct comprehensive cost-benefit analyses, but almost never ask the question regarding marginal return on the dollar. It may be possible to extend the kind of empirical inquiry we have started to derive more granular data about budget returns. For example, comparing the historical budgets of multiple state water or air quality programs against movements in relative environmental quality indicators could begin to provide more insight than is possible in a single-agency/single-medium study like ours.

One of the limitations of our study was the lack of such historical data going far back. It would be useful, therefore, if agencies and other institutions began even more comprehensive and granular accounts of budget investments over time. As program budgets scale up, are cut, or stay flat, agencies should monitor relevant environmental quality indicators and conduct analyses like ours. And as institutions design new intermediate products, perhaps by leveraging emerging technologies such as big data or machine learning, research should be conducted from inception to track its costs and to detect shifts in the relevant environmental quality metrics. Better yet, experiments could be conducted to provide a more controlled research environment. For example, inspections at water polluting facilities could be boosted in one watershed compared to another similar watershed and changes in water quality measured.

In short, our message is to begin tracking the data necessary to refine our understanding of the marginal returns to environmental quality from investments in budgets for different institutions and their intermediate products. Of course, designing such research is challenging: the

environmental baseline must be established, other possible factors such as pollutant transport and economic fluctuations accounted for, and conditions carefully monitored and measured. Different lag times between budget investment and changes in environmental quality will complicate assessment of any one program and comparisons across programs. And the ultimate conundrum is that, particularly in times of austerity and budget cuts, new budgets for this kind of research could be hard to come by. But even those in favor of cutting budgets ought to appreciate the benefits of funding research to inform which budgets to cut and by how much! The point, however, is that no research of this kind is being conducted at all, at least none that has been reported, and these tools need to be developed if there is to be any meaningful traction on the higher-level questions that follow.

Assessing and Maintaining Resilience. Since the early 2000s, there has been an explosion of theory and research on the theme of organizational resilience in the business enterprise context.[67] There has also been a rising focus by agencies like EPA on how they can promote resilience in environmental quality.[68] Only recently, however, has the resilience theme been pointed at public agencies themselves—how to make and keep them resilient.[69] Notwithstanding privatization rhetoric, the public turns to agencies like EPA, and not generally to the private sector, to protect against failures like the Flint drinking water crisis and to respond when they nonetheless occur, when return on the dollar is not the primary concern. Further research on what supports and sustains public agency resilience, including the baseline investments needed to put it in place, is thus desperately needed. Moreover, to the extent that the baseline investment needed to sustain agency resilience is considered off the table for purposes of the return on the dollar question, which it should be, its magnitude needs better definition.

Evaluating and Comparing Intermediate Products. This question requires researchers to consider which intermediate goods are most important to environmental quality. From a historical perspective, there may be much to learn from EPA's strategic response to Congressional zero-budgeting strategies. Indeed, it may be the case that budget cuts on the margins do not really influence environmental quality. The converse of this analysis is worth considering, as well. Which aspects of environmental quality are most at risk from reduced EPA activity and which are less vulnerable to backsliding? This research would focus on those agency functions which most depend on non-substitutable options. In other words, certain agency resources can be substituted with private or market resources in periods of austerity (perhaps such as training and education), while others cannot as easily (perhaps such as regulation development and enforcement). Likewise, for substitutable

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intermediate products, which institution does a better job at production? For example, EPA might be more efficient at providing educational materials, but industry more efficient at providing training.

Allocating Between Institutional Actors. Armed with a better handle on which intermediate products provide the best return and which institutions are most capable and efficient at producing them, macro-level research could begin to focus on broader comparisons of overall institutional performance over time. We anticipate that there remain today many high-yield options that represent low-hanging fruit. For example, private governance initiatives such as contractual supply chain control are relatively new, but can yield significant gains in environmental quality. Research could be devoted to identifying such opportunities and tracking investment and returns.

Over time, of course, as an institution's low-hanging fruit is picked off, the overall marginal yield of further investment in that institution should fall and eventually level off. Indeed, this may be precisely what has happened with EPA—why its budget and environmental quality do not appear correlated in any significant way. It may be that over time different institutions level off at different marginal yields, which could help guide investment decisions. Institutions with persistently lower marginal yields could then begin experimentation by with innovative new intermediate products and production methods which, if they produce high marginal yields, would be a focal point for new budget investment. Research as to which institutional actors have the best innovation track record can support that investment decision as well. Again, cost-benefit analysis cannot produce the information needed to guide these kinds of decisions.

The difficulty of providing empirical answers to the questions we have raised should provide for caution and humility. The production function of environmental quality is truly complex. This explains in large part why our literature search uncovered virtually no scholarship on the questions set out above. Seeking to answer these questions, even at a preliminary level, will require an interdisciplinary research effort among lawyers, economists, and political scientists, at least.

CONCLUSION

While difficult to study, the relationship between EPA funding and environmental quality is a research area of fundamental importance, raising questions that bear on major issues of public debate. Importantly, while our focus has been on the environment our larger point holds true for any agency whose mission centers on improvement of social welfare. Developing methods to measure budget yield, assessing and maintaining resilience, evaluating and comparing intermediate products, and allocating between institutional actors are no less relevant for OSHA and the Department of

Health and Human Services as for EPA. Our hope is that this article's exploration of the issues provides a useful base upon which future scholarship can build.