

# Industrial Policy and Decarbonization: The Case of Nuclear Energy in France

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## Abstract

We assess industrial policy's role in decarbonization by examining the expansion of nuclear energy in France following the 1973 oil crisis. Within a decade, France initiated construction of 51 new reactors. This resulted in more than a 60 percent reduction in carbon dioxide emissions from electricity and heat production, and over 20 percent reduction in total CO<sub>2</sub> emissions. Emission reductions began six years after the policy was announced, with an average abatement cost of -\$20 per metric ton of CO<sub>2</sub>. We show that the government's ability to insulate the policymaking process from opponents was crucial for the political success of the reform.

**JEL classification:** O25; Q54; Q58

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# 1 Introduction

The last few years have witnessed a dramatic shift in climate policymaking. Governments around the world have embraced industrial policy as a key strategy for reducing carbon emissions and promoting domestic economies. They are turning to subsidies, loan guarantees and local content requirements, in addition to, and in many cases instead of, conventional policies like carbon pricing. A recent example is the Inflation Reduction Act – “the largest climate bill in U.S. history” (Thompson, 2022) – which allocates over \$390 billion toward decarbonization via industrial policy. However, despite this political shift, we know surprisingly little about the environmental and economic effectiveness of ‘green’ industrial policy, as well as its political economy (Rodrik, 2014; McKenzie, 2023).

We study the case of the Messmer Plan in France to provide insight on the effect of large-scale industrial policy on carbon emissions and abatement costs, as well as on the conditions that make such a reform politically feasible. Adopted in 1974 in response to the oil price shock of 1973, the Messmer Plan sought to transform the French electricity sector by rapidly and dramatically expanding nuclear energy. The government used loan guarantees, public financing, contracts with suppliers and streamlined planning procedures to enable the state-owned utility Électricité de France (EDF) to secure large amounts of capital and construct reactors at scale and speed (Campbell, 1986; Lucas, 1979). EDF ordered and began construction on 51 new reactors in the decade after the Plan’s announcement. As a result, the share of nuclear power in electricity production rose from 8 percent in 1973 to 80 percent in 1990, while the share of fossil fuels declined from 65 percent to 7 percent (IEA, 2022a).

While the Messmer Plan was not originally aimed at carbon reduction, we analyze it as an early form of green industrial policy due to the resurgence of nuclear energy in modern climate policy discourse. In 2022, the European Commission endorsed nuclear energy as a ‘green investment’, underscored by Thierry Breton, the Commissioner for the Internal Market in the EU, who emphasized nuclear’s “fundamental role” in the transition away from fossil fuels (Gröndahl, 2022). In parallel, French President Emmanuel Macron has championed a “nuclear renaissance” as part of his vision for Europe’s low-carbon future (Alderman, 2022). In Sweden, historically a frontrunner in the use of carbon pricing, the government’s new climate policy advocates for a large-scale expansion of nuclear energy, with the stated goal of 10 new reactors (Government Offices of Sweden, 2023). Adjusted for differences in population size, this expansion matches the scale of France’s Messmer Plan. On the other side of the Atlantic, the US has included production tax credits for nuclear energy as part of the climate provisions of the Inflation Reduction Act (Bistline, Mehrotra, and Wolfram, 2023). However, nuclear’s role in climate policy remains divisive. Critics contend it is too slow and costly to build, and thus not as effective as renewables in addressing climate change (Schneider and Froggatt, 2021; Haywood,

Leroutier, and Pietzcker, 2023). This skepticism is exemplified by Germany, which has been decommissioning its nuclear reactors since 2011 and closed its last reactors in 2023.

Using a comparative case study design, we evaluate the effects of the Messmer Plan based on four pillars of effective climate policy: emissions reductions, timeframe for achieving reductions, cost of abatement, and political feasibility. In the context of climate change, delays between policy implementation and realised emission reductions are crucial, as the accumulating atmospheric stock of greenhouse gases exacerbates future warming. Additionally, abatement costs and political feasibility are factors that significantly influence the content, design, stringency and adoption of climate policies.

In the first part of the paper, we empirically estimate carbon emission reductions, the duration from project announcement until emission reductions began and the associated abatement cost. To achieve this, we employ the synthetic control method (Abadie, Diamond, and Hainmueller, 2010, 2015) to construct a credible counterfactual – a weighted average of other OECD countries that represents the outcome in France if the Messmer Plan had not been implemented. Comparing the outcome in France to this counterfactual scenario, we find that the extensive push for nuclear energy led to a more than 60 percent reduction in carbon dioxide ( $\text{CO}_2$ ) emissions from electricity and heat production and a more than 20 percent reduction in total  $\text{CO}_2$  emissions in an average year between 1980-2005. Importantly, we find substantial emission reductions outside of electricity and heat production, in the industrial, residential and services sectors, which we attribute to fuel-switching. Furthermore, we find that six years elapsed from the announcement of the Messmer plan until emission reductions commenced and compute an average abatement cost of -\$20 per metric ton of  $\text{CO}_2$  reduced, indicating that the policy reduced carbon emissions at a net economic gain. These results show that rapid and substantial decarbonization is possible through active state intervention, and that ambitious industrial policy in the energy sector can be an environmentally and economically efficient climate policy.

While a large-scale expansion of nuclear energy may appear as a straightforward means to reduce  $\text{CO}_2$  emissions, the underlying dynamics are more complex. A simple 'back-of-the-envelope' calculation risks both over- and underestimating emission reductions, and overlooks policy-relevant issues such as substitution between nuclear and fossil fuels and the timing of abatement.

For instance, a naive differences-in-differences approach comparing France to the OECD average would imply substantially larger emission reductions in the electricity and heat sector than our synthetic control estimate suggests. At the same time, the Messmer Plan enabled further emission reductions through increased electrification and fuel-switching in the residential, services, and industrial sectors – effects that would be entirely missed in a narrow analysis of electricity production alone. Providing a robust and unbiased estimate of the Plan's impact requires a credible counterfactual that mir-

rors France’s energy profile in the 1970s – marked by high reliance on imported oil and a small but declining domestic coal industry. Countries such as the US, Canada, and other non-European OECD members had very different energy profiles at that time. By applying country-specific weights, we give greater weight to countries with similar import dependence, allowing us to construct a counterfactual that more accurately reflects France’s experience during the oil crises.

Additionally, it remains critical to determine whether the added nuclear capacity displaced fossil fuel generation or merely supplemented it (York, 2012). This distinction is crucial, as only net reductions contribute to meeting the climate targets set by the Paris Agreement. It is particularly salient in the context of France at that time, where no carbon pricing mechanisms or other mitigation policies existed to discourage continued fossil fuel use. Relatedly, understanding when abatement effects materialize is essential, especially given the lengthy construction periods associated with modern nuclear reactors and the urgency to achieve net-zero emissions within the next two to three decades (Masson-Delmotte et al., 2018).

Finally, the broader economic and distributional costs of such ambitious climate policies are frequently debated and cited as reasons to weaken current climate initiatives (e.g., Finnegan, 2023). In this context, employing a rigorous comparative case study design and establishing a credible counterfactual is essential for accurately assessing the scope, timing and costs of emission reductions across various sectors of the economy.

However, even though the Messmer Plan eventually led to substantial emission reductions, at a time delay of only six years and at a negative abatement cost, it should not be taken as a foregone conclusion that the adoption and implementation of the Plan would be politically successful. In the latter part of our paper, we examine the political economy of the Messmer Plan. We show how France’s *dirigiste* policy style during this period - characterized by an autonomous and technocratic bureaucracy, policymaking centralized around a powerful executive, state-ownership of key firms and control over capital allocation - enabled the government to insulate the policymaking process and prevent the Plan’s opponents from obstructing decision making. The analysis points to the key role that insulation plays in enabling governments to overcome opposition to adopt and implement large-scale reforms that upset incumbent interests (Finnegan et al., 2025; Meckling et al., 2022).

Our study contributes to existing literature in several ways. First, by analysing emission reductions relative to a counterfactual scenario, it provides causal estimates of the environmental effects of nuclear energy policy. Existing empirical research on potential emission reductions from nuclear energy deployment relies primarily on time-series data from individual countries, using Granger causality tests to estimate the causal relationship between nuclear energy and CO<sub>2</sub> emissions (Iwata, Okada, and Samreth, 2010; Menyah and Wolde-Rufael, 2010; Apergis et al., 2010). Although these studies generally

conclude that increased nuclear energy usage leads to reduced CO<sub>2</sub> emissions, the lack of a counterfactual inhibits our ability to make causal inferences.

Second, this paper extends the empirical literature evaluating climate policies. A growing body of research has analysed the environmental effect of carbon pricing, finding that it effectively reduces carbon emissions (see, for example: Andersson, 2019; Colmer et al., 2022; Leroutier, 2022). However, fewer studies have explored the environmental effectiveness of green industrial policy and findings have been mixed. Research on the effect of Germany’s nuclear energy phase-out and simultaneous support of renewable energy as part of the *Energiewende* has found that it has increased carbon emissions (Knopf et al., 2014; Jarvis, Deschenes, and Jha, 2022). In contrast, evaluations of China’s green industrial policy, which promotes initiatives like electric vehicle and solar panel production and adoption, have found a decrease in carbon emissions and other air pollutants (Zhang et al., 2022; Song and Zhou, 2021). Additional causal analysis of green industrial policy across contexts is needed to better understand the effects of this important and increasingly utilized policy instrument.

Third, we add to the empirical literature on expansive industrial and research and development (R&D) policies, commonly termed as ‘moonshot’ or ‘big push’ initiatives. These policies, like the Messmer Plan, are distinguished by their targeted focus on specific technologies or regions, substantial public investments, and their aspiration for transformational outcomes (Juhász, Lane, and Rodrik, 2023). Most empirical research indicates prolonged positive economic impacts in the regions directly affected by these policies.<sup>1</sup> Our work extends this literature by examining the environmental consequences of large-scale initiatives.

Fourth, we contribute to the emerging literature in political science on the politics of green industrial policy. Scholars have shown how the ideas underpinning green industrial policy have risen to prominence over the past three decades (Meckling and Allan, 2020), as well as provided clear conceptualizations of green industrial policy and theorized its political dynamics both domestically and internationally (Allan, Lewis, and Oatley, 2021; Meckling, 2021). Moreover, work has shown the institutional underpinnings of national patterns of industrial specialization and innovation (Nahm, 2021). We add to this effort by uncovering the political conditions that foster large-scale industrial reform. Specifically, we identify one key mechanism for reform - insulation - and trace how it enabled the French government to adopt and implement expansive nuclear energy policy.

Last, our paper intersects with the literature on directed technical change (Acemoglu, 1998, 2002; Popp, 2019). One objective of the Messmer Plan was to actively shape the technological development of nuclear energy. A seminal paper by Acemoglu et al. (2012)

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<sup>1</sup>Examples include analysis of the attempt to modernize the economy of the Tennessee Valley region in the US in the 1930s (Kline and Moretti, 2014); the massive spending on R&D by the US during WWII (Gross and Sampat, 2023); and the US space program in the 1960s (Kantor and Whalley, 2023).

explores directed technical change and climate mitigation policies, advocating for an optimal strategy that employs both carbon pricing and research subsidies for green technologies. Notably, carbon pricing affects the variable (fuel) costs of energy production, which are crucial for fossil fuels, while industrial policy reduces the fixed (capital) costs, which enhances the competitiveness of zero-carbon alternatives. Consequently, carbon pricing and industrial policy emerge more as complements than substitutes within climate policy in the energy sector, and empirical research should focus on both (Andersson and Finnegan, 2025).

The remainder of the paper is organized as follows. Section 2 discusses the concept of green industrial policy. Section 3 provides background on the Messmer Plan. Section 4 describes the data and method used to estimate emission reductions. Section 5 presents the main results, including impacts on emissions, abatement costs, and the timing of reductions. Section 6 analyzes the political economy of the policy. Section 7 evaluates what we learn from the French case for contemporary green industrial policy debates. Finally, Section 8 concludes.

## 2 Industrial Policy to Address Climate Change

One key way to mitigate climate change is to reduce the relative price of zero-carbon technologies. This can be done by either increasing the price of fossil fuels or by reducing the price of zero-carbon alternatives. While a variety of policy instruments can achieve these goals, economists have tended to focus on carbon pricing (Akerlof et al., 2019; Nordhaus, 2008). We turn attention to another instrument: industrial policy.

Industrial policy refers to government measures aimed at promoting the growth and transformation of sectors that it views as essential to future economic growth, employment and innovation (Krugman and Obstfeld, 2009). More recently, green industrial policy has emerged as a tool to address climate change (Rodrik, 2014; Meckling, 2021). Its purpose is twofold: environmental and economic. It seeks to mobilize government efforts towards decarbonization and to foster the development of zero-carbon technologies and domestic firms in an effort to increase employment, innovation and growth in green sectors. Governments can employ a range of tools to achieve these aims, including subsidies, direct loans, loan guarantees, local content requirements, tax credits and research grants to support and facilitate research and development (R&D). In this way, green industrial policy operates on a larger scale and encompasses broader objectives compared to carbon pricing or regulatory (command and control) approaches that focus solely on emissions.

Recent examples of green industrial policy include the Inflation Reduction Act passed in the US in 2022. The IRA involves more than \$390 billion in government expenditure towards energy security and climate change mitigation, using tax credits, grants, loans

and local content requirements to promote low-carbon energy production, the electrification of transport and support of domestic employment and manufacturing in low-carbon sectors (Bistline, Mehrotra, and Wolfram, 2023).<sup>2</sup> Similarly, China has relied on a variety of green industrial policies to reduce emissions and grow its market share in zero-carbon technologies (Altenburg and Assmann, 2017; Harrison, Martin, and Nataraj, 2017). At the European Commission there are discussions about the possibility of responding with similar subsidies and incentives in support of low-carbon industries within Europe (Camps and Saz-Carranza, 2023). For policymakers, it is crucial to know whether implementing large-scale green industrial policies is indeed an effective climate mitigation policy.

The argument for green industrial policy stems from the existence of market failures caused by both positive and negative externalities, for which traditional market mechanisms often fail to account (Acemoglu, 2023; Rodrik, 2014). The further development of low-carbon technologies by one firm creates positive spillover effects on other firms in the sector, such as technological innovation that reduces manufacturing costs and knowledge sharing, and the value of these spillovers are not fully captured by investors in the developing firm. Without government support, the amount of private expenditure on R&D would thus be below the socially optimal. Furthermore, low-carbon technologies directly compete with fossil fuels, and in most markets, the social costs associated with carbon emissions from fossil fuel combustion are either insufficiently priced or not priced at all. Due to this market failure, the market equilibrium will allocate too many resources towards fossil-fuel technologies, and therefore the 'second-best' policy of government support for low-carbon substitutes is warranted and justified. Lastly, there are local co-benefits of improved health from switching from fossil fuels to low-carbon alternatives in the transport and energy sector, by a reduction in air pollutants such as nitrogen oxides and particulate matter (Parry, Veung, and Heine, 2015). As with carbon emissions, the market typically does not price the damages caused by these local air pollutants.

Economists commonly object to industrial policy on two main grounds (Pack and Saggi, 2006; Rodrik, 2008, 2014). First, they argue that policymakers lack the necessary information to accurately identify the industries or firms most deserving of support. Put differently, governments are bad at picking 'winners'. And there are indeed numerous examples of government support for specific firms that have later failed (Hufbauer and Jung, 2021). Second, they caution that government support can stimulate rent-seeking behavior and potentially foster corruption. In defense of industrial policy, Rodrik (2014) responds that with well-designed industrial policy we should see some supported firms fail, otherwise the government is underperforming by not taking on enough risk and thereby reducing their average return on investments. Furthermore, Rodrik points out that rent-

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<sup>2</sup>It is important to note that the future of the Inflation Reduction Act is uncertain at the time of writing. The Trump administration has frozen funding disbursements under the policy and the US Senate is debating whether to repeal some of its tax credits.

seeking is a potential issue with all government policies, not only for industrial policy, and can be overcome with appropriate institutional designs. Lastly, Acemoglu (2023) emphasizes that because the negative externalities of fossil fuel usage are quantifiable, green industrial policy need not rely on government picking winners among technologies, industries or firms. Instead, it involves correcting these measurable distortions without requiring government agencies to possess superior predictive capabilities.

### 3 Background to the Messmer Plan

In less than a year, from October 1973 to March 1974, the global price of oil quadrupled from around \$3 to almost \$12 per barrel (Davenport and Wayth, 2023). This first oil crisis resulted from production cuts and embargoes by the Organization of Arab Petroleum Exporting Countries (OAPEC) in retaliation for the West’s support of Israel in the Yom Kippur War – an armed conflict in October of 1973 between Israel and a coalition of Arab nations led by Egypt and Syria.

On the eve of the price shock, oil supplied nearly 70 percent of France’s total energy needs, with the vast majority of that oil being imported (IEA, 2022c).<sup>3</sup> As a result, the country was economically vulnerable to rapid changes in the oil price. In response to the price shock, Prime Minister Pierre Messmer announced an ambitious nuclear energy program on March 6th, 1974 that would reduce France’s reliance on imported oil and increase energy security (Wade, 1980; Ikenberry, 1986; Jasper, 1990).

At the same time, the Messmer Plan had economic aspirations. It aimed to generate growth, innovation, competitiveness and employment in the nuclear sector. In the period after the Second World War, the French state sought to restructure industries across a range of sectors into larger units, or ‘national champions’, that would be leaders in their sectors at home and abroad (Hall, 1986; Hall, Hayward, and Machin, 1994; Schmidt, 1996; Zysman, 1983). In the case of nuclear, the goal was for the country’s firms to be internationally competitive and capture export markets along the entire supply chain (Lucas, 1979, 1985; Thomas, 1988). French firms would be world leaders in reactor design and manufacturing, plant engineering, operator training, fuel enrichment and waste disposal and reprocessing, and over the longer term, have the technological lead in fast breeder reactors.

The government relied on a variety of policy instruments to implement the Messmer Plan. First, it channeled large amounts of capital to the nuclear sector using public finance and loan guarantees.<sup>4</sup> Public funding and loans to nuclear power approximately

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<sup>3</sup>In 1973, France’s oil self-sufficiency was just 1.7 percent, defined as the share of indigenous oil production in the total energy supply of oil.

<sup>4</sup>State loans and loan guarantees are among the most frequently used types of industrial policy, especially in high- and middle-income countries (Juhász, Lane, and Rodrik, 2023).



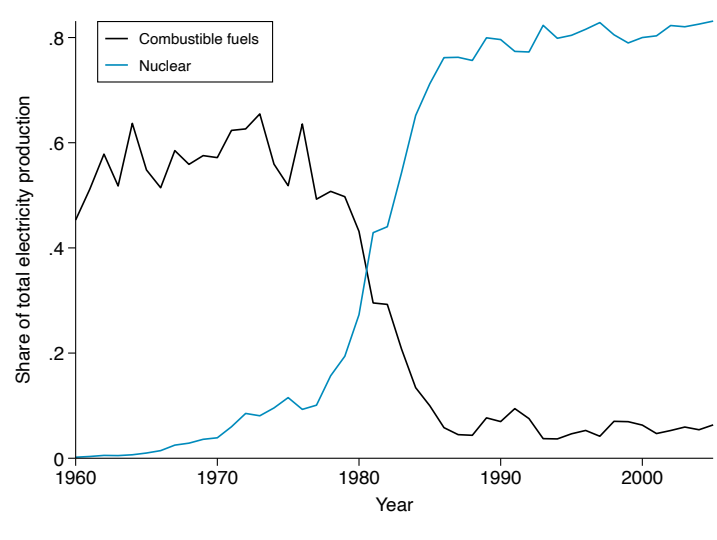


Figure 1: Electricity Production in France from Combustible Fuels and Nuclear Energy

tripled between 1975 and 1976 (Lucas, 1979, Ch. 3). At the same time, the government used loan guarantees to underwrite the debt that EDF took on, which enhanced the company's credit rating and reduced its borrowing costs. Of all sources of capital, loans constituted the largest form of investment (Jasper, 1990, Ch. 9; Lucas, 1979, Ch. 3). Around half of lending came from the French nationalized banking sector and half from foreign investors, especially the US. EDF was the third largest borrower on US capital markets in 1976, just after Ford and General Motors.

Second, the government used multiannual contracts with Framatome, the main reactor manufacturer (Lucas, 1979, Ch. 3). Framatome and its suppliers needed demand guarantees to make the large investments necessary for increasing production capacity in 1974-76 to meet the Plan's goals. In addition to contracts, the state also expressed a political commitment to purchase reactors via its five-year economic plans, which set ambitious targets for nuclear power.

Last, the Ministry of Industry designed siting and authorization procedures to allow for a large program of reactors to be completed on time (Thomas, 1988, Ch. 8). The process was simple and requirements were specified in general terms to enable flexibility. Moreover, nuclear authorization decisions had the status of government decrees and were therefore practically immune from legal challenge (Campbell, 1988, Ch. 8).

Perhaps surprisingly, government civil nuclear R&D expenditures did not significantly increase after the Plan's adoption. Data from the French Court of Audit's (Cours des comptes) 2012 report shows that annual R&D spending was around €1.1 billion (2010 euros) from 1957 to 1969 (Cour des Comptes, 2012, 37-39). For the 1970-1989 period, it was estimated to be €1 billion (2010 euros). The Court of Audit itself noted that spending during the 1970s and 1980s was "equivalent to that of the previous period"

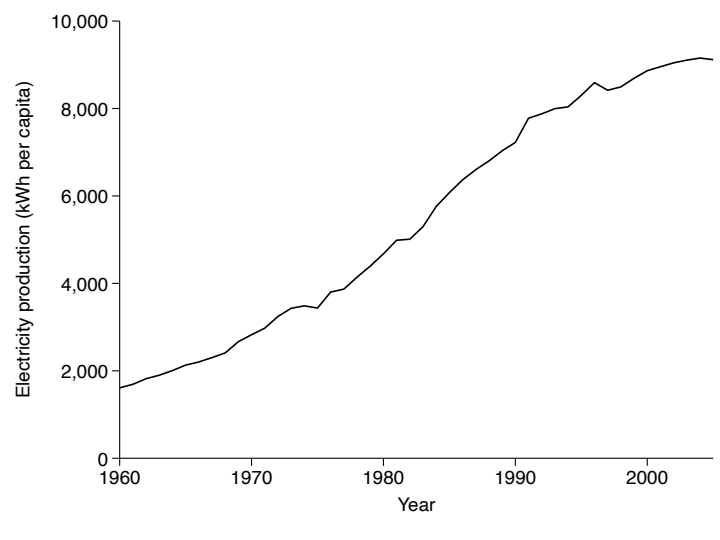


Figure 2: Electricity Production in France: 1960-2005

Note: Included is electricity from both main activity producers and autoproducers.

(Cour des Comptes, 2012, 39).<sup>5</sup>

With the capital, contracts and planning procedures in place, EDF ordered 16 new reactors in 1974, matching the total number of all reactors ordered before the Messmer Plan. These new reactors had a combined output of 14,400 MWe (megawatt electric). For comparison, the previously ordered reactors totaled less than 9,000 MWe (Thomas, 1988, Ch. 8). In 1976, EDF ordered an additional 12 reactors, and a total of 51 reactors were ordered and began construction in the decade following the announcement of the Messmer Plan (Thomas, 1988; IAEA, 2023a). The work on the first three plants – Tricastin, Gravelines, and Dampierre – started in late 1974, and they were connected to the grid in 1980. Of the 51 reactors ordered, 43 came into commercial operation in the 1980s, six in the first half of the 1990s and two in the year 2000 (IAEA, 2023a).

Figure 1 illustrates the proportions of combustible fuels and nuclear energy used in electricity production in France. Before the announcement of the Messmer Plan, between 1960 and 1973, combustible fuels accounted for approximately 50-60 percent of total electricity production. The share of oil increased in the early 1970s and reached a peak of 40 percent in 1973, making oil the primary energy source for electricity production at the time of the first oil crisis. Then, from 1980 onwards, there is a significant decline in the use of combustible fuels and a simultaneous rapid increase in the use of nuclear energy. Since the late 1980s, nuclear energy has consistently provided around 80 percent of total electricity production in France, while combustible fuels contribute less than 10 percent, and the remainder is supplied by hydropower (IEA, 2022a).

<sup>5</sup>Ideally, the Court of Audit report would also include data on the costs of the Messmer Plan to the government. Although Chapter 1 of the report includes information on costs related to construction, engineering, fuel and other aspects of nuclear power, these costs are not separated for government versus firms, unfortunately.

Total electricity production also increased from 1960 to 2005. Figure 2 demonstrates this trend. In 1960, annual electricity production per person was approximately 1,600 kilowatt hours (kWh). By 2005, production had multiplied more than five times, exceeding 9,000 kWh per person. Hence, not only did electricity supply undergo significant fuel switching, but there was also a simultaneous increase in overall electricity production. This large increase in production will play a key role in the later analysis of emission reductions in sectors outside of electricity and heat production.

## 4 Data and Method

### 4.1 Data

To assess the environmental impact of the Messmer Plan, we employ annual panel data on CO<sub>2</sub> emissions for France and 23 other OECD countries, spanning the years 1960 to 2005.<sup>6</sup> While our primary analysis concentrates on emissions originating from the electricity and heat sector, we also examine total emissions and explore additional relevant sectors such as industry, residential and services. The data is gathered from the International Energy Agency (IEA, 2022b), and emissions from electricity and heat production contains the sum of emissions from plants that produce either electricity, heat or both (co-generation plants). Included in the emissions data are CO<sub>2</sub> emissions from combustible fuels.<sup>7</sup> Energy produced using nuclear power plants is classified as a zero-carbon source. Last, CO<sub>2</sub> emissions are measured in metric tons per capita.

In our main analysis, we focus on emissions from 'main activity producers,' plants that supply energy to the public, and exclude emissions from 'autoproducers'. Autoproducers are private plants that produce electricity and heat on-site for their own use to support their primary activity (e.g. a paper mill or a steel plant). As such, these emissions are commonly allocated elsewhere. In line with the IPCC guidelines on greenhouse gas inventories (IPCC, 2006), we allocate autoproducers' emissions to the industry sector in our analysis of total emissions.

It is important to note that for 1960-1973, the IEA data on emissions from electricity production cannot separate emissions from main activity producers and autoproducers (IEA, 2021). As a result, the apparent drop in emissions in 1974 (see Figure 3) is partly mechanical, reflecting the shift to reporting only main activity producers. Regardless, all countries in the sample are treated identically in terms of how the emissions data is computed over time, and autoproducer emissions are relatively minor – averaging just 16 percent of total electricity and heat emissions in our OECD sample during 1974–2005.

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<sup>6</sup>We include all countries that were OECD members in 1973.

<sup>7</sup>In our dataset, CO<sub>2</sub> emissions primarily stem from fossil fuel combustion – oil, coal (including peat) and natural gas – with minor contributions from biofuels and waste in later years of the sample period.

Given this, we do not expect that combining the two emission sources before 1974 will create issues for our identification strategy. We present evidence in support of this assertion later on.

Our analysis ends in 2005. We chose this year because it marks the start of the European Union Emissions Trading System (EU ETS), which is a potential confounder for our study since it incentivized fuel switching in the electricity sector by putting a price on CO<sub>2</sub> emissions from electricity and heat production within the EU. In total, our sample period of 1960-2005 offers us 14 years of pretreatment data and 32 years of posttreatment data.

From the original donor pool of OECD countries we exclude Luxembourg and Turkey. Luxembourg is excluded due to missing data on CO<sub>2</sub> emissions from electricity and heat production in the years 1974-1976 and we exclude Turkey to avoid interpolation bias. Interpolation bias can occur when we include countries in the donor pool that are too dissimilar to the treated unit – especially on important predictors of the outcome variable (Abadie, Diamond, and Hainmueller, 2015). In 1973, GDP per capita – a key predictor of CO<sub>2</sub> emissions – is much lower in Turkey compared to other OECD countries. For example, it is around a third of the level for France. Similarly, CO<sub>2</sub> emissions per capita from electricity and heat in Turkey are less than one seventh of the level in France. That said, excluding Turkey has no impact on our main results since, when included in the sample, Turkey obtains zero weight in synthetic France – our constructed counterfactual.

## 4.2 The Synthetic Control Method

To establish the causal impact of the Messmer Plan on CO<sub>2</sub> emissions from electricity and heat production we contrast France with a selection of countries similar to it in relevant aspects but unaffected by a 'treatment' equivalent to the Messmer Plan.

Let  $J + 1$  be the number of countries in our sample, and let  $j = 1$  denote France. The countries are observed for time periods  $t = 1, 2, \dots, T$  with periods both prior to treatment  $1, 2, \dots, T_0$  and after  $T_0 + 1, T_0 + 2, \dots, T$ . The counterfactual, 'synthetic France', is constructed as a time-invariant weighted average of the unaffected control countries and represented by a vector of weights  $W = (w_2, \dots, w_{J+1})'$ . The weights are restricted to be non-negative  $0 \leq w_j \leq 1$  and sum to one  $w_2 + \dots + w_{J+1} = 1$ .

Our selection of  $W$  is designed to minimize the difference between France and the control units on key predictors of the outcome variable, as well as on the outcome variable itself during the pretreatment period. We use four key predictors: two economic indicators – GDP per capita and degree of urbanisation – and two emission-related indicators – electricity production using combustible fuels and domestic oil and coal production.<sup>8</sup> Electricity production from combustible fuels is included to match with countries with a

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<sup>8</sup>More details and data sources are available in Appendix A1.

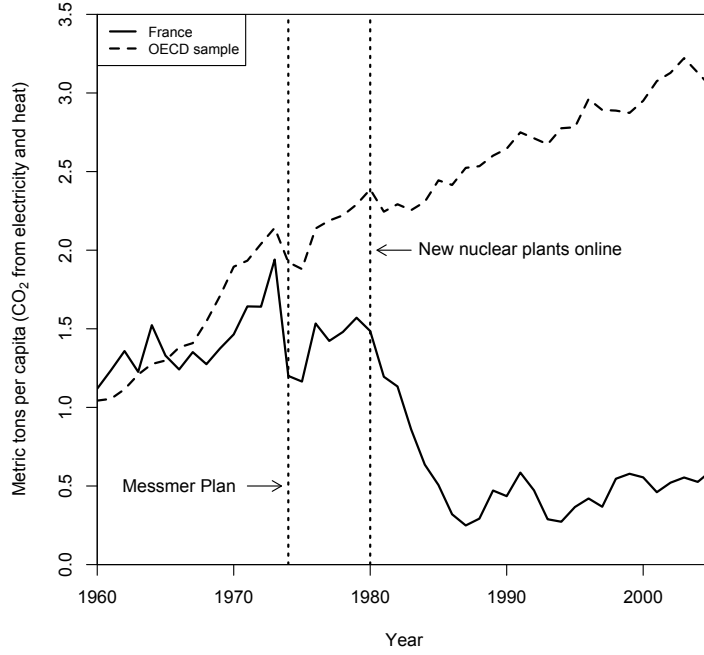


Figure 3: Path Plot of per capita CO<sub>2</sub> Emissions from Electricity and Heat during 1960-2005: France versus OECD average

similar reliance on fossil fuels before treatment, while domestic production is an indirect measure of the ability to switch from imported to domestically produced fossil fuels.

With a long pre-intervention period, an accurate match on the outcome variable indicates that both observed predictors and unobserved factors with possibly time-varying effects impact France and its synthetic counterpart similarly (Abadie, Diamond, and Hainmueller, 2015). We have 14 years of pre-treatment data (1960-1973) and an additional 6 years (1974-1979) before the first new nuclear reactors became operational. A close fit on CO<sub>2</sub> emissions between France and its counterfactual during this 20-year period suggests successful matching on all relevant variables.

## 5 The Environmental Effect of the Messmer Plan

Figure 3 compares per capita CO<sub>2</sub> emissions from electricity and heat production in France with the unweighted average of the 21 OECD countries in our donor pool. The figure illustrates why we prefer the synthetic control method over a difference-in-differences approach for our analysis. Specifically, the growth rate in emissions differs substantially in the pretreatment period. From 1960 to 1973, per capita emissions in the OECD sample increase by an average of 0.088 tons per year, compared to only 0.041 tons in France, a difference that is statistically significant. With synthetic control, we can assign weights to minimize the influence of countries that either heavily relied on fossil fuels or had minimal fossil use in the pretreatment period. This targeted weighting reduces both over-

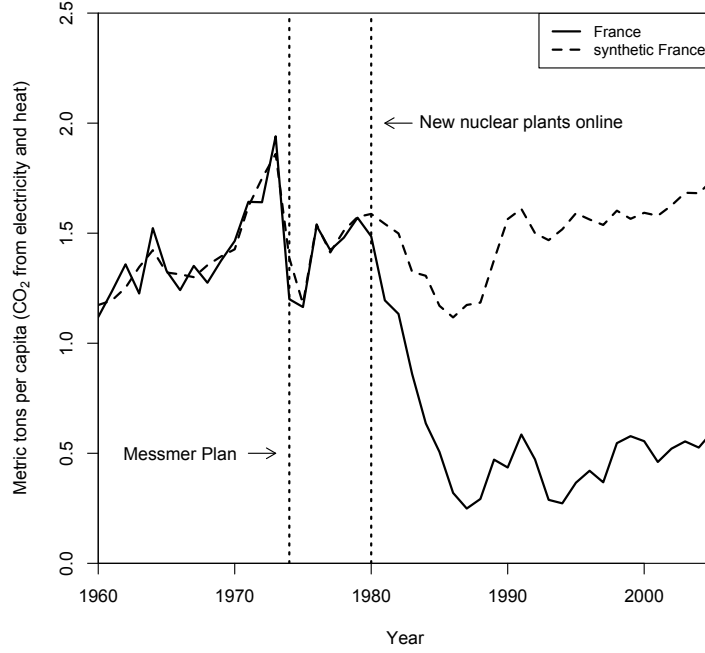


Figure 4: Path Plot of per capita CO<sub>2</sub> Emissions from Electricity and Heat during 1960-2005: France versus Synthetic France

and underestimation of emission reductions in the posttreatment period. Furthermore, we can give greater weight to countries with energy profiles similar to France’s prior to treatment. In the 1960s and early 1970s, France became increasingly dependent on imported oil and had a small but declining domestic coal industry – unlike the US and many other non-European OECD countries. While France and the OECD average had similar levels of energy self-sufficiency in the early 1960s, above 50 percent, by 1973, France had fallen below 25 percent, whereas the OECD average was around 43 percent and rising. By emphasizing countries with similar import dependence, we construct a counterfactual that better reflects France’s exposure to the two 1970s oil crises and their impact on emissions.

## 5.1 France and its Synthetic Counterfactual

Figure 4 shows the evolution of CO<sub>2</sub> emissions per capita from electricity and heat production in France and its synthetic (weighted) counterfactual from 1960-2005. The two series closely track each other in the pretreatment period of 1960-1973 and in the transitional period of 1974-1979. There are rather large movements in the outcome variable during this time frame, but the tight co-movement between France and synthetic France indicate that the volatility is due to common factors, such as the oil price shock in 1973. Then, as newly commissioned reactors come online in 1980 and onward, there is a sharp drop in emissions in France, which is not matched by a similar emissions trajectory in the counterfactual scenario. Interestingly, there is a drop in emissions in synthetic France in

Table 1: Country Weights in Synthetic France

Country	Weight	Country	Weight	Country	Weight
Australia	0	Greece	0.002	Norway	0
Austria	0.262	Iceland	0	Portugal	0.143
Belgium	0.351	Ireland	0	Spain	0
Canada	0	Italy	0	Sweden	0
Denmark	0	Japan	0	Switzerland	0.198
Finland	0	Netherlands	0	United Kingdom	0
Germany	0.043	New Zealand	0.001	United States	0

*Note:* All weights are between  $0 \leq w_j \leq 1$  and  $\sum w_j = 1$ .

the first half of the 1980s, that is later reversed by the end of that decade. This decrease and later increase is likely driven by the increase in oil prices after the second oil crisis in 1979 – caused by supply fears after the Iranian Revolution – followed by a sharp price decrease in 1986. An advantage of using aggregated emissions data and a comparative case study approach with weights is that we are able to capture the likely confounding effect of this oil price increase since it affects France and the synthetic counterfactual similarly.

For the validity of the identification assumption, it is crucial that there is a good fit on the outcome variable between 1974-1979 – immediately after the Messmer Plan was enacted, but before its expected impact on emissions. The similarity in emission levels during this intermediate period indicates that we have successfully matched on observed and unobserved predictors of emissions and that the inability to separate autoproducers’ emissions in the pretreatment period did not compromise our identification strategy.

The country weights  $W$  used to construct synthetic France are reported in Table 1. CO<sub>2</sub> emissions from electricity and heat production during the pretreatment period in France are most accurately replicated by a weighted combination of Belgium, Austria, Switzerland, Portugal, and Germany, with descending weights in that order. The remaining countries in the donor pool receive weights that are smaller than one percent.

The country weights are chosen using predictors of CO<sub>2</sub> emissions from electricity and heat production. To safeguard against specification searches and p-hacking (Abadie, 2021), we only use data from 1960-1973 to determine the country weights and exclude data after the Plan was announced. Table 2 compares the pretreatment values for these predictors in France with those in synthetic France and the arithmetic mean for the 21 OECD countries in the donor pool. On all predictors, France and its counterfactual have almost identical values and a better fit compared to France and the average of the OECD sample. For the first four key predictors, the difference between France and synthetic France is less than one percent, except for domestic oil and coal production where the value for France is five percent lower.

Table 2: Predictor Means for CO<sub>2</sub> Emissions from Electricity and Heat

Variables	France	Synth France	OECD Sample
GDP per capita	13705.0	13703.5	13116.7
Urban population	69.8	69.8	69.4
Electricity from combustible fuels per capita	1555.4	1546.1	1810.2
Oil and coal production per capita 1972	423.1	443.8	872.7
CO <sub>2</sub> emissions from electricity and heat per capita 1973	1.9	1.9	2.1
CO <sub>2</sub> emissions from electricity and heat per capita 1969	1.4	1.4	1.7
CO <sub>2</sub> emissions from electricity and heat per capita 1964	1.5	1.4	1.3

*Notes:* All key predictors, except oil and coal production, are averaged for the ten year period before treatment, 1964-73. GDP per capita is Purchasing Power Parity (PPP) adjusted and measured in 2005 U.S. dollars. Urban population is measured as the percentage of total population. Electricity production from combustible fuels is measured in kWh per capita. Oil and coal production in 1972 is measured in kilograms of oil equivalent per capita. CO<sub>2</sub> emissions are measured in metric tons. The last column reports the averages of the 21 OECD countries in the donor pool.

As predictors we also include three years of pre-intervention values of the outcome variable, emissions in 1973, 1969, and 1964 – one, five and ten years prior to the implementation of the Messmer Plan. We include lagged values for two reasons. First, we are interested in matching not only the growth rate of CO<sub>2</sub> emissions but also the overall level of those emissions. Second, adding these lags improves matching on unobservable variables that may have time-varying effects (Abadie, Diamond, and Hainmueller, 2010; Abadie, 2021). Table 2 shows that there is a good match also on these lagged predictors.

Lastly, to quantify the scale of the Messmer Plan, we evaluate the difference in the number of nuclear reactors under construction and in operation in France and its counterfactual, before and after the Plan’s announcement. Using this metric, the Messmer Plan significantly bolstered the nuclear energy program in France, leading to a more than six-fold expansion in reactors constructed post-1974 compared to the counterfactual scenario. This expansion suggests that, absent the Plan, France would have built only about 8 reactors in the decade after 1974 – rather than the 51 it actually constructed.<sup>9</sup>

## 5.2 Emission Reductions from Electricity and Heat Production

The marked increase in reactor construction had a significant impact on CO<sub>2</sub> emissions. The gap plots in Figure 5 show the difference in emissions from electricity and heat production between the two ‘countries’ from 1960-2005, highlighting the Messmer Plan’s causal effect on posttreatment emission reductions. Panels (a) and (b) are computed as the difference in emissions in each year and measured in metric tons per capita and percentage change, respectively.

There is a smooth and steady increase in the size of emission reductions in the 1980s as more and more reactors come online. Emission reductions level off thereafter. In an average year from 1980-2005, the point estimate for CO<sub>2</sub> emissions reductions from

<sup>9</sup>Additional details on how we quantified the Messmer Plan’s scale can be found in Appendix A.2.



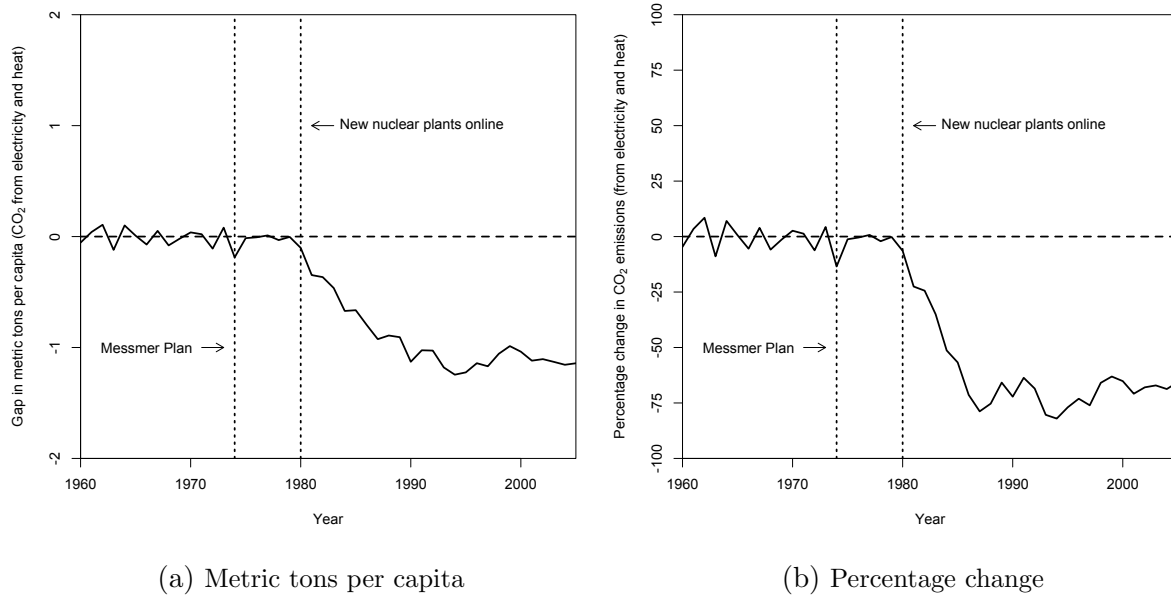


Figure 5: Gap in per capita CO<sub>2</sub> Emissions from Electricity and Heat between France and Synthetic France

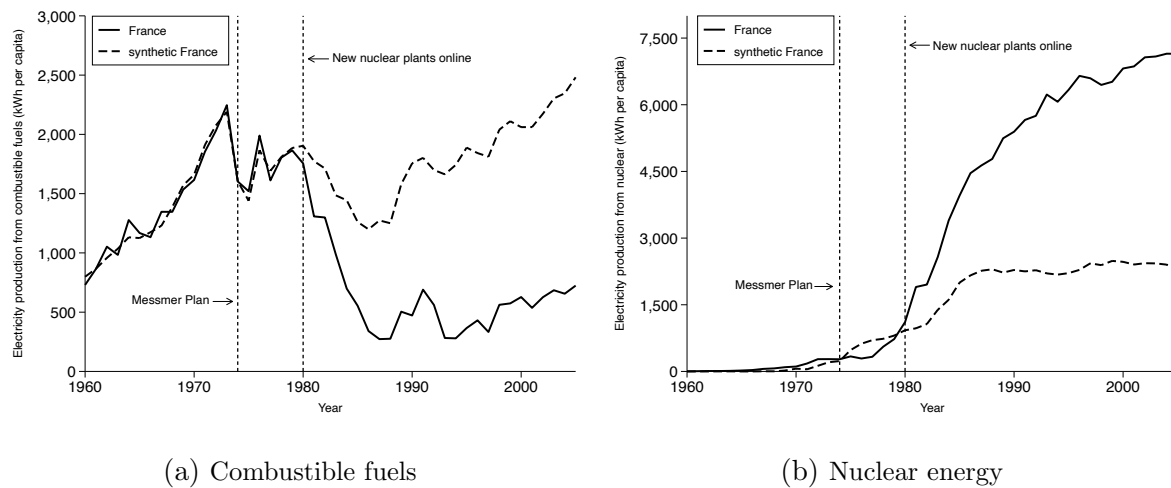


Figure 6: Electricity Production between 1960-2005: France versus Synthetic France

Note: Electricity production is measured in kWh per capita and only includes electricity from main activity producers between 1974 and 2005.

electricity and heat production as a result of the Messmer Plan is 62 percent with a range of 60 to 67 percent.<sup>10</sup> This equates to 0.92 metric tons per capita (range 0.82 to 1.19). The largest emission reduction is achieved in 1994 at 82 percent (range 80 to 85), a reduction of 1.25 metric tons per capita (range 1.10 to 1.55). Absolute emissions are also substantially reduced from an annual average of 75.8 Mt of CO<sub>2</sub> between 1974-1979 to an average of 33.0 Mt between 1980-2005.

The causal effect of the Messmer Plan on France's energy mix is illustrated in Figure 6. Panel 6a reveals a strong similarity between France and its synthetic counterpart regard-

<sup>10</sup>Ranges are calculated using leave-one-out tests. See Section A.3 of the Appendix for details.

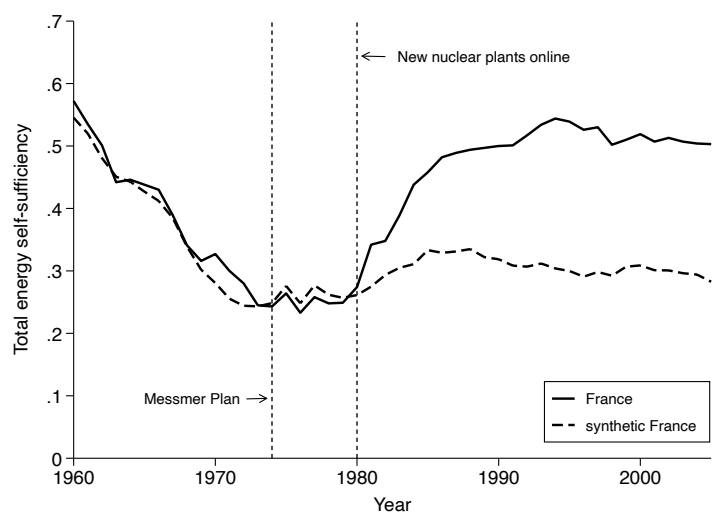


Figure 7: Energy Self-Sufficiency between 1960-2005

Note: Energy self-sufficiency is the ratio between national production and consumption of primary energy in a year. As such, the measure shows how dependent the country is on imports for its energy needs.

ing the volume of electricity generated from combustible fuels between 1960 and 1979. However, from 1980 onwards, the trajectories diverge significantly, with synthetic France producing over three times more electricity from combustible fuels than France by 2005. The trend for nuclear energy production, displayed in Panel 6b, mirrors the decoupling observed for combustible fuels, but in the opposite direction. Starting from similar low levels in the two decades from 1960 to 1979, nuclear energy production in France begins to surge relative to the counterfactual from 1980 onwards. By 2005, France’s nuclear energy production was roughly triple that of synthetic France.

Lastly, the Messmer Plan was also successful in achieving its stated aim of increasing energy security by reducing France’s dependence on imported oil. Figure 7 shows that France and its counterfactual experience a similar decline in energy self-sufficiency in the pretreatment period but as new nuclear reactors come online, the two series diverge. From 1990 onward, France is again above 50 percent in self-sufficiency, returning to the level observed at the start of our sample period.

### 5.3 Significance Testing of Main Results

To determine the statistical significance of the estimated emission reductions from electricity and heat production we perform two tests: the in-space placebo test (Abadie, Diamond, and Hainmueller, 2015) and a  $t$ -test for synthetic controls (Chernozhukov, Wuthrich, and Zhu, 2023).<sup>11</sup>

For the in-space placebo analysis, each country in the donor pool is iteratively treated

<sup>11</sup>The results from robustness tests – in-time placebo, ‘leave-one-out’, specification searching and a placebo sector test – are presented in Appendix A3.

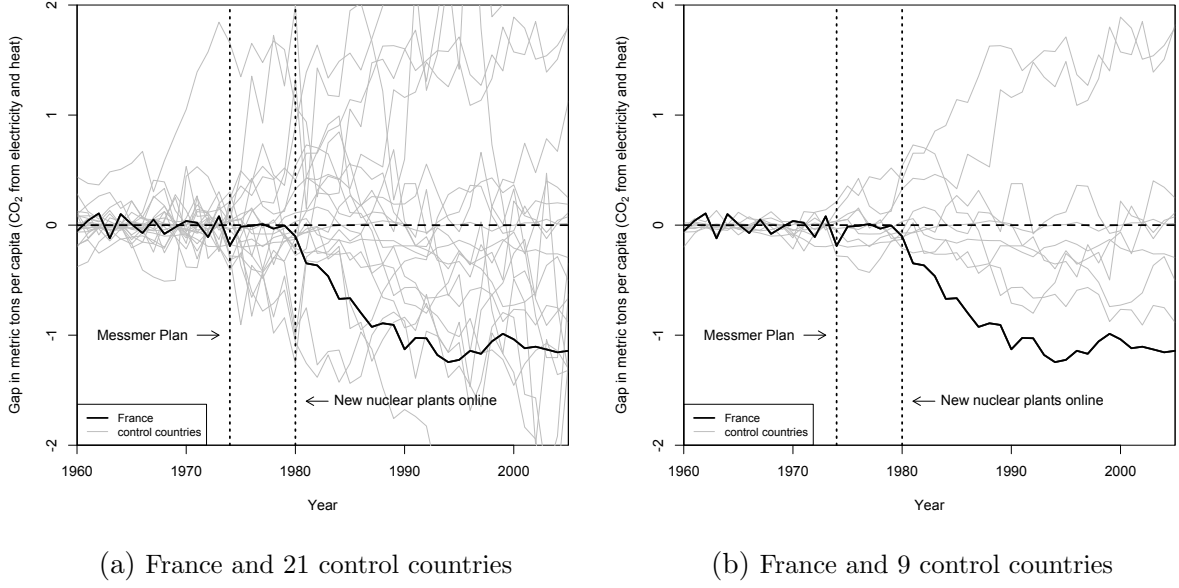


Figure 8: Permutation Test: Per capita CO<sub>2</sub> Emissions Gap in France and Placebo Gaps for the Control Countries

Note: The left figure shows the gap in CO<sub>2</sub> emissions in France and placebo gaps in all 21 control countries. The right figure shows the gap in France and placebo gaps in 9 control countries (excluding those with a pretreatment MSPE double that of France).

as if it had experienced the intervention, with synthetic counterparts derived using the predictors from Table 2. This approach allows us to assess whether the estimated emission reductions obtained for France are particularly large by comparing them to the placebo outcome for all other countries in the donor pool. This kind of permutation test draws inferences and calculate  $p$ -values by finding the percentage of countries with outcomes as large as, or larger than, the result found for France.

The results of the in-space placebo test are shown in Figure 8. As frequently observed, the synthetic control method can fail to find convex combinations of other countries that accurately reflect pretreatment period outcomes (Abadie, Diamond, and Hainmueller, 2011; Andersson, 2019). This is especially true for 'outliers'; in our case, countries with consistently the highest (e.g., the US) or the lowest (e.g., Norway) emission levels before treatment. When we exclude countries with a poor pretreatment fit, defined here as having a mean squared prediction error (MSPE) more than twice as large as France's, we are left with the ten countries illustrated in Panel (b).<sup>12</sup> France here displays the largest emission reduction in the posttreatment period, especially from 1980 and onwards, and the  $p$ -value of estimating an emission reduction of this size is thus  $1/10 = 0.10$ .

A method complementary to the (classical) in-space placebo test is the "t-test for syn-

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<sup>12</sup>The pretreatment MSPE is defined as  $MSPE = \frac{1}{T_0} \sum_{t=1}^{T_0} \left( Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \right)^2$

thetic controls” (Chernozhukov, Wuthrich, and Zhu, 2023). It facilitates the estimation and inference of the average treatment effect over time, without the necessity of permutations, and yields confidence intervals against which we can assess the significance of the results.<sup>13</sup> Setting the posttreatment period to start in 1980, when new reactors came online, we find an average emission reduction of 1.003 metric tons of CO<sub>2</sub> per capita, which is significant at both the 10% level (confidence interval of 1.279 to 0.732) and the 5% level (confidence interval of 1.408 to 0.602).<sup>14</sup>

## 5.4 Potential Spillover Effects

Our estimated emission reductions attributed to the Messmer plan could be biased if the Plan affected either nuclear energy policy in the countries that constitute synthetic France or electricity trading between them and France. In this section, we analyze the possibility of spillover effects and find little evidence that they are a significant concern.

### 5.4.1 Nuclear energy policy spillovers

If neighboring countries reduced their nuclear energy deployment in response to the Messmer Plan, opting instead to rely on electricity imports from France, this would bias our estimated reductions by increasing observed emissions in the countries that make up the synthetic control. However, for such a strategy to have been viable in the early 1970s, policymakers would have had to anticipate a series of developments that were far from certain at the time. For example, they would have had to foresee that: European electricity markets would become increasingly liberalized, allowing for large-scale cross-border electricity flows; France would successfully implement the Messmer Plan, overcoming political, economic and social hurdles that had stalled or derailed similar large-scale nuclear programs in other countries; France would increase electricity exports significantly, well beyond the modest levels seen in the 1960s and 1970s; and French nuclear electricity would become cost-competitive with domestic fossil-based generation, making imports economically attractive. Each of these assumptions involved substantial uncertainty when viewed from the vantage point of the early 1970s.

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<sup>13</sup>Note that the *t*-test methodology proposed by Chernozhukov, Wuthrich, and Zhu (2023) utilizes only the lagged values of the outcome variable as predictors. As a result, this specification does not include our full set of predictors from Table 2. Despite this, the emission reduction estimates are similar to our main results.

<sup>14</sup>The results are also significant at the 10% and 5% level if we set the posttreatment period to start in 1974. We have set  $K = 3$ . Chernozhukov, Wuthrich, and Zhu (2023) use a  $K$ -fold cross-fitting procedure to correct for potential bias of the synthetic control approach. The method divides the pretreatment period into  $K$  number of blocks, and there is a tradeoff in the choice of  $K$  – larger  $K$  leads to shorter confidence intervals but affects coverage accuracy – with the authors recommending setting  $K = 3$ , arguing that this choice “yields a good balance between coverage accuracy and length” (p. 7). For more information about the method, see section 2.2 of their paper.

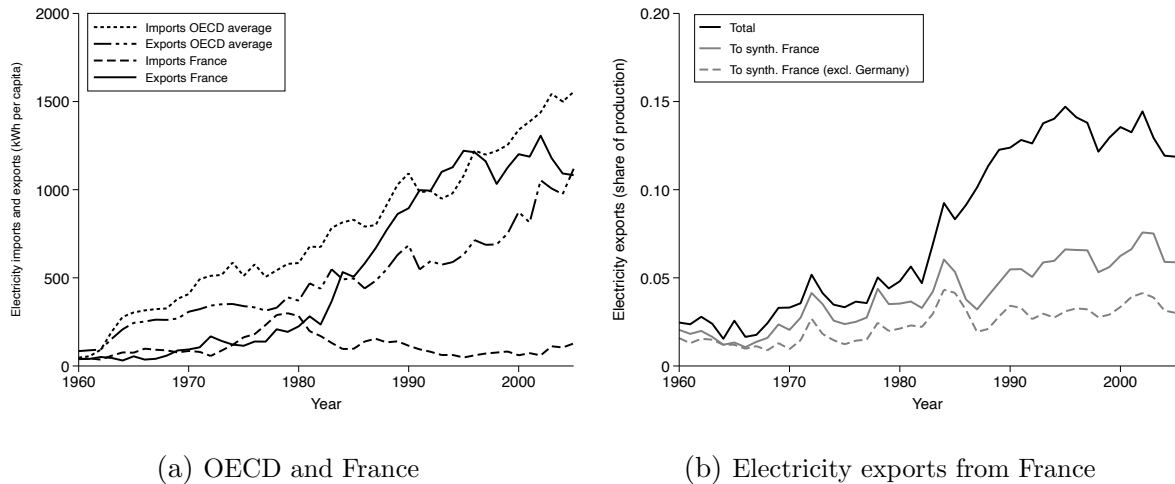


Figure 9: Electricity Imports and Exports: 1960-2005

From 1960 to 1990, the European electricity market was dominated by vertically integrated national monopolies. Cross-border electricity trading existed but was a small share of electricity production and often limited to bilateral contracts, primarily implemented for grid-stability and not driven by market forces (Batalla-Bejerano, Paniagua, and Trujillo-Baute, 2019). Figure 9a shows that France did neither export nor import much electricity in the 1960s and 1970s, especially compared to the OECD average. For instance, electricity exports were only around 40 percent of the level in an average OECD country in the 1970s.

Electricity trading within Europe did increase in the 1980s. However, it was not until the late 1990s – with the adoption of the First Energy Package in 1996 and the beginning of EU-wide electricity market liberalization in 1999 – that internal EU market integration began (Batalla-Bejerano et al., 2019). This was 25 years after the adoption of the Messmer Plan and, even then, France’s participation in the liberalization process was limited, since it only complied with the minimum requirement of a 25 percent market opening (Le Quesne, 2000). Furthermore, many countries were cautious about relying on electricity imports for energy security reasons. Germany, for example, maintained legislation in the 1980s requiring its industry to purchase electricity generated from domestic coal rather than French imports (Jasper, 1990).

Regarding the price competitiveness of nuclear energy compared to fossil fuels, this only became apparent in hindsight, following external shocks such as the 1979 oil crisis and the tightening of air pollution regulation in Europe in the 1980s, which increased coal prices (Smith et al., 2011; IEA, 2015).<sup>15</sup> These developments could not have been foreseen in the early 1970s.

On the other hand, if the countries in synthetic France increased their nuclear energy

<sup>15</sup>The convention on Long-Range Transboundary Air Pollution (LRTAP) went into effect in 1983, and the protocol on the Reduction of Sulphur Emissions was implemented in 1985, both with the aim of reducing sulphur dioxide emissions in Europe.

ambitions as a result of the Messmer Plan, this would again bias the estimated emission reductions – as observed emissions in synthetic France will now be lower than they would have been in the absence of the Messmer Plan. However, data on nuclear energy deployment in counterfactual countries do not support this scenario.

Austria had a nuclear power program in place in the early 1970s with a plan for three nuclear power plants. The first, the Zwentendorf nuclear power plant, began construction in 1972 and was finished in 1978. However, the plant never went into commercial operation following a referendum on nuclear energy in November 1978. After this, no new nuclear reactors were initiated.

Belgium has two nuclear power plants, Doel and Tihange, which began construction in 1969 and 1970, respectively. Doel is comprised of four reactors and Tihange has three. The decision to build each of these seven reactors was taken before the announcement of the Messmer Plan (IAEA, 2020). No more reactors or nuclear power plants were ordered after this.

Germany has built 36 nuclear reactors in total. Of these, 13 began construction between 1974 and 1982 – after the Messmer Plan was announced – but only one of these 13 was ordered after 1976 (Campbell, 1988). Nevertheless, Germany’s weight in the synthetic counterfactual is just four percent, so any potential spillover effect should be small.

Portugal has built no nuclear reactors. At the peak of its programme, Switzerland had five nuclear reactors, with four still in operation today. All reactors began construction before the Messmer Plan was announced. The last reactor to begin construction was Leibstadt on January 1st, 1974.

Taken together, there is no evidence that the countries in synthetic France increased their nuclear energy ambitions in response to the Messmer Plan.<sup>16 17</sup>

#### 5.4.2 Electricity trading spillovers

Even if the Messmer Plan did not affect nuclear energy policy in the countries of synthetic France in the decade immediately following its implementation, it is conceivable that by the mid-1980s – when new reactors from the Plan came online and France’s electricity exports began to increase – these countries scaled back or postponed their own energy investments in favor of importing French electricity. However, this hypothesis also receives

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<sup>16</sup>The countries in the synthetic counterfactual were not unique with regards to their slowdown in the deployment of nuclear reactors. For instance, the US did not order any new reactors between the late 1970s and the end of our sample period, and the vast majority of US reactors in operation today were ordered before 1974 (Davis, 2012).

<sup>17</sup>Apart from nuclear energy, governments tended to promote sources of electricity upon which they historically relied. For Austria, Portugal, and Switzerland this meant hydropower (Nunes 2018; Wagner et al 2015), while for Belgium and Germany it meant coal (Sill 1986; Storchmann 2005). Several policy tools were used, including subsidies and public financing. To our knowledge, no donor country pursued a large-scale industrial policy for either hydropower or coal.

limited support from the data.

Figure 9a illustrates that electricity trading increased across all OECD countries over time, with France showing a similar upward trend for exports. Yet, electricity production also significantly increased in all OECD countries during this time. In France, total electricity production grew more than seven-fold from 1960 to 2005. To account for this, Figure 9b plots French electricity exports relative to electricity production.

This relative measure shows an increased export share in the posttreatment period, averaging about 11 percent of total electricity production. However, the share of exports going to countries making up synthetic France remains relatively stable, and increasing only slightly in the posttreatment period.

On average, between 1980-2005, 5.4 percent of France’s annual electricity production is exported to countries in synthetic France, while imports from these countries represent 1.3 percent of France’s electricity consumption. Therefore, the spillover effects from electricity trading between France and its synthetic counterpart are relatively modest. Excluding Germany – which has a small weight in synthetic France – further reduces this spillover, with exports to synthetic France then accounting for just 3.1 percent of annual electricity production during the posttreatment period.<sup>18</sup>

In conclusion, we expect few spillover effects of the Messmer Plan on nuclear energy policy and electricity trading in synthetic France countries. Any that do exist are likely small and unlikely to significantly bias our emission reduction estimate.<sup>19</sup>

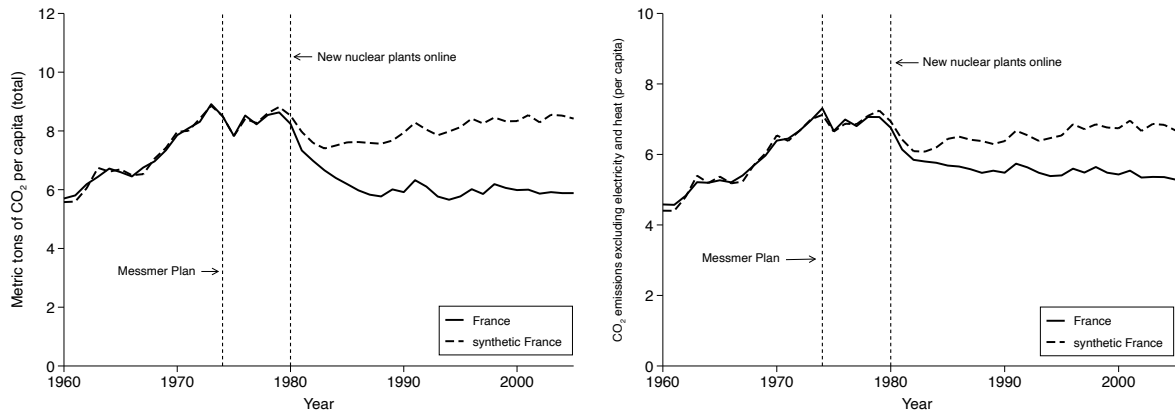
## 5.5 Total Emission Reductions

While the Messmer Plan primarily impacts electricity and heat production, it may also indirectly influence CO<sub>2</sub> emissions in other sectors. Using the country weights specified in Table 1, we evaluate the consequences of the Messmer Plan on France’s total CO<sub>2</sub> emissions. Figure 10a indicates that from 1980 onward, the average per capita reduction in emissions amounts to 1.88 metric tons, which is a 23 percent reduction in total CO<sub>2</sub> emissions. This number is almost exactly double the emissions reduction we observed solely in the electricity and heat sector, which was 0.92 metric tons per capita. As shown in Figure 10b, the remaining 0.96 metric ton reduction in emissions between 1980 and 2005 comes from sectors other than electricity and heat production. Specifically, industry accounts for a relative reduction of 0.51 metric tons, while the residential and

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<sup>18</sup>Beyond synthetic countries, France also exported electricity to Italy, Luxembourg, Spain and the UK – just over half of all electricity exports are going to these four countries in the posttreatment period. The noticeable increase in exports in the mid-1980s coincides with the completion of an undersea electric cable between France and the UK in 1986. Before this, there was almost no electricity exports to the UK from France.

<sup>19</sup>Appendix A.4 provides further spillover analysis by estimating emission reductions from a consumption-based approach, adjusted for electricity trading. This approach shows slightly larger emission reductions from the Messmer Plan in the posttreatment period compared to our main results, although the difference is small.



(a) Total CO<sub>2</sub> emissions

(b) Excluding electricity and heat emissions

Figure 10: Path Plot of CO<sub>2</sub> Emissions 1960-2005: France versus Synthetic France

Note: Panel (a) depicts total CO<sub>2</sub> emissions per capita, while panel (b) excludes emissions from electricity and heat production.

services sectors together contribute another 0.45 metric tons.<sup>20</sup> Interestingly, the emission reductions from these sectors also coincide with the roll-out of new nuclear reactors from 1980 onward.

To account for this additional emissions cut of almost 1 ton per capita, we explore two separate hypotheses, which are not necessarily mutually exclusive. The first posits that fuel-switching occurred. If the Messmer Plan led to an increase in electricity production, beyond merely replacing fossil fuels with nuclear energy, it would likely result in a decrease in electricity prices. This price reduction could prompt a shift away from fossil fuels in other sectors, encouraging greater electricity consumption instead, particularly in the industrial, residential and services sectors.<sup>21</sup> This would result in a comparative emissions reduction relative to a counterfactual scenario. The second hypothesis suggests that a relative economic downturn in France during the post-treatment period suppressed CO<sub>2</sub> emissions.

Figure 11 charts the trajectories of electricity production and household electricity prices between France and its synthetic counterpart. Until 1980, electricity production followed parallel trends. Subsequently, France witnessed a faster growth rate for a decade, coinciding with the extensive rollout of new nuclear reactors. Although the growth rates re-aligned in the 1990s, France's total electricity production consistently outpaced that of

<sup>20</sup>We merged the residential and services sector data, as the IEA was unable to differentiate oil consumption between these sectors before 1985 (IEA, 2022, p. 129). Furthermore, we allocated emissions from autoproducers to the industry sector, as recommended by the IPCC guidelines. Lastly, no relative emission reductions were observed in the transport, agriculture, and forestry sectors between 1980-2005.

<sup>21</sup>These three sectors combined account for nearly 90 percent of France's total electricity consumption during our study period. Since electric vehicles were not a meaningful part of the vehicle fleet during our study period, the transport sector could not benefit from an increased supply of electricity as an energy source. In 2005, electricity provided less than 3 percent of the energy consumed in the transport sector in France, and the average during the period 1980-2005 was around 1.5 percent.



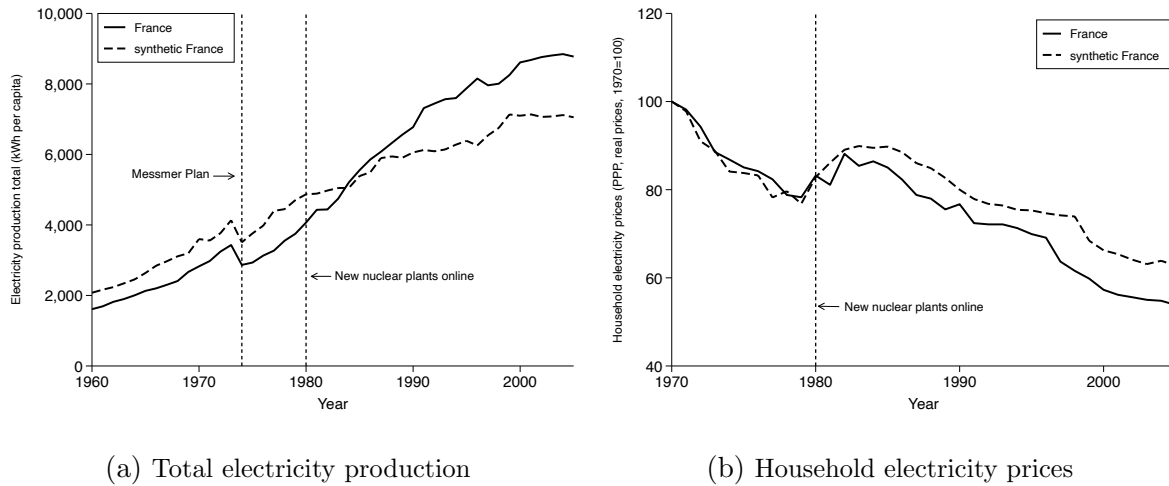


Figure 11: Total Electricity Production and Prices: France versus Synthetic France

Note: Electricity production is measured in kWh per capita, and only includes electricity from main activity producers between 1974-2005. Electricity prices include taxes and are measured in real terms and adjusted for differences in purchasing power. To ease comparisons over time, the prices are given as an index, with 1970=100. Note that panel (b) starts in 1970, due to missing data for years prior.

its synthetic counterpart. This elevated level of production contributed to lower household electricity prices in France from 1980 onward, as illustrated in Panel 11b.<sup>22</sup>

For an increase in electricity production and a concurrent drop in household electricity prices to occur, the supply curve must shift outward. This typically occurs when the marginal cost of production falls – due to technological progress or reduced input costs. In France, this outward shift was also driven by EDF’s anticipation of growing future demand, encouraged by the Messmer Plan’s emphasis on electrification and long-term demand projections (Brouard and Guinaudeau, 2015). Consequently, nuclear capacity expanded significantly, both through new plant construction and additional reactors at existing sites. This increased supply helped reduce electricity prices. Furthermore, the shift from fossil fuels to nuclear power likely lowered marginal costs, reinforcing the price decline. In the 1980s, nuclear energy became more cost-competitive, aided by rising oil prices after the 1979 oil crisis, that increased prices of all fossil fuels in France (IEA, 2025a), and the phase-out of cheaper high-sulphur coal (Smith et al., 2011; IEA, 2015).

To investigate the validity of the fuel-switching hypothesis, we examine energy consumption across the economy, focusing on both electricity and combustible fuels. In Figure 12, we observe a notable increase in the proportion of energy consumption derived from electricity within the residential, services and industry sectors. Concurrently, there is a corresponding decline in the proportion of energy obtained from combustible

<sup>22</sup>Since at least the early 1970s, EDF operated under multi-year state agreements that included pricing frameworks, which remained unchanged until EU market liberalization in the late 1990s (Hancké, 2002). As Figure 11b shows, electricity prices in France and its counterfactual tracked closely in the 1970s but diverged after 1980, with French prices falling more sharply. This indicates that the Messmer Plan contributed to lower electricity prices – even under continued price regulation.

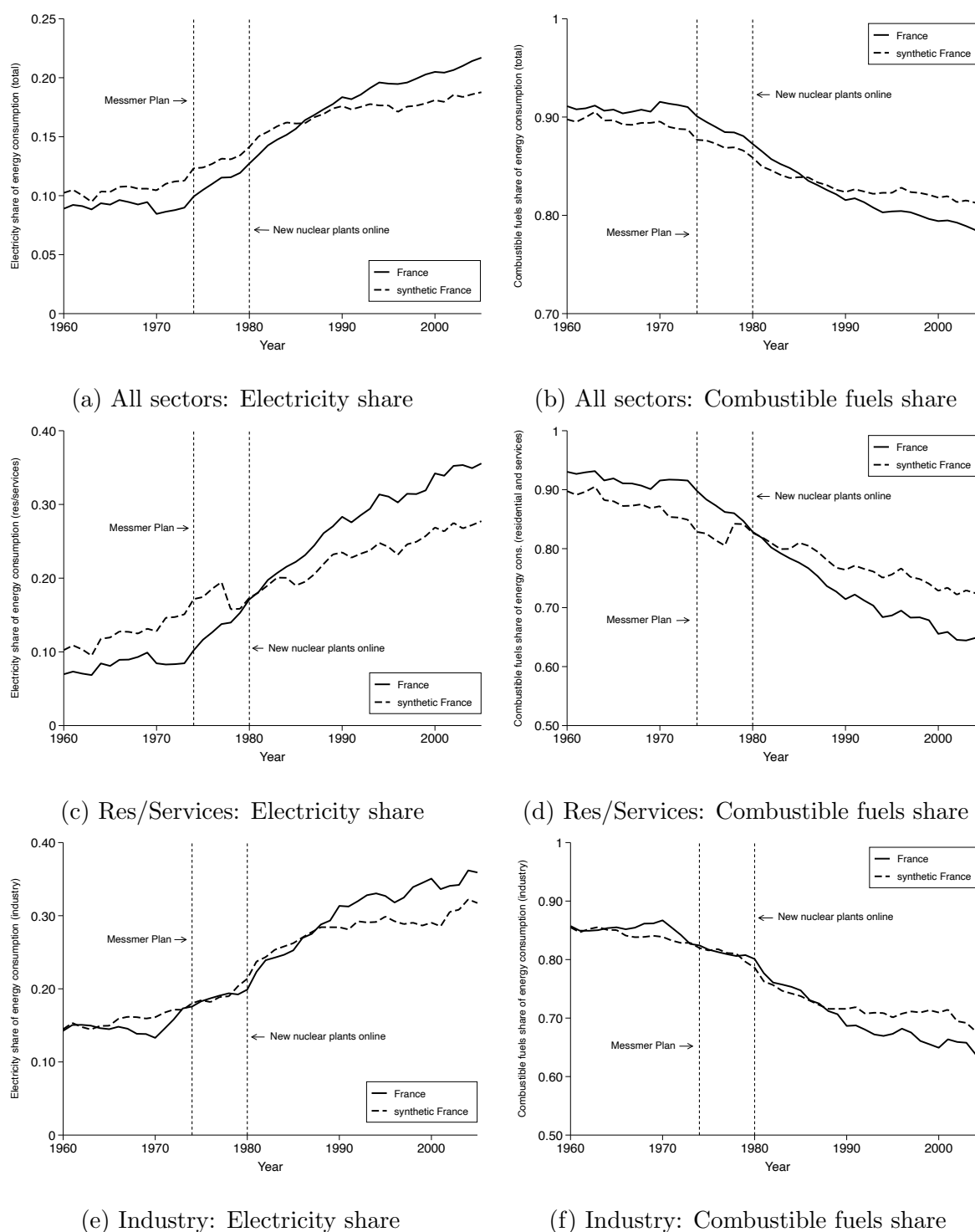


Figure 12: Electricity and Combustible Fuels share of Energy Consumption

Note: The figure shows the share of energy consumption coming from electricity (left-hand side) and combustible fuels (right-hand side), respectively. To make aggregation and comparisons possible, all energy sources were first converted into oil equivalents. Panels (a)-(b) depict the shares out of total energy consumption – the combination of industry, residential, services, transport, agriculture and forestry, fishing and other. Panels (c)-(d) depict the shares in the residential and services sectors, and panels (e)-(f) depict the shares in the industrial sector.

Source: International Energy Agency (2022) – World Energy Balances.

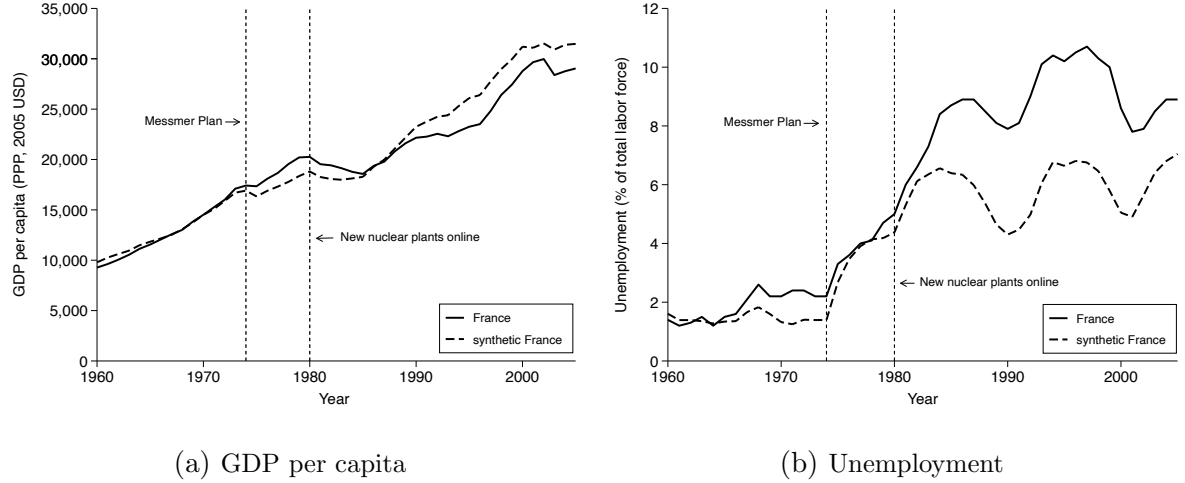


Figure 13: GDP per capita and Unemployment between 1960-2005: France versus Synthetic France

Note: GDP per capita is Purchasing Power Parity (PPP)-adjusted and measured in 2005 U.S. dollars. Unemployment is measured as percentage of total labor force.

fuels. This trend supports the notion of fuel-switching, which offers an explanation for the observed reductions in CO<sub>2</sub> emissions from sectors other than electricity and heat production.<sup>23</sup>

To explore the alternative hypothesis regarding potential emissions reductions driven by an economic downturn, we analyze the two macro variables of gross domestic product (GDP) and unemployment. In Figure 13, the evolution of real GDP per capita during the pretreatment period aligns closely, followed by a slightly higher GDP level in France after the initial oil crisis and until the mid-1980s. However, from 1990 onwards, France's GDP level shows a relative decline. This trend is reflected in the unemployment rate, with France consistently experiencing a notably higher unemployment rate – on average, 2.8 percentage points higher – compared to synthetic France between 1980 and 2005. These macroeconomic indicators lend credence to the alternative hypothesis, suggesting the presence of a relative economic downturn, which, in turn, may have contributed to reduced CO<sub>2</sub> emissions, given the well-established correlation between economic growth and CO<sub>2</sub> emissions (Holtz-Eakin and Selden, 1995; Sheldon, 2019; Mardani et al., 2019).

We have evidence in support of both hypotheses, and they do not need to be mutually exclusive. To establish which hypothesis has the largest effect on relative emission reductions, we conducted a regression analysis aimed at determining the magnitude of the confounding effect originating from the macro variables of GDP and unemployment. This analysis was compared against the effect resulting from the increased share of nuclear energy in electricity production, with all variables calculated as the gap between France and synthetic France.

<sup>23</sup>In appendix A.5, we further decompose energy use by individual fuels: electricity, oil, natural gas, and coal.

Table 3: Regression Results for Gap in Total CO<sub>2</sub> Emissions Estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Nuclear share	-5.089*** (0.286)			-4.455*** (0.307)		-4.782*** (1.018)	-4.443*** (0.690)
GDP per capita		0.594*** (0.093)		0.125*** (0.042)	0.226*** (0.065)		0.125*** (0.040)
Unemployment			-0.640*** (0.054)		-0.482*** (0.063)	-0.047 (0.112)	-0.002 (0.081)
Observations	46	46	46	46	46	46	46
$R^2$	0.953	0.624	0.794	0.966	0.836	0.953	0.966

Note: All variables are computed as the gap between France and Synthetic France. The dependent variable is the gap in total per capita CO<sub>2</sub> emissions (metric tons). The gap in the share of nuclear is measured in percentage points (divided by 100). Real GDP per capita is Purchasing Power Parity (PPP)-adjusted and measured in 2005 U.S. dollars (thousands). Unemployment is measured as percentage of total labor force. Newey-West standard errors in parentheses; heteroscedasticity and autocorrelation robust. The constant is omitted from the output.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The following OLS regression model was tested:

$$\Delta CO2_t = \alpha + \Delta X_t \beta + \epsilon_t \quad (1)$$

where  $\Delta CO2_t$  is the annual gap between France and its synthetic counterpart in total per capita CO<sub>2</sub> emissions;  $\Delta X_t$  is a vector of the key explanatory variables: the annual gaps in the share of nuclear in electricity production, GDP per capita and unemployment; and  $\epsilon_t$  is idiosyncratic shocks. The time period runs from 1960-2005, with 46 observations in total.

Table 3 provides the results. When running each explanatory variable separately, all the coefficients are statistically significant and have the expected signs, with the gap in the share of nuclear showing the largest predictive power with an  $R^2$  of 0.95. However, when running the full model (column 7) the coefficient for GDP is reduced by almost 80 percent in size and the coefficient on unemployment is now close to zero and no longer statistically significant. The coefficient for the nuclear gap is, however, significant and similar in size in all regression models where it is included.

Using the average gap in the share of nuclear between 1980-2005 of 39.2 percentage points we compute an average emission reduction in the posttreatment period of 1.74 metric tons of CO<sub>2</sub> per capita. The average gap in GDP is -\$1169 in the same time period, which gives an average emission reduction of 0.15 metric tons per capita. Lastly, the average gap in unemployment of 2.8 percentage points gives an average emission reduction of <0.01 metric tons per capita.

Adding up the effects of the three key explanatory variables we calculate a total average emission reduction of 1.89 metric tons in the posttreatment period, which matches the 1.88 metric tons that we compute from Figure 10a. Of this total, the gap in nuclear explains 92 percent, and the macro variables of GDP and unemployment explains the remaining 8 percent. The conclusion we draw from the regression result is that fuel-switching likely accounts for the largest share of the emission reductions found in the non-electricity and heat sectors in the posttreatment period, and that the relative economic downturn, while significant, is less impactful.

## 5.6 Timeframe for Emission Reductions

As shown in Figures 4 and 5, our results indicate a delay of six years between the policy announcement and the onset of emission reductions – what we term the “transitional period”. Yet, despite this initial lag, the emission reductions were substantial and swift once the reactors became operational. By 1984, ten years after the Messmer Plan’s announcement, France’s CO<sub>2</sub> emissions from electricity and heat production had halved, compared to the counterfactual scenario, and by 1987 they had dropped almost 80 percent.

The length of the transitional period matches well the average build time of the new reactors. From construction start to commercial operation, the reactors ordered between 1974-1976, just following the announcement of the Messmer Plan, had an average build time of 75.4 months (just over six years), with a standard deviation of 9.7 months and a range of 59 months to 100 months (IAEA, 2023a). This average is similar to the average build time of seven years for all nuclear reactors that have ever been completed in France. While this time frame does not include planning and permit acquisition, it remains notably shorter than the most recent European examples. For instance, Finland’s Olkiluoto 3 reactor, which began construction in 2005, only became commercially operational in 2023. Similarly, construction of Flamanville 3 in France began in 2007 and was connected to the grid toward the end of 2024.

The average build time in France was also shorter than reactor construction times in other countries during this time period, such as Sweden, the US, and Germany. A likely explanation for the relatively shorter construction times in France were the standardized reactor type used throughout the implementation of the Messmer Plan and streamlined planning procedures (Campbell, 1988).

## 5.7 Abatement Cost

For the final part of our empirical analysis we calculate the average abatement cost associated with the Messmer Plan. This cost represents the total expense incurred for reducing emissions through the policy, divided by the total reduction in CO<sub>2</sub> achieved.

To estimate the total cost of emission reductions, we first calculate the cost of electricity production in France from 1980 to 2005. We then subtract the cost of the same amount of electricity production in the counterfactual scenario where the Messmer Plan was not implemented. This counterfactual scenario reflects how France’s electricity source mix would have evolved without the adoption of the industrial policy.

To compare electricity production costs across different sources, we use the concept of Levelized Cost of Electricity (LCOE). It is typically used to compare the cost of adding new capacity across technologies. LCOE accounts for all costs related to the entire lifespan of a power plant, including capital construction, operation, maintenance, fuel, decommissioning and waste management. These costs are adjusted for inflation and discounted back to their present value, summed up and then divided by the expected amount of electricity produced. LCOE estimates are sensitive to the specific circumstances of each country, considering factors such as labor and fuel costs. This means that the LCOE for a particular technology will vary from one country to another in the same year. When calculated properly, the LCOE gives an estimate of the average cost of producing one unit of electricity from a given technology in a specific year and country, often expressed in US dollars per megawatt-hour (MWh). While LCOE has limitations (see, for instance, Joskow, 2011; IEA, 2015), it remains a widely used metric for comparing electricity generation costs across technologies, countries and time.

Using the levelized cost concept, we compute the average abatement cost (AAC) of the Messmer Plan as follows:

$$AAC = \frac{1}{N} \sum_{t=1980}^{2005} \left( \frac{(LCOE_t^{FRA} - LCOE_t^{synFRA}) * elecprod_t^{FRA}}{(CO2_t^{synFRA} - CO2_t^{FRA})} \right) \quad (2)$$

where  $LCOE_t$  represents the average levelized cost, taking into account the fuel mix in year  $t$ ;  $elecprod_t$  denotes electricity production from main activity producers in year  $t$ ; and  $CO2_t$  is the total amount of carbon dioxide emissions from the economy.

When using equation (2), we make three simplifying assumptions. First, to compute  $LCOE_t^{synFRA}$  we use the fuel mix in synthetic France in each year, but the levelized cost estimates for different technologies in France. This is done to reflect the likely ‘true’ cost of electricity production within France in the scenario where the Messmer Plan is not adopted. Second, we assume that electricity production from hydropower remains unaffected by the Messmer Plan.<sup>24</sup> Consequently, we measure electricity production from main activity producers net of hydropower, and the average LCOE is computed based on the shares of nuclear and combustible fuels in this adjusted electricity production. Third, we use the levelized cost of coal to represent all combustible fuels. This choice is primarily influenced by data availability, as the IEA (2015) provides consistent LCOE

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<sup>24</sup>Electricity production from hydropower is relatively stable in France between 1960-2005 at an average annual production of around 1,000 kWh per capita.

Table 4: Data for Abatement Cost Calculation

	1981	1984	1989	1992	1998	2005
Nuclear LCOE	60.66	40.44	56.20	58.50	47.93	32.12
Coal LCOE	47.63	72.72	81.22	90.25	68.95	41.17
Nuclear share France	59.0	82.7	91.1	91.0	91.9	90.5
Nuclear share synthetic France	35.4	52.7	58.5	57.3	53.9	47.1
Electricity production	3.22	4.10	5.76	6.32	7.02	7.89
Total reduction in CO <sub>2</sub>	0.63	1.10	1.66	1.94	2.27	2.54
Abatement cost	15.0	-36.6	-28.7	-35.2	-24.7	-10.0

Notes: The levelized cost of nuclear and coal is computed using a 5% discount rate and measured in 2013 USD/MWh. Nuclear share refers to the proportion of nuclear energy in total electricity production from main activity producers, excluding hydropower. Electricity production represents output from main activity producers (excluding hydropower) and measured in MWh per capita. CO<sub>2</sub> emission reductions are measured in metric tons per capita. Finally, abatement cost is measured in USD per metric ton of CO<sub>2</sub>.

estimates for coal and nuclear in France between 1980-2005, but only sparsely for natural gas and no estimates are given for oil. However, coal constitutes more than three fourths of the combustible fuels used for electricity production in France between 1980-2005, and the levelized cost of natural gas consistently exceeds that of coal for those years that an estimate for natural gas is given. Thus, using the levelized cost of coal to represent all combustible fuels reduces the overall cost of the counterfactual scenario.

We sourced our LCOE data from the IEA (2015). The data originates from reports prepared in collaboration by the IEA, the OECD and the Nuclear Energy Agency, with figures provided for the years 1981, 1984, 1989, 1992, 1998, and 2005. While these estimates are not annual, they do span most of the post-treatment period we are interested in. The LCOE calculations were done using a 5% discount rate and presented in units of 2013 USD per MWh. The estimates are given in Table 4, along with information on fuel shares, electricity production figures and the reductions in total CO<sub>2</sub> emissions.

Using equation (2) and the data in Table 4, we find an average abatement cost of -\$20 per metric ton of CO<sub>2</sub>. The negative average abatement cost indicates that the Messmer Plan turned out to be an opportunity to reduce carbon emissions with a net economic gain. The substitution away from combustible fuels and towards nuclear energy in France reduced the overall cost of electricity production relative to the counterfactual scenario. On top of the cost savings from electricity production, the substitution towards nuclear energy also resulted in a reduction of carbon emissions – directly from the production of electricity and heat, but also in other sectors due to fuel-switching. The total net effect was an average abatement value of \$20 per metric ton of CO<sub>2</sub> reduced.

Keep in mind that it is the relative cost advantage of nuclear compared to coal that

matters for the average abatement cost. While the LCOE of nuclear in France was relatively flat during the 1980s and declined notably between 1992 to 2005, similar trends were observed across other OECD countries (IEA, 2015).<sup>25</sup> What is more relevant for our analysis is that nuclear became increasingly cost-competitive relative to fossil fuels during the 1980s. The LCOE of coal in France rose sharply during this period. This increase was likely due to efforts in the 1980s to reduce sulphur dioxide (SO<sub>2</sub>) emissions that contributes to acid rain. These efforts led to the phase-out of cheaper, high-sulphur coal – raising fuel costs – and to the adoption of more expensive technologies at coal-fired power plants, such as scrubbers, which increased operational costs (Smith et al., 2011). In addition, the cost of coal (and natural gas) likely rose in response to the second oil crisis that began in 1979, as higher oil prices prompted substitution toward alternative fossil fuels (IEA, 2025a).

A potential objection to our estimated negative abatement cost is that the LCOE of coal we use is too high since the numbers include construction cost. If the fossil fuel plants were already built, we should exclude the construction cost from our LCOE estimates. However, it is essential to consider four key factors. First, the substantial increase in electricity production during our sample period (see Figure 2) suggests that France would have needed to build numerous new combustible fuel plants even if it had not adopted nuclear power. Second, fuel, operation and maintenance costs constitute the largest portion – around two thirds – of the levelized cost for coal-fired power plants in France (IEA, 2005). Third, even if a plant is already constructed, spreading out construction costs over the plant’s lifetime aligns with common accounting practices, similar to how capital expenditures are handled in a firm’s financial reports. Lastly, the social costs of local air pollution from coal plants are not accounted for, which, if included, would increase the LCOE estimates for coal.

## 6 The Political Economy of the Messmer Plan

The sections above establish large and significant emissions reductions associated with the Messmer Plan, as well as its costs. Here we explain the political economy of adopting and implementing the reform. We focus considerable attention on politics and policymaking because, though seemingly obvious, it is important to stress that the political success of the Plan was essential for it to lead to emissions reductions. And it was not obvious ex-ante that the Messmer Plan would be politically successful. It entailed a large-scale and capital-intensive intervention in the economy to restructure a pre-existing electricity

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<sup>25</sup>While France followed a similar time *trend* in nuclear LCOE as other OECD countries, the Messmer Plan likely helped keep costs at a lower *level* by reducing capital costs and standardizing reactor types, siting and authorization procedures. Throughout the posttreatment period, France’s nuclear LCOE remains consistently about 20 percent below the average OECD level.



sector of a major industrialized country. Such dramatic reforms to the status quo are difficult for any government to achieve. To be sure, similar large-scale nuclear plans in other industrialized democracies, such as Project Independence in the US or those in the UK, failed to achieve their goals (Campbell, 1988; Helm, 2004; Jasper, 1990; Williams, 1980). Moreover, as we describe below, the Plan faced intense opposition from many groups in French society. We explain the political success of the Plan by highlighting how the government insulated the policymaking from the Plan’s opponents.

Before doing so, we briefly outline several conditions that set the scene for a large-scale expansion of nuclear power.<sup>26</sup> First, given France’s high dependence on imported oil (see Section 3 above), the 1973 oil price spike constituted a significant exogenous shock, which presented the government with a clear and present energy crisis that required a response. Second, thanks to policy support since the Second World War, the infrastructure for a large-scale nuclear program was in place in France when the oil shock hit. Last, political and policymaking institutions in France provided the basis for a centralized, technocratic and insulated policymaking process that could be controlled from the executive branch. While all industrialized democracies were affected by the oil price shock and many had pre-existing nuclear programs similar to that of France, none expanded nuclear power at a similar pace and scale. As we show below, the key variable that set France apart from otherwise similar countries was its political and policymaking institutions, which enabled the government to insulate policymaking and prevented the Plan’s opponents from obstructing its adoption and implementation.

## 6.1 Explaining Political Success

Recent work in political science points to two political pathways that governments can use to overcome opposition to far-reaching energy reforms (Finnegan et al., 2025; Meckling et al., 2022). The first is *insulation*, which entails shielding, or insulating, the policymaking process from opponents so as to reduce their ability to influence the outcome. It can be enabled in several ways, for example, the delegation of policymaking to autonomous bureaucracies or technocratic bodies, centralized policymaking with few veto points and low levels of electoral competition and electoral accountability. With insulation, policy change occurs despite continuing opposition from opponents. The second mechanism is *compensation*, which aims to reduce the costs that opponents face as they transition to the new status quo, so as to incentivize them to cooperate and support reform. Here policy change occurs with the approval or indifference of opponents. Compensation can also take several forms, including direct financial payments, subsidies, tax cuts, phased implementation, transitional assistance and worker retraining. As we show below, in the case of the Messmer Plan, governments relied primarily on the insulation pathway.

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<sup>26</sup>For full details see Appendix A.6

### 6.1.1 Opposition to the Messmer Plan

Opposition to the Plan came from virtually all corners of French society (Brouard and Guinaudeau, 2015; Lucas, 1979; Papon, 1979; Jasper, 1990, Ch 9). Organized groups of nuclear scientists and engineers criticized the government's secrecy on nuclear matters and opposed the Plan on the grounds that it was too large and that there were unsolved challenges related to nuclear energy. At the same time, economists at the Institute of Energy Economics and Law (Institut Économique et Juridique de l'Énergie (IEJE)) in Grenoble challenged the Plan's assumptions around future energy demand, costs and possible risks. Fossil fuel industries opposed a large expansion of nuclear power, as well as the substitution of electricity for fossil fuels in industrial and residential sectors, notably heating. The country's second largest trade union, the French Democratic Confederation of Labour (CFDT), opposed the Plan and proposed a three-year moratorium on nuclear construction on the basis that France had little experience building the new PWR reactors and such a massive build out was costly and risked worker safety.

Environmental groups vociferously opposed the expansion of nuclear energy (Chafer, 1985; Kitschelt, 1986; Jasper, 1990, Ch 9). Groups had called for a moratorium on nuclear energy before 1973 and intensified their calls in response to the Messmer Plan. They mobilized opposition at the national level in Paris and at the local level, especially in areas where reactors were to be built. Indeed, almost every site chosen for reactor construction was met with local opposition. Opposition turned violent in the late 1970s when protesters bombed EDF buildings and a newly built, but unloaded, reactor. In addition to direct action, groups used the courts to try to block policy change.

Opposition political parties did not take an expressly antinuclear position (Brouard and Guinaudeau, 2015; Nelkin and Pollak, 1980; Jasper, 1990, Ch 5 and 9). However, they attacked the size and suddenness of the Plan, the way that EDF could 'buy off' local governments to get their reactors approved, the lack of public discussion and that the Plan would only profit large industry. By 1977, the Socialists, one of the largest opposition parties, was calling for a two-year moratorium on nuclear construction.

Last, public opinion oscillated during the period (Brouard and Guinaudeau, 2015, 146; Fagnani and Moatti, 1984, 272; Nelkin and Pollak, 1980, 135). While initially positive, the public mood turned antinuclear by 1977. By the early 1980s it was slightly positive again before turning negative after the Chernobyl disaster in 1986.

While antinuclear opposition was pronounced in France, it is not obvious that it was altogether more pronounced than in other industrialized democracies. Indeed, governments across countries faced opposition to nuclear expansion from experts, opposition political parties, legal challenges and civil society (Campbell, 1988; Jasper, 1990; Kitschelt, 1986). Though, as we describe below, none were as effective at overcoming it as governments in France.

### 6.1.2 Overcoming opposition via insulation

The key variable in the French case was the capacity of the government to overcome the Plan's opponents via insulation. Once the executive had decided to pursue the Messmer Plan, it put the full weight of the *dirigiste* state into action behind it.<sup>27</sup> First, the country's autonomous state bureaucracy was the primary locus of policymaking and it was impermeable to outside pressure. External actors simply had no formal way to intervene. For example, while there were some consultative processes, such as those associated with the siting of reactors (e.g., the Ornano Plan), they tended to be mere formalities and offered no opportunity to affect the rollout of the policy or block it (Campbell, 1988, Ch 8; Fagnani and Moatti, 1984, 265; Jasper, 1990, 165; Lucas, 1979, Ch 7). Furthermore, nuclear licensing decisions had the status of government decrees and were practically immune from legal challenge (Campbell, 1988, Ch 8). And unlike in other countries where referenda could be called by parliament or citizens, only presidents can call them under the French constitution, which prevented a national vote on nuclear power.

Second, a strong executive vis-à-vis parliament meant that the President and the autonomous bureaucracy it controlled could adopt the Messmer Plan as part of its routine economic planning process rather than through parliamentary wrangling. Indeed, there was neither a debate nor vote on the Messmer Plan in the National Assembly (Fagnani and Moatti, 1984, 265; Papon, 1979, 94). Such a centralized institutional setting protected the Plan from a wide variety of oppositional forces. It prevented opposition parties, as well as government parliamentarians, from obstructing it in the legislature. Furthermore, it prevented business, trade unions, outside experts and the anti-nuclear movement from obstructing the Plan via parliamentary channels, for example by lobbying opposition lawmakers to oppose it. The case was much different in places like the US or UK, where legislatures and bureaucracies were less insulated and opponents were able to lobby politicians, legislative committees and civil servants on nuclear policy (Campbell, 1988, Ch 5; Helm, 2004, Ch 5).

Third, the state's ownership stake in the most important nuclear energy-related firms made it difficult for business to mount an effective opposition. Even though EDF operated as a private sector firm, because the state wholly owned it, it could be compelled to act in a way that was consistent with the goals of the Messmer Plan. The same was true for the reactor manufacturer Framatome and fuel company COGEMA. In contrast, private firms dominated the nuclear sector in most other industrialized democracies. Additionally, opposition from fossil fuel interests was stymied by their lack of power in the planning process, especially compared to EDF (Lucas, 1979, Ch. 5).

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<sup>27</sup> *Dirigisme* is a type of policymaking whereby governments play a strong directive role in the economy in pursuit of national goals (Hall, 1986, Ch 6; Hall, Hayward, and Machin, 1994, Ch 9; Schmidt, 1996, Ch 2). See Appendix A.6 for a detailed discussion of it in France.

Fourth, the state’s capacity to influence the allocation of capital enabled it to channel finance to the nuclear industry (Jasper, 1990, 174-75; Lucas, 1985, 37). As described in Section 3 above, this constituted the primary industrial policy instrument associated with the Messmer Plan and happened in two ways. Capital was directly lent to EDF to build nuclear plants via the nationalized banking sector and the Ministry of Finance. Additionally, the state used loan guarantees to underwrite the debt that EDF took on in foreign credit markets, especially the US. The result was that the state could channel large amounts of capital to the sector and insulate key firms from the pressures of investors and capital markets. This was not the case in places like Germany, Sweden and the US where governments had fewer tools to directly allocate capital (Campbell, 1988, Ch 8). Moreover, given its ownership structure, EDF was not as tightly constrained by financial considerations. It had little need to return short-term profits, which meant it could stick to its long-term plan of nuclear expansion, even in the face of rising near-term costs (Fagnani and Moatti, 1984, 266). The situation was very different in the US, for example, where the sector was crippled as private companies, unsupported by government, were unable to bear the rapidly increasing short-term costs of nuclear expansion in the late 1970s (Campbell, 1988, Ch 6; Fagnani and Moatti, 1984, 266; Thomas, 1988, Ch 4 and 5).

The insulated policy process in France contrasts markedly with other industrialized democracies, where institutions enabled outside groups to influence, and in many cases block, nuclear expansion. In places like Sweden and Italy, antinuclear referenda were initiated by opposition parties and civil society, and in both cases succeeded (Brouard and Guinaudeau, 2015; Jasper, 1990). In Germany, antinuclear advocates leveraged the courts and lobbied opposition political parties to slow down nuclear expansion (Campbell, 1988, Ch 8). Federalism and separation of powers meant that nuclear policymaking in the US was especially decentralized and fragmented, and therefore porous to outside influence, particularly in the implementation phase. Federal policymaking was stymied by civil society and state and local governments, who used legal challenges, laws and referenda to block nuclear expansion (Campbell, 1988, Ch 5). Because of the inability of many governments to overcome opposition to nuclear power, by the early 1980s nuclear expansion had slowed considerably in many countries and altogether collapsed in the US (Campbell, 1988; Jasper, 1990).

### **6.1.3 Policy stability**

Simply because a policy is adopted and implemented does not mean that it will stay in place over the long term. This is especially true in the context of deeply fractious issues such as nuclear energy. A critical ingredient for achieving the deep emissions reductions that we estimate above was that France’s nuclear policy was not reversed. It

survived decades of changing governments, shifting political winds, and oscillating public approval. Without this policy stability, it is unlikely that it would have resulted in such large reductions. Indeed, as described above, the stability of French nuclear policy makes it an outlier compared to many of its peers, where nuclear energy faltered significantly in the 1980s as a result of political opposition, court challenges, referenda and policy reversal.

In France, the Plan was sustained because the state's powerful autonomous bureaucracy continued to support it and no political coalition emerged that was strong enough to overturn it. As described above, the opposition Socialist Party was hostile to the policy early on, and their reticence continued throughout the 1970s. In the lead up to the 1981 election, the party ran on a platform of nuclear policy reform, including a moratorium on nuclear orders pending a national debate and referendum, and the expansion of coal and renewables (Thomas, 1988, 213). However, after winning power, the new Socialist President François Mitterand did not dramatically change course or call a referendum. The most significant of his reforms was to reduce new reactor orders from an average of five per year after 1973 to three in 1982 and two in 1983, 1984, and 1985 (Fagnani and Moatti, 1984; Thomas, 1988, 213-15). Though, this was likely due as much to sharply reduced electricity demand forecasts as to partisanship. Additionally, planning procedures were amended to allow greater local participation in site selection.

By the mid-1980s, French political parties had depoliticized nuclear power and a cross-party consensus had emerged in support of it (Brouard and Guinaudeau, 2015; Fagnani and Moatti, 1984; Nelkin and Pollak, 1980). This is unsurprising given that, as we describe above, most nuclear plants were under construction or completed by this time, meaning that any phaseout would be costly and leave many stranded assets. Furthermore, the rapid growth of the sector meant that nuclear industrial interests, including companies and labor unions up and down the supply chain, had become consolidated as a powerful political force that resisted major changes to policy (Thomas, 1988, Ch 8; Jasper, 1990, Ch 13).

Beyond political parties, there is little evidence that significant calls for reversal emerged either within the state bureaucracy or from other parts of the business community. Moreover, the antinuclear movement within civil society had all but disappeared by the early 1980s (Jasper, 1990, 237) and public opinion turned more positive (Brouard and Guinaudeau, 2015). Though, even if these events had not transpired, a reversal of nuclear policy would be unlikely given the prevailing cross-party consensus and the lack of possibilities for a national referendum.

## 7 What can we learn from the Messmer Plan?

The Messmer Plan offers a historical case study of rapid nuclear energy expansion leading to large and cost-effective emissions reductions. However, the context in which nuclear power operates today is different. To assess the relevance of our findings for contemporary green industrial policy debates across today’s OECD countries<sup>28</sup> (i.e., the external validity of our analysis), we evaluate the extent to which key conditions that enabled the success of the Messmer Plan are still valid today, including: (1) nuclear power being a viable carbon-free technology that can be deployed at scale; (2) relatively short reactor construction times; (3) nuclear being cost-competitive, especially with the help of policy that reduces capital costs; (4) a carbon-intensive electricity grid; and (5) the government being able to overcome political opposition.

Overall, we find that nuclear is still a viable carbon-free electricity option, however governments today have more choice than in the 1970s. Most notably, wind and solar are mature carbon-free technologies with often much shorter build times compared to nuclear, especially in Europe. Moreover, the costs of wind and solar tend to be lower. Just as in the 1970s, governments today can rely on the same types of policy tools (state finance, loans and loan guarantees) to lower the cost of capital for carbon-free energy projects. Similarly, many electricity grids across the OECD today are equally, and in some cases more, carbon-intensive than France’s in the 1970s, suggesting that large-scale emissions reductions from green industrial policy are still possible. Regarding political economy, overcoming opposition to reform is still as critical an ingredient today as it was in the 1970s. Furthermore, governments today can still rely on the same political pathway for doing so – insulation – as French policymakers did. In sum, while the exact technological choice may be different today, given the longer menu of carbon-free options and the costs, construction times and political economy associated with each, the core insight of our study remains relevant: ambitious, state-driven green industrial policy can be a politically-feasible strategy to achieve rapid and substantial reductions in carbon emissions on a scale necessary to meet global climate targets.

At the time of the first oil price shock in 1973, nuclear and hydropower represented the only large-scale technologies for electricity generation apart from fossil fuels (and because hydro is dependent on natural factors, it was not available to all countries). Today, nuclear power is still a viable, large-scale and carbon-free energy technology.<sup>29</sup>

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<sup>28</sup>We focus on today’s OECD countries because they are high-income democracies most comparable to France. A discussion of energy policy in China and the Global South is important, as the conditions there are different in many ways, especially related to build times, costs, and policymaking processes. However, those regions are not our focus here.

<sup>29</sup>We recognize that nuclear’s role in climate mitigation policy is divisive, with critics arguing that it is too slow and costly to build, and thus not as effective as renewables in reducing emissions (Schneider and Froggatt, 2021; Haywood, Leroutier, and Pietzcker, 2023). We do not seek to weigh in on this important debate here, but rather present the full range of existing carbon-free technologies.

Currently, around 11 large-scale conventional reactors are under construction in OECD countries, 17 are planned and around 79 have been proposed (WNA, 2025). Furthermore, the scale of some new nuclear programs is on par with the Messmer Plan. For example, the Swedish government recently announced a program for 10 new reactors, which, adjusted for population size, matches the scale of the French experience (Government Offices of Sweden, 2023). More broadly, nuclear plays an important role in limiting warming to below 2°C in the majority of global emissions scenarios (IAEA, 2023b). That said, it is not the only carbon-free electricity source available to governments today. Unlike in the 1970s, renewable technologies like wind and solar are mature, offering governments today a longer menu of carbon-free options.

In terms of construction times and costs, there are important differences between the French experience and today. The Messmer Plan’s reactors had a notably, and historically, short average construction time of around six years. More recent examples of reactor construction across OECD countries present a varied picture. Since 2000, 24 reactors have come into commercial operation (IAEA, 2025).<sup>30</sup> Average build times for these were around five years in Japan, nine in South Korea and 10 in the US.<sup>31</sup> Build times have been longer in Europe, with Czechia’s two reactors taking around 15 years on average, France’s Flamanville 3 taking 17 years and Finland’s Olkiluoto 3 taking 18 years. In contrast, commissioning times for renewables have been much shorter. In the OECD, according to one study, they are around two years for solar PV, three years for onshore wind and five years for offshore wind, on average (Gumber, Zana, and Bjarne, 2024).

Long construction times increase environmental and economic costs. Environmentally, they delay emissions reductions and increase the stock of GHGs in the atmosphere. Economically, they increase the levelized cost of electricity for a given energy source. France achieved significant emission reductions with a negative abatement cost thanks to nuclear power’s once lower LCOE compared to fossil fuels. However, this dynamic has since shifted. Construction costs for nuclear rose in France during the implementation of the Messmer Plan, pushing up nuclear’s LCOE over time (Bocard, 2014; Grubler, 2010; Cour des Comptes, 2012). Simultaneously, the cost of wind and solar has decreased. In France in 2020, utility-scale solar PV and onshore wind had a lower LCOE compared to new nuclear,<sup>32</sup> while commercial solar PV, residential solar PV and offshore wind were more expensive (IEA, 2020a).

According to LCOE estimates from the IEA, the basic cost pattern observed in France

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<sup>30</sup>Two in Czechia connected to the grid in 2000 and 2002; one in Finland in 2022; one in France in 2024; five in Japan between 2001-2009; 12 in South Korea between 2001-2023; and three in the US connected in 2016, 2023, and 2024.

<sup>31</sup>US build time excludes the Watts Bar-2 reactor, which began construction in 1973 and suffered unprecedented delays. It did not come into commercial operation until 2016.

<sup>32</sup>Extending the operational life of existing nuclear reactors (i.e., nuclear LTO) had a lower LCOE than new nuclear.

applies more generally for OECD countries (IEA, 2020b).<sup>33</sup> In Europe in 2020, onshore wind and utility-scale solar PV were cheaper than nuclear, and offshore wind was more expensive.<sup>34</sup> In the US, utility-scale solar PV and onshore and offshore wind were cheaper than nuclear – a pattern found more recently by Bilicic and Scroggins (2025) as well. Japan is different. There nuclear had a lower LCOE than utility-scale solar PV and onshore and offshore wind. Given their favorable costs in most contexts today, it is no surprise that solar PV and onshore wind account for the vast majority of newly-installed electricity capacity in the OECD and worldwide (OECD, 2023; IEA, 2025b).

Carbon-free electricity sources are capital intensive, and therefore their LCOEs depend heavily on the cost of capital. This was true for nuclear in the 1970s and is still true for nuclear and renewables today (IEA, 2020b; Worland, 2023). Crucially, the Messmer Plan used state finance, loans and loan guarantees to reduce capital costs for nuclear expansion. By the mid-1980s France enjoyed the lowest LCOE for nuclear among the OECD (IEA, 2015). Today, policy instruments for reducing capital costs are just as relevant for green industrial policy. For example, the Swedish government intends to rely on loans and loan guarantees to support its large-scale nuclear expansion (Government Offices of Sweden, 2023).

France’s electricity grid was very carbon-intensive before the adoption of the Messmer Plan, with fossil fuels accounting for 50-60 percent of electricity production (Figure 1 above). This meant that it could achieve large emissions reductions by transitioning to nuclear. While today several OECD countries have relatively clean grids (e.g., Sweden and the UK), many still have grids that are similarly, or even more, carbon-intensive than France’s in the 1970s, such as Australia, Japan, Poland and the US. This suggests that emissions reductions of similar magnitude to the Messmer Plan remain possible today.

The last condition is politics. The Messmer Plan generated significant political opposition. To overcome it, successive French governments were able to insulate the policy-making process through use of the state’s autonomous and technocratic bureaucracy and centralized decisionmaking. Without this, the Plan would likely not have been adopted and implemented at scale, and therefore would not have achieved large emissions reductions. Today, opposition to transformative green industrial policy is just as apparent as it was in the 1970s. Just consider the US Inflation Reduction Act, which the newly-elected Trump administration is actively seeking to unravel. Furthermore, insulation remains just as much of a viable political pathway to overcoming opposition. Similar to France, jurisdictions today, such as California, rely on autonomous bureaucracies to shield poli-

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<sup>33</sup>Looking beyond the OECD, we see a similar pattern in China and India (IEA, 2020b). In China in 2020, onshore wind and utility-scale solar were less expensive than nuclear, while offshore was more expensive. In India, onshore wind and utility-scale solar were also less expensive than nuclear (there is no estimate for offshore wind as India does not have any offshore wind projects).

<sup>34</sup>Costs for nuclear in the IEA data should be interpreted with some caution as they are based on a very limited set of projects (one in Europe, one in the US and one in Japan) (IEA, 2020b).



cymaking from opponents (Meckling et al., 2022). In other contexts, electoral rules and low electoral competition have provided the basis for insulation and enabled governments to increase climate policy stringency (Finnegan, 2022a,b; Finnegan et al., 2025). What is more, in contexts where insulation has not been feasible, governments have alternatively used compensation as a political pathway to overcome resistance from opponents (Finnegan, 2022b; Finnegan et al., 2025). For example, Germany’s coal phaseout relies on large payments to coal-related businesses, workers and regions as a way to secure their support.

Today, just as in the 1970s, we expect that ambitious, state-driven industrial policy can achieve rapid and significant emissions reductions. While different technological choices will be made in different contexts, a modern equivalent of the Messmer Plan would likely invest in a variety of carbon-free electricity technologies, rather than just one, and prioritize wind and solar given its relatively lower costs and shorter build times. What is more, similar to the Messmer Plan, governments today would likely need to rely on policy instruments that reduce capital costs. Additionally, they should seek to leverage complementarities between green industrial policy and carbon pricing to further drive down emissions (Andersson and Finnegan, 2025).<sup>35</sup> Finally, just as in the French case, crucial to the success of any green industrial policy today will be policymakers ability to overcome political opposition.

## 8 Conclusion

Governments around the world are turning to green industrial policy and increased electrification to decarbonize their economies and drive economic competitiveness. We assess the ability of these policies to reduce emissions by analyzing the case of France. In response to the 1973 oil price shock, France launched the Messmer Plan, an ambitious industrial policy to both enhance energy security by replacing fossil fuels with nuclear in electricity production and grow an internationally competitive French nuclear industry. Using state financing, loan guarantees, contracts with suppliers and streamlined planning procedures, the government incentivized and supported the rapid roll out of nuclear energy. Politically, the Plan faced intense opposition. To overcome it, the government relied on the dirigiste policymaking style of the French state to insulate decision making and implement nuclear expansion over the objections of the antinuclear movement, the fossil fuel industry, academic experts, trade unions and opposition political parties. The

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<sup>35</sup>Rapid decarbonization requires lowering the cost of capital for zero-carbon energy, especially in a high interest rate environment. In contrast, fossil fuel generation predominantly relies on variable fuel costs, which carbon pricing will raise. An effective climate policy would thus be to reduce the relative price of zero-carbon energy sources through a dual approach of green industrial policy and carbon pricing. This approach could be revenue-neutral if the proceeds from the carbon price are used to fund green industrial policy. For a full discussion see Andersson and Finnegan (2025).

French experience contrasts markedly with that of other industrialized democracies, such as the US, the UK, and Germany, where political forces prevented a radical transition toward nuclear.

As a result of the Messmer Plan, we find that carbon dioxide emissions from electricity and heat production fell by more than 60 percent in the years that followed. For the economy as a whole, there was a more than 20 percent reduction in total CO<sub>2</sub> emissions in an average year, due, in large part, to increased electrification. It took around six years from the announcement of the policy until emission reductions commenced and the average abatement cost was -\$20 per metric ton of CO<sub>2</sub>. These findings show that ambitious industrial policy can be an environmentally and economically efficient, as well as politically feasible, tool for mitigating carbon emissions in the energy sector. Indeed, our results provide strong evidence that active state intervention in the form of industrial policy can quickly and dramatically decrease emissions. We are not aware of any other single policy that has been shown to decrease emissions on the same scale, and as rapidly, as the Messmer Plan in France.

While our study is ambitious in scope, there is opportunity for more research on the local effects of green industrial policy. Our analysis primarily addresses the global environmental impact of the Messmer Plan, focusing on the reduction of carbon dioxide emissions. However, the Plan likely also resulted in decreased local air pollutants, particularly in areas where fossil fuel plants were decommissioned due to the rise in nuclear energy production. This reduction in local pollutants could have significant benefits for nearby populations, as decreases in air pollution are linked to improved outcomes in areas like infant mortality and academic performance (Chay and Greenstone, 2003; Ebenstein, Lavy, and Roth, 2016). Moreover, our analysis has focused on the 'green' aspects of green industrial policy, without assessing local economic impacts, such as changes in employment and economic growth in the areas affected by the Messmer Plan. A comprehensive estimation of local costs and benefits of the Plan, considering local air pollution, employment and economic growth, represents a promising area for further study.

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## A Appendix – For Online Publication

### A.1 Data Sources

- Carbon dioxide (CO<sub>2</sub>) emissions. Measured in metric tons per capita. Source: IEA (2022b). Available at: <https://doi.org/10.5257/iea/co2/2022>.
- GDP per capita (PPP, 2005 USD). Expenditure-side real GDP at chained PPPs, divided by population. Source: Feenstra, Inklaar, and Timmer (2013), "The Next Generation of the Penn World Table". Available at: [www.ggdc.net/pwt](http://www.ggdc.net/pwt).
- Urban Population. Measured in percentage of total. Source: The World Bank (2015) WDI Database. Available at: [data.worldbank.org/indicator](http://data.worldbank.org/indicator).
- Electricity production. Measured in kWh per capita. Source: IEA (2022a). Available at: <https://doi.org/10.5257/iea/elec/2022>.
- Domestic oil and coal production. Measured in kilogram of oil equivalent per capita. Sources: International Energy Agency: Oil Information (2022 Edition) <https://doi.org/10.5257/iea/oil/2022>; International Energy Agency: Coal Information (2022 Edition) <https://doi.org/10.5257/iea/coal/2022>.
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- Household electricity prices. Source: International Energy Agency: World Energy Prices (2020 Edition). Available at: <https://doi.org/10.5257/iea/wep/2020>.
- Energy consumption from electricity and combustible fuels. Measured in oil equivalents. Source: World Energy Balances (IEA 2022c). Available at: <https://dx.doi.org/10.5257/iea/web/2022>.
- Emission Factors. Source: IEA (2024). Available at: <https://www.iea.org/data-and-statistics/data-product/emissions-factors-2024>.
- Energy Prices. End-use energy prices. Source: ?. Available at: <https://www.iea.org/data-and-statistics/data-product/energy-prices>

## A.2 The Scale of the Messmer Plan

Measuring the magnitude of an industrial policy can be challenging (Juhász, Lane, and Rodrik, 2023). Especially compared to quantifying policy instruments like carbon taxes, which can be expressed in tangible terms such as cents per litre of gasoline or the percentage increase in coal prices. Accurately assessing the scope of an industrial policy is nonetheless important. It allows us to grasp the policy’s scale and expected impact in easily comprehensible units.

To quantify the scale of the Messmer Plan, we computed the difference in the number of nuclear reactors either under construction or in operation in France and its counterfactual, before and after the plan’s announcement. This calculation was adjusted to account for variations in population sizes across countries in 1974.

By the time the Messmer Plan was announced in 1974, France already had nuclear power plants in commercial operation or under construction. Of the five countries in the donor pool that receive a positive weight, Portugal never deploys nuclear power plants during our sample period. Austria, Belgium, Switzerland, and Germany, on the other hand, all have nuclear power plants in operation – or where construction had started – both before and after the Messmer Plan was enacted.<sup>36</sup>

Prior to 1974, both France and synthetic France had a similar number of reactors under construction or in operation, with about 3 reactors per ten million people. However, following the announcement of the Messmer Plan, France began construction on an additional 9.5 reactors per ten million people, whereas synthetic France only added 1.5 reactors.<sup>37</sup> Thus, according to this measure, the Messmer Plan resulted in a more than six-fold increase in the number of nuclear reactors constructed after 1974, compared to the counterfactual scenario.

The six-fold increase in reactor construction suggests that, absent the plan, France would have built only about 8 reactors in the decade after 1974 – rather than the 51 it actually constructed. While France was already on a nuclear expansion path (as reflected in the synthetic control, which also shows post-1974 additions), the Messmer Plan delivered a substantial acceleration.

The increase in nuclear reactors due to the Messmer Plan is further reflected in the net electricity capacity from nuclear energy. While France and synthetic France had similar nuclear capacity in the transitional period, an average of 0.85 gigawatt-electric (GWe) per ten million people between 1974-1979 in France and 0.89 GWe in synthetic France, this grew to just over 10 GWe in France by 2005 but only 2.9 GWe in synthetic France.

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<sup>36</sup>Austria built and finished the Zwentendorf nuclear power plant between 1972-1978, but the plant was never put into commercial operation following a referendum on nuclear energy in November of 1978.

<sup>37</sup>For synthetic France, there were four reactors in Belgium and 13 in Germany that began construction after 1974. Note, however, that the reactors in Belgium were ordered before 1974 (IAEA, 2020), as were most of the reactors in Germany (Campbell, 1988).

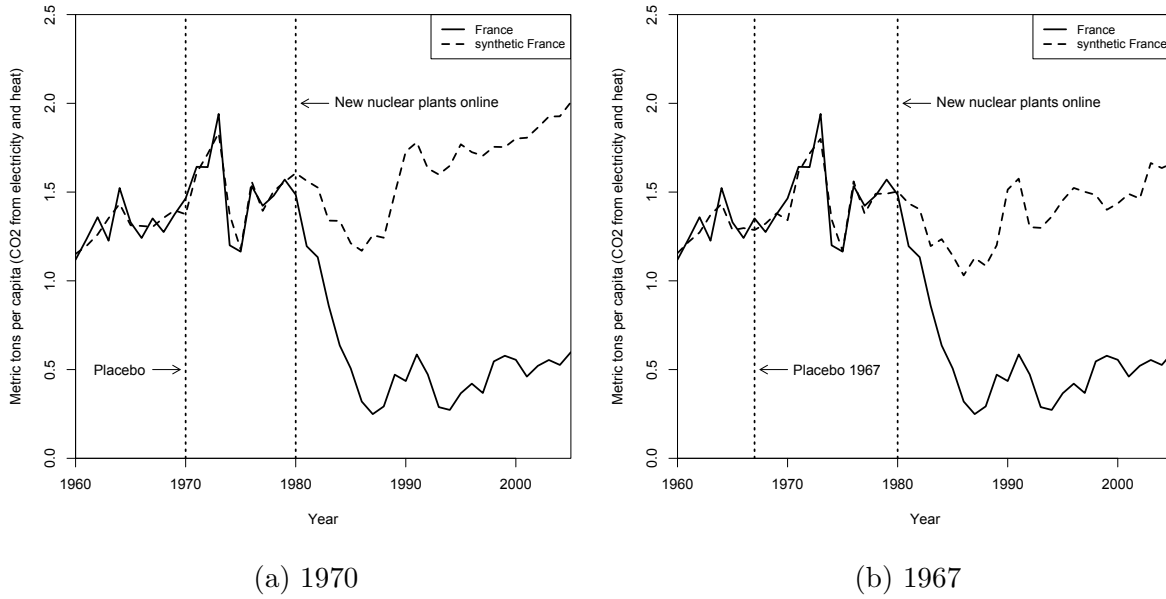


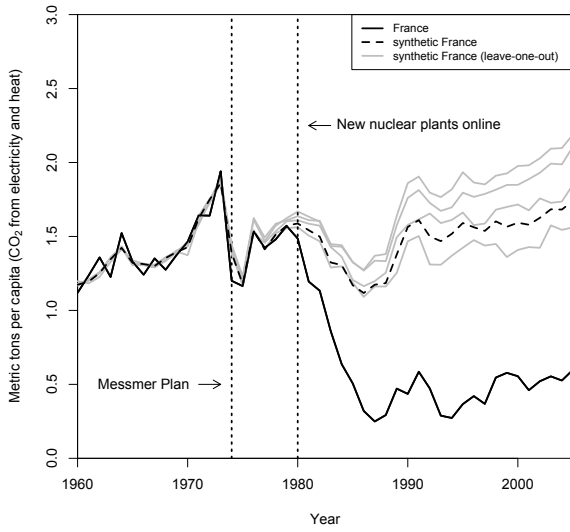
Figure 14: Placebo In-Time Tests: 1970 and 1967

### A.3 Robustness Tests

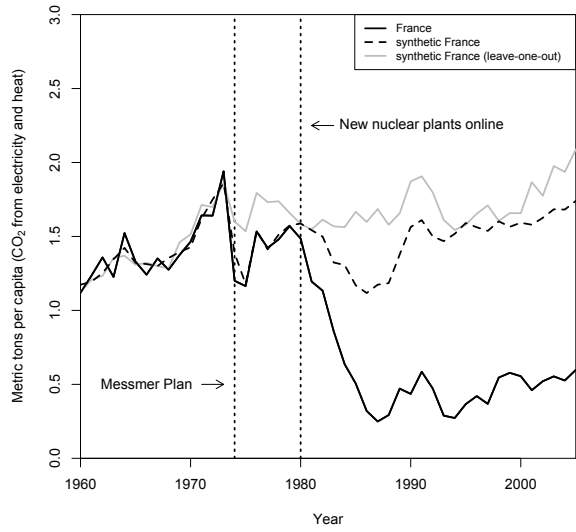
To test the robustness of the main results, we perform a range of tests: in-time placebo, leave-one-out, specification searching, and placebo sector.

With the "in-time" placebo test, we adjust the treatment year to 1970 and 1967, periods before the Messmer Plan's implementation, constructing counterfactuals with data only from years before these dates. Our objective is to verify the absence of a divergence in the emissions trajectories between France and synthetic France before 1980 – prior to the operationalization of the first new nuclear reactors. An observed placebo effect would raise questions about our claimed causal effect from the Messmer Plan. Figure 14 shows that no placebo effect is found as the two series remain aligned until 1980. This is consistent with the results from the main specification and the existence of the transitional period between 1974-1979 in this study reduces the need for the in-time placebo test.

In the leave-one-out test, we aim to investigate whether the posttreatment results primarily depend on one or more control countries, and whether the accuracy of the pretreatment fit relies on the inclusion of a specific control country. Furthermore, we use this test to estimate a range for our causal effects. To do so, we iteratively eliminate one of the five countries that received a weight larger than one percent. The results, presented in Figure 15, indicate emission reductions ranging from 59.8 percent (when Portugal is excluded) to 67.1 percent (when Germany is excluded). All but one of these alternative estimates is above our point estimate of 62 percent, suggesting our main estimate is conservative and sits at the lower end of the range observed in our robustness checks.



(a) Excluding AT, DE, PT, and CH



(b) Excluding Belgium

Figure 15: Leave-One-Out Tests

*Notes:* In panel (a) we have iteratively excluded Austria, Germany, Portugal, and Switzerland from the donor pool. In panel (b) we have excluded Belgium.

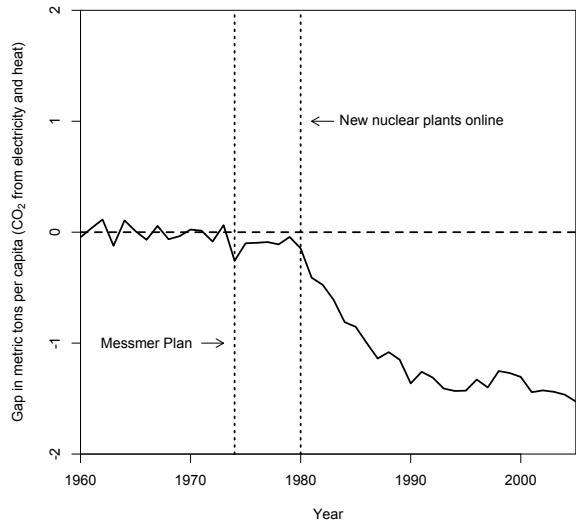
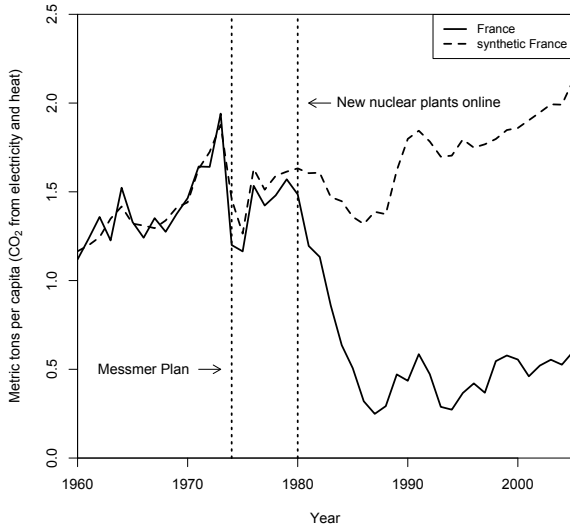


Figure 16: Benchmark Specification

It is important to note that the inclusion of Belgium seems necessary to capture the effects on emissions from the two oil crises. In panel (b) of Figure 15, where Belgium is excluded, we obtain a poorer fit in the transitional period compared to the main specification, and we also don't obtain the "slump" in emissions in synthetic France in the 1980s. Similar to France, Belgium used oil as the primary energy source for electricity



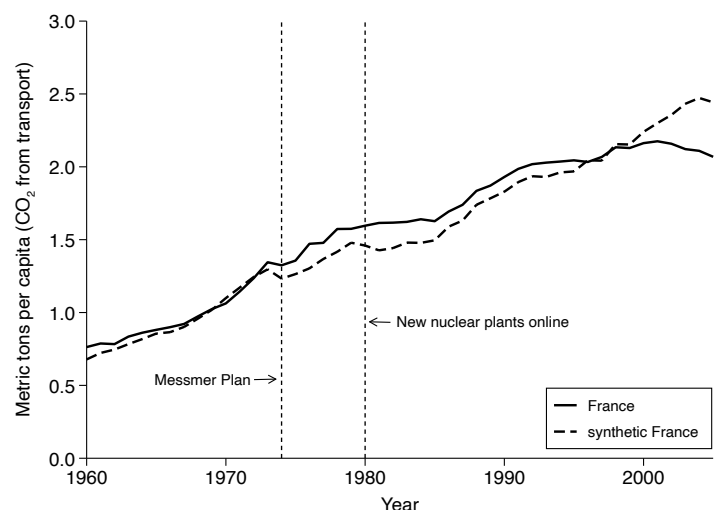


Figure 17: Placebo Sector: Transport

production in the early 1970s and was still heavily dependent on oil at the time of the second oil crisis. Furthermore, Belgium also had existing nuclear power plants at the time of the first oil crisis.<sup>38</sup> Taken together, Belgium is likely the country most similar to France when it comes to the fuel mix in the pretreatment period – and thus an important inclusion in the donor pool to be able to create a credible “twin” – which may explain why it is given the largest weight in synthetic France, of around one third.

A potential concern with the synthetic control method is that the choice of key predictors of the outcome variable and the chosen lags of the outcome variable has a large impact on the estimated results and thus creates opportunities for specification searching. Following the recommendation of Ferman, Pinto, and Possebom (2020) we therefore constructed a counterfactual using all (and only) the pretreatment lags of the outcome variable. This benchmark specification produces similar results as our main specification. The largest weight in synthetic France is still given to Belgium and Austria, and Germany and Portugal still receive meaningful weights. In the path and gap plots in Figure 16, we see a good fit in the pre-treatment period, and, compared to the main specification, slightly poorer fit in the interim period and larger relative emission reductions from 1980 and onwards.

For the last robustness check, we do a placebo sector test: comparing the trajectories of emissions in a sector that arguably should not be affected by the Messmer Plan. For this purpose we picked the transport sector, where the level of emissions is similar in size to emissions from electricity and heat production, and where, during the sample period, oil was always the main source of energy – electric vehicles is not a meaningful portion

<sup>38</sup>Belgium has two nuclear power plants, Doel and Tihange, that began construction in 1969 and 1970, respectively, and with seven reactors in commercial operation – four in Doel and three in Tihange. The decision to build the first three reactors, Doel 1 and 2, and Tihange 1, was taken in 1966 and the decision to expand with four more reactors, Dole 3 and 4, and Tihange 2 and 3, was taken in 1973 (IAEA, 2020).

of the vehicle fleet at this time.

Figure 17 shows that transport emissions in France and synthetic France closely match in the years before the Messmer Plan was implemented. Then, from 1974 until the mid-1990s, emissions were relatively higher in France, around 7.5 percent on average, before decreasing in the final years of our observation period. The significant relative reduction in emissions within the electricity, heat, industry, residential, and services sectors from 1980 and onwards was not mirrored in the transport sector.

## A.4 Consumption-Based Perspective

In this section, we estimate the Messmer Plan’s impact on emissions from a consumption perspective, adjusting for electricity imports and exports. Two methods are employed:

*Simple Trade-Adjustment.*— In this method, we adjust electricity production by adding imports and subtracting exports, providing an estimate of actual domestic electricity consumption. We then multiply this consumption figure by the national emission factors – for France and synthetic France respectively – to estimate consumption-based emissions.

This approach is intuitive and transparent. It directly reflects how much electricity is used domestically and applies country-specific average emissions intensities. Our simpler measure is available for all years in our sample period (1960–2005) for France and synthetic France.

*Trade-Adjusted (Refined).*— This method uses trade-corrected emissions factors from the IEA. They are computed using detailed bilateral trade data for electricity (imports and exports) and country-specific emission factors for each trading partner (IEA, 2024, Ch 4). The goal is to calculate a more precise consumption-side emission factor for each country, reflecting the actual carbon intensity of traded electricity flows. This refined measure is available from 1990–2005 for synthetic France and 1960–2005 for France.

The consumption-based methods, shown in Figure 18 as “simple trade-adjustment” and “trade-adjusted”, consistently point to larger emission reductions than our main production-based estimate. The simpler approach yields average reductions of 65.4% (1980–2005) and 74.9% for the later part of the posttreatment period (1990–2005) – when almost all the Messmer Plan reactors were in commercial operation. The more detailed method using IEA correction factors produces a slightly higher estimate for the later part: 76.6% (1990–2005). However, the overall difference across approaches is modest. For the period 1990–2005, the range of estimated reductions lies between 70.5% (production-based) and 76.6% (trade-adjusted).

While the refined (IEA-corrected) method is more data-intensive and methodologically sophisticated, it may not necessarily be more accurate. There are several reasons to treat the simpler method as at least equally valid. First, much of the trade for synthetic

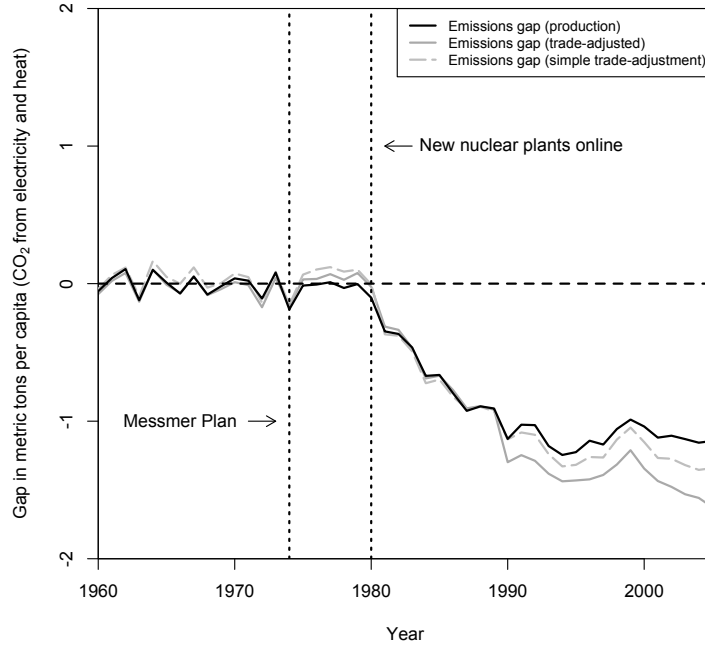


Figure 18: Consumption-based vs. Production-based emissions estimates

France occurs between its constituent countries (e.g., in-between Germany, Switzerland, Austria), resembling regional balancing within synthetic France more than traditional international trade. This is reflected in synthetic France’s trade balance being close to zero – imports and exports largely offset each other.

Second, countries like Austria and Switzerland serve as transit hubs for electricity (e.g., French exports to Italy via Switzerland), meaning electricity attributed as “imported” to these countries may not actually be consumed there. This can distort emissions accounting in the IEA-based method.

As such, the refined method may introduce bias to the emissions estimate from electricity consumption due to transit effects (“wheeling”) and the within-synthetic France trade.

## A.5 Decomposition of Fuel-Switching Effect

In this section, we further decompose energy use in the residential, services, and manufacturing sectors to examine the fuel-switching effect attributed to the Messmer Plan, focusing on the individual fuels: electricity, oil, natural gas, and coal. Overall, following the roll-out of new nuclear reactors in 1980, there is a substitution away from oil and towards electricity and natural gas.

Figure 19 show the shares of electricity and fossil fuel consumption in the combined residential and services sectors in France and synthetic France. Two main conclusions

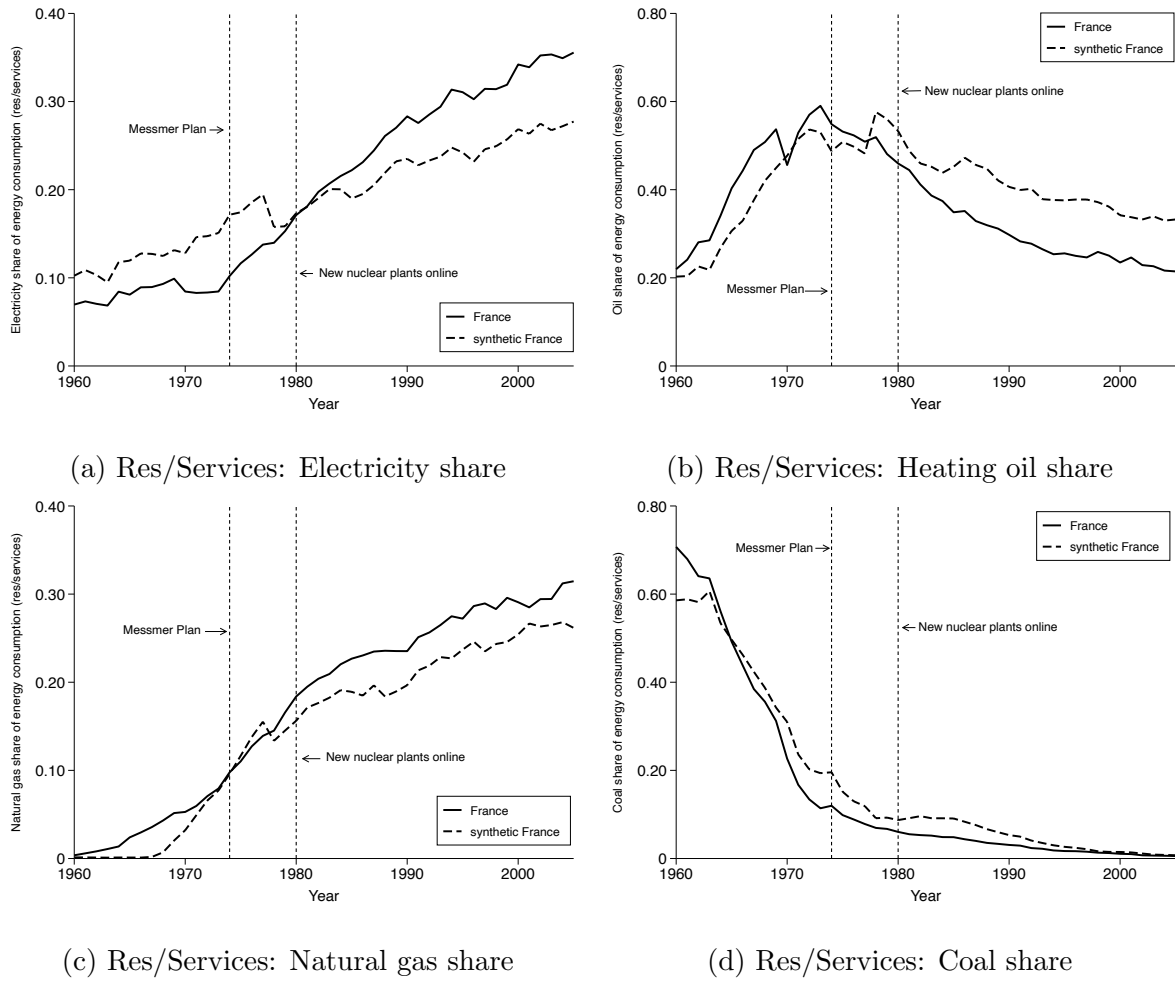


Figure 19: Decomposition of Energy Consumption in Residential and Services Sectors

Note: The figure shows the share of energy consumption coming from electricity and combustible fuels. To make aggregation and comparisons possible, all energy sources were first converted into oil equivalents. Source: International Energy Agency (2022) – World Energy Balances.

emerge. First, France exhibits a shift away from heating oil and toward electricity, relative to its synthetic counterfactual. This timing aligns with the rollout of new nuclear reactors and a relative decline in electricity prices in France. This increase in electricity use is likely driven by electric heating, rather than greater appliance use, since appliance adoption should be the same in synthetic France (driven, for instance, by economic growth). Second, coal trends downward in both France and its synthetic counterfactual during the entire sample period, whereas there is an increase in natural gas in France compared to its counterfactual in the posttreatment period.

Taken together, the evidence points to a relatively stronger fuel-switching pattern in France, specifically from heating oil to electricity and natural gas.

We interpret this as a causal outcome of the Messmer Plan. The rollout of nuclear reactors drove down electricity prices, creating stronger incentives to substitute away from heating oil. Fossil fuel prices – especially for oil – should have evolved similar

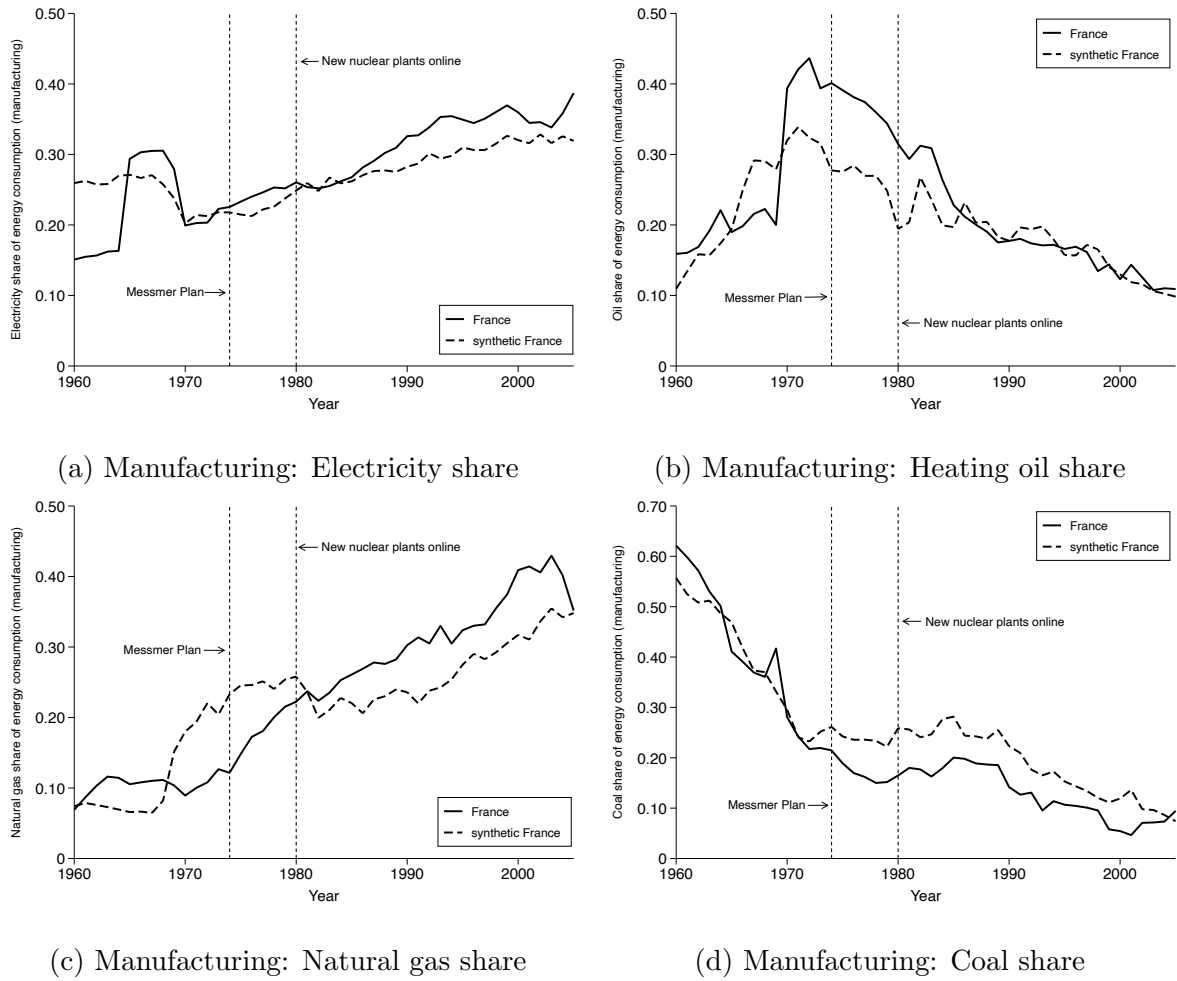


Figure 20: Decomposition of Energy Consumption in the Manufacturing Sector

Note: The figure shows the share of energy consumption coming from electricity and combustible fuels. To make aggregation and comparisons possible, all energy sources were first converted into oil equivalents. Source: International Energy Agency (2022) – World Energy Balances.

across France and its counterfactual, so the observed differential likely reflects the relative price advantage for electricity in France. While reduced heating oil usage may have occurred along both intensive and extensive margins (e.g., reduced indoor temperature vs. switching fuels), the synthetic control should capture changes on the intensive margin.

Within the industrial sector, manufacturing is by far the largest energy consumer – with over 90 percent of the total energy consumed in the three sectors of mining, construction, and manufacturing. Figure 20 decomposes energy usage in the manufacturing sector. In panel (a), we see a relative shift to electricity consumption in France, compared to the counterfactual, from 1980 and onwards.<sup>39</sup> Focusing on the period of 1970–2005, there is a shift also within the group of fossil fuels. Coal usage continues to trend downward in both France and its synthetic counterfactual, whereas there is a relative substitution away from oil to natural gas in France compared to its counterfactual.

<sup>39</sup>Note that the data at this disaggregated level is more variable for the 1960s, with a break in 1965 for France “when more detailed data on electricity consumption became available” (IEA, 2021, p.62).

## **A.6 The Conditions for Reform**

Here we describe in detail the conditions that set the scene for the Messmer Plan in France.

### **A.6.1 Exogenous shock**

Scholars of political economy have long pointed out how exogenous shocks and crises can facilitate far-reaching reforms (e.g., Baumgartner and Jones, 1993; Collier, Collier et al., 1991; Gourevitch, 1986; Ikenberry, 1988). During these ‘critical junctures’ the limitations of existing policy arrangements are laid bare, and actors search for new ideas, instruments, and institutions that can respond to the challenge of the times. Politics and policymaking are rendered more fluid and ideas previously considered radical become practical. The 1973 oil price shock constituted such a critical juncture and presented governments with a clear and present crisis that needed a response. Indeed, in its aftermath all industrialized democracies sought to reform their energy sectors to reduce dependence on imported oil (Finnegan et al., 2025).

### **A.6.2 Technological capacity**

In many ways, the infrastructure for a large-scale nuclear program was in place in France when the oil shock hit (Grubler, 2010; Jasper, 1990, Ch 5; Lucas, 1979; Naudet, 1993; Thomas, 1988, Ch 8). On the eve of the price shock, the country had eight reactors in commercial operation and five under construction. It had developed significant expertise in nuclear engineering through long-standing investments in research and development to the public nuclear research body Commissariat à l’Énergie Atomique (CEA). The firms Framatome and COGEMA, as well as a broader national supply chain of electro-mechanical producers, had expertise and experience related to reactor design, manufacturing, fuel production and commission and maintenance services. Finally, EDF, the national utility, could construct and operate nuclear power stations.

Technologically, EDF and CEA had resolved their conflicts over reactor choice, settling on US-licensed Westinghouse pressurized water reactors (PWRs) and abandoning the domestic graphite-gas design. This enabled an initially fragmented French nuclear supply chain to standardize exclusively on the Westinghouse PWR design (Campbell, 1988, Ch 8; Thomas, 1988, 218). This was not the case in the UK, for example, where political debates about reactor choice endured throughout the 1970s and stymied its nuclear rollout (Helm, 2004; Williams, 1980).

Lastly, an off-the-shelf plan for rapid expansion was available when the price shock hit. The PEON (Production d’Électricité d’Origine Nucleaire) Commission, which advised the government on nuclear energy development, had coincidentally laid out a roadmap for a

significant nuclear build out of 13,000 MWe in its April 1973 report, six months before the price shock.

Consequently, by the time the oil price spiked in October 1973, the French government did not need to develop a nuclear industry from scratch nor design a policy for rapid expansion, but rather only put its weight behind existing plans and actors.

It is crucial to point out, however, that while exogenous shocks and technological capacity are important for understanding the French case, these factors alone do not explain the political success of the Messmer Plan. All industrialized countries were affected by the oil price shock and many had pre-existing nuclear programs similar to those of France, yet not all expanded nuclear power at a similar pace and scale. The key variable that set France apart from otherwise similar countries was its political and policymaking institutions.

### **A.6.3 Political and policymaking institutions**

Institutions are formal and informal rules that structure political, economic, and social interaction (North, 1991; Thelen and Steinmo, 1992). They vary across countries and shape politics and policymaking by affecting the degree of power actors have over policy outcomes.

In the postwar period, French political institutions were characterized by *dirigisme* – a type of policymaking whereby governments play a strong directive role in the economy in pursuit of national goals (Hall, 1986, Ch 6; Hall, Hayward, and Machin, 1994, Ch 9; Schmidt, 1996, Ch 2). Dirigisme describes institutional arrangements as well as policies, and contrasts with neoliberal policymaking styles that minimize state intervention. Under dirigisme, governments tend to focus on steering production and investment and can unilaterally intervene in the economy. While this route was not always taken by French governments, it was typically used to pursue ‘heroic’ policies that were central to the government’s agenda and/or national security, such as nuclear energy (Schmidt, 1996).

Several key institutions undergirded French dirigisme during this period. First, an autonomous state bureaucracy comprised of highly trained civil servants recruited from the elite grandes écoles with deep technical expertise and long-term employment security was the primary locus of policymaking and could be impermeable to outside interests (Suleiman, 1974; Schmidt, 1996, Ch 7). Second, and relatedly, civil servants in the Planning Commission used indicative economic plans to outline the allocation of resources among the major sectors of French industry (Hall, 1986, Ch 7; Hall, Hayward, and Machin, 1994, Ch 9). Third, the financial system was based primarily on bank lending, which empowered the French state to use the nationalized banking sector to selectively provide capital to firms and industries in alignment with its broader economic goals (Hall, Hayward, and Machin, 1994, Ch 9; Zysman, 1983, Ch 3). Last, decision-making

was centralized within a powerful executive headed by the President with a majority in the National Assembly (Keeler, 1993). Opposition parties and, given the unitary nature of the French state, regional authorities had little influence.

Beyond these general factors, characteristics of energy policymaking and the energy sector in particular offered the state additional capacity for intervention. State engineers belonging to the *Corps d'État* (*Corps des Mines* and *Corps des Ponts*) strongly identified with the national goal of energy independence and were responsible for the nuclear program within the ministries, especially the Ministry of Industry, as well as holding top management positions within EDF and the CEA (Finon and Staropoli, 2001, 185). Additionally, authorities responsible for nuclear safety and siting were integrated within the Ministry of Industry and the CEA, which worked to streamline implementation (Finon and Staropoli, 2001, 185). Last, the state was a majority shareholder in the country's most important energy-related firms, including EDF, the nuclear manufacturer Framatome and the nuclear fuel producer COGEMA, and nuclear research and development was coordinated through the CEA, a public body. Taken together, this provided the conditions for an autonomous, centralized, and technocratic policymaking process that could be controlled from the executive branch.

The case was very different in other industrialized democracies. Policymaking in nearly all other similar countries was less autonomous and less centralized under the control of the executive. Countries like the US had strong legislative and judicial branches that could obstruct or veto executive action (Campbell, 1988). Most other countries had bureaucracies that were more permeable to the influence of outside interests groups. Policymaking processes in these countries also offered more access to the public and outside critics, in the form of public hearings and consultations, than in France. At the same time, almost no other industrialized country had a state planning system as powerful as France. Similarly, financial systems in peer countries tended to be private and outside of direct state control, as were key nuclear-related firms.