Analysis of The Ozone Regulation Effect on Employment and industry output in the US

Group 4: Ardhi Wadhana, Rio Pramudita, Faiz Philarette, Sophie Hsiao, Takato Murai

1. Introduction

Ozone regulation stands at the forefront of environmental policy, playing a pivotal role in shaping both economic dynamics and ecological health in the United States. After decades of implementation, Ozone Regulations in the US have brought considerable implications for health and air quality. Some economists consider this policy as a costly policy since it affects industrial output and labor earnings. However, some support this regulation because the benefit that comes within it outweighs the costs. This question should be answered by having an assessment of this policy considering cost and benefit that are related to this policy.

This comprehensive exploration delves into the United States' Ground-level Ozone Regulation, particularly governed by the National Ambient Air Quality Standards (NAAQS), and assesses its intricate effects on the national economy. This study does not only scrutinize the implications for employment and industry in the US due to ozone regulations, but also extend the analysis to air quality and health. This research aims to unravel the interconnected web between ozone regulation, economic activities, air quality, and health. By understanding the nuanced dynamics of ozone regulation, this study aims to provide policymakers and stakeholder with holistic assessment based on evidence and economic model.

2. Ground-level Ozone Regulation

The management of ground-level ozone in the United States is overseen by the National Ambient Air Quality Standards (NAAQS). These standards are a set of laws related to outdoor air quality that were created under the Clean Air Act by the U.S. Environmental Protection Agency (EPA). The primary objective of the Environmental Protection Agency (EPA) is to safeguard human health and the environment by mitigating substantial hazards, facilitating and undertaking scientific investigations, and formulating and implementing regulatory measures regarding the environment.[1]

A. The evolution of Ground-level Ozone Regulation

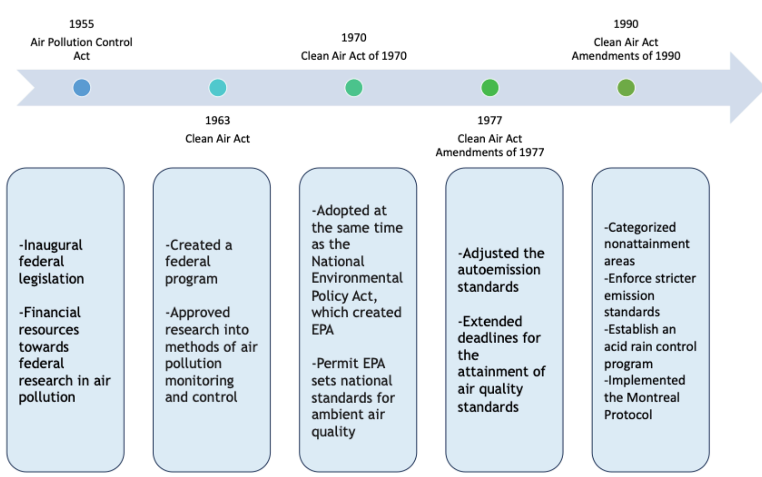

Figure 1. The evolution of Ground-level Ozone Regulation

[1]United States Environemntal Protection Agency (EPA). (n.d.).Environmental Protection Agency (EPA). Retrieved from https://www.usa.gov/agencies/environmental-protection-agency

a. Air Pollution Control Act (1955)

The Air Pollution Control Act of 1955 marked a significant milestone as the inaugural federal legislation addressing the issue of air pollution, which allocated financial resources towards federal research in air pollution.[2] Nonetheless, the Act acknowledged air pollution as a significant problem that might jeopardize public health rather than giving the federal government the power to control it.[3]

b. The Clean Air Act Amendments (1963)

The act created a federal program and approved research into methods of air pollution monitoring and control within the U.S. Public Health Service.[4]

c. The Clean Air Act Amendments of 1970

This act permitted the creation of extensive national and local laws to restrict emissions from mobile and stationary (industrial) sources; and the National Ambient Air Quality Standards (NAAQS), State Implementation Plans (SIPs), New Source Performance Standards (NSPS), and National Emission Standards for Hazardous Air Pollutants (NESHAPs) are the four main regulatory initiatives that have an impact on stationary sources.[5] The 1970 amendments set the rules for how the EPA sets national standards for ambient air quality. They also required a 90% drop in emissions from new cars by 1975, set up a program to make sure that major new sources of air pollution use the best control technology available, created a program to regulate air toxics, and gave the federal government a lot more power to enforce the rules.[6] This highly significant piece of law was adopted at the same time as the National Environmental Policy Act, which created the Environmental Protection Agency (EPA) in the United States to carry out the many mandates contained in these Acts.[7]

d. The Clean Air Act Amendments of 1977

Requirements for sources in non-attainment regions for NAAQS—a region that fails to achieve one or more federal air quality standards—were included in the 1977 CAAA.[8]

e. Clean Air Act Amendments of 1990

Amendments made to the act in 1990 encompassed the following provisions: (1) categorize nonattainment areas based on the degree to which they surpass the standard, customizing planning, deadlines, and controls to suit the status of each area; (2) enforce stricter emission standards for automobiles and other mobile sources of pollution; (3) mandate the use of reformulated and alternative fuels in the most polluted regions; and (4) revise the air toxics section by instituting a new program of technology-driven standards and tackling the issue of excessive pollution; (5) Introduce a marketable allowance scheme to facilitate flexible implementation of an acid rain control program; (6) mandate the establishment of a permit program administered by the state for the operation of significant air pollutant sources; (7) execute the Montreal Protocol to gradually eliminate the majority of ozone-depleting chemicals; and (8) revise the enforcement provisions to align with those of other pollution control acts, including granting the EPA the authority to levy administrative penalties.[9]

B. National Ambient Air Quality Standards (NAAQS)

The act mandates that the EPA establish National Ambient Air Quality Standards (NAAQS) for air pollutants (Section 109).[10] To date, the EPA has issued NAAQS for the following six air pollutants or

[2] EPA. (n.d.). Evolution of the Clean Air Act. Retrieved from https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act
[3] EPA (n 1)
[4] EPA (n 1)
[5] EPA (n 1)
[6] Congressional Research Service. (2022). Clean Air Act: A Summary of the Act and
Its Major Requirements. p.1. Retrieved from https://crsreports.congress.gov/product/pdf/RL/RL30853
[7] EPA. (n.d.). Learn about NEPA. Retrieved from https://www.epa.gov/nepa/what-national-environmental-policy-act
[8] EPA (n 1)
[9] EPA (n 1)
[10] The U.S. Government Publishing Office. (2013). United States Code, 2013 Edition, Title 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 85 - AIR POLLUTION PREVENTION AND CONTROL, SUBCHAPTER I - PROGRAMS AND ACTIVITIES, Part A - Air Quality and Emission Limitations, Sec. 7409 - National primary and secondary ambient air quality standards. Retrieved

pollutant groups: lead, sulfur dioxide (SO2), particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), carbon monoxide (CO), ozone, and lead (Pb).[11] The legislation requires the EPA to assess the scientific data that forms the foundation of the standards every five years and, if required, modify the standards.[12]

C. Nonattainment

The act determines the "design value" for categorizing nonattainment areas using air quality monitoring devices, and these categories have been modified twice in tandem with the ozone standard revision.[13] After EPA modified the ozone standard, ppm averaged over a one-hour period changed from 0.08 ppm in 1997, to 0.075 ppm in 2008, and eventually to 0.07 ppm in 2015.

Table 1 and 2 shows the change of nonattainment areas. In the first nonattainment requirements under 1979 Standard, 98 areas were classified in one of the four categories, and only Los Angels represented for Extreme category. Thanks to the clean air progress, the number of nonattainment area turns into 49 from 98 under the 2015 standards as of July 2022 with the stricter design values than the previous design ones.

Table 1. Ozone Nonattainment Classifications under the 1979 Standard as of 1990[14]

Class	Marginal	Moderate	Serious	Severe	Extreme
Deadline	1993	1996	1999	2005-2007[a]	2010
Areas[b]	42 areas	32 areas	14 areas	9 areas	1 area
Design Value	0.121 ppm-0.138 ppm	0.138 ppm-0.160 ppm	0.160 ppm-0.180 ppm	0.180 ppm-0.280 ppm	≥0.280 ppm

a. Areas with a 1988 design value between 0.190 and 0.280 ppm had 17 years to attain; others had 15 years.
b. Number of areas in each category as of the date of enactment.

Table 2. Ozone Nonattainment Classifications under the 2015 standard as of 2022[15]

Class	Marginal	Moderate	Serious	Severe[a]	Extreme
Deadline	2021	2024	2027	2033-[a]	2038
Areas[b]	38 areas	1 areas	5 areas	3 areas	2 areas
Design Value[c]	0.071 ppm-0.081 ppm	0.081 ppm-0.093 ppm	0.093 ppm-0.105 ppm	0.105 ppm-0.163 ppm	≥0.163 ppm

D. Air Quality Implementation Plans

In accordance with Section 110 of the legislation, states are obligated to develop and submit State Implementation Plans (SIPs) to the EPA for verification of their adequacy in meeting statutory obligations. These plans are developed using emission inventories and computer models to forecast the likelihood of air quality violations; furthermore, the state is responsible for implementing supplementary controls on existing sources of emissions to prevent "exceedances" of the standards.[16] According to the

from https://www.govinfo.gov/content/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapI-partA-sec7409.htm

11 Congressional Research Service. (2022). Clean Air Act: A Summary of the Act and Its Major Requirements. p.3. Retrieved from https://crsreports.congress.gov/product/pdf/RL/RL30853

12 EPA. (n.d.). Process of Reviewing the National Ambient Air Quality Standards. Retrieved from https://www.epa.gov/criteria-air-pollutants/process-reviewing-national-ambient-air-quality-standards

13 Congressional Research Service. (2022). Clean Air Act: A Summary of the Act and Its Major Requirements. p.4. Retrieved from https://crsreports.congress.gov/product/pdf/RL/RL30853

14 Congressional Research Service. (2022). Clean Air Act: A Summary of the Act and Its Major Requirements. p.5. Retrieved from https://crsreports.congress.gov/product/pdf/RL/RL30853

15 Congressional Research Service. (2022). Clean Air Act: A Summary of the Act and Its Major Requirements. p.5. Retrieved from https://crsreports.congress.gov/product/pdf/RL/RL30853

16 Congressional Research Service. Clean Air Act: A Summary of the Act and Its Major Requirements (2022). pp.3~4. Retrieved from https://crsreports.congress.gov/product/pdf/RL/RL30853

1990 amendments, failure to submit a SIP, submit a SIP that is insufficient, or fail to implement a SIP will result in penalties from the EPA.[17]

Implementation plans are also classified into regional level, and federal level, called Tribal Implementation Plans (TIPs)[18], and Federal Implementation Plans (FIPs)[19], respectively. Figure 1 shows the classification of the Air Quality Implementation Plans.

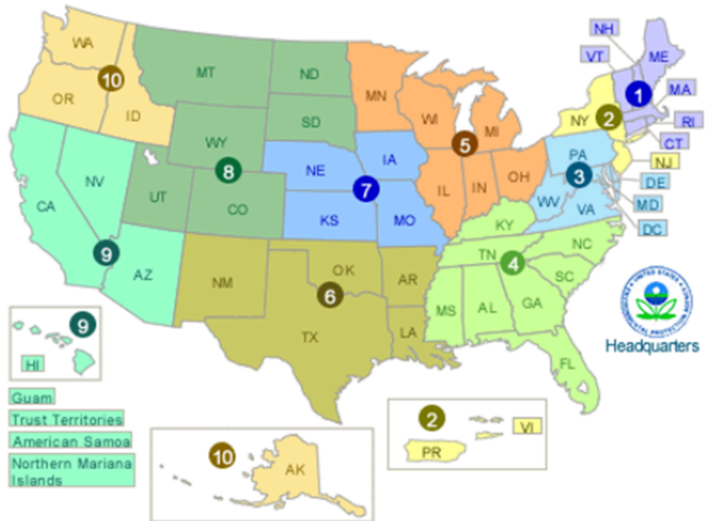

Figure 2. Classification of the Air Quality Implementation Plan[20]

Table 3 illustrates the characteristics of SIPs in California State (CA) and New York State (NY). The suggested SIP actions in CA outline the regulatory and strategic methods required to implement cleaner technologies and fuels, aiming to comply with air quality standards within the deadlines set by the Clean Air Act. These initiatives collectively represent CARB's pledge to secure all needed reductions from state-regulated sources to adhere to the 70 ppb ozone standard and require the federal government to further implement regulations for air quality internationally. New York's SIP focuses on controlling emissions in densely populated areas, particularly in New York City, as well as addressing pollution from transportation and industrial sources, which will contribute to achieving and maintaining the national ambient air quality standards (NAAQS) for ozone, and these measures are in line with the requirements outlined in the Clean Air Act.

Table 3. Characteristics of SIP in CA and NY

State	Characteristics of SIP
California (2022 State Strategy for the	Proposed Measures: ● On-Road Medium- and Heavy-Duty Vehicles

[17] The U.S. Government Publishing Office. (2013). United States Code, 2013 Edition, Title 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 85 - AIR POLLUTION PREVENTION AND CONTROL, SUBCHAPTER I - PROGRAMS AND ACTIVITIES, Part A - Air Quality and Emission Limitations, Sec. 7410 - State implementation plans for national primary and secondary ambient air quality standards. Retrieved from https://www.govinfo.gov/content/pkg/USCODE-2013-title42/html/USCODE-2013-title42-chap85-subchapI-partA-sec7410.htm
[18] EPA. (n.d.). Basic Information about Air Quality TIPs.Retrieved from https://www.epa.gov/air-quality-implementation-plans/basic-information-about-air-quality-tips
[19] EPA. (n.d.). Basic Information about Air Quality TIPs.Retrieved from https://www.epa.gov/air-quality-implementation-plans/basic-information-about-air-quality-fips
[20] EPA. (n.d.). Approved Air Quality Implementation Plans. Retrieved from https://www.epa.gov/air-quality-implementation-plans/approved-air-quality-implementation-plans

SIP[21])	○ Advanced Clean Fleets Regulation including Accelerate Zero-Emission Vehicles (ZEV) adoption and Zero Emissions Trucks Measure ● On-Road Light-Duty ○ On-Road Motorcycles New Emissions Standards ○ Clean Miles Standard ● Off-Road Equipment ● Consumer Products ○ Guide rule development and ensure emissions reductions are based on the state-of-the-science ● Residential and Commercial Buildings ○ Reduce emissions from new residential and commercial space and water heaters sold in CA. ● Pesticides ○ The agency responsible for regulating the sale and use of pesticides in CA developed a regulation to address both cancer and acute risk to non-occupational bystanders from the use of Volatile Organic Compounds (VOC), 1,3-DIchloropropene (1,3-D)
New York (Regulatory SIP Revisions)	Regulatory SIP Revisions: ● Stationary Combustion Installations (approval on June 5, 2023) ○ This revision is to implement measures to control air pollution caused by particulate matter (PM) involving adjustments to current regulations specified in New York's Codes, Rules, and Regulations (NYCRR) that enforce control measures for PM emissions sources.[22] ● Gasoline Dispensing Sites and Transport Vehicles (approval on February 9, 2023) ○ This revision is to address gasoline dispensing sites and transport vehicles, including the removal of Stage II vapor recovery requirements and the enhancement of Stage I vapor recovery systems at gasoline stations, along with mandating that transport vehicles comply with current Federal U.S. Department of Transportation (DOT) standards.[23] ● Architectural and Industrial Maintenance (approval on October 3, 2022) ○ Targeting control measures for architectural and industrial maintenance coatings to implement strategies that will reduce VOC emissions, contributing to the achievement and maintenance of national air quality standards for ozone.[24] ● Consumer Products (approval on September 16, 2022) ○ This revision is to control air pollution caused by volatile organic compounds (VOC), involving changes to New York's Codes, Rules,

[21] The California Air Resources Board. (2022). 2022 State Strategy for the State Implementation Plan. Retrieved from https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

[22] The Office of the Federal Register (OFR) of the National Archives and Records Administration (NARA). (2023). Approval and Promulgation of Implementation Plans; New York; Particulate Matter Control Strategy. Retrieved from https://www.federalregister.gov/documents/2023/06/05/2023-11684/approval-and-promulgation-of-implementation-plans-new-york-particulate-matter-control-strategy

[23] The OFR of the NARA. (2023). Approval and Promulgation of Implementation Plans; New York; Gasoline Dispensing, Stage I, Stage II and Transport Vehicles. Retrievd from https://www.federalregister.gov/documents/2023/02/09/2023-02674/approval-and-promulgation-of-implementation-plans-new-york-gasoline-dispensing-stage-i-stage-ii-and

[24] The OFR of the NARA. (2022). Approval of Air Quality Implementation Plans; New York; Revisions to Architectural and Industrial Maintenance Coatings. Retrieved from https://www.federalregister.gov/documents/2022/10/03/2022-21355/approval-of-air-quality-implementation-plans-new-york-revisions-to-architectural-and-industrial

	and Regulations (NYCRR) related to the regulation of Consumer Products. to endorse strategies for controlling VOC emissions.[25] • Oil and Natural Gas Sector (approval on August 25, 2022) ◦ This revision outlines New York's regulatory measures for the oil and natural gas industry facilities within its territory, aligning with the EPA's 2016 Control Techniques Guidelines (CTG) for this sector. The goal of this approval is to incorporate these regulations into New York's SIP and fulfill the obligations set by the CTG.[26]

3. Impact on Air Quality and Health

Since the implementation of CAA Amendments of 1990, average concentration of air pollutants and total emission of key air pollutants has continued to decline while economic growth has continued in the US (Figure 4 and Figure 5).

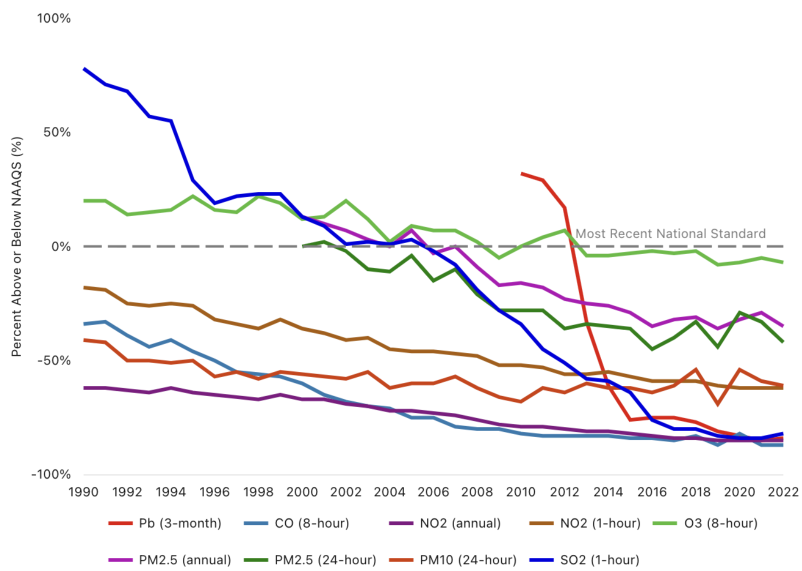

Figure 3. Change of National Air Pollutant Concentration Averages
Source: Environmental Protect Agency[27]

Many literature have said that air pollution negatively impacts on health. According to Ross et.al. (2012), air pollution can affect prenatal conditions and be associated with low birth weight and infant mortality. Also, Schlenker and Walker (2016) found that daily spikes in air pollution increase asthma and respiratory

---

[25] The OFR of the NARA. (2022). Approval of Air Quality Implementation Plans; New York; Consumer Products. Retrieved from https://www.federalregister.gov/documents/2022/09/16/2022-19831/approval-of-air-quality-implementation-plans-new-york-consumer-products

[26] The OFR of the NARA. (2022). Approval and Promulgation of Implementation Plans; New York; Oil and Natural Gas Control Measures. Retrievcd from https://www.federalregister.gov/documents/2022/08/25/2022-18323/approval-and-promulgation-of-implementation-plans-new-york-oil-and-natural-gas-control-measures

[27] EPA. (2023). Annual Air Report. Retrieved from https://gispub.epa.gov/air/trendsreport/2023/#introduction

illnesses, especially among children and elders[28]. Also, Zivin and Neidell (2012) examined ozone as having significant negative effects on both hours worked and productivity[29].

There is some evidence that local air quality has improved after the 1990 Clean Air Act amendments. Aufhammer, Bento, and Lowe (2009) examine the non-attainment designation led to average air quality improvements by 10 - 14 percent[30]. Bishop, Ketcham, and Kuminoff (2018) also found that the air quality improved by 10% below baseline levels after the policy. This evidence proved that the ozone regulation especially the 1990 Clean Air Act brings a positive impact on air quality.

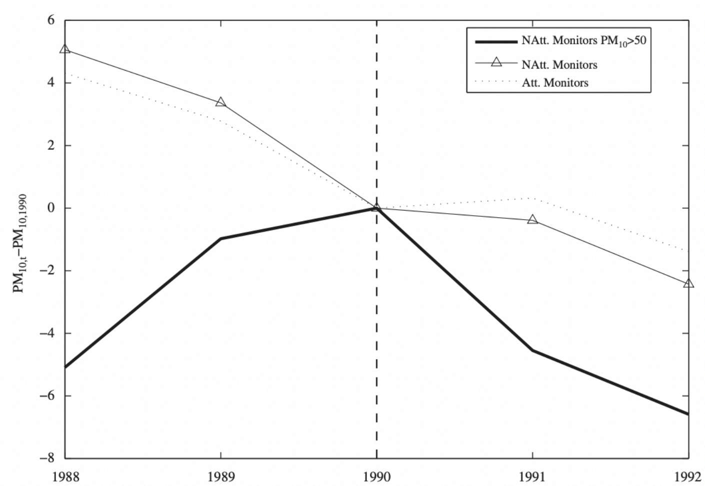

Figure 4. Changes in PM10 concentrations prior and post nonattainment status designation.

Improvement of local air quality has positively affected people's health and well-being. According to Barreca, Neidell, and Sanders (2017), the value of lives saved due to SO_2 permit trading, a program introduced after the 1990 Clean Air Acts, reached $134 billion per year by 2005 compared to the costs of the programs that was $3 billion per year. Therefore, ozone regulation can positively impact the health of the people.

4. Impact on economy

Clean Air Act also has effect on manufacturing total productivity. According to, Greenstone, List, and Syverson[31] (2012), the estimated loss of total factor productivity is caused by the environmental regulation in nonattainment counties (the counties with pollutant concentrations that exceeds federal standard). It is important to note that emitters of the regulated pollutant in nonattainment counties are subject to greater regulatory oversight than emitters in attainment counties. The nonattainment designation is associated with a 2.6 percent decline in measured total factor productivity (TFP) among plants that emit the targeted pollutants. The 2.6 percent decline, however, is likely to underestimate the impact of the regulation. This is mainly because the comparisons of the firms are for emitters and

[28] Schlenker, W., & Walker, R. 2016. "Airports, Air Pollution, and Contemporaneous Health," The Review of Economic Studies, Volume 83, Issue 2, Pages 768–809, https://doi.org/10.1093/restud/rdv043
[29] Zivin, J., and Neidell, M. 2012. "The Impact of Pollution on Worker Productivity." American Economic Review, 102 (7): 3652-73. DOI: 10.1257/aer.102.7.3652
[30] Auffhammer, M., Bento, A., & Lowe, S. (2009). "Measuring the Effects of the Clean Air Act Amendments on Ambient PM10 Concentrations: The Critical Importance of a Spatially Disaggregated Analysis". Journal of Environmental Economics and Management, 58(1), 15-26. https://doi.org/10.1016/j.jeem.2008.12.004
[31] Greenstone, M., List, J., & Syverson, C. 2012. "The Effects of Environmental Regulation on the Competitiveness of U.S. Manufacturing," NBER Working Papers 18392, National Bureau of Economic Research. https://www.nber.org/papers/w18392

non-emitters, while it is likely that it that some of the non-emitter group was also affected by the Clean Air Act, albeit less intensively.

There is also the fact that the TFP estimation is done with a revenue approach, so it is a product of price, while the correct outcome of the production should be in total physical output. Estimation is also done by assuming that surviving plants would continue to operate, where it is very likely that the most harmed plants could shut down. In their research, Greenstone, List, and Syverson (2012) corrected the confounding of price increases and output declines and sample selection on survival produces, which therefore gave a much larger estimate of declines. It estimates that TFP is declining by 4.8 percent for polluting plants in nonattainment counties, which is roughly equal to an annual economic cost from the regulation of manufacturing plants of roughly $21 billion in 2010 dollars.

Walker (2013) highlighted the cost of environmental regulations in a way of reallocation[32]. Reallocation occurs when the industry is regulated and therefore moves the production to other sectors or locations. In terms of labor inputs, this reallocation could be framed in terms of ‘‘jobs lost”. Walker also noted that if workers lose job -or industry-specific skills and/or experience long periods of unemployment following job transitions, the cost of reallocating the workforce could be quite high. The reallocation of sectors and locations due to the 1990 Clean Air Act reduces labor input. The reduction of workers’ earnings reached $5.4 billion (in 1990 dollars) or a 20% loss compared to preregulatory earnings due to the policy (Walker, 2013). These costs were mostly due to a combination of delays in finding a new job and lower earnings in future jobs.

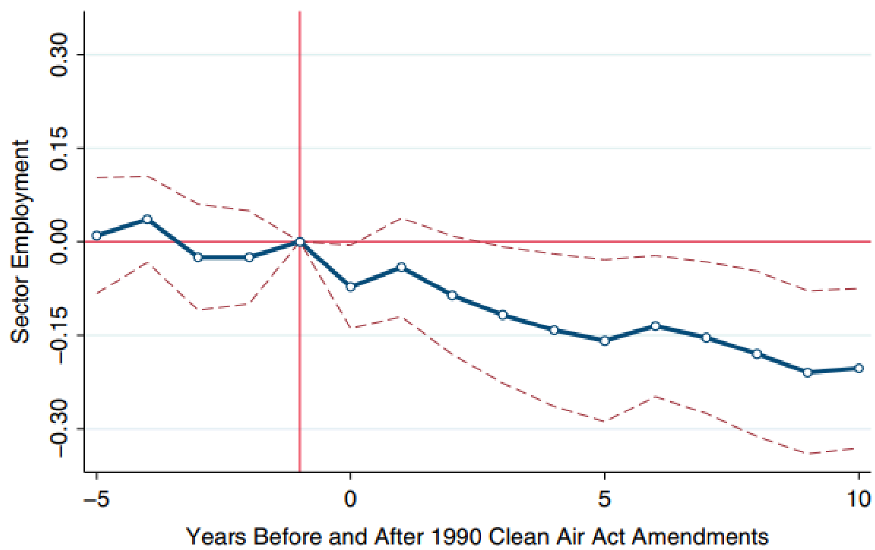

Figure 5. Sector employment 5 years prior and 10 years post the CAA for nonattainment counties.

The graph above shows that at the beginning of the year of the regulatory change, employment in polluting sectors in newly regulated counties began to fall, reaching levels nearly 10% below 1990 employment levels in the five years after the regulatory change (or 15% below the counterfactual employment trends). These show the extent of the workers' loss due to the regulation and nonattainment designation. Walker also posited that workers in newly regulated sectors are disproportionately more likely to exit to a completely different industry after the regulations, relative to before. Furthermore,

[32] Walker, R. W. 2013. “The Transitional Costs of Sectoral Reallocation: Evidence From the Clean Air Act and the Workforce,” The Quarterly Journal of Economics, Volume 128, Issue 4, November 2013, Pages 1787–1835, https://doi.org/10.1093/qje/qjt022

workers are more likely to transition to a different industry within the same county. This shows that most of the job transitions in the regulated sectors occurred within the same labor market rather than across the labor market. Given that Walker also explains that most of the costs of reallocation occur through costly job transitions associated with sectoral downsizing, it suggests the vulnerability of the workers should there be any environmental regulation that hampers their respective industries.

Even though there was a considerable loss of workers' earnings, this loss recovered in subsequent years. It can be due to some reasons such as there were a few employees that remain in the regulated sectors so, the earnings increase or anything else. There are also possibilities that the recovery is likely because rapid earnings recovery comes from the fact that most of these regulations occur in dense, urban labor markets. Workers are likely able to reintegrate themselves into the workforce more quickly in these ‘‘thicker’’ labor markets than elsewhere where alternative job options are limited (Walker, 2013). The fact that in the regulated sector, the workers' earnings can be recovered over time means that the ozone regulation has short-term negative effects on workers, but in the long run, it will recover.

5. EPA's Periodic Report on the CAA Cost and Benefit Analysis

The Clean Air Act (CAA) requires the EPA to develop periodic reports estimating the benefits and costs of the Act. These reports aim to provide Congress and the public with comprehensive, peer-reviewed information on the CAA's social benefits and costs, covering human health, welfare, ecological resources, and the impact on the U.S. economy. Additionally, the EPA intends to use these reports to inform decisions on future investments in air pollution research, addressing the marginal costs and benefits of the 1990 Clean Air Act Amendments (CAAA).

Published by the EPA in 2011, this report is the latest in a series resulting from the Second Prospective analysis of the 1990 Amendments. The first report, a retrospective analysis from 1997, demonstrated that the nation's investment in clean air was justified, with benefits exceeding costs by a factor of 10 to 100. The 1999 prospective analysis indicated that implementing the CAAA would bring greater benefits to the U.S.

Table 4. Emission impact model

POLLUTANT	1990	2000			2010			2020		
		WITHOUT-CAAA	*WITH-CAAA*	REDUCTION	*WITHOUT-CAAA*	*WITH-CAAA*	REDUCTION	*WITHOUT-CAAA*	*WITH-CAAA*	REDUCTION
VOC	25,790	24,477	17,798	*6,679*	26,742	14,117	*12,626*	31,288	13,704	*17,584*
NO_x	25,917	26,688	20,837	*5,851*	28,517	13,640	*14,877*	31,740	10,092	*21,647*
CO	154,513	127,093	107,691	*19,403*	134,151	86,705	*47,447*	155,970	84,637	*71,332*
SO_2	23,143	25,129	15,319	*9,810*	26,831	10,347	*16,484*	27,912	8,272	*19,640*
PM_{10}	25,454	26,418	21,143	*5,275*	26,405	20,413	*5,992*	28,280	20,577	*7,702*
$PM_{2.5}$[1]	5,527	5,822	5,489	*333*	5,924	5,241	*682*	6,368	5,297	*1,072*
NH_3	3,656	4,136	3,983	*153*	4,405	4,224	*181*	4,787	4,587	*200*

[1] $PM_{2.5}$ without-CAAA emissions were adjusted from previously reported values by reducing emissions from non-EGU industrial point sources and area sources.

The report models seven emissions, which can be seen in the table above, with ozone and PM 2.5 used to estimate social benefits. Two emission inventory scenarios, with-CAAA and without-CAAA, are used to calculate the net impact, which can be seen in the figures below.

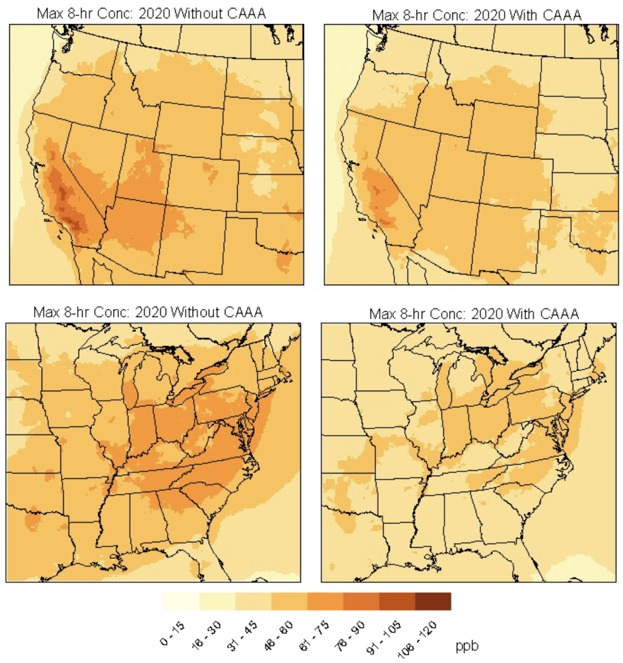

Figure 6. 8-hour ground level ozone model in two scenarios and two regions

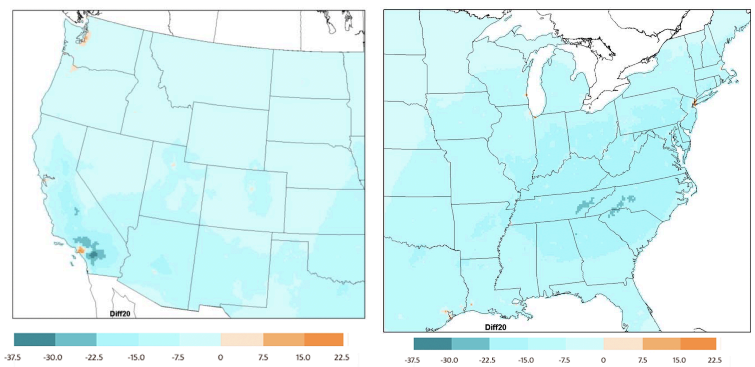

Figure 7. Change between the two scenarios in 8-hour ozone level in two regions

Direct costs estimated from this act can be seen in the table below. The cost is divided into 6 sectors across 3 different analysis periods (2000, 2010, and 2020). The growth in costs between 2000 and 2020 partially reflects population growth during this period and the corresponding increase in emissions-generating activity (e.g., increased vehicle miles traveled, and increased industrial output demand). Normalized for population growth, annual costs increase from approximately $70 per capita in 2000 to $170 per capita in 2010 and $190 per capita in 2020. These results suggest that annual costs per capita grew by approximately 170 percent between 2000 and 2020, whereas annual costs (not normalized for population) grew by approximately 230 percent during this period.

Table 5. Direct cost analysis

SOURCE CATEGORY	ANNUAL COST (MILLION 2006$) 2000	2010	2020
Electric Utilities	**$1,370**	**$6,640**	**$10,400**
Non-EGU Industrial Point Sources	**$3,130**	**$5,190**	**$5,140**
NO_x SIP Call	$0	$134	$133
MACT	$1,500	$3,010	$2,920
National VOC Rules, RACT, and New CTGs	$439	$464	$534
Refinery Settlements	$0	$295	$324
1-Hour Ozone SIP Measures	$1,030	$1,130	$1,090
PM_{10} SIP Measures	$163	$152	$146
Onroad Vehicles and Fuels	**$14,400**	**$25,700**	**$28,300**
Motor Vehicle Emission Standards	$4,400	$7,650	$7,760
California and National LEV	$562	$2,030	$2,090
Fuels	$4,820	$9,830	$11,200
Motor Vehicle I/M programs	$4,630	$6,250	$7,260
Nonroad Vehicles and Fuels	**$298**	**$359**	**$1,150**
Nonroad Engines/Vehicle Standards	$298	$219	$320
Fuels	$0	$140	$831
Area Sources	**$663**	**$693**	**$766**
RACT and New CTGs	$446	$442	$490
Ozone Transport Commission Model Rules	$134	$181	$212
1-Hour Ozone NAAQS	$82	$70	$64
Local Controls	**$0**	**$5,260**	**$6,180**
8-Hour Ozone NAAQS	$0	$4,270	$4,390
$PM_{2.5}$ NAAQS	$0	$977	$687
Clean Air Visibility Rule	$0	$0	$1,100
Sub-Total Excluding Unidentified Measures	**$19,900**	**$43,900**	**$52,000**

As shown in the Table below, our central estimate implies that PM and ozone reductions due to the CAAA in 2020 will result in 230,000 avoided deaths. These avoided deaths are valued at $1.8 trillion (2006$). This avoided deaths in 2020 would increase total deaths by about 9.5 percent in 2020. The 230,000 avoided deaths are about 16 percent of the total mortality from the top four causes of death in the US in 2002: heart disease (over 600,000 deaths); cancer (over 550,000 deaths); stroke (over 130,000 deaths); and chronic lower respiratory disease (just less than 130,000 deaths).

Table 5. Direct benefit analysis

		INCIDENCE			VALUATION (MILLIONS 2006$)		
ENDPOINT	POLLUTANT	5^{TH} %ILE	MEAN	95^{TH} %ILE	5^{TH} %ILE	MEAN	95^{TH} %ILE
Mortality							
Mortality[1]	PM, Ozone	45,000	230,000	490,000	$170,000	$1,800,000	$5,500,000
Morbidity							
Chronic Bronchitis	PM	12,000	75,000	130,000	$3,100	$36,000	$130,000
Non-fatal Myocardial Infarction	PM	80,000	200,000	300,000	$6,200	$21,000	$48,000
Hospital Admissions, Respiratory	PM, Ozone	24,000	66,000	110,000	$320	$1,100	$1,800
Hospital Admissions, Cardiovascular	PM	52,000	69,000	84,000	$1,400	$2,000	$2,600
Emergency Room Visits, Respiratory	PM, Ozone	64,000	120,000	180,000	$22	$44	$69
Acute Bronchitis	PM	-7,000	180,000	340,000	-$4	$94	$220
Lower Respiratory Symptoms	PM	1,200,000	2,300,000	3,300,000	$18	$42	$76
Upper Respiratory Symptoms	PM	620,000	2,000,000	3,300,000	$17	$60	$130
Asthma Exacerbation	PM	270,000	2,400,000	6,700,000	$15	$130	$390
Minor Restricted Activity Days	PM, Ozone	91,000,000	110,000,000	140,000,000	$3,800	$6,700	$10,000
Work Loss Days	PM	15,000,000	17,000,000	19,000,000	$2,300	$2,700	$3,000
School Loss Days	Ozone	2,200,000	5,400,000	8,600,000	$190	$480	$770
Outdoor Worker Productivity	Ozone	N/A	N/A	N/A	$170	$170	$170

Table 6. Direct cost and benefit comparison

	ANNUAL ESTIMATES			PRESENT VALUE ESTIMATE
	2000	2010	2020	1990-2020
Monetized Direct Costs (millions 2006$):				
Low [a]				
Central	$20,000	$53,000	$65,000	$380,000
High [a]				
Monetized Direct Benefits (millions 2006$):				
Low[b]	$90,000	$160,000	$250,000	$1,400,000
Central	$770,000	$1,300,000	$2,000,000	$12,000,000
High[b]	$2,300,000	$3,800,000	$5,700,000	$35,000,000
Net Benefits (millions 2006$):				
Low	$70,000	$110,000	$190,000	$1,000,000
Central	$750,000	$1,200,000	$1,900,000	$12,000,000
High	$2,300,000	$3,700,000	$5,600,000	$35,000,000
Benefit/Cost Ratio:				
Low[c]	5/1	3/1	4/1	4/1
Central	39/1	25/1	31/1	32/1
High[c]	115/1	72/1	88/1	92/1
Costs per Premature Mortality Avoided (2006$):				
Central	$180,000	$330,000	$280,000	Not estimated

The table above demonstrates that the benefits of the CAAA significantly exceed its costs, making it a sound policy. Present value estimates show benefits exceeding costs by a factor of 32 to one, with a high estimate exceeding costs by roughly 90 to one. While acknowledging the reliance on specific data, models, and assumptions, the wide margin between estimated benefits and costs, along with uncertainty analysis, suggests the likelihood of benefits being less than costs is extremely low under any alternative assumptions.

Several limitations exist, including only accounting for the learning-by-doing cost reduction and not considering the effects of technological advancement/innovation. Additionally, although the CBA was linked with economic projections, the economy itself (e.g., industrial productivity) is, to a certain extent, influenced by the CAA, creating uncertainty about the final equilibrium.

Some peer-reviewed studies suggested, at the time of this report's publication in April 2011, that the direct costs of pollution control measures inadequately represent the total costs of environmental protection. This is due to the effects of pollution abatement on industrial productivity, which is directly influenced by any environment-related limitation. While direct cost estimates do not capture these productivity effects, the literature is unclear on the magnitude and direction of these indirect effects. Some studies found that pollution control negatively affects productivity, while others found the impact to be positive or ambiguous. Barbera and McConnell (1986) identified a negative impact, while Barbera and McConnell (1990) and Gray and Shadbegian (1994) found an ambiguous impact, and Morgenstern et al. (1998) found a positive impact. To comprehensively assess the impact on the economy, this analysis integrated a CGE model as supplementary information to the CBA.

To address the aforementioned problem, a CGE is utilized to supplement this CBA. CGE models simulate the flow of commodities and factors of production (i.e., labor, capital, and natural resources) among producers and households to assess how a change in policy or an economic shock affects the size and composition of the economy. Households in CGE models own factors of production that they supply to firms in exchange for wages and other forms of income. Firms use these factors in conjunction with intermediate inputs to produce goods and services, which are sold to other industries and consumers. Goods and services can also be exported, and imported goods can be purchased from other countries.

The general equilibrium component of CGE modeling requires comprehensive market coverage, with all sectors in the economy in balance, and all economic flows accounted for. Establishing equilibrium conditions necessitates that every commodity produced must be purchased by firms or consumers within the United States or exported to foreign consumers. Although a simplifying assumption, this condition is consistent with production in the actual economy over time. The outputs generated by the CGE include GDP, consumption, and an economic welfare measure known as Hicksian equivalent variation (EV). EV is based on the concept of willingness-to-pay, representing the maximum amount a household would pay for a particular good or service given its budget constraint.

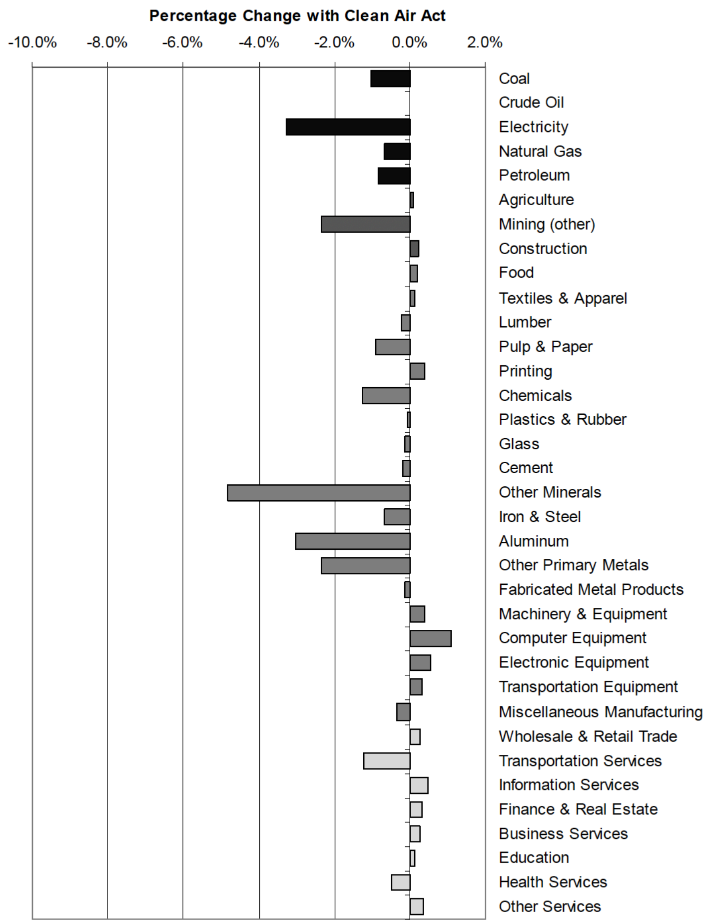

Figure 8. Impact of the CAA to industry by sector

The results presented in the table below suggest that over time, the positive macroeconomic impacts of CAAA-related labor force and medical expenditure impacts slightly outweigh the negative macroeconomic effects of CAAA compliance costs. For 2010, the results in the labor force-adjusted case show a reduction in GDP and consumption relative to the without-CAAA scenario, but the corresponding changes become positive in 2020. This largely reflects the rapid growth in the CAAA labor force effect between 2010 and 2020 (67 percent) relative to the growth in CAAA compliance expenditures (25 percent). We expect the CAAA-related labor force effect to grow more quickly than CAAA compliance expenditures during this period because, unlike compliance expenditures, the labor force effect is cumulative for health endpoints with the most significant effect on the size of the labor force (i.e., premature mortality, chronic bronchitis, and AMI). In addition, the mortality effect is delayed relative to the time costs are incurred to reduce exposures because of the impact of the cessation lag.

The results in the table below also suggest that the Amendments lead to an increase in household welfare, measured as the change in EV, under the labor force-adjusted case for both the 2010 and 2020 target years. The projected 0.8 percent increase in welfare for 2010 stands in contrast to the projected 0.21

percent reduction in GDP for that year and the 0.03 percent reduction in consumption. The fact that welfare rises while economic output declines indicates that, under the with-CAAA scenario, households allocate a greater share of their time endowment to leisure (and less to labor) than under the without-CAAA scenario. This reallocation of household time also occurs under the cost-only case, but it only partially offsets the negative welfare impact of reduced consumption. Under the labor force-adjusted case, the increase in leisure more than offsets the welfare loss associated with reduced consumption.

Table 7. Indirect cost - benefit result using CGE (above: cost only; bottom: labor benefit adjusted)

VARIABLE	MODEL RUN	2010	2015	2020
GDP	With Clean Air Act ($ billion)	$15,027	$17,338	$20,202
	Without Clean Air Act ($ billion)	$15,106	$17,430	$20,312
	Change ($ billion)	−$79	-$93	−$110
	% change	−0.52%	-0.53%	−0.54%
Consumption	With Clean Air Act ($ billion)	$10,969	$12,699	$14,881
	Without Clean Air Act ($ billion)	$11,023	$12,761	$14,956
	Change ($ billion)	−$54	-$62	−$75
	% change	−0.49%	-0.49%	−0.50%
Hicksian EV (annual)	Change ($ billion)	−$54	-$62	−$75
	% change	−0.38%	-0.38%	−0.39%

Notes:
1. Results are expressed in year 2006 dollars.

VARIABLE	MODEL RUN	2010	2015	2020
GDP	With Clean Air Act ($ billion)	$15,027	$17,338	$20,202
	Without Clean Air Act ($ billion)	$15,059	$17,350	$20,197
	Change ($ billion)	−$32	-$12	$5
	% change	−0.21%	-0.07%	0.02%
Consumption	With Clean Air Act ($ billion)	$10,969	$12,699	$14,881
	Without Clean Air Act ($ billion)	$10,972	$12,696	$14,876
	Change ($ billion)	−$3	$3	$5
	% change	−0.03%	0.02%	0.03%
Hicksian EV (annual)	Change ($ billion)	$11	$22	$29
	% change	0.08%	0.13%	0.15%

Notes:
1. Results are expressed in year 2006 dollars.

6. Policy Recommendation

For the impact on the health and economy based on empirical study, it is concluded that the benefits outweigh the loss. The US government should continue to implement the ozone regulation (CAA). The benefit of health well-being is considerably high, but the trade-off is there would be a high cost during the transition that impacts employment and sectoral productivity. To address that, ozone regulation needs to be accompanied with an industrial policy that ensures just transition and distributional impacts. There should be a need to conduct more empirical research on a broader magnitude to know more about the cost and benefit of this policy.

Also, the assessment of green investments as industrial policy found that one additional green job yields the creation of 4.2 new jobs in non-tradable activities[33]. The green jobs are predominantly high-skilled

[33] Vona, F., Marin, G., & Consoli, D. 2018. "Measures, drivers and effects of green employment: evidence from US local labor markets, 2006–2014," Journal of Economic Geography, Volume 19, Issue 5, September 2019, Pages 1021–1048, https://doi.org/10.1093/jeg/lby038

and pay a positive wage premium of about 4% relative to comparable occupations. By having stringent ozone regulation, there should be potential to open more green jobs. The government should direct the industry to move their capital to green industries to get both environmental and positive economic benefits from Ozone Regulations.

Finally, EPA's concluded that direct impact calculations result in very good benefits compared to the cost in more than 30 to 1 ratio. This conclusion is also supplemented by CGE model which results in the Act providing higher GDP in the long run and greater household welfare.