The Political Economic Determinants of Nuclear Power: Evidence from Chernobyl (Preliminary)*

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Abstract

The rapid growth of nuclear power plants (NPP) declined dramatically after Chernobyl, especially in countries with democratic governments which had the highest number of NPPs at the time. To understand the mechanisms driving such change, we examine two case studies in detail: the United States and the United Kingdom. In the U.S., we document that: (a) after the Chernobyl accident, campaign contributions to House and Senate races from fossil fuel special interest groups became strongly associated with negative votes on nuclear-related bills, and such donations increased significantly; and (b) newspapers with more fossil fuel advertisements published more anti-nuclear articles after Chernobyl, while we do not observe significant changes in advertisement spending by the fossil fuel industry. In the U.K., MPs sponsored by mining unions were much more likely to give anti-nuclear speeches in parliament after Chernobyl. We examine air pollution as a downstream outcome of reduced nuclear investment. We estimate that the decline in NPP caused by Chernobyl led to the loss of approximately 141 million expected life years in the U.S., 33 in the U.K. and 318 million globally.

Keywords: Energy Investment, Special Interest Group Capture, Sustainability

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"Oil would be worth a lot less if more of the world's energy needs were provided by atomic fission" – Rod Adams, Engdahl, F. William (2012) *A Century of War: Anglo-American Oil Politics and the New World Orders.*

1 Introduction

A key challenge for the 21st century is to mitigate climate change caused by burning fossil fuels as world population and energy demands continue to grow. Critical to this effort is the transition to alternative energy sources. One of the most reliable sources of low-carbon power is nuclear, which generates little pollution and does not depend on fossil fuel reserves.[1] Nuclear energy experienced tremendous growth during the 1960s and 70s when it was seen as the solution for future energy needs. However, the early enthusiasm waned by the 1980s and only 10% of the world's energy is nuclear today. The decline in nuclear investment has been particularly notable in countries with democratic governments, which had the most NPP growth in the earlier decades and almost no new NPP construction since the mid-1980s. The rapid early growth is not surprising given that these included the world's wealthiest countries, which were on the technological frontier of nuclear energy and had the financial resources for constructing new NPPs. More surprising is the near complete stop of new NPP construction in recent decades, especially since the same countries avidly promote clean energy, have the financial capacity to afford newer, safer and more efficient NPPs, which are arguably still more reliable and cost effective than other clean energy sources.[2]

In this paper, we offer a political economic explanation for the dramatic global slowdown of nuclear energy growth. The largest growth of NPPs took place in wealthy countries which were also democracies. In democratic systems, special interest groups are known to have influence on government policy (Grossman and Helpman, 2001). Nuclear energy competes with and threatens the fossil fuel industry. This paper asks a simple question: did fossil-fuel special interests leverage the 1986 Chernobyl reactor meltdown and the public fear that it triggered to influence government policy against nuclear investment in the democracies with the most NPPs at the time?

We address this question in several steps. First, we examine the cross-country data on NPPs. We construct a cross-country panel of NPPs and other economic and political variables and document that after the Chernobyl accident, there was an immediate and permanent decline in the growth of NPPs

[1] The main "pollution" from nuclear energy is the disposal of spent rods. The only natural resource required for nuclear energy are water and uranium or plutonium. We discuss this more in the Background section.

[2] See Background Section.

worldwide. This was driven by countries with democratic governments, which also had the largest economies and the most NPPs at the time.

The second part of our paper uses granular micro data to provide positive evidence on the role of fossil fuel interests in two democracies: the U.S. and the U.K.. Our choice of countries is motivated by the fact that both countries had many NPPs at the time of Chernobyl, broadly similar democratic systems, and importantly, data which allow us to tie fossil fuel interests to elected officials and popular media.

At the time of Chernobyl, the U.S. had more NPPs than any other country. U.S. NPPs had grown at a rapid rate since the 1950s, despite the earlier and relatively small partial meltdown at the Three Mile Island in 1979. The rise in nuclear energy was viewed as a direct threat by the fossil fuel industry, which had been lobbying against nuclear investment since the 1950s.

To understand whether fossil fuel special interests took advantage of Chernobyl to reduce nuclear investment, we first document that Chernobyl was covered extensively by U.S. newspapers and that there was much public discussion about the fear of NPP meltdowns. Then, we examine whether fossil fuel campaign contributions increase after Chernobyl, and how they affect voting on important nuclear-energy bills in the House and Senate. Both relationships are ambiguous *ex ante* because the public fear caused by Chernobyl could have been a complement or a substitute to campaign contributions in influencing the politicians' vote against nuclear energy.

For this analysis, we construct a panel dataset on campaign contributions and voting patterns for the U.S. House of Representative and the Senate. We identify every donation made by a fossil fuel company to a congressman. We also identify all nuclear-related bills in the House and the Senate, and manually code various features of each bill, such as whether it is "anti-nuclear" or "high-stakes." We find that campaign contributions from the fossil fuel industry increased after Chernobyl. And within the same congressman, fossil fuel campaign contributions were associated with more negative votes on subsequent nuclear energy bills, which is true only in the post-Chernobyl period, and is particularly salient for those high-stakes and pivotal bills. These results are consistent with the hypothesis that fossil fuel special interests took advantage of Chernobyl to fight against nuclear investment.

Another way that fossil fuel interests could have swayed public opinion is through media outlets. We construct a large sample of U.S. newspaper articles and advertisement and show that, while the amount of fossil fuel advertisements appears to be relatively inelastic in the short run, newspapers with higher amounts of pre-existing fossil fuel advertisements started to publish significantly more anti-nuclear articles after Chernobyl, relative to their peers that relied less on fossil fuel advertisements. This is consistent with the interpretation that profit-maximizing media outlets that were captured by fossil fuel also took advantage of Chernobyl to shape public opinion and policy using their platforms.

The U.K. was in the midst of the Thatcher-led conservative government's fight to reduce the power of the mining unions when Chernobyl melted down. The conservative government saw nuclear energy as a key way to reduce reliance on British coal miners. Thus, the public fear triggered by Chernobyl provided an opportunity for coal-related interest groups to lobby against nuclear energy. An advantage of the U.K. context is that the connection to coal-related interest groups is very stark because miners unions officially sponsor Members of Parliament (MPs) of their choice. Thus, we can compare the behaviors of MPs with miners union sponsorship to those without such sponsorships and see if they become more negative towards nuclear energy after Chernobyl. The main disadvantage of the U.K. context for our study is that there are almost no votes on nuclear energy regulation in parliament. Thus, we cannot examine voting outcomes.

As with the U.S. analysis, we first document that Chernobyl was widely covered by U.K. news and that there was much public discussion about the fear of NPP meltdowns. Then, we construct a constituency-level panel that contains information about whether a MP was sponsored by a miners union, MP's party affiliation and other characteristics, and whether the MP spoke for or against nuclear energy in a given year-month. The latter variable is constructed by analyzing the texts of parliamentary minutes. We document that after Chernobyl, MPs sponsored by miners unions were much more likely to speak against nuclear energy. This is true when comparing MPs sponsored by miners unions to all other MPs, when comparing them to MPs who were sponsored by other union types, or when comparing within Labor Party MPs. An alternative explanation is that MPs sponsored by miners unions care more about public safety. The data suggest that this is unlikely: we document that they are not more likely to speak about other public safety or public health issues. The results for the U.K. are consistent with those from the U.S. in showing that the fossil fuel interest groups became more active after Chernobyl.

In the final part of the paper, we consider the downstream outcomes of reduced nuclear energy investment. There are advantages and disadvantages. The main advantage is safety. If there are fewer reactors, then the chances of reactor meltdowns are lower. The main disadvantage is that the decline in nuclear energy delayed the shift away from fossil fuels, which had adverse effects on air pollution and health. Because reactor meltdowns are low probability events and the damages from meltdowns can greatly vary, we are unable to rigorously quantify the safety benefits, which can potentially be very important.

We are able to provide an alternative assessment of nuclear safety by examining the age of reactors. We document that the decline in new NPPs in democracies after Chernobyl was accompanied by an increase in the average age of the NPPs in use. To satisfy the rise in energy demand, reactors built prior to Chernobyl continued operating past their initially scheduled retirement dates. Using data on NPP incident reports, we show that such plants are more likely to have accidents. The data imply that Chernobyl resulted in the continued operation of older and more dangerous NPPs in the democracies.

Finally, we examine the consequences on air pollution using data on the location of NPPs and satellite-based pollution measures for 2000–2020 to estimate the relationship between NPP and air pollution. Our estimates, together with an off-the-shelf calculation of the relationship between air pollution and life years imply that the reduction in NPPs after Chernobyl resulted in the loss of 318 million life years since 1986. This estimate highlights the practical relevance of our results, but should not be interpreted literally. These results show that the lack of nuclear investment was likely to have had significant social costs. However, it is beyond the scope of our paper to make welfare statements because we cannot fully assess the expected costs of reactor meltdowns or other benefits of nuclear power, such as the geopolitical advantages of energy self-reliance for countries without fossil fuel reserves.

Our paper is the first to systematically study the causes of the stagnation in nuclear energy investment, or provide evidence on the political economy drivers. It contributes to two strands of the literature. First, the findings speak to the growing literature on the economics of nuclear power. In the U.S., existing works have documented that deregulation of the electricity market in the late 1990s led to improved efficiency of nuclear power plants (Davis and Wolfram, 2012), which did not cause any detectable deterioration in safety standards (Hausman, 2014); and the closure of a major nuclear power plant in 2012 left a generation void that was filled by additional in-state natural gas generation, which increases generation costs and carbon dioxide emissions (Davis and Hausman, 2016). Most relatedly, Jarvis, Deschenes and Jha (2022) finds that when Germany closed half of its nuclear power plants following the Fukushima accident in 2011, local air pollution increased significantly due to the burning of more fossil fuel, which leads to a social cost of three to eight billion Euros per year, suggesting that policy-makers substantially overestimate the risk/cost of nuclear accidents in their cost-benefit analysis of nuclear regulations. Our paper complements Jarvis et al. (2022) by showing that the environmental impacts of nuclear power plant closure exist globally over a longer range of time, and by investigating the political economic mechanisms that lead to such inefficient policy outcomes.

Second, it adds to our knowledge on the political economic determinants of energy, environmental and climate policies. A long-standing literature on the politics of environmentalism has studied how interest groups lobby to affect environmental policies in their favor (e.g., Oates and Portney, 2003). More recently, List and Sturm (2006) finds that governors facing close re-election races may adjust environmental spending to win over "single issue voters" who prioritize environmental issues. Knittel (2006) shows that interest group strength affects the adoption of state-level electricity regulation. Cragg and Kahn (2009) documents that higher emissions lead to lower voting for carbon-reducing legislation. Stokes (2016) documents that anti-renewable-energy groups could mobilize voters to punish incumbents for their climate policies. Holland, Hughes, Knittel and Parker (2015) finds that campaign finance plays an important role in blocking more efficient climate policies. Shapiro (2021) shows that as a result of industries lobbying for low tariffs on their inputs, import tariffs and non-tariff barriers are substantially lower on dirty than on clean industries across most countries globally. Our paper complements these earlier studies by providing evidence for nuclear development, and by quantifying the safety and environmental costs of such slowdown in nuclear.

The paper is organized as follows. Section 2 presents the background. Section 3 presents the cross-country evidence. Section 4 presents the within-country evidence from the U.S. and the U.K. Section 6 discusses the downstream effects of reduced nuclear energy on nuclear energy safety and air pollution. Section 7 concludes.

2 Background

2.1 Nuclear Power Plants

A nuclear reactor generated electricity for the first time on September 3, 1948, in the United States; and generated power for an electric grid for the first time on June 27, 1954 in the Soviet Union. The first full-scale power station opened in 1956 in the United Kingdom. Today, the International Atomic Energy Agency (IAEA) reports that there are 441 nuclear reactors in operation in 30 countries around the world.

Uranium or Plutonium is used to fuel nuclear power plants. Nuclear power stations typically have high capital costs (construction and maintenance), but relatively low direct fuel costs. We will later also discuss the high regulatory costs of nuclear power.

Nuclear power is stable, its capacity factor, defined essentially as how often a plant produces power, is 2.8 to 3.8 times higher than the other energy sources. At the same time, nuclear is also relatively clean. Its annual NOx emissions (a precursor to smog), SO2 emissions (which contribute to acid rain and haze), and CO2 emissions (which contribute to global warming) are less than one percent of the fossil fuel average (Batkins, Rossetti and Goldbeck, 2017). The main environmental cost is radioactive waste disposal. In principle, spent nuclear fuel can be recycled to avoid the disposal problem. But in practice, fuel and disposal prices have been so low that there has not been much bulk recycling of NPP waste.

Many have argued that since the late 1980s, most NPP construction has been slowed by regulation. Regulation can increase safety and efficacy of the plants. Regulation can also increase costs (Institute for Energy Research, 2018). Moreover, the regulation for nuclear plants often change during the construction process, which introduces uncertainty. While the exact process varies across countries, a general problem is that regulatory authorities are often unable to commit to requirements at any point in the construction process because regulators and citizens are able to protest after the approval of the plant and before its completion. Regulators often introduce new requirements while a plant is already under construction and shift the regulatory goalposts, which cause significant cost over runs (Hess, 2018).

The IER identifies regulatory costs as a key factor discouraging new build. A study of NPP construction also concluded that licensing, regulatory delays, and back-fit requirements were significant contributors to the rising cost trend (Institute for Energy Research, 2018; Lovering, Yip and Nordhaus, 2016).

The problem is particularly prominent for democratic governments because the approval process is more open to the influences of voters and special interest groups. For example, in the United States, "The American Action Forum (AAF) found the average nuclear plant bears an annual regulatory burden of around \$60 million — \$8.6 million in regulatory costs, \$22 million in fees to the Nuclear Regulatory Commission (NRC), and \$32.7 million for regulatory liabilities" (Institute for Energy Research, 2018). Of the 51 reactors currently under construction worldwide, only three are in Western and Central Europe (UK, France and Finland), and two are in the U.S. (World Nuclear Association, 2019; Cross, 2019).

The U.S. NRC requires six-to-seven-years to approve NPPs. The total construction time afterwards ranges from decades to indefinite. Cost overruns and changing regulatory requirements during the construction process sometime forces construction to be abandoned after significant sunk costs have been made. This often leads investors to abandon construction after already sunk billions of dollars of investment. Worldwide, companies have stopped construction on 90 reactors since the 1980s. 40 of those were in the U.S. alone. For example, in 2017, two South Carolina utilities abandoned two unfinished Westinghouse AP1000 reactors due to significant construction delays and cost overruns. At the time, this left two other U.S. AP1000 reactors under construction in Georgia. The original cost estimate of $14 billion for these two reactors rose to $23 billion. Construction only continued when the U.S. federal government promised financial support. These were the first new reactors in the U.S. in decades. In contrast, recent NPPs in China have taken only four to six years and $2 billion dollars per reactor.

When considering the choice of investing in nuclear energy versus fossil fuel energy, note that a typical natural gas plant takes approximately two years to construct(Lovering et al., 2016).

2.2 Chernobyl

There have been three reactor meltdowns in history. The first one was a partial meltdown of the reactor at Three Mile Island, Pennsylvania, on March 28, 1979. The Chernobyl disaster that is the focus of this study occurred on 26 April 1986 in the north of the Ukrainian SSR in the Soviet Union. The Fukushima Daiichi nuclear disaster occurred on March 11, 2011 in Ōkuma, Fukushima Prefecture, Japan. On the seven-point International Nuclear Event Scale (INES), the Three-Mile Island accident is rated at Level 5 "Accident with Wider Consequences", while Chernobyl and Fukushima are rated at INES Level 7, the maximum severity of accidents.

The Soviet government delayed telling local residents about the disaster for 36 hours. In the next two days, April 27th and 27th, 1986, Swedish air monitors detected large amounts of radiation in the air which they traced to the USSR and U.S. spy satellite photos showed the devastation of the meltdown.[3] On April 28th, Soviet news acknowledged the accident and this was followed by extensive coverage around the world.

Unless otherwise stated, all information below is taken from The Chernobyl Forum (Kinley III, 2006).

The Chernobyl reactor meltdown was caused by a combination of operator negligence and critical

[3]https://www.history.com/news/chernobyl-disaster-timeline

design flaws. The core melted down and subsequent explosions ruptured the reactor core and destroyed the reactor building. This was immediately followed by an open-air reactor core fire. It released air-borne radioactive contamination for around nine days. The wind blew north and west. Approximately 70% of fallout landed in Belarus SSR, which experienced black rain. Significant amounts of fallout also landed in the Ukrainian and Russian SSRs. Much of it deposited on mountainous regions such as the Austrian and Swiss Alps, the Welsh mountains and the Scottish Highlands, where adiabatic cooling caused radioactive rainfall. Sweden and Norway also received heavy fallout when the contaminated air collided with a cold front-induced rainfall. Other countries that were affected include Finland and Bulgaria. Groundwater was generally unharmed, with the exception of the exclusion zone around Chernobyl which was affected by waste disposal. Radioactive contamination of fish caused short-term concern in parts of the U.K. and Germany and long-term concerns in the affected areas of Ukraine, Belarus and Russia and parts of Scandinavia.

To contain the damage, a protective sarcophagus was built to enclose Chernobyl by December 1986, followed by another sarcophagus in 2017. The initial emergency response, together with later decontamination of the environment, required more than 500,000 personnel and an estimated US$68 billion (2019 USD). Between five and seven percent of government spending in Ukraine is still related to Chernobyl. In Belarus, Chernobyl-related expenses fell from twenty-two percent of the national budget in 1991 to six percent by 2002.

The RMBK reactor used at Chernobyl was popular in central and eastern Europe. After the accident, all RBMK units were studied and upgraded to address the design deficiencies that contributed to Chernobyl. There was also a mass effort to improve shutdown mechanisms, operational safety and regulatory oversight.

The accident in Chernobyl attracted worldwide attention and raised much more alarm about nuclear safety than the earlier Three-Mile Island accident. In direct response to the Chernobyl disaster, the International Atomic Energy Agency strengthened its safety protocols. Signatory member states pledged to provide notification of any nuclear and radiation accidents that occur within their jurisdictions that could affect other states, and to provide support and assistance for radiological emergencies.

Chernobyl had a notable negative effect on public opinion about nuclear energy. There is little systematic polling data from the time. Survey data from Finland suggest that the share of individuals having positive opinion of nuclear energy fell dramatically in the immediate aftermath of Chernobyl from 35% to 22%, while the share of negative attitudes rose from 32% to 44% (OECD, 2010). The fact that large meltdowns affect public opinion is easier to see in the Fukushima accident, for which there is much better polling data. For example, in the U.S., Gallup suggests that the share of Americans in favor of nuclear energy dropped from 62% in 2010, one year before the accident, to 44% in 2016, five years afterwards (Riffkin, 2016).

3 Cross-Country Evidence

This section uses cross-country data to document several stylized facts that will help motivate the within-country analysis. The primary cross-country data source is the Power Reactor Information System (PRIS) from the International Atomic Energy Agency (IAEA). PRIS contains data on a variety of indicators, such as the number of operating reactors by country-year, total capacity of operating reactors by country-year, number and capacity of reactors under construction by country-year. Democracy scores come from Polity IV. Data on reserves, consumption, and production of oil, gas, coal, and biofuels are from the U.S. Energy Information Administration (EIA).

We merge these data into a country-year panel with countries that ever built a nuclear power plant. In total, there are 34 such countries. We then gather additional information on the generational design, ownership status, and number of recorded accidents for each of our 1,000 nuclear reactors using publicly available sources such as IAEA's International Nuclear Information System Repository and government documents.

We begin by plotting the number of operating nuclear reactors worldwide over time. Figure 1a shows that there is a rapid rise from 1960 to 1985, but the rise flattens out immediately after Chernobyl and remains at the flatter slope in the subsequent decades. Figure 1b plots the *net growth* in the number of operating reactors over time. We fit a polynomial to the data and also plot the 95% confidence interval. There is a sharp, discontinuous drop after the Chernobyl accident.

Next, we show that most of this decline is due to a sharp reduction in the growth of nuclear operating reactors in countries with democratic governments: countries with a 1985 Polity IV score of 8 or higher. In our sample, they are Argentina, Belgium, Canada, Finland, France, Germany, India, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom, and the United States.[4]

Figure 1a plots the number of all NPPs in democracies (in blue) juxtaposed against the number of NPPs worldwide (in red). Throughout the period, democracies hosted the vast majority of NPPs.

[4] Countries in our sample a 1985 Polity IV score below 8 are Armenia, Bangladesh, Belarus, Brazil, Bulgaria, China, Czech Republic, Hungary, Iran, Kazakhstan, South Korea, Lithuania, Mexico, Pakistan, Romania, Russia, Slovakia, Slovenia, South Africa, Taiwan, Turkey, Ukraine, and the UAE.

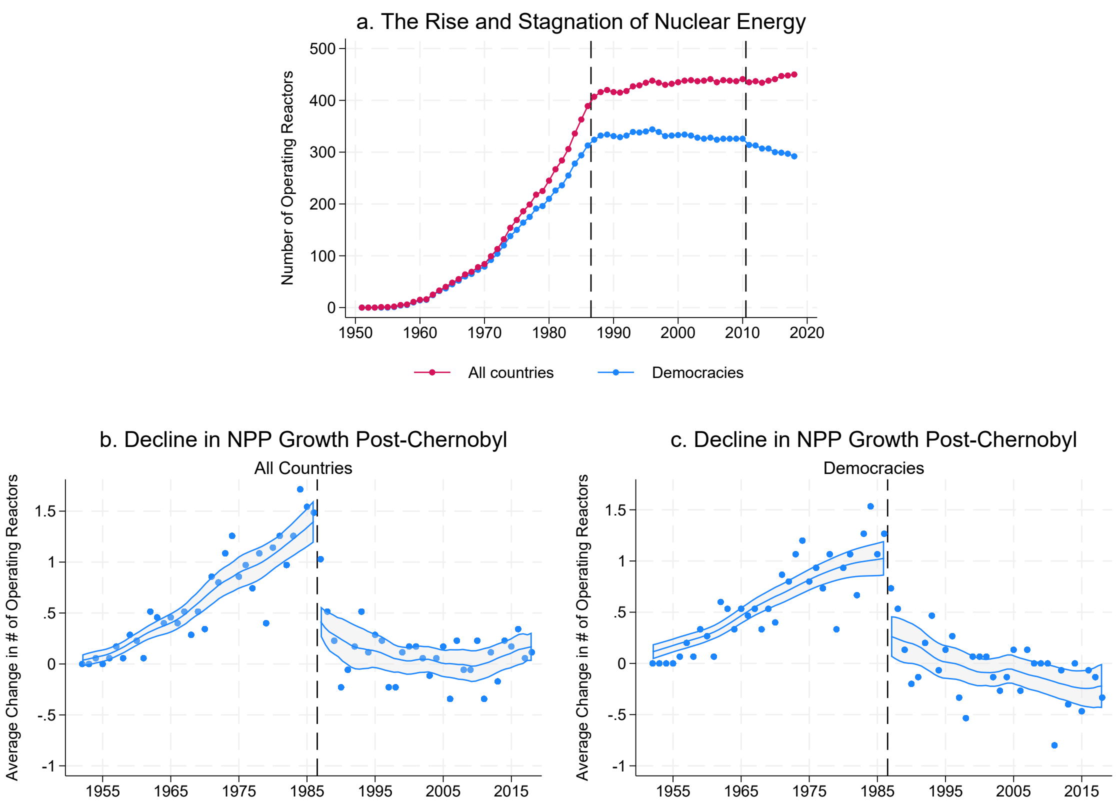

Figure 1: NPP Growth Over Time

In fact, 294 out of 363 reactors as of 1985 were in democratic countries. The country that had the most reactors in 1985, 90, was the United States. It was followed by France at 43 and the United Kingdom at 38. Similar to the worldwide patterns, in democratic countries, the number of NPPs was growing at a fast rate during the 1960s, 70s and early 1980s but after the Chernobyl accident, the NPP growth has halted. Figure 1c shows this more vividly by plotting the annual growth in NPPs for democracies. We fit a polynomial to the data and also plot the 95% confidence interval. The figure shows that prior to Chernobyl, democratic countries experienced high growth in NPP; however, the pace of growth discontinuously declined at the time of the Chernobyl accident. Prior to Chernobyl, the average country built around one NPP per year. After Chernobyl, that number immediately fell to less than one per every other year and later converged to zero.

To assess the statistical significance of these relationships, we estimate the following regression:

$$y_{it} = \beta PostChernobyl_t + \Gamma X_{it} + \gamma_i + \varepsilon_{it} \tag{1}$$

where y_{it} is the growth in the number of nuclear power plants in country i in year t. On the right hand side, we include a dummy variable for "post Chernobyl" and country fixed effects. We will estimate this specification both for all countries and for countries that were democracies as of 1985 and not. Standard errors are clustered at the country level.

Table 1 column (1) presents the estimates for all countries with only country and year fixed effects. Column (2) adds a country's logarithm of GDP per capita from the Maddison Project Database as a control variable to account for the fact that countries with larger economies can better afford to construct NPPs. Alternatively, column (3) adds the country-year linear trends to account for their long-run divergence in economic development. Across these specifications, the growth in the number of operating nuclear reactors declined sharply by 0.3 to 0.7 fewer operating nuclear reactors per year.

Columns (4)-(6) report similar estimates for democratic countries only while columns (7)–(9) report the results for the remaining countries in our sample. Columns (5)–(6) and (8)–(9) show that accounting for GDP or country-specific trends, NPP growth declined in all countries after Chernobyl, but the decline is much larger in democracies, which had more reactors and were experiencing higher growth prior to Chernobyl. These estimates also confirm the statistical significance of the decline in NPP growth that was illustrated by the earlier figures.

Table 1: The Impact of Chernobyl on NPP Growth

	Dependent Variable: Yearly Growth in # of Operating Reactors								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Countries			*Democracies Only*			*Other Countries*		
Dep. Var. Mean	0.206	0.218	0.206	0.304	0.304	0.304	0.129	0.140	0.129
Dep. Var. SD	0.949	0.979	0.949	1.273	1.273	1.273	0.566	0.595	0.566
Post Chernobyl	-0.301**	-0.683***	-0.609***	-0.696***	-1.189***	-1.006***	0.012	-0.277**	-0.295**
	(0.127)	(0.185)	(0.168)	(0.228)	(0.370)	(0.331)	(0.091)	(0.101)	(0.113)
Log GDP per capita		0.456***			0.682**			0.362*	
		(0.161)			(0.242)			(0.187)	
Country FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country-Specific Trends			Y			Y			Y
Obs	2,176	2,035	2,176	960	960	960	1,216	1,075	1,216
Countries	34	34	34	15	15	15	19	19	19
R-squared	0.14	0.17	0.26	0.18	0.20	0.26	0.12	0.19	0.30

Notes: Columns (1)-(3) report the results for all countries that have ever had a nuclear power plant. Columns (4)-(6) report the results for a subset of these countries that had a Polity IV democracy score equal to or above eight out of ten as of 1985. Columns (7)-(9) report the results for the countries with the score below eight. The standard errors in parentheses are clustered at the country level. * p<0.1, ** p<0.05, *** p<0.01.

Motivated by the fact that the global decline in NPPs after Chernobyl is driven by liberal democracies and the political power of special interest groups in such political structures, we hypothesize that fossil fuel interests to advantage of the safety concerns arising after Chernobyl to reduce nuclear investment. In the next two sections, we will examine detailed data on fossil fuel interests in the U.S. and the U.K.. These two countries were amongst the first innovators of nuclear power, had a large number of NPPs at the time of Chernobyl, and also have granular data that allow us to tie fossil fuel interests to elected officials.

4 The United States

The main goal of the within-U.S. exercise is to address three questions: i) are fossil fuel donations related to congressional voting behaviors on nuclear-related issues, and how was this relationship affected by the Chernobyl accident; ii) are fossil fuel advertisements related to media sentiment in the coverage of nuclear energy, and how was this relationship affected by the Chernobyl accident; and iii) did the fossil fuel industry adjust its campaign contributions and media expenditures after the Chernobyl accident.

The United States was a global leader in nuclear power, and despite the Three Mile Island accident in 1979, the U.S. remained the largest investor in nuclear energy in the early 1980s. Figure 2 plots the number of NPPs over time for the U.S. It shows a steep rise during the 1960s, 70s and early 1980s, even after the Three Mile Island partial meltdown. After Chernobyl, the number of NPPs fully stopped growing.

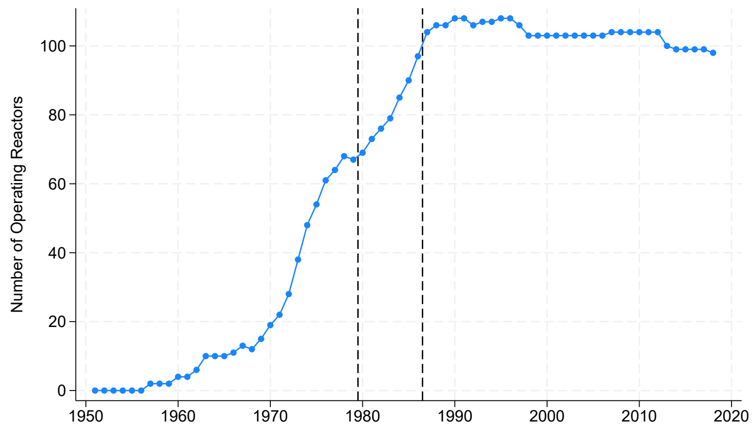

Figure 2: Total Number of Operating Nuclear Reactors in the US over time

In the U.S., opposition to nuclear came mainly from two sources. The first was the fossil fuel industry. Nuclear energy competed with other energy providers. In the 1980s, most non-nuclear energy came from fossil fuels. Thus, the expansion of nuclear energy was a direct threat to the profits and relevance of fossil fuel, and the fossil fuel industry responded by actively fostering an anti-nuclear agenda through both lobbying and media campaigns.

As an example for fossil fuel lobbying, throughout the 1960s, the coal industry invested significant resources in a lobby group called the National Coal Policy Council (NCPC), which was an alignment that included coal mining companies, coal miner unions, railroad companies, coal mine equipment companies and coal burning utility companies. The NCPC directly challenged the federal government's programs designed to make the peaceful atom an economically viable competitor against fossil fuel.[5]

In terms of fossil fuel media influence, for example, it has been documented that in 1954, the then President of the National Academy of Sciences (NAS), who was on the board of trustees of the Rockefeller Foundation, was asked by several of his fellow trustees to compile a report on the risk of atomic radiation. The report ended up being highly critical of atomic radiation than previous standards (and was later criticized by some for exaggerating radiation risk), and was promoted extensively in the New York Times, whose publisher at the time was also a trustee of the Rockefeller Foundation.[6]

The second source of opposition to nuclear power came from environmental groups. Starting in the mid 1970s, groups such as the Sierra Club in the U.S. began to lobby against nuclear (Environmental Progress, 2023). It is worth noting that, behind many anti-nuclear activities carried out by environ-

[5]Source: https://atomicinsights.com/above-board-competition-in-energy-markets-finally-emerging/

[6]For more details, see: https://atomicinsights.com/how-did-leaders-of-the-hydrocarbon-establishment-build-the-foundation-for-radiation-fears/

mental groups, one can find the fingerprints of the fossil fuel industry. For example, in 1970, the head of the Atlantic Richfield Co., a major U.S. petroleum company at the time, contributed $200,000 to Friends of the Earth, which was strongly anti-nuclear (Engdahl, 1993).[7]

To more rigorously understand the role of the fossil fuel industry in shaping anti-nuclear policies in the U.S., our analysis will examine the relationships between fossil fuel donations and voting on nuclear related policies in the House and Senate, and between fossil fuel advertisements and news coverage about nuclear energy in major newspapers, with a focus on how these relationships changed before and after the Chernobyl accident.[8] In addition, we also investigate whether the Chernobyl accident affected fossil fuel campaign contributions and advertisement spendings.

4.1 Public Salience of Chernobyl

Before we begin our analysis, we will first document that the Chernobyl accident was salient to the American public and that it triggered widespread fear and concern about nuclear safety in the U.S.. News reports of Chernobyl started on April 28th, within three days after the meltdown. It was widely reported in all major news outlets and mediums: print, radio, and television.

To document the salience of the news, we examine newspaper articles with the word “Chernobyl”. As an example, Panel (a) of Figure 3 plots the number of articles in the New York Times over time. It shows a sudden and dramatic increase in news about Chernobyl that lasts for several months. Panel (b) of Figure 3 plots the number of articles that mention “safety”, “fallout”, or “meltdown”; and Panel (c) of Figure 3 plots the number of generally anti-nuclear articles over time. We extract all news articles related to nuclear energy, and use ChatGPT to help identify whether an article is generally anti-nuclear. The figures show that the # of both types of articles (which are not mutually exclusive) increase after Chernobyl. These figures are consistent with the conventional wisdom that knowledge about the accident was pervasive in the U.S. and there was significant public concern over the safety of NPPs.

We also examine the # of articles that mention “Three Mile Island” to see if news outlets linked the two reactor accidents. Panel (d) of Figure 3 shows that the New York Times began mentioning "Three Mile Island" more frequently immediately following the Chernobyl accident.

[7] In 2007-2010, the Sierra Club accepted $25 million USD from an energy company (Walsh, 2012).

[8] Note that we are unable to observe gifts or spending for environmental organizations because most of them are private and do not disclose such information. Also, there is no systematic data on the patrons behind non-commercial advertisements.

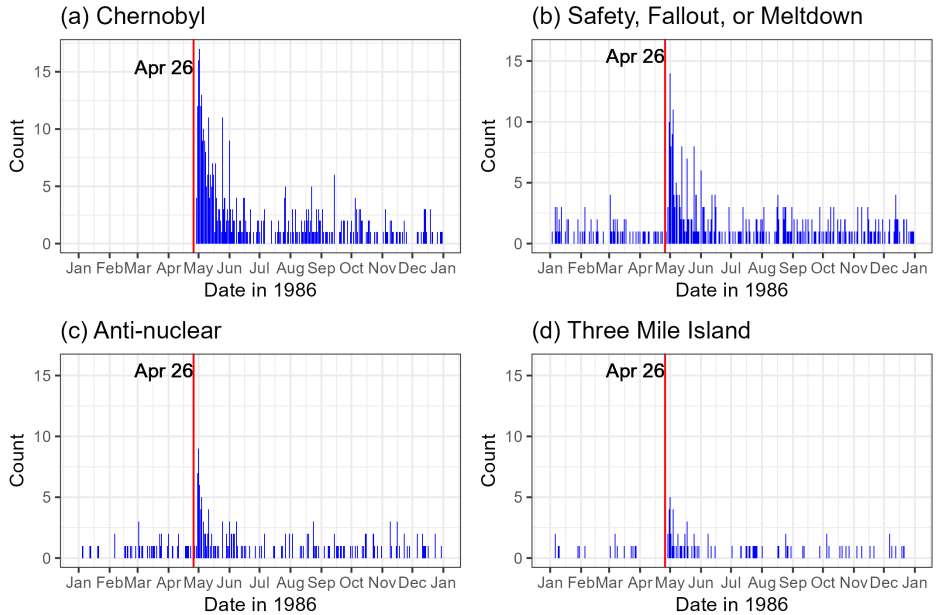

Figure 3: Number of Articles in the New York Times in 1986

4.2 Fossil Fuel Donations and Congressional Voting on Nuclear Bills

U.S. nuclear energy development is regulated by the Nuclear Regulator Commission (NRC), an independent agency created by Congress in 1974. The NRC is ultimately overseen by Congress, which votes on bills that specify the NRC's mandate, funds, sets objectives, such as increasing or reducing regulations, research, the number of reactors.

To understand the extent to which campaign donations can affect the actual nuclear policy making, and how this channel of potential policy influence responds to the Chernobyl accident, we link fossil fuel industry's campaign donations to the recipients' congressional voting records in nuclear-related bills.[9] Then, we manually label each bill as pro or anti-nuclear based on how the proposed policy would likely affect the profit and operational costs of the nuclear industry. See the Data Appendix for examples. This in turn allows us to define three outcome variables at the congressman-by-bill level: i) *Pro Nuclear Vote*, a dummy variable that equals one if a congressman votes pro in a pro-nuclear bill or against in an anti-nuclear bill; ii) a dummy variable that equals one if a congressman votes pro in an anti-nuclear bill or against in a pro-nuclear bill; and iii) *Absentia*, a dummy variable indicating whether a congressman is in absentia in a nuclear-related bill.

Our hypothesis is that, for a given congressman, fossil fuel donations might reduce pro-nuclear

[9] Congressional voting records are from voteview.com, and nuclear-related bills are identified by keyword filtering and manual checking.

votes and increase anti-nuclear ones. This relationship would be particularly salient after Chernobyl if the accident increased the returns to lobbying, which could happen if public fear complements lobbying efforts in the congress member's decision process. It can also happen if there are increasing returns to the amount of contribution (i.e., the relationship between the amount of contributions and negative votes is convex).

To investigate, we estimate the following equation:

$$vote_{ijt} = \alpha \text{Fossil Donations}_{it} + \beta \text{Fossil Donations}_{it} \times post_t + \lambda_i + \tau_j + \gamma_t + \epsilon_{ijt}, \quad (2)$$

where the voting behavior of congressman i on bill j in cycle t, $vote_{ijt}$, is a function of: donations he received from fossil fuel firms, Fossil Donations$_{it}$, and its interaction with a dummy variable for post Chernobyl, $post_t$; a vector of congressman fixed effects, λ_i, bill fixed effects, τ_j, and cycle fixed effects, γ_t. Standard errors are clustered at the state level.

Table 2 column (1) examines the likelihood of voting pro-nuclear amongst all nuclear-related bills, column (2) examines the likelihood of voting anti-nuclear amongst all nuclear-related bills, and column (3) examines the likelihood of abstentions amongst all nuclear-related bills.

The table shows that prior to Chernobyl, campaign contributions from fossil fuel are not associated with less pro-nuclear votes, while after Chernobyl, contributions are negatively associated with voting pro-nuclear and positively associated with voting anti-nuclear. The interaction coefficients are positive and statistically significant in columns (1)-(2), indicating that the elasticity of voting behaviors with respect to campaign contributions increased after Chernobyl.

In contrast, as shown in column (3), fossil fuel donations are positively associated with abstentions in nuclear-related bills prior to Chernobyl, but this relationship completely disappears in the post-Chernobyl periods. This is consistent with a scenario where congressmen who had been swayed by contributions from being pro-nuclear to neutral (absent) prior to Chernobyl, are being swayed by contributions to being anti-nuclear after Chernobyl.

To better understand the dynamics of the effects, we separately estimate the effect of fossil fuel donation on nuclear-related vote by each cycle, and plot the estimates in Figure 4. As can be seen, there does not seem to be any obvious pre-trend in the associations between fossil fuel donation and nuclear-related vote, but a strong correlation emerges immediately after Chernobyl, and persists (albeit less saliently) in the subsequent cycles. This is consistent with the interpretation that the Chernobyl

Table 2: Fossil Fuel Donations and Congressman-bill Level Votes, 1979-2014

Dependent Variable	Pro-nuclear vote	Anti-nuclear vote	Absent from voting
	(1)	(2)	(3)
Fossil Donation	0.050	-0.139***	0.090***
	(0.047)	(0.048)	(0.033)
Post Chernobyl × Fossil Donation	-0.134***	0.223***	-0.092***
	(0.047)	(0.052)	(0.033)
Sum of Coeff.	-0.083	0.084	-0.002
P-value of the sum	0.000	0.000	0.877
Pre-period Dep. Var. Mean	0.352	0.527	0.119
Post-period Dep. Var. Mean	0.401	0.558	0.040
N	37203	37203	37203
R2	0.36	0.31	0.16
Cycle FE	X	X	X
Congressman FE	X	X	X
Bill FE	X	X	X

Notes: The standard errors in parentheses are clustered at the state level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

accident significantly raised the return to anti-nuclear lobbying.

Important Nuclear Bills Not all bills are equally important. To gauge the economic significance of fossil fuel influence in nuclear policy making, we construct two measures that can proxy for the importance of a nuclear-related bill. The first measure is "pivotal," which refers to the subset of bills where yes-votes are 40% to 60% of all votes. The second measure is "high-stakes," for which we read through the bills and manually code high-stakes bills as those that directly affect nuclear development and investment. There are 37 such bills (see Appendix Table A.2).

In Table 3, we modify our baseline interaction specification, by further interacting Fossil Donations$_{it}$ and Fossil Donations$_{it} \times post_t$ with the two measures of bill importance — $Pivotal_j$ and $HighStakes_j$. As shown in columns 1 and 2, our baseline effects on votes are entirely driven by those pivotal votes: fossil fuel donation has no detectable impact on votes in pre-Chernobyl bills (regardless of closeness), and after Chernobyl, pivotal bills, instead of non-pivotal ones, are the cases where congressional votes get significantly swayed to become more anti-nuclear. In contrast, the effects on abstentions appear to be more concentrated in non-pivotal bills (column 3). These results indicate that fossil fuel donations likely influence policy more through the intensive margin rather than the extensive margin.

In columns 4 and 5, we see that pre-Chernobyl fossil fuel donations are associated with more (less) pro-nuclear (anti-nuclear) votes in high-stakes bills. This likely reflects the selection of fossil fuel

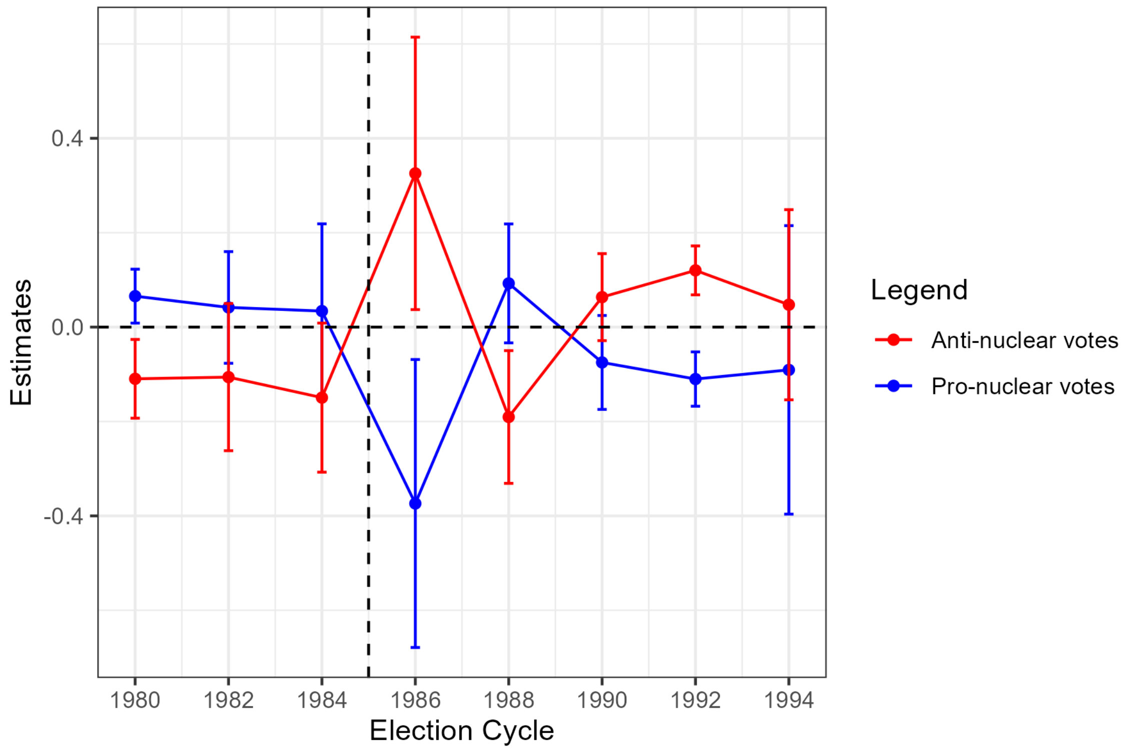

Figure 4: Dynamic Effect of Fossil Fuel Donation on Pro-nuclear Votes

donations: when a congressman is more likely to vote more pro-nuclear in an important bill, fossil fuel companies have stronger incentives to sway his votes. The fact that the congressmen remain more pro-nuclear even after receiving fossil fuel donations speaks to the lack of effectiveness in fossil fuel lobbying prior to Chernobyl. In contrast, after the Chernobyl accident, as reflected by the significant triple interaction terms, the recipients are no longer more pro-nuclear in their subsequent votes, indicating increased lobbying effectiveness by the fossil fuel industry. Column (6) demonstrates a similar pattern for abstention compared to pivotal bills.

Taken together, our results indicate that the fossil fuel influence in post-Chernobyl nuclear policy making is substantive, rather than just performative: by mostly swaying congressional votes in pivotal and high-stakes nuclear bills, fossil fuel donations might have shaped U.S. nuclear policies in economically significant ways.

Table 3: Fossil Fuel Donations and Congressman-bill Level Votes on Important Nuclear Bills, 1979-2014

Dependent Variable	Pro-nuclear vote (1)	Anti-nuclear vote (2)	Absent from voting (3)	Pro-nuclear vote (4)	Anti-nuclear vote (5)	Absent from voting (6)
Fossil Donation	0.043	-0.146**	0.107***	-0.057	-0.015	0.074**
	(0.049)	(0.058)	(0.037)	(0.055)	(0.057)	(0.031)
Post Chernobyl × Fossil Donation	-0.060	0.168***	-0.113***	-0.027	0.092	-0.069**
	(0.045)	(0.058)	(0.036)	(0.052)	(0.056)	(0.032)
Fossil Donation × Pivotal bill	0.020	0.028	-0.053			
	(0.057)	(0.078)	(0.054)			
Post Chernobyl × Fossil Donation × Pivotal bill	-0.269***	0.207**	0.069			
	(0.078)	(0.095)	(0.051)			
Fossil Donation × High-stake Bill				0.442***	-0.514***	0.069
				(0.097)	(0.132)	(0.072)
Post Chernobyl × Fossil Donation × High-stake Bill				-0.443***	0.538***	-0.090
				(0.101)	(0.138)	(0.072)
Pre-period Dep. Var. Mean	0.352	0.352	0.527	0.527	0.119	0.119
Post-period Dep. Var. Mean	0.401	0.401	0.558	0.558	0.040	0.040
N	37203	37203	37203	37203	37203	37203
R-squared	0.36	0.32	0.16	0.36	0.32	0.16
Cycle FE	X	X	X	X	X	X
Congressman FE	X	X	X	X	X	X
Bill FE	X	X	X	X	X	X

Notes: The standard errors in parentheses are clustered at the state level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.3 Campaign Contributions after Chernobyl

Our findings so far suggest that the Chernobyl accident increased the marginal return to anti-nuclear lobbying, which is consistent with a scenario where the accident shift congressmen from being staunchly pro nuclear to being open to the idea of opposing nuclear investment. In theory, since lobbying is an intermediate input to the final output of "anti-nuclear influence/policy," such an increase in the return to lobbying could have ambiguous impacts on the amount of lobbying effort. For example, when it becomes easier to convince congressmen to vote anti-nuclear, fossil firms may either increase their lobbying expenditure (anti-nuclear policies become "cheaper," increasing demand for such policies), or decrease it (the desired anti-nuclear policy requires less lobbying expenditure to achieve, leading firms to substitute resources to other domains).[10] To investigate whether fossil fuel interest groups leveraged Chernobyl to lobby against nuclear investment, we examine campaign contributions from fossil fuel companies to the members of Congress before and after Chernobyl. In the presence of the aforementioned countervailing forces, our estimates will capture the net average effect.

This analysis uses a firm and election-cycle level panel for the years 1979 to 2014. We choose this window due to the availability of the campaign contributions records in the Database on Ideology, Money in Politics, and Elections (DIME). For every firm that made at least one campaign contribution in DIME, we search its profile and manually classify whether its primary business lies in the fossil fuel industry. We end up with 381 fossil fuel firms that ever made campaign contributions.

The dynamic relationship between fossil fuel contributions and donations before and after Chernobyl is characterized by the following event study specification:

$$Donations_{it} = \sum_{k \neq -1} \beta_k Fossil_i \times \mathbb{1}\{t = k\} + \lambda_i + \gamma_t + \epsilon_{it}. \quad (3)$$

where the dependent variable is the amount of donations from firm i during cycle t. $Fossil_i$ is equal to 1 if the firm is in the fossil-fuel industry, $\mathbb{1}\{t = k\}$ represents the vector of event study dummies where the cycle immediately before Chernobyl is omitted for comparison. λ_i is a vector of firm fixed effects and γ_t is a vector of cycle fixed effects. Standard errors are clustered at the firm level. Firm fixed effects account for time-invariant differences across firms such as the fact that firms vary in size and some firms always donate more than other firms. Cycle fixed effects account for changes over time that affect all firms, such as the fact that campaign donations have generally increased over time.

Figure 5 plots the coefficients. There are no pre-trends. Prior to the Chernobyl accident, the fossil

[10] This is similar to the concept of "rebound effect" in environmental economics — when appliances become more energy efficient, total energy consumption may either increase or decrease.

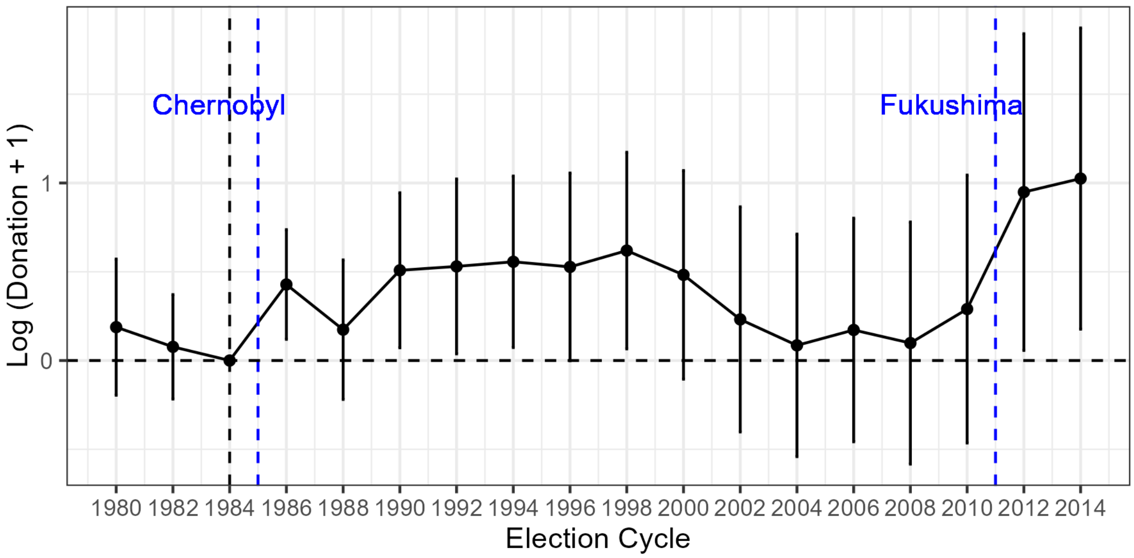

Figure 5: Event study for donations from fossil energy firms

fuel industry had similar trajectories in campaign contributions as non-energy firms. After Chernobyl, we observe a relative increase in campaign donations from fossil fuel firms. The timing of the pattern is reassuring, as fossil fuel companies increase contribution precisely after Chernobyl. The Chernobyl effect lasted for more than a decade, before it gradually wane out in the 2000s. After the Fukushima accident in 2011, however, we observe another major spike in campaign donations from the fossil fuel industry, which further corroborates the narrative that the fossil fuel industry leverages nuclear accidents as opportunities to exert more political influence.

In Table 4, we quantify these effects. Column (1) examines the log of donations plus 1 to allow for observations that make no donations. Column (2) examines the log of donations without adding one – i.e., the intensive margin. All observations that do not make any donations drop out of the estimate. Column (3) examines a dummy variable for any donation – i.e., the extensive margin. All observations that do not make any donations drop out of the estimate. The DiD estimates confirm the event study patterns: fossil fuel campaign contributions increased by 40.5% (48.9%) in the cycle (decade) immediately following the Chernobyl accident, converged back to normal in the 2000s, and then surged by another 145.5% after the Fukushima accident. Overall, in the event of a major nuclear accident, the positive forces turn out to outweigh the negative ones, and as a result, Chernobyl increases fossil fuel lobbying.

Table 4: Fossil Fuel Firms and Donations, 1979-2014

Dependent Variable	Log (Donation + 1) (1)	Log (Donation) (2)	Any Donation (3)
Fossil Fuel Firms × Cycle 1986	0.340*	-0.095	0.041**
	(0.173)	(0.286)	(0.019)
Fossil Fuel Firms × Cycles 1988-1998	0.398*	0.247	0.038*
	(0.221)	(0.278)	(0.022)
Fossil Fuel Firms × Cycles 2000-2010	0.138	0.358	0.007
	(0.286)	(0.328)	(0.029)
Fossil Fuel Firms × Cycles 2012-2014	0.898**	0.896**	0.066
	(0.405)	(0.422)	(0.041)
Mean of Dep. Var.	1.940	9.543	0.203
S.D. of Dep. Var.	3.961	2.149	0.402
N	12977	2638	12977
R-squared	0.48	0.84	0.39

Notes: The standard errors in parentheses are clustered at the firm level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Taken together, our analysis of U.S. politics shows that Chernobyl triggered significant public fear and concern about nuclear energy. At the same time, campaign contributions from fossil fuel companies increased after Chernobyl, and these contributions were associated with a strong shift towards voting more negatively on pivotal bills that affected the costs of constructing and maintaining NPPs. These results are consistent with our hypothesis that fossil fuel leveraged Chernobyl to reduce U.S. nuclear investment.

4.4 Fossil Fuels and U.S. News Outlets

Fossil fuel interests can also influence policy by shaping public opinion. One way to do this is via news outlets. Anti-nuclear advertisements can directly influence readers' opinions about nuclear energy. Qualitative evidence suggests that the fossil fuel industry has indeed been paying for anti-nuclear advertisements, but it is hard to evaluate the prevalence of such practice because there is no systematic data on the patrons behind non-commercial advertisements.[11] Nevertheless, even for those advertisements that appear neutral or silent about nuclear energy, such as purely commercial advertisements for fossil fuel, they can potentially affect anti-nuclear news coverage if the management of profit-maximizing news outlets believe that future advertisement revenues could be contingent on how

[11] For example, the American Petroleum Institute was reported to organize opposition to pro-nuclear legislation in Harrisburg through an initiative called No Nuclear Bailouts. API has paid for social media ads and mail pieces hammering House Bill 11, which would include nuclear in the portfolio of "alternative energy" sources that count towards utilities' requirements for carbon-free power sources. Source: https://climatecoalition.org/who-opposes-nuclear-energy/

they report on nuclear power, either directly so by influencing the fossil fuel's choice of advertisement platforms, or indirectly so by impacting the profits of fossil fuel firms and thus their advertisement expenditures. This can in turn influence public opinion.

Therefore, in this section, we explore the relationship between fossil fuel advertisement spending and nuclear coverage in major U.S. newspapers. We obtain historical newspaper records in the U.S. from four databases: Proquest, Newsbank, Newspaper.com, and Newspaperarchive.com, and download all pages in the six months before and after Chernobyl for all the top 3 most circulated daily newspapers in each state as of 1986. Following Dell, Carlson, Bryan, Silcock, Arora, Shen, D'Amico-Wong, Le, Querubin and Heldring (2023), we apply a deep-learning OCR model, which is fine-tuned to identify newspaper layouts and convert the graphical newspaper copies into textual data. We then search in the newspaper contents the names of all the major fossil fuel companies and other top seventy companies in the Fortune 500 list.[12] For each returned article, we ask ChatGPT to help identify whether it is an advertisement. We also extract all newspaper articles related to nuclear energy, and use ChatGPT to categorize each article's attitude as positive, negative, or neutral about nuclear energy.

Note that a key difference between the media response and legislative response to Chernobyl lies in their time-sensitiveness. In the legislative process, months or even years of extensive research and negotiations are usually needed before a nuclear-related bill can be proposed and eventually voted on, while campaign donations can be made flexibly in any election cycle. As a result, as shown in the previous sections, the impact of Chernobyl on the legislative process unfolded over more than an entire decade, giving fossil fuel firms enough time to adjust their campaign donations accordingly, and also giving congressmen enough time to change their nuclear-related stances after receiving such donations. In stark contrast, as demonstrated in Section 4.1, media response to Chernobyl is much more short-lived. After the accident, major newspapers essentially had a short time window of a few weeks to have extensive coverage about nuclear energy, after which public interest quickly shifts to other issues. This time-sensitive nature, combined with the fact that advertisement is usually contracted in batches well in advance of their actual publishing dates, leaves limited room for fossil fuel firms to effectively "buy" additional anti-nuclear coverage by suddenly spending more on advertisements after Chernobyl.

In light of this, it is perhaps not surprising that, as shown in Table 5, unlike the surge in campaign donations, fossil fuel companies did not significantly increase their advertisement spendings following the Chernobyl accident.

[12]The arbitrarily chose seventy companies are due to time constraints. We will expand this number in the future.

Table 5: Fossil Fuel and Newspaper Advertisement, 1985/10-1986/7

Dependent Variable	Log (Advertisement + 1)			
	(1)	(2)	(3)	(4)
	Total Ad	NonJob Ad	Job Ad	FrontPage Ad
Fossil Fuel × Post Chernobyl	-0.184	-0.170	-0.160	-0.122
	(0.126)	(0.123)	(0.112)	(0.099)
Mean of Dep. Var.	3.475	3.243	2.103	0.468
S.D. of Dep. Var.	2.530	2.520	1.961	0.794
N	855	855	855	665
R2	0.95	0.95	0.92	0.65
Month FE	X	X	X	X
Company FE	X	X	X	X

Notes: The standard errors in parentheses are clustered at the newspaper level. * p < 0.1, ** p < 0.05, *** p < 0.01.

Motivated by such time-invariant feature of fossil fuel advertisements in the short run, instead of studying the impact of newly launched fossil fuel advertisements after Chernobyl, we focus on how pre-existing fossil fuel advertisements, which proxy for the importance of the fossil fuel industry for a newspaper's long-run profitability, affect that newspaper's post-Chernobyl reporting on nuclear energy. Specifically, to investigate whether newspapers with stronger pre-existing ties to fossil fuel companies became more anti-nuclear after Chernobyl, we estimate the following event study specification:

$$Log(1 + Negative_{it}) = \sum_{k \neq -1} \beta_k FossilAd_i \times \mathbb{1}\{t = k\} + \lambda_i + \gamma_t + \epsilon_{it}. \quad (4)$$

where $Negative_{it}$ is the number of anti-nuclear-energy articles published in newspaper i in month t. $FossilAd_i$ is the log share of fossil fuel advertisements in newspaper i in the six months prior to Chernobyl (relative to advertisements by other top 70 firms in Fortune 500). We control for newspaper fixed effects, months fixed effects, and the standard errors are clustered at the newspaper level.

Figure 6 shows that newspapers with more vs. less pre-existing fossil fuel advertisements did not show any differential trends in nuclear energy coverage prior to Chernobyl. However, after Chernobyl, newspapers with stronger pre-existing fossil fuel ties showed significantly stronger anti-nuclear sentiment in their contents in the following months. As quantified in Table 6, an 100 percent increase in pre-existing fossil fuel advertisements is associated with a more than 20 percent increase in anti-nuclear newspaper articles, and the effect exists for both job and non-job advertisements. This alleviates the concern that this relation might be fossil fuel firms trying to expand after seeing a negative shock to their main competitor. Column (4) suggests that the result is also not entirely driven by front-page advertisements.

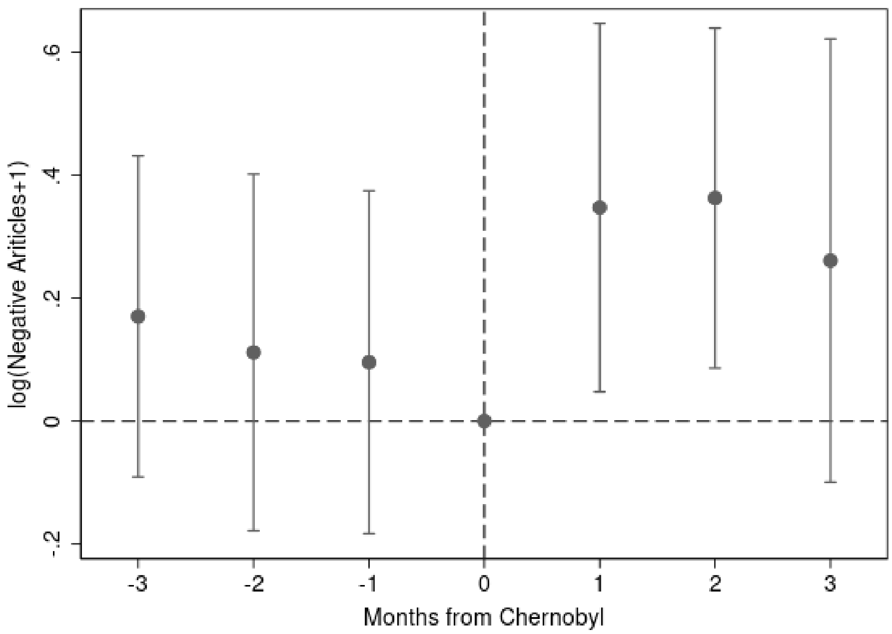

Figure 6: Fossil Fuel Advertisements and Negative Nuclear Coverage in US Newspapers

Table 6: Fossil Fuel Advertisement and Newspaper Sentiment, 1985/10-1986/7

Dependent Variable	Log (NegativeArticle + 1)			
	(1)	(2)	(3)	(4)
	Total Ad	NonJob Ad	Job Ad	FrontPage Ad
Log(Ratio) × Post Chernobyl	0.224***	0.227**	0.107**	0.125*
	(0.085)	(0.098)	(0.0246)	(0.069)
Mean of Dep. Var.	1.981	1.981	1.981	1.981
S.D. of Dep. Var.	0.989	0.989	0.989	0.989
N	846	846	819	837
R2	0.74	0.74	0.74	0.73
Month FE	X	X	X	X
Newspaper FE	X	X	X	X

Notes: The standard errors in parentheses are clustered at the firm level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

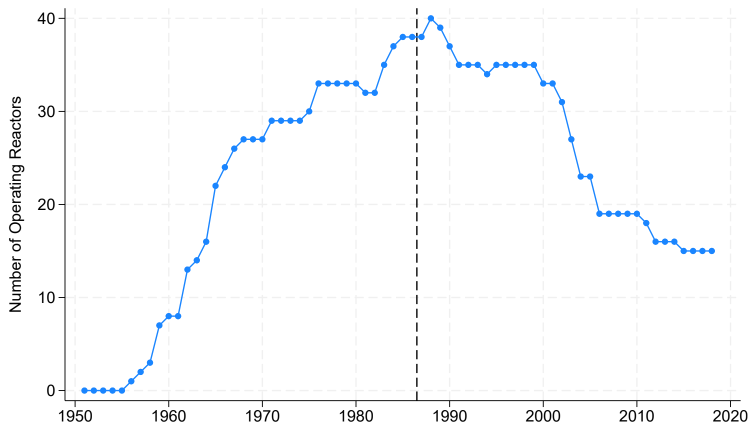

Figure 7: Total Number of Operating Nuclear Reactors in the UK over time

5 The United Kingdom

The United Kingdom had 38 nuclear reactors in operation in 1985, the third highest number in the world. Nuclear energy was seen as an important alternative to coal, which was in steady and rapid decline. The decline of coal was accompanied by intense political conflict between coal miners' unions and the Conservative government (1970-1997). The National Coal Board advocated the closure of many mines that were deemed unproductive. The National Union of Miners (NUM), the national organization of local miners' unions, responded with strikes. These were successful in 1972 and 1974, but unsuccessful in 1984-85, where large government stockpiles prepared by the Thatcher-led government (1979-1990) outlasted the eleven-month strike. This was the last large miners strike in the U.K. (Moore and Thatcher, 2013).

Chernobyl took place one year after the 1984-85 strike. Although U.K. coal production had been in steady decline, coal workers and miners' unions still exerted influence. In 1980, 213 mines produced 130 million tons of coal and employed 237,000 people in the U.K.. In 1990, 65 mines produced 93 million tons of coal and employed 49,000 people. At the end of 1985, a few months before Chernobyl occurred, there were 133 mines that produced 94 million tons and employed 114,000 workers in the U.K. (Department for Energy Security and Net Zero, 2023).

The goal of our analysis is to investigate whether miners' unions took advantage of Chernobyl to lobby against nuclear energy investment.

Figure 7 plots the number of NPPs over time. We observe a steady increase over time that reverted soon after Chernobyl.

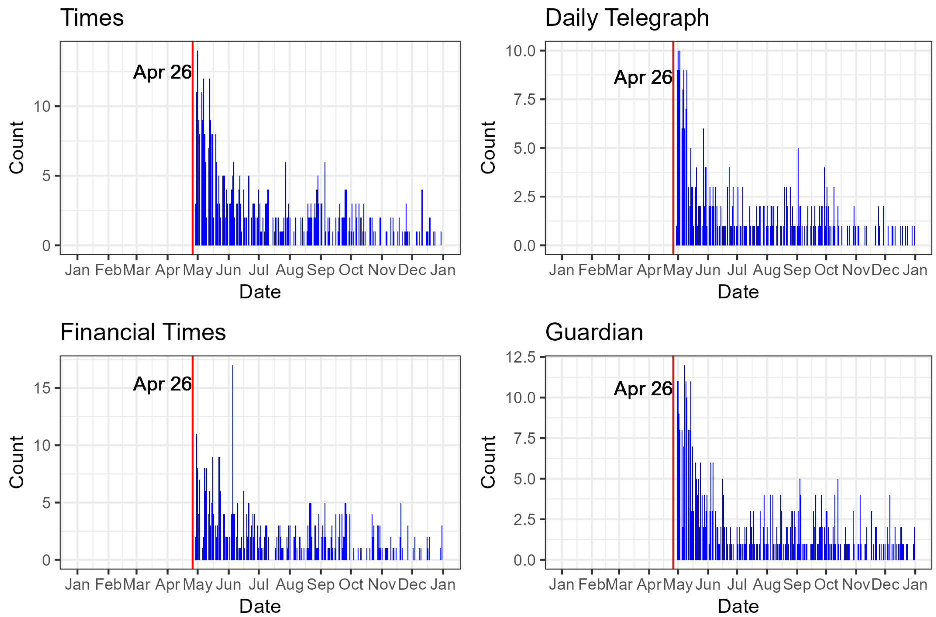

Figure 8: Number of Articles about Chernobyl in UK Newspapers in 1986

5.1 Public Knowledge of Chernobyl

As with the U.S. analysis, we first document the salience of Chernobyl for the U.K. public. News about Chernobyl first broke in the U.K. on April 28, 1986, and was covered widely by all outlets in the following days and weeks. As we discussed in the Background Section, radioactive rain fell onto parts of Scotland, and there was much concern about direct impacts from the Chernobyl fall out. The UK government imposed a ban on the farm products from close to 10,000 farms with more than 4 million sheep; some of these restrictions lasted until 2012.

Figure 8 plots the # of all articles with "Chernobyl" from Times, Daily Telegraph, Financial Times, and Guardian in the days before and after Chernobyl. It shows as sudden increase in news that lasts for 30 days. Figure 9 plots the # of articles that mention "safety", "fallout", "meltdown"; and Figure 10 plots the # of generally anti-nuclear articles over time. The figures show that the # of both types of articles (which are not mutually exclusive) increase after Chernobyl. These figures are consistent with conventional wisdom that knowledge about the accident was pervasive in the U.K. and there was significant public concern over the safety of NPPs.

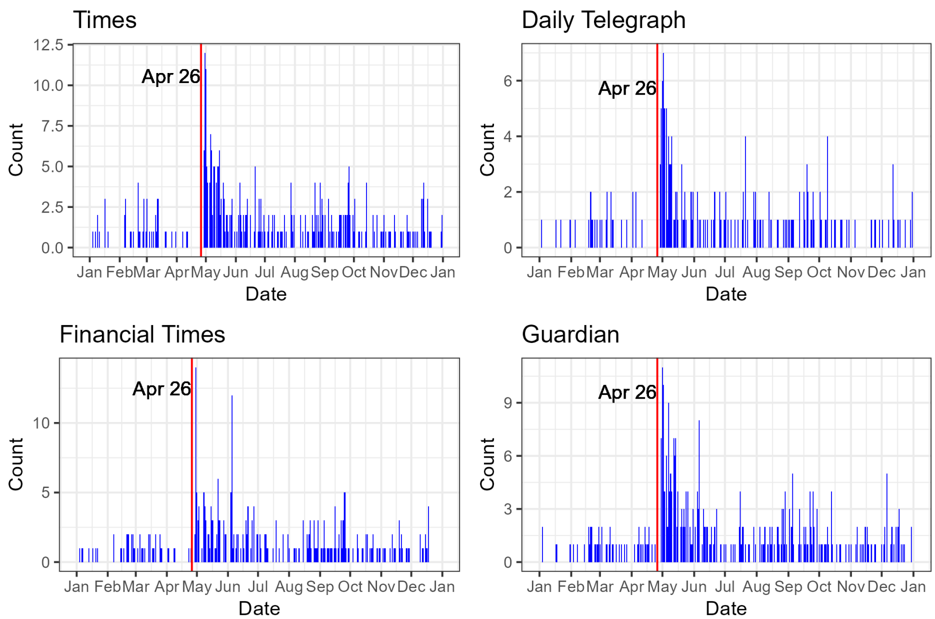

Figure 9: Number of Articles Mentioning "safety", "fallout" or "meltdown" in UK Newspapers in 1986

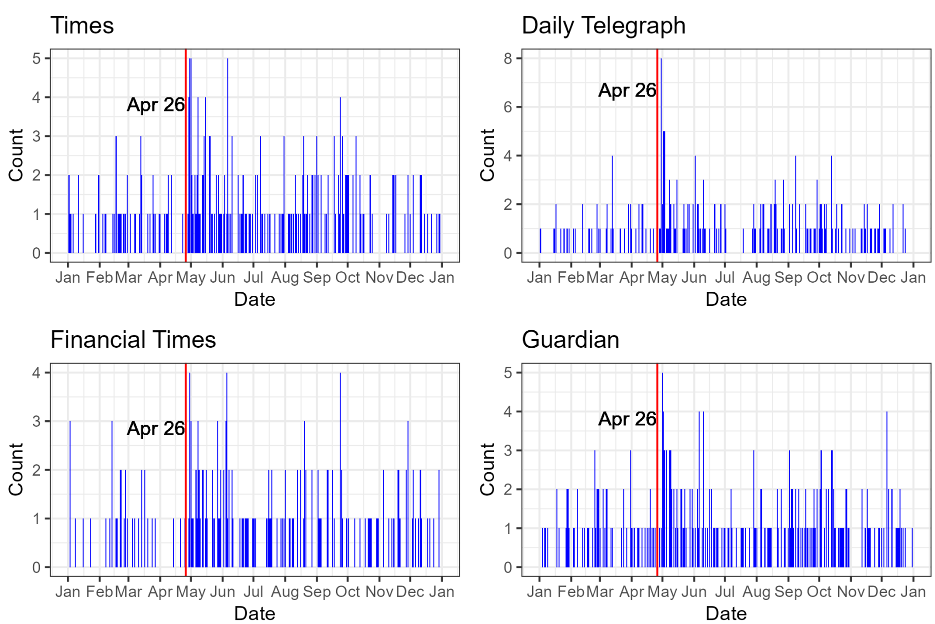

Figure 10: Number of Anti-nuclear Articles in UK Newspapers in 1986

5.2 Miners Sponsorship and MP Anti-Nuclear Speeches

This section investigates the relationship between an MP's connection to a miner union and his expressed political attitude towards nuclear energy after Chernobyl. If fossil fuel special interests took advantage of Chernobyl to fight against nuclear, then we should see and increase in negative for MPs sponsored by miners' unions relative to other MPs after Chernobyl.

The main outcome measure is the extent to which the MP speaks against nuclear investment in Parliament. We do not examine voting outcomes because Parliament rarely votes on nuclear-related issues during this period. Most decisions are made by a central board, which has broad discretion. We use machine learning methods to identify speeches that are anti-nuclear (32%), neutral (50%) and pro nuclear (18%).[13] We construct a constituency and month-level panel during 1983–1989, three years before and after the Chernobyl accident.

We follow Fouirnaies (2019) and identify whether an MP is sponsored by a miners' union.[14] All miner-union-sponsored MPs are in the Labour Party. The Labour Party founding documents gave unions exclusive right to sponsor MP candidates. Such (transparent) sponsorship was unique to the Labour party. Candidates could only be sponsored by one union in a particular election.

Our hypothesis is that miners unions took advantage of Chernobyl to promote the anti-nuclear agenda. To investigate this, we examine the relationship between whether an MP is sponsored by a miners' union and the number of anti-nuclear speeches the MP gives in parliament. If our hypothesis is correct, then we should observe an a positive relationship after Chernobyl, and the slope should be steeper than before Chernobyl. This can be characterized by the following equation:

$$y_{icmt} = \beta Mining_{ic} \times Post_{mt} + \gamma_{ic} + \lambda_{mt} + \varepsilon_{icmt}, \tag{5}$$

where the number of anti-nuclear speeches by MP i in constituency c in month m and year t, y_{icmt}, is a function of: the interaction of an indicator of whether a mining union sponsored the MP in the previous electoral campaign, $Mining_{ic}$, and an indicator of whether the speech took place during or after April 1986, $Post_{mt}$; γ_{ic} are the MP-constituency fixed effects and λ_{mt} are the year-month fixed effects. Standard errors are clustered at the MP-constituency level.

Table 7 presents the results. Column (1) examines the number of speeches with anti-nuclear

[13] In the U.K., the central regulatory body makes more decisions that the U.S. NRC. Similarly, we do not present estimates for mining sponsorships as an outcome because there is little shuffling across MPs in sponsorships during this period.

[14] We thank Alex Fouirnaies for kindly sharing these datasets with us. 98% of all mining-union-sponsored MPs in our sample were sponsored by either the Miners' Federation of Great Britain or the National Union of Mineworkers.

sentiment as the dependent variable. 10% of these speeches mention "Chernobyl." 43% mention "coal." The interaction coefficient is 0.128. It is statistically significant at the 5% level. This is a sizable effect since the mean number of ant-nuclear speeches is 0.021 and the standard deviation is 0.206. In other words, MPs sponsored by miner's unions increase the number of anti-nuclear speeches by around one-half of a standard deviation after Chernobyl.

Column (2) examines the number of speeches that discuss nuclear energy. Column (3) examines the number of speeches that mention "Chernobyl." Column (4) examines the number of anti-nuclear speeches that mention Chernobyl. Column (5) examines the number of anti-nuclear speeches that mention "coal". Column (6) examines the number of anti-nuclear speeches that mention "coal." Column (7) examines the number of speeches that mention "nuclear." We find that the interaction coefficient is positive for all of these outcomes.

Table 7: Differential Change in Antinuclear Rhetoric by UK MPs Sponsored by a Mining Union.

	(1) # of speeches with anti-nuclear sentiment	(2) # of speeches talking about nuclear energy	(3) # of speeches mentioning Chernobyl	(4) # of antinuclear speeches mentioning Chernobyl	(5) # of speeches mentioning coal	(6) # of antinuclear speeches mentioning coal	(7) # of speeches mentioning "nuclear"
Post-Chernobyl × Mining-Union Sponsored	0.128** (0.059)	0.293** (0.135)	0.077** (0.032)	0.078** (0.032)	0.482* (0.253)	0.120** (0.060)	0.270** (0.115)
Observations	34,727	34,727	34,727	34,727	34,727	34,727	34,727
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MP-constituency FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dep. Var. Mean	0.021	0.079	0.015	0.003	0.236	0.008	0.204
Dep. Var. SD	0.206	0.516	0.162	0.065	1.083	0.104	0.84

Notes: The sample is restricted to 1983–1989, i.e., three years before and three years after the Chernobyl disaster. Standard errors in parentheses are clustered at the MP level. *** p<0.01, ** p<0.05, * p<0.1.}

Table 8 presents the results of several falsification tests. Column (1) examines the # of speeches that mention "nuclear weapons." Miners' unions were not known to have a strong stance about nuclear weapons, which were an important topic of discussion at the time. Thus, we view this as a falsification test. We find a small and statistically imprecise interaction coefficient. Columns (2)–(5) show that mining-union sponsored MPs did not become more worried about health and environment in their speeches more generally. Column (6) shows no statistically significant differential change in the total number of speeches. Finally, Column (7) shows that MPs sponsored by other, non-mining-related, unions did not see a spike in the number of antinuclear speeches post-Chernobyl.

Table 8: Other Speech Outcomes for UK MPs Sponsored by a Mining Union.

	(8) # of speeches talking about nuclear weapons	(2) # of speeches mentioning hospitals	(3) # of speeches mentioning health	(4) # of speeches mentioning clean water	(5) # of speeches mentioning clean air	(6) Total # of speeches	(7) # of speeches with anti-nuclear sentiment
Post-Chernobyl × Mining-Union Sponsored	0.004	-0.049	-0.049	-0.000	0.057	0.479	
	(0.014)	(0.042)	(0.064)	(0.001)	(0.043)	(0.316)	
Post-Chernobyl × Sponsored by a Non-Mining Union							0.003
							(0.009)
Observations	34,727	34,727	34,727	34,727	34,727	34,727	34,727
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MP-constituency FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dep. Var. Mean	0.067	0.214	0.577	0.002	0.003	1.720	0.021
Dep. Var. SD	0.428	0.807	1.728	0.045	0.080	2.983	0.206

Notes: The sample is restricted to 1983–1989, i.e., three years before and three years after the Chernobyl disaster. Standard errors in parentheses are clustered at the MP level. *** p<0.01, ** p<0.05, * p<0.1.}

To explore the dynamics of the estimates, we estimate a similar equation to equation 5 except that we replace the interaction with the post-Chernobyl dummy variable with the interactions of miner's union sponsorship and yearly indicators. We also omit the monthly indicators and keep only the yearly dummies for illustration purposes. For brevity, we focus on the number of anti-nuclear speeches. Figure 11 plots the estimates. The coefficients for the yearly dummy variables (in grey), which reflect the number of anti-nuclear speeches from MPs who are not sponsored by miners' unions, show that MPs who are not sponsored by miners' unions increase the number of anti-nuclear speeches slightly after Chernobyl. The interaction coefficients (in red), which reflect the differential number of anti-nuclear speeches by MPs who are sponsored by miners' unions, show that MPs sponsored by miners' unions made a similar number of anti-nuclear speeches as other MPs before Chernobyl and in the few months immediately after the accident. However, starting in 1987, and especially in the run-up to the parliamentary elections held in spring that year, MPs sponsored by miners' unions make many more speeches against nuclear energy. The effect is persistent over time.

These results are consistent with our hypothesis that mining unions used Chernobyl as an opportunity to reduce nuclear energy investment. Unfortunately, we are unable to observe voting behavior because the Parliament rarely votes on nuclear related issues, which are governed by a central board.

6 NPP Safety and Air Pollution

Together, the cross-country and within-country evidence so far supports the hypothesis that fossil fuel interests attempted to foster a global decline of NPPs after Chernobyl. Such a decline in new NPPs

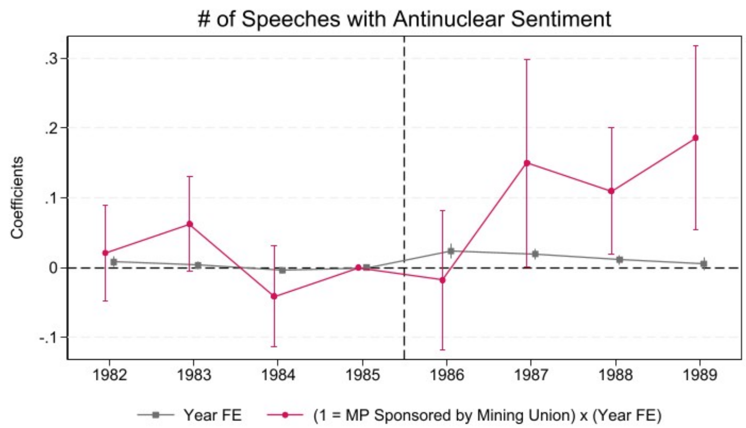

Figure 11: Differential Change in Antinuclear Rhetoric, Event Study

can have positive and/or negative effects for well-being. The main positive effect is safety. Fewer NPPs mean less chances of nuclear reactor meltdowns. Unfortunately, we are unable to quantify this important potential outcome because of the lack of data. Meltdowns are very rare events. The decline in new NPPs can also have negative effects. The two main ones are safety of existing plants and air quality. We discuss both below.

6.1 Safety

NPP operators have improved operating procedures to reduce the possibility of reactor meltdowns. Safety has also improved with new technology. Chernobyl, Three-Mile Island and Fukushima were all Generation II reactors constructed in the 1960s and 70s. The first Generation III NPP was built in 1996. Seven Generation III NPPs operate currently in Japan, China, and India. Nuclear scientists are currently research Generation IV NPPs.[15] Experts agree that new power plant designs (Generation III+) are safer (as measured by the probabilistic risk assessments for core damage frequency, CDF) by many orders of magnitude. Generation III reactors have been improved to have lower core damage frequencies (3 to 60 events per 100 million reactor-years versus 1,000 events per 100 million reactor years). They address the problems from past accidents by including passive safety features that do not

[15] The Bureau of Labor Statics (BLS) keeps data on both the "Incidence Rates of Nonfatal Occupational Injuries" and fatalities. From 2006 to 2015, the nuclear generation industry is on average 4.7 times safer than hydroelectric power, five times safer than fossil fuel, 6.6 times safer than electric power transmission, and nearly seven times safer than natural gas distribution. For fatalities, the picture is the same. Since 2003, BLS has recorded just one fatality for nuclear power generation, which was unrelated to radiation exposure. There have been 12 fatalities in hydroelectric power, 39 in fossil power, and 184 in electric power distribution. However, this doesn't account for the number of power plants in each respective industry. There are hundreds of fossil fuel power plants and only 61 nuclear plants. Yet, on this count, nuclear still leads the field in safety. Per terawatt hour of electricity generation (equivalent to 1,000 gigawatts), nuclear is still the safest: 2.9 times safer than hydroelectric, 128 times safer than solar, and 131 times safer than fossil fuel power generation (Batkins et al., 2017).

require active controls or operator intervention but instead rely on gravity or natural convection to mitigate the impact of abnormal events. For comparison, note that Gen III AP1000 designs, which is popular in South Korea and have been adopted by the U.S. in Georgia, have a 1/60 million chance of CDF in a year, which exceeds U.S. Nuclear Regulatory Commission (NRC) requirements by a factor of 6,061. In contrast, older Gen II plants, which constitute all other currently operating plants in the U.S. today have a 1/20000 CDF per year, and is two times safer than NRC requirements.[16]

Since newer NPPs are safer, the reduction in the number of new NPPs over time implies a reduction in NPP safety relative to the counterfactual of a steady pace of replacing older NPPs with newer ones. To quantify this, we examine the effect of Chernobyl on the risk of accidents (those that are smaller than meltdowns), which are a function of plant age.

Wheatley, Sovacool and Sornette (2017) compile a comprehensive dataset on the universe of incidents and accidents that had material relevance to safety, caused property damage, or resulted in human harm between 1950 and 2014.[17] We use Poisson regressions to estimate the relationship between the age of the reactor and generation of the reactor model. Then, we use the estimates and data on reactor age and model generation to predict risk over time for all NPPs that have ever operated in the world. Predicted risk is increasing in a convex manner with respect to age, and is significantly higher for older generation plants at any given age (see Appendix Figure A.3).

Figure 12 plots average predicted risk for NPPs over time. Panel (a) shows the global NPP risk, which increases sharply since the early 1990s, which reflects the fact that the global decline in NPP development after Chernobyl contributed to the aging of existing NPPs worldwide. Panel (b) separately plots the trends in predicted nuclear risk for democratic and non-democratic countries. The faster increase in nuclear risk in democracies is consistent with our cross-country results on NPP development: after the Chernobyl, the democracies, not constructing new NPPs while still facing increases in energy demand, had to delay the retirement of old, early-generation NPPs, which exposes them to substantially higher nuclear risk compared to their authoritarian counterparts, who built new, third-generation NPPs that are much safer. Panel (c) further zooms into two specific democratic countries, the U.S. and the U.K., where we observe patterns broadly similar to that for all democracies.

To quantify these graphical patterns, Table 9 re-estimates the cross-country regressions with NPP reactor age, reactor generation and predicted risk as the dependent variables. Columns (1)-(3) confirm

[16]See Batkins et al. (2017).

[17]To be included in the sample, a nuclear accident needs to appear in a published source, such as peer-reviewed academic literature, press releases, project documents, public utility commission filings, reports, and newspaper articles.

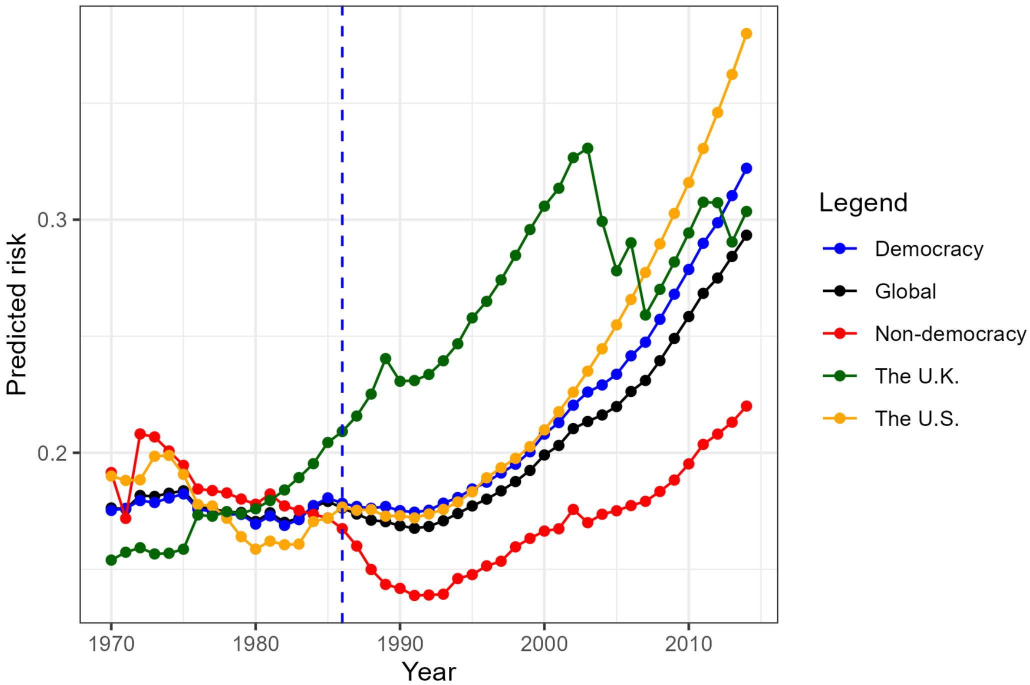

Figure 12: Predicted Risk for NPPs

that, after the Chernobyl accident, democracies started having older, earlier-generation, and riskier NPPs relative to their non-democratic counterparts.

Taken together, the estimates are consistent with the narrative that the slowdown of new NPP construction promoted the use of older plants and delayed the adoption of newer safer plants. Note that we do not take into account the specific reactor model type in this analysis. Our analysis captures the main safety improvements, which are between generations, but we do not measure differences across models within the same generation. This is because differences in models within the same generation are often country-specific (e.g., only Soviet and Soviet-allied countries used the RBMK reactor, one of many generation II models) and the accident data are believed to be comprehensive and representative for countries with democratic governments, but under-reported by other countries Wheatley et al. (2017).

Table 9: Chernobyl and average reactor age, reactor generation and predicted risk

Dependent Variable	Reactor age	Generation	Predicted risk
	(1)	(2)	(3)
Post Chernobyl × Democracy	3.750**	-0.656***	0.053**
	(1.587)	(0.215)	(0.025)
Mean of Dep. Var.	10.450	1.249	0.196
S.D. of Dep. Var.	11.254	0.942	0.055
N	2210	2210	1329
R2	0.93	0.79	0.67
Year FE	X	X	X
Country FE	X	X	X

Notes: The standard errors in parentheses are clustered at the country level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6.2 Air Quality

One of the main supposed benefits of nuclear energy relative to fossil fuels is that it produces little ambient air pollution while operating.[18] This section attempts to quantify the effect of the slowdown in NPPs after Chernobyl on emissions and health.

Our main measure of air pollution is Aerosol Optical Depth (AOD), which reflects the amount of solid and liquid particles suspended in the atmosphere, and is commonly used as an omnibus proxy for air quality. AOD is calculated based on satellite images, since the particles in air change the way the atmosphere reflects and absorbs visible and infrared light. We obtain our AOD data from NASA's Terra satellite with Moderate Resolution Imaging Spectroradiometer (MODIS).[19] The data provide information on the monthly average AOD for all 1 x 1 degree grids worldwide, during 2001 to 2020.

To understand the impact of NPPs on air pollution, we study how the operation of new NPPs affects the average AOD of the nearest city (in terms of straight-line distance). The relationship can be characterized as the following:

$$y_{it} = \beta \mathbb{1}[\text{NPP is operational}]_{it} + \Gamma X_{i,t-1} + \gamma_i + \delta_t + \varepsilon_{it} \tag{6}$$

where y_{it} is the AOD in the city adjacent to NPP i in year t; $\mathbb{1}[\text{NPP is operational}]_{it}^{k}$ is a dummy variable that equals one after the NPP is operational; $X_{i,t-1}$ is the lagged population and nighttime lights of the city adjacent to NPP i; γ_i and δ_t are NPP and year fixed effects. We define an NPP as operational when at least one reactor is turned on. The standard errors are clustered at the NPP level.

[18] Mining and refining uranium ore, creating reactor fuel, the construction of the NPP, and the disposal of spent rods can create pollution and/or carbon dioxide.

[19] For more details, see Platnick, King, Meyer, Wind, Amarasinghe, Marchant, Arnold, Zhang, Hubanks and et al. (2015).

Table 10: NPP Operation and City AOD

	Dependent Variable: AOD				
	(1)	(2)	(3)	(4)	(5)
NPP Operation	-60.912***	-67.804***	-46.591***	-68.584***	-67.642***
	(16.861)	(17.396)	(16.665)	(17.352)	(17.363)
Other Energy		Y	Y	Y	Y
DPI × Year FE					
Lagged Population/Nighttime Lights		Y	Y	Y	Y
(Latitude,Border,Coast) × Year FE		Y	Y	Y	Y
Mean Temperature, Temperature Range		Y	Y	Y	Y
Unit FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Dep. Var. Mean	240.1	238.7	238.9	239.9	243.7
Dep. Var. SD	106.8	111.1	111.1	116.0	116.5
R2	0.92	0.93	0.93	0.94	0.93
Sample	all	all	drop China	drop Russia	drop US
Observations	470,866	412,613	406,933	371,191	357,666

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 10 column (1) shows that following the operation of a local NPP, a city's AOD falls by more than 46, which is more than 15% of a reduction from the baseline mean. Column (2) shows that the estimates are robust to controlling for the mean and range of yearly temperature, as well as the specific dynamics of country, latitude, border, coast, and reserves for other energy sources.[20] Column (3) omits the U.S., the largest consumer of energy in the 2000s. The estimates are similar. Column (4) omits China, which has been the largest contributor in recent years. The coefficient is much smaller in size. One reason for why NPPs reduce emissions more in China could be because the extremely high levels of pollution when NPPs are introduced and the more forceful shut down of fossil fuel plants after NPPs are introduced in China. Since nuclear energy did not play an important role in China until after 2014, we will interpret the estimates in column (4) as the most relevant for our study.

One concern may be that NPPs are introduced to places that are already experiencing a decline in pollution because these are the places that are more motivated to promote green energy. To investigate this, we estimate the dynamic effects of NPPs on AOD. We repeat the previous estimation but replace

[20] Appendix Table A.3 lists the definitions and sources of all the variables used in this analysis.

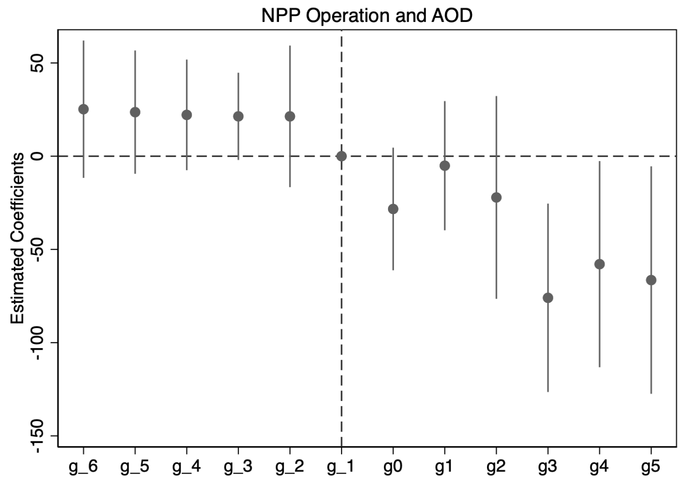

Figure 13: Event Study Estimates: NPP and Ambient Air Pollution

the post operation dummy variable with dummy variables for each year before and after the NPP becomes operational. Figure X plots the dynamic coefficients. We observe no pre-trend in AOD prior to the start of operation of an NPP, and a distinct decline in AOD after the NPP starts operating. AOD continues to decline for several years afterwards. Since the start year of an NPP is defined by the first year that at least one reactor started working, the downward-sloping trend in the post-operation period could reflect the fact that new NPPs are gradually launching their reactors over time and/or that polluting energy production (e.g., coal) declines gradually in response to the NPP.

Back of the Envelope Calculations (preliminary) We use the estimate in Table X column (3) to calculate the potential aggregate health impacts caused by the Chernobyl-induced slow down of NPP construction. The calculation involves three main steps. First, following the estimates provided by NASA, we convert our estimated NPP-AOD relationship into an NPP-PM2.5 relationship.[21] Second, following the estimates provided by the Air Quality Life Index (AQLI), we convert the estimated PM2.5 reductions to the potential increases in life expectancies in each region (Energy Policy Institute at the University of Chicago, 2018). Third, linking the estimated gains in life expectancies to grid-level population data, we calculate the total life years that are lost due to the global slowdown of NPP construction.[22]

According to our calculations, the construction of an additional NPP, by reducing the total total

[21] Source: Gupta and Follette-Cook (2018).

[22] Here we are assuming that the NPPs that were not constructed due to Chernobyl would have been located in regions at least as populated as the existing NPP locations.

suspended particles (TSP) in the ambient environment, could on average save 816,058 additional life years. According to our baseline estimates (Table 1), over the past 38 years, Chernobyl reduced the total number of NPPs worldwide by 389, which is almost entirely driven by the slowdown of new construction in democracies.[23] Our calculations thus suggest that, globally, more than 318 million expected life years have been lost in democratic countries due to the decline in NPP growth in these countries after Chernobyl. A simple extrapolation of time-series trends would indicate that the U.S. reduced 173 NPPs after Chernobyl, and the U.K. 40. Therefore, our estimates suggest that 141 (33) million life years have been lost in the U.S. (U.K), due to the slowing down of nuclear development.

An important caveat for the interpretation comes from the fact that our pollution data start in 2001, sixteen years after Chernobyl. If the relationship between NPP and emissions change over time, then our estimates will be biased. For example, if the capacity for energy production of NPPs grow over time such that the amount of fossil fuels that an NPP can replace increases, then our estimates using recent data will overstate the amount of pollution reduction and lives saved from NPP. Alternatively, if overall demand for energy has increased over time such that NPPs today displace less fossil fuels than in the 1980s, then our estimates will understate the amount of fossil fuels displaced by NPP and lives saved. Thus, the estimates in this section should not be interpreted literally. We provide them only to illustrate the point that in the counterfactual where NPPs continued to grow at the same rate as before Chernobyl, air pollution would have likely been much lower, which in turn, would have had significant health benefits,

7 Conclusion

In the post-WWII era, nuclear energy promised to be a source of affordable and clean energy. But investment and enthusiasm fell precipitously after the Chernobyl reactor meltdown. This study provides novel evidence that the political economic interests of fossil fuel interests played a role in the decline. In the U.S., we show that the fossil fuel industry leveraged the Chernobyl accident to lobbying for more anti-nuclear policies in congress, and managed to influence votes in those pivotal and high-stakes bills; in addition, newspapers with stronger pre-existing ties to fossil fuel also published more anti-nuclear articles after Chernobyl. In the U.K, miners unions also took advantage of Chernobyl to have their representatives giving more anti-nuclear speeches in parliament.

[23] We multiply the average reduction in NPP annual growth by the number of countries and the number of years: 0.301*34*38=388.9.

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Figure A.1: Map of Nuclear Reactors in the World, 1985

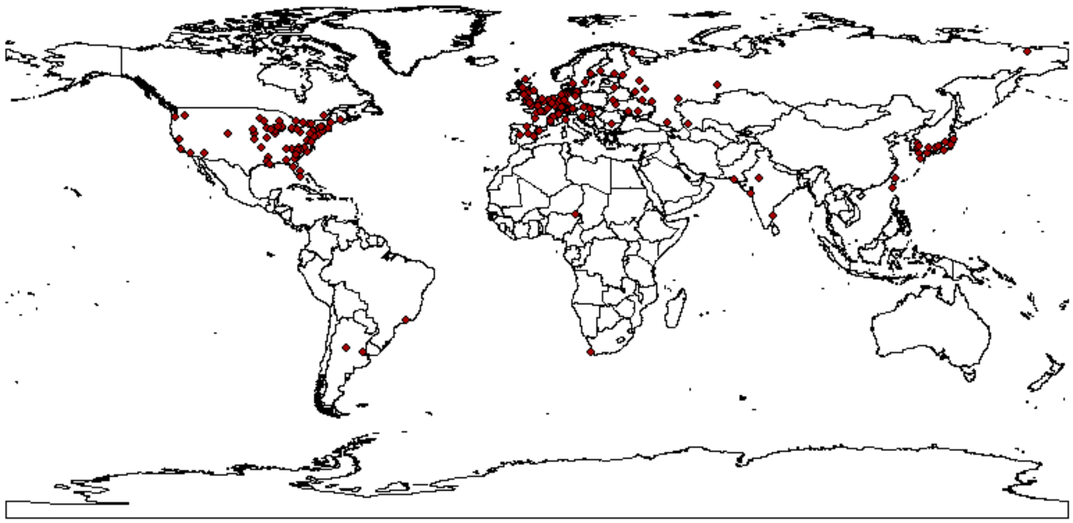
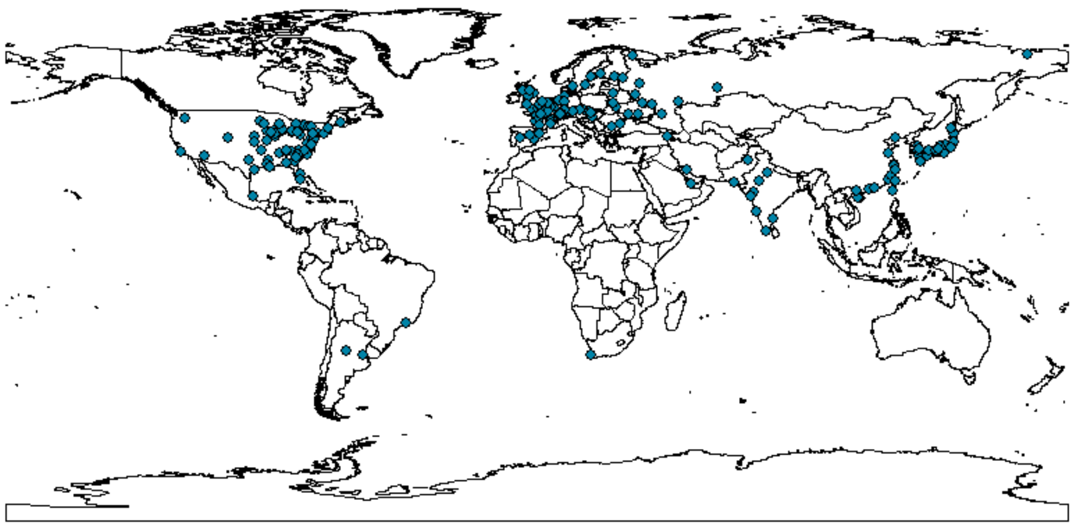


Figure A.2: Map of Nuclear Reactors in the World, 2020



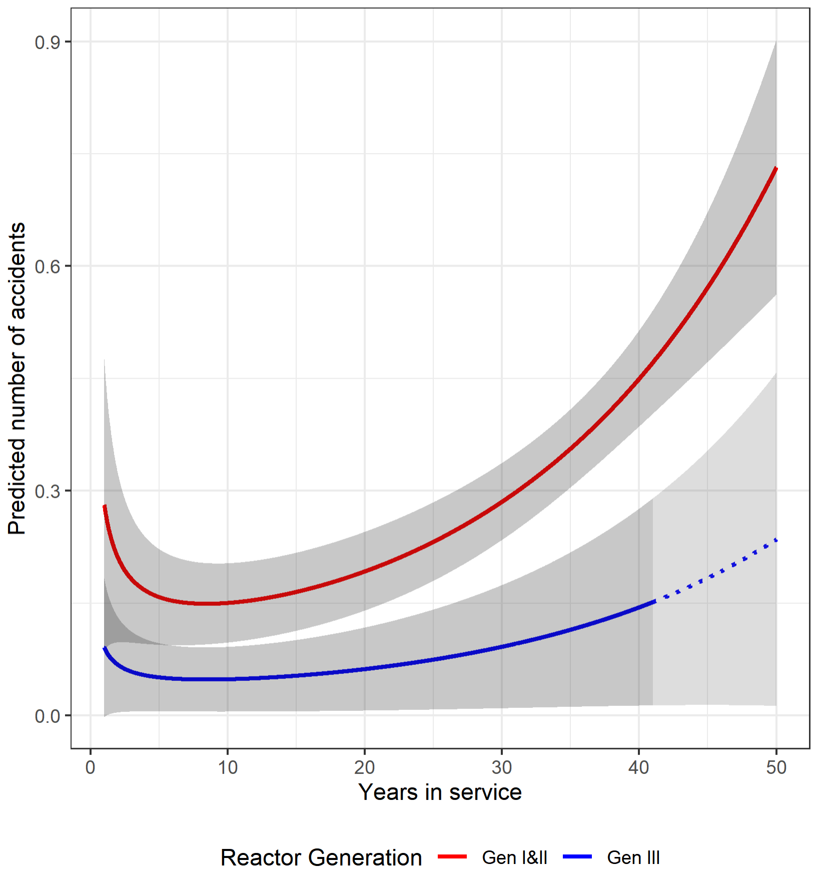


Figure A.3: Age and NPP Accidents

Table A.1: List of All Countries that Ever Built a NPP with Their Democracy Scores in 1985

Country	Polity IV Democracy Score in 1985
Argentina	8
Armenia	0
Belgium	10
Brazil	7
Bulgaria	0
Canada	10
China	0
Czech Republic	0
Finland	10
France	8
Germany	10
Hungary	0
India	8
Iran, Islamic Rep.	0
Italy	10
Japan	10
Kazakhstan	0
Korea, Rep.	0
Lithuania	0
Mexico	1
Netherlands	10
Pakistan	0
Romania	0
Russian Federation	0
Slovak Republic	0
Slovenia	1
South Africa	7
Spain	10
Sweden	10
Switzerland	10
Taiwan	0
United Kingdom	10
Ukraine	0
United States	10

Table A.2: List of Nuclear-Related Congressional Bills by Stakes

Table: Policy topics

Topics	Number of bills	Stakes
international nuclear agreements	15	high
appropriations for (nuclear and nonnuclear) energy research programs	13	high
construction, licensing and shutdown of nuclear power plants and reactors	7	high
supply of nuclear fuel	2	high
nuclear waste management	28	low
export control of nuclear goods and technology	9	low
nomination of members for NRC and other nuclear departments	9	low
authorization act for NRC	7	low
nuclear proliferation prevention	7	low
safety regulations of nuclear material and facilities	4	low
management of nonnuclear energy	3	low
Chernobyl nuclear disaster commemoration	2	low
response to nuclear emergencies	2	low
compensation for victims of nuclear accident	1	low
reorganization of nuclear departments	1	low

A Example of Pro-nuclear and Anti-nuclear Bills

Pro-nuclear bill: H.R.8401 - Nuclear Fuel Assurance Act — 94th Congress (1975-1976)

A bill to authorize cooperative arrangements with private enterprise for the provision of facilities for the production and enrichment of uranium enriched in the isotope 235, to provide for authorization of contract authority therefor, and for other purposes.

Anti-nuclear bill: H.R.8378 - Nuclear Waste Policy Act — 96th Congress (1979-1980)

A bill to establish licensed permanent repositories for transuranic waste, high-level radioactive waste, and spent fuel, to authorize State compacts for the establishment and operation of regional repositories for low-level radioactive waste, and for other purposes.

B U.S. Campaign Contributions from Fossil Fuel Firms

Our U.S. the Database on Ideology, Money in Politics, and Elections (DIME), ranging from 1979 to 2014. From this dataset, we retrieved all contributors based on a comprehensive list of energy companies. For every firm that made at least one campaign contribution in DIME, we search its profile and manually classify whether its primary business lies in the fossil fuel industry. We end up with 381 firms in the fossil fuel industry that ever made contributions. The final database contains fossil fuel firms that have made at least one contribution during our sample period. Firms in the list were manually checked for accuracy. For every donation made to a congressman, we know the donor, the recipient, the timing of the donation, and its amount.

Table A.3: List of Variables Used in Pollution Regressions

Variable	description	source
AOD	Aerosol Optical Depth Land Mean from product MOD08_M3 (2001-2020)	https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/products/MOD08_M3
SO2	Total Column Amount SO2 from product OMSO2e (2005-2020)	https://disc.gsfc.nasa.gov/datasets/OMSO2e_003/summary
Coal Power Units	Units (>30MW) from coal power plants around the world	https://globalenergymonitor.org/projects/global-coal-plant-tracker/tracker/
NPP Oper	Becomes 1 when nuclear reactors operate on the site	https://en.wikipedia.org/wiki/List_of_commercial_nuclear_reactors
LST mean	Land Surface Temperature day mean from product MOD11C3 , monthly data (2001-2020)	https://lpdaac.usgs.gov/products/mod11c3v006/
LST range	Range of monthly LST day mean from product MOD11C3 (2001-2020)	https://lpdaac.usgs.gov/products/mod11c3v006/
LST diurnal range	Average day and night difference of the monthly LST from product MOD11C3 (2001-2020)	https://lpdaac.usgs.gov/products/mod11c3v006/
Border	Whether the city is on the border of its country	
Coast	Whether it's a coastal city	
NTL	harmonized global nighttime light (1992-2020)	https://www.nature.com/articles/s41597-020-0510-y#Sec8
Population density	UN WPP-Adjusted Population Density (2000, 2005, 2010, 2015, 2020), interpolated	https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-adjusted-to-2015-unwpp-country-totals-rev11
Hydropower	Global Development Potential Indices for hydropower (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download
Concentrated Solar Power	Global Development Potential Indices for concentrated solar power (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download
Photovoltaic Solar Power	Global Development Potential Indices for photovoltaic solar power (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download
Oil	Global Development Potential Indices for oil (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download
Gas	Global Development Potential Indices for gas (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download
Coal	Global Development Potential Indices for coal (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download
Wind	Global Development Potential Indices for wind (2016)	https://sedac.ciesin.columbia.edu/data/set/lulc-development-potential-indices/data-download