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Article

Exploring Enablers for an Ambitious Coal Phaseout

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Abstract
To reach the mitigation goals of the Paris Agreement, many countries will have to phase out their coal power plants prematurely, i.e., before the end of their normal lifetimes, which will lead quite possibly to significant stranded assets. This could present a major challenge, particularly for many of the rapidly developing countries whose electricity demand is growing and which are currently expanding their coal fleets. Recent research shows that countries with aging power plants and decreasing coal consumption are more inclined to phase out coal, but little is known about where, why, and how coal power plants are being prematurely retired. In the context of the hybrid Paris Agreement, attention is increasingly shifting to domestic mitigation capacities and, alongside this—given the vested interests involved in different sectors—to state capacity to implement the transformations required to achieve deep decarbonization. In this article, we aim to study those capacities in the context of coal phaseout. We use a recent and comprehensive global dataset on coal power plants and employ a mixed-methods research design to (a) identify general emerging patterns with respect to premature coal fleet retirement, and (b) derive stylized types of political strategies to prematurely retire coal power plants. We find state capacity to be a robust predictor of general and premature coal retirement, and we identify three main strategies that countries have used to date to prematurely retire coal: (a) *rein-in* using top-down regulatory enforcement of environmental, climate, or other regulations that affect the operating licenses of coal plants; (b) *buy-out* or provision of compensation to companies and regions to appease vested interests; and (c) *crowd out* where accelerating market and price dynamics in the power sector crowd out coal. We propose that future research should explore more systematically the kinds of strategy that might be most promising in the regions and countries needing to rapidly phase out coal, taking into account their political structures, and also the implications that such strategies might have for global mitigation efforts.

Keywords
climate mitigation; coal phaseout; premature coal retirement; strategic state capacity

Issue
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1. Introduction

Around one-quarter of global greenhouse gas (GHG) emissions can be attributed to coal plants in the power sector (Cui et al., 2019). There is clear agreement in climate science that to increase the probability of reaching the goals of the Paris Agreement, the use of unabated coal in the power sector needs to decline rapidly (Cui et al., 2019; Spencer et al., 2018; Tong et al., 2019). All pathways likely to limit warming to 2°C or below show a near elimination of coal by 2050 (Intergovernmental Panel on Climate Change, 2022). This implies that many rapidly developing countries, where the majority of coal capacity has been added in the last two decades (Tong et al., 2019), would need to prematurely retire their coal fleet, that is, close their coal power plants before its usual operating lifetime of 40–60 years is complete. This places the burden of stranded assets disproportionately on those rapidly developing regions (Edwards et al., 2022). Overall, coal phaseout raises concerns related to equity in international climate politics (Jakob et al., 2020) and also to "societal feasibility" (Spencer et al., 2018), given that fast rates of coal decline have rarely been observed historically (Vinichenko et al., 2021).

There is a growing amount of research focusing on coal phaseout (Blondeel et al., 2020; Diluiso et al., 2021; Jewell et al., 2019; Steckel & Jakob, 2021) that highlights the importance of "vested interests" and "carbon lock-in'' to explain why the phasing out of coal is so challenging. Membership of the prominent "Powering Past Coal Alliance" (PPCA; a coalition of national and subnational governments, businesses, and organizations working to advance the transition from unabated coal power generation to clean energy) is mainly confined to countries with a relatively old coal fleet or a low share of coal in electricity generation (i.e., where the influence of vested interests is on the decrease; Jewell et al., 2019). In this article, we focus on the newly developed notion of "strategic state capacity" which is defined as "the ability of the state to mobilize or demobilize interest groups in pursuit of policy goals" (Meckling & Nahm, 2021, p. 493). To date, studies on the political economy of coal phaseout have focused on material interests (e.g., age of coal fleet, share in power production, etc.), institutional settings (climate governance structures, policies), and regime types (Blondeel et al., 2020; Jakob & Steckel, 2022; Rentier et al., 2019), and less on actual political strategies and capacities to implement them against vested interests.

The key objective of the study is to explore whether and how countries with higher levels of state capacity enable a more ambitious coal phaseout. We contribute to the growing body of research by using a mixed-methods research design to answer the following research questions: (a) Is there any systematic evidence to show that countries with higher levels of state capacity are better equipped to phase out coal? and (b) What strategies do countries use to prematurely retire power plants? To answer these questions, in Section 2 we briefly discuss the state of the coal sector, highlighting that almost three-quarters of the current coal fleet is less than 20 years old. In Section 3, we explore how past literature has looked at the patterns of coal phaseout and we focus on explaining some of the key mechanisms that link state capacity to the ability to overcome vested interests. We discuss the methods and results of our quantitative analysis in Section 3.1, and of our qualitative analysis in Section 3.2. In general, we find state capacity to be a robust predictor of the overall share of retired coal capacity as well as of the prematurely retired share, and the operationalization of state capacity that we use adds more explanatory detail than relying on a log of GDP per capita, which is a widely used proxy for state capacity. With China and India both being on a path of growing state capacity, increasing capacity to phase coal out prematurely can be expected in those countries. State capacity alone, however, will not be enough to overcome vested interests. Decision makers would need to implement political phaseout strategies to overcome, mediate, or align vested interest within their countries. Distributive effects must also be taken into account at the global level where conflicts related to historic emissions and equity will shape overall global mitigation efforts. In our qualitative analysis, we identify three broader strategies currently deployed across a wide range of countries: (a) *rein-in* with a top-down regulatory enforcement of environmental, climate, or other regulations that affect the operating licenses of coal plants; (b) *buy-out*, namely, paying compensation to companies and regions to appease vested interests; and (c) *crowd out* where accelerating market and price dynamics in the power sector crowd out coal in the power sector. In our conclusion we call for more detailed research into those strategies, and the contexts in which they emerge—research that could become relevant in the future.

2. Current State of the Coal Sector

All pathways likely to limit warming to 2°C or below show a near elimination of coal without Carbon Capture and Storage (CCS) by 2050 (Intergovernmental Panel on Climate Change, 2022). To demonstrate the scale of the global challenge of phasing out coal, we summarize historical data and the most up-to-date data from the coal sector by using coal power plant data from the Global Power Plant Tracker Database (Global Energy Monitor, 2022). To make it easier to compare recent data with the outputs from scenarios, we aggregate country-level data in Figure 1 into four Integrated Assessment Model (IAM) regions (Europe, North America, India+, and China+), which cover the largest share of the current installed coal capacity. We provide the full list for regional categorization in the Supplementary Material, Table S1. Figure 1 highlights two main trends that we wish to emphasize: (a) There was a major build-up of new coal fleet after 2006, and (b) the coal scale-up in the China+ region has developed at an unprecedented rate, reaching over 1000 GW by 2021, which roughly corresponds to 50% of the current total global coal capacity installed.

As decisions about closing or refurbishing existing coal infrastructure are strongly influenced by the national political and economic context, we further provide the most recent coal sector snapshot at the country level in Figure 2. In Figure 2 (A) we can see that there are four countries that have successfully managed to phase out coal: Austria, Belgium, Portugal, and Sweden. As all these countries are relatively small or had a relatively small coal capacity in global terms (for example, Sweden had only two coal power plants to retire), the total amount of phaseout out is small in the overall global equation of coal capacity. A more promising impact on global mitigation efforts could be achieved if countries that currently have a relatively high share of coal capacity and an older fleet (a mean operational age of over 40 years), such as, for example, Russia and the US (indicated in blue), would retire their existing coal fleets. Retiring coal power plants in countries where the coal fleet is on average older than 20 years would account for about 500 GW or one-quarter of the current global coal capacity. The scale of the challenge represented by coal phaseout is shown particularly clearly in

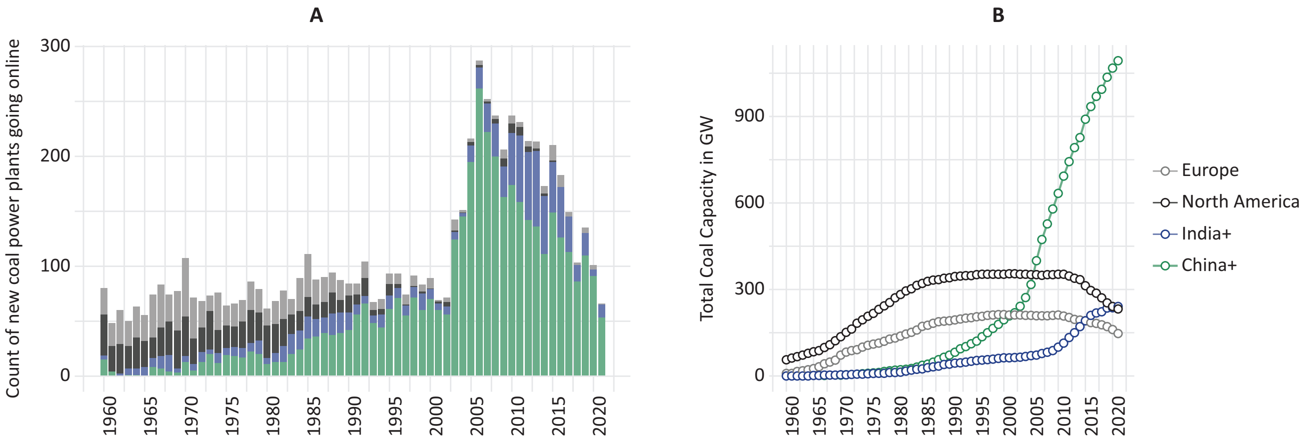

Figure 1. Figures A and B are based on data from the Global Power Plant Tracker Database (Global Energy Monitor, 2022) and aggregated into key IAM regions. China+ includes China (including Hong Kong), Cambodia, Korea (DPR), Laos (PDR), Mongolia, Vietnam; India+ includes India, Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka. For the full list of regional categorization see the Supplementary Material, Table S1. Figure A shows the number of new coal power plants going online in a given year for a given region. Figure B is based on calculations that include all operating power plants and exclude retired ones, and shows the total installed coal capacity in a given year and a given region in GW.

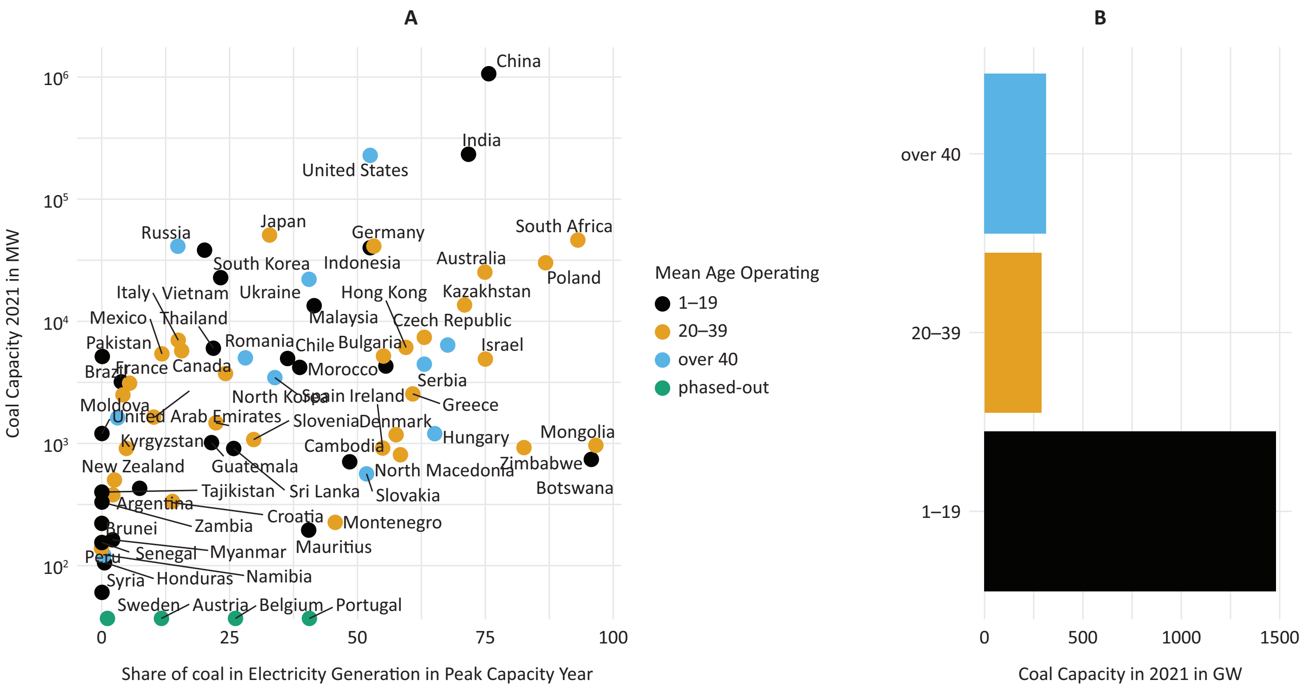

Figure 2. Figures A and B are based on data from the Global Power Plant Tracker Database (Global Energy Monitor, 2022) and from the World Bank Indicator on the share of coal in electricity generation. In Figure A, the x-axis shows the share of coal in electricity generation (in %) in the year in which peak installed coal capacity was achieved; for countries where coal capacity is growing, the latest available data are used. This should indicate the level of domestic challenge that a country might face with coal phaseout. The y-axis indicates the total installed coal capacity as of 2021 in MW using logarithmic scale to highlight the importance of a country in the global context (i.e., to indicate the absolute coal capacity compared to other countries). The "Mean Age Operating" is calculated based on the mean age of all currently operating power plants and weighted by their capacity. Figure B shows the sum of coal capacity in GW for all countries that fall within a given "Mean Age Operating" category in 2021.

Figure 2 (B), which highlights that around 1500 GW or three-quarters of the current global coal capacity is less than 20 years old.

3. Prospects of Coal Phaseout and the Role of State Capacity

To reach the mitigation goals of the Paris Agreement, an essential and key strategy is to stop emitting GHGs into the atmosphere and thus to phase out coal. In Section 2 we highlighted the scale of the challenge that a coal phaseout presents for certain regions and especially for certain countries. Based on this, it is not surprising that the division along developed- and developing-country lines was reflected in the most recent climate negotiations at COP26. While developed countries with quite old coal fleets, led by the UK, sought to include the call for a coal phaseout in the cover decision of United Nations Framework Convention on Climate Change's (UNFCCC) COP26, emerging economies—established users with growing coal capacities—tried to weaken the declaration by referring to arguments of equity and historical emissions. In the end, the UNFCCC document summarizing agreements from COP26 included the objective to accelerate efforts towards "the phasedown of unabated coal power" (UNFCCC, 2021, p. 3) rather than phaseout, as stated in the initial draft.

There is a general agreement in the current scientific literature that it is the "coal lock-in," or the "degree to which a society is locked-in on investments, resources, assets and activities related to coal" (Rentier et al., 2019, p. 621) that makes coal phaseout particularly difficult. The member countries of the PPCA whose objective is to phase out coal have in common a weak coal industry or being a climate leader (Blondeel et al., 2020, p. 9); they also have a lower share of coal in electricity generation, older coal power plants, and no majorly increasing energy demand (Jewell et al., 2019). Studying the UK coal phaseout from a historical perspective, Turnheim and Geels (2012) conclude that, normally, for a technological regime to be destabilized and an old technology to be replaced, multiple processes need to be aligned such as, for example, political support, economic viability of alternatives, and declining public support. Against this backdrop and given the current global coal landscape (Figure 2), the prospects for a global coal phaseout in alignment with Paris Agreement goals would seem rather bleak.

Nonetheless, we do observe overall increasing ambition in climate mitigation (Ou et al., 2021), and there are countries that have phased out coal or have pledged to phase out coal before 2030. The Netherlands, which is a member of the PPCA, has committed to retiring three large coal-powered plants by 2029 (total capacity: 2.4 GW) that went online in 2015 (i.e., after only 14 years of operation). China recently pledged not to build new coal power plants oversees (Ni et al., 2021). The UK, one of the initiators of the PPCA, managed to commit to phasing out coal despite initial major societal and industry opposition. There are thus many examples where vested interests in the coal sector could be overcome.

Meckling and Nahm (2021) argue that "strategic state capacity" or the ability of countries to mobilize or demobilize interests could be a useful notion with a view to understanding why certain countries manage to implement climate policies that are more ambitious. Depending on the type of political system (polity) when dealing with different interest groups, a country's government might consider: (a) recruiting allies, (b) aligning interests, (c) limiting access, or (d) quieting interests. Using Germany's coal phaseout agreement as one of the case studies, Meckling and Nahm (2021) identify that Germany was able to conciliate interests through compensation, by offering a package worth €40 billion to affected regions. The main insight of their study is that some "governments are able to pursue state goals against interest group opposition and not in others, even when bureaucratic capacity does not vary" (Meckling & Nahm, 2021, p. 22).

Building on work by Meckling and Nahm (2021), we focus on the role of (strategic) state capacity in the context of coal phaseout by proposing a mixed-methods research design where we explore: (a) whether there is a systematic link between levels of state capacity and progress in terms of the phasing out of coal using quantitative methods, and (b) what other types of strategy beyond compensation are used by countries to phase out coal and how these could be linked to the level of state capacity using qualitative methods. Overall, there have been many single or comparative case studies of coal phaseout (Diluiso et al., 2021; Markard et al., 2021; Oei et al., 2020; Rentier et al., 2019) but only a few studies including cases that would shed more light on generalizable patterns (Blondeel et al., 2020; Jewell et al., 2019; Steckel & Jakob, 2021; Vinichenko et al., 2021). This is not surprising, given that there are not very many cases where coal phaseout has been observed and, additionally, it is not very clear how countries in the different stages of coal phaseout (Nacke et al., 2022) should be compared. The concept of state capacity is also difficult to operationalize (Savoia & Sen, 2015) and many past analyses of technologies to date have used GDP per capita as a proxy for state capacity (Brutschin et al., 2021; Jewell et al., 2019). We address the methodological issues pertaining to quantitative analysis and to the results in Section 3.1 and we discuss the approach to, and results of, the qualitative analysis in Section 3.2.

3.1. Quantitative Analysis of Coal Phaseout

To assess whether there is a systematic link between the phasing out of coal and state capacity, we propose to focus on cross-country variation in the degree to which coal has been phased out to date. In our model specifications we use a linear regression model with robust standard errors to account for heteroskedasticity in residual distribution. We focus on the role of state capacity and include a range of additional control variables that might be linked to the observed cross-country variation. In what follows, we describe in greater detail the measurement of our dependent variable (the degree to which coal has been phased out), how we propose to measure state capacity, and the other additional variables that we include to assess the robustness of the link between state capacity and the ability to phase out coal. It is essential to note that this type of analysis does not allow any claims to be made about the causal link between state capacity and coal phaseout. There are many other confounding variables that could be highly correlated with state capacity and coal phaseout. We can, however, in the qualitative part of our analysis (Section 3.2) further explore the plausibility of linking state capacity to progress in coal phaseout.

Past analyses have looked at membership of the PPCA as a possible indicator of a country's commitment to phasing out coal (Blondeel et al., 2020; Jewell et al., 2019). This measure could, however, miss some interesting cases such as China and the US, which are not members of the PPCA, but are prematurely retiring parts of their coal fleet (as we also briefly discuss in Section 3.2). In our analysis, we aggregate power plant data from the Global Power Plant Tracker Database (Global Energy Monitor, 2022) where, for most power plants, it is reported when a power plant went online, its total capacity, and the year it was retired. This detailed information enables different combinations of data to be aggregated for a given country. Ideally, we wish to identify countries where we can observe the trend of a declining coal fleet stock and incorporate information about the share of fleet that has been prematurely retired. As an initial measure we thus propose to use the share of prematurely retired coal capacity (coal power plants that are bigger than 100 MW and less than 30 years old) of the total capacity in the peak year, to which we later refer as "*premature*." Yet countries might retire many power plants prematurely without substantially decreasing their overall coal stock or, in other words, without a real trend toward coal phaseout. We thus use *two additional measures* to also account for those trends: (a) share of retired coal capacity in total capacity in the peak year (based on the year in which a country reached peak capacity; i.e., after which capacity did not substantially increase) which we refer to as "*retired total*," and (b) share of peak capacity as a share of the current capacity which we refer to as "*peak versus current*" (calculated to indicate the retired share in the current capacity). As shown in Table S2 of the Supplementary Material, we report, for each country, the year coded as the peak year and the values for all three measures; apart from a few exceptions, there is a general overlap across the three measures. The Netherlands is a particularly interesting example, given that, compared to peak capacity, a substantial share of the country's coal capacity has already been retired (over 60%, and around 30% even prematurely); but because of recent new build-ups, the current share of coal capacity is still at around 70% of peak capacity. Thus, what we observed in the Netherlands was a recent upgrade of its coal fleet. The Netherlands is still committed to a complete coal phaseout by 2029.

As our focus is on state capacity, our research requires a quantifiable definition of state capacity that ideally goes beyond the general measures of bureaucratic quality. Broadly, state capacity refers to the general ability of a state to implement goals and policies (Cingolani, 2013). There are many different ways to operationalize state capacity (Hanson & Sigman, 2021; Savoia & Sen, 2015) that focus on different functions of a state. Recently, Hanson and Sigman (2021) developed a new operationalization of state capacity that covers three of its key domains: extractive, coercive, and administrative. This new variable is based on 21 indicators *(Administrative efficiency*, *Bureaucratic quality*, *Census frequency*, *Efficiency of revenue mobilization*, *Fiscal capacity*, *Information capacity*, *Law and order*, *(log) Military personnel per 1,000 in population*, *(log) Military expenditures per capita*, *Monopoly on use of force*, *(log) Police officers per 1,000 in population*, *Quality of budgetary and financial management*, *Quality of public administration*, *Rigorous and impartial public administration*, *State antiquity index*, *State authority over territory*, *Statistical capacity*, *Taxes on income as % of taxes*, *Taxes on international trade as % of taxes*, *Total tax revenue as % of GDP*, *Weberiannes*) and covers the period from 1960 to 2015. This measure goes beyond a narrow measurement of administrative or bureaucratic capacity, like, for example, the World Bank Governance indicators, which focus on government effectiveness, rule of law, corruption, voice and accountability, political stability, and regulatory quality. Depending on the year, this state capacity measure from Hanson and Sigman (2021) ranges from −2.31 to 2.96, with the highest levels of state capacity being estimated for Denmark. For our regression analysis we use the state capacity value for the year in which a given country reached peak capacity, while for countries in which coal capacity is still increasing we use the value from the latest year available.

The selection of additional control variables for our key model specifications is not only guided by general frameworks highlighting the key drivers of national climate policies (Lamb & Minx, 2020), but also based on other past findings pertaining to coal phaseout (see Table 1 for an overview of all variables, definitions, sources, and some basic descriptive statistics). For all control variables we pick the values at the peak coal capacity year; for countries which have not yet reached peak in their coal capacity, we take the most recent available data. As mentioned earlier, a widely used proxy for state capacity is a log of GDP per capita, which we obtained from the World Bank World Development Indicators and which is reported in constant international US$2017. Carbon lock-in and vested interests are often proxied by measuring the share of coal (or other

Table 1. Overview of the variables included in the quantitative analysis.

Variable	Exact measurement	Source	Mean/SD	Min–Max	N
The share of prematurely retired coal capacity in the total capacity in the peak year	Taking the total prematurely retired coal capacity (coal power plants that are bigger than 100 MW and younger than 30 years) and dividing it by the total installed coal capacity in the year in which country reached peak capacity	Own calculations based on Global Energy Monitor (2022)	2.35/6.46	0–33.63	81
Share of retired coal capacity	Taking the total retired coal capacity and dividing it by the total installed coal capacity in the year in which the country reached peak capacity (maximum capacity over the observed time span)	Own calculations based on Global Energy Monitor (2022)	19/29.25	0–100	81
Share of peak capacity as a share of the current capacity	One minus the ratio between capacity in the peak year and capacity in 2021	Own calculations based on Global Energy Monitor (2022)	84/28.73	0–100	81
Log GDPpc	GDP per capita PPP constant international US$2017	World Bank World Development Indicators (WDI). Variable: GB.XPD.RSDV.GD.ZS	9.72/0.89	7.34–11.34	72
State capacity	extractive, coercive, and administrative capacity based on 21 indicators	Hanson and Sigman (2021)	0.96/0.83	−0.78–2.87	69
Coal reserves	R/P ratio of total proved reserves	BP (2021)	1.17/3.8	0–23	81
Share of coal in electricity generation	Electricity production from coal sources (% of total)	World Bank World Development Indicators (WDI). Variable: eg.elc.coal.zs	34.22/28.74	0–96.6	72
Federal Government	Dummy variable coded 1 if there are independent sub-federal units (states, provinces, regions, etc.) that impose substantive constraints on national fiscal policy	Henisz (2017)		0–1	78
Liberalization Index	Ranges from 0 to 8 from non-liberalized to completely liberalized power sector	Erdogdu (2011) and Urpelainen and Yang (2019)	5.92/2.14	0–8	76
Climate Emergency	Share of population in a given country that answered yes to the question "Do you think climate change is a global emergency?"	Flynn et al. (2021)	67.07/8.26	50–81	28

fossil fuels) in electricity generation (Lamb & Minx, 2020). We thus include a similar variable which is reported in World Bank Development Indicators. Apart from that we also include a measure of coal reserves (reserves to production ratio) from the British Petroleum Statistical Review (BP, 2021). To additionally control for whether it is more challenging to phase out coal in a more federalized or a more centralized state, we included a binary measure from the Political Constraint Dataset, which is coded 1 if there are independent sub-federal units (states, provinces, regions, etc.) that impose substantive constraints on national fiscal policy (Henisz, 2017). As it might be easier to switch to new cheaper technologies and overcome vested interests in more liberalized markets (Brutschin et al., 2021), we also include a liberalization index that ranges from 0 to 8 from a non-liberalized to completely liberalized power sector and was collected for developed and developing countries by Erdogdu (2011) and Urpelainen and Yang (2019). Finally, there is a growing interest in understanding how public opinion might affect the levels of climate policy ambition. Unfortunately, there are only a few datasets that provide this variable. Nonetheless, as an additional sensitivity, we include data from the recent Peoples' Climate Vote Survey (Flynn et al., 2021), which reports the share of population in a given country that answered yes to the question "Do you think climate change is a global emergency?" As there are only 28 countries for which data is available from the published report, the overall number of observations included in the models including the "climate emergency" variable is fairly low.

We report the main results in Figure 3 using regression coefficient plots, which display the regression coefficient as a dot and ranges of 90% confidence intervals (we also report full regression tables for each specification in the Supplementary Material). If the confidence interval does not contain the zero value (marked by the red line), the results are statistically significant at the 10% statistical significance level. This visualization makes it easier to compare results, especially when there is more than one dependent variable. The main difference between the results presented in Figure 3 (A) and Figure 3 (B) is that Figure 3 (B) includes a "climate emergency" variable, with a substantially reduced sample size. By including a "climate emergency" variable, the direction of effect for most of the variables holds, yet many are no longer statistically significant because of the small sample size and thus possibly the lack of adequate variation.

Overall, we see that the effect of state capacity, our main variable of interest, is robust across many different specifications (we also report some alternative specifications, including different control variables, in the Supplementary Material). While we cannot state with certainty that state capacity per se causes some states to be more successful than others at phasing out coal, we do, however, find that countries with higher state capacity are both generally and systematically associated with a higher degree of coal phaseout. Apart from that, there are two other key interesting findings pertaining to the connection between liberalization of the power sector and whether a country has a federal government structure. As expected, countries with a more liberalized power sector seem to have a higher degree of coal phaseout than those without. Finally, for the dependent variable that measures the share of prematurely retired coal capacity, we also observe that countries with independent federal units have generally lower shares of prematurely retired coal capacity.

The main goal of this part of our analysis was to assess whether there is a systematic link between state capacity and the degree of coal phaseout. It is, however, also essential to understand which specific strategies

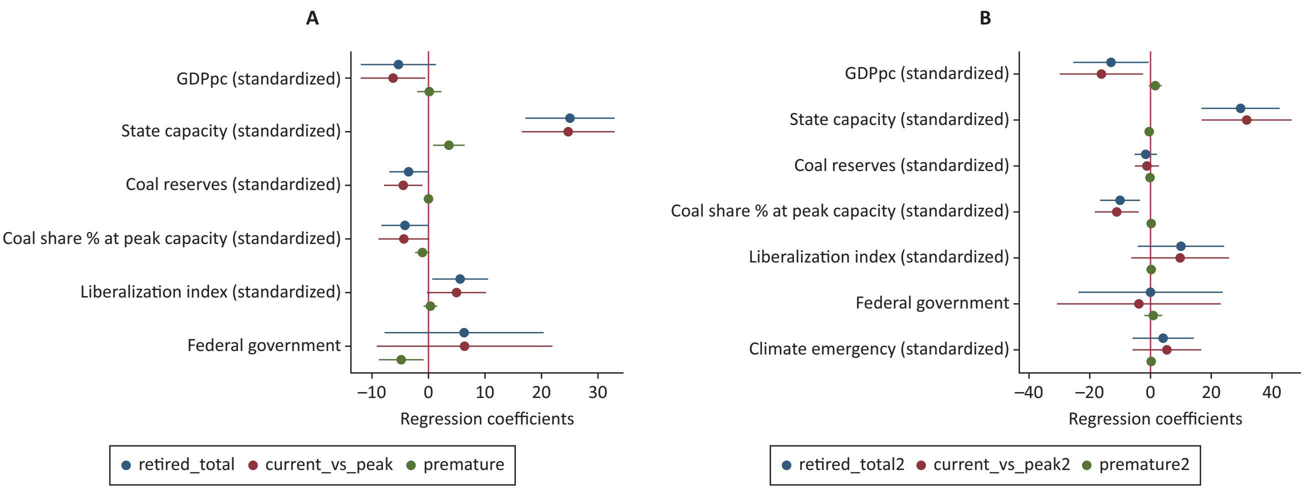

Figure 3. A and B show the results from the main analysis using the three measurements of the degree of coal phase out discussed in the text ("premature," "current versus peak," and "retired total") and standardized independent variables. Figure B show the sensitivities that include the "climate emergency" variable, which substantially reduced the sample size. Note: If the confidence interval does not contain the zero value (marked by the red line), the results are statistically significant at the 10% statistical significance level.

certain states use to overcome vested interests. We explore this part in the following Section 3.2.

3.2. Key Strategies to Prematurely Retire Coal

As the Paris Agreement is a hybrid agreement, in which soft modes of coordination between signatories dominate rather than top-down regulatory mandates (Aykut et al., 2022), it is essential to gain a better understanding of domestic mitigation capacity. Identifying existing strategies to counter vested interests is particularly important in the context of future climate policymaking, as societal transformations toward deep decarbonization are associated with distributive effects across sectors, interest groups, regions, etc. (Mildenberger, 2020; Victor et al., 2019). As well as enabling the quantitative analysis of enablers of premature coal phaseout, the global data from the Global Power Plant Tracker allows the political strategies of state actors that facilitate coal phaseout and counter vested interests to be qualitatively identified. The data allow "actions on the ground" with regard to coal phaseout practices to be explored in different countries and help identify commonalities and differences between different political strategies and approaches. Although Meckling and Nahm's (2021) notion of strategic state capacity focuses on "advanced industrialized economies" and is based on case studies from France, Germany, the US, and California, we argue that their proposed concept is a good starting point for exploring the development of research designs that allow mitigation capacities to be qualitatively explored, especially in countries and sectors with well-established and strong vested interests.

As in the previous quantitative analysis which, in part, focused on prematurely retired coal power plants, we identified coal-fired power plants and units larger than 100 MW and less than 30 years old. In a first step, we applied these selection criteria to the Global Energy Monitor database and identified 46 cases of prematurely closed coal plants. Figure 4 provides an overview of this selection by plant size in MW and plant age. It shows that China stands out by retiring many small and young units, while several EU countries have retired units between 20 and 30 years old; Germany is an outlier because it has retired some very young and large units. In this section, we attempt to shed more light on these developments and identify patterns of policy coal phaseout strategies based on an exploratory qualitative analysis of the Global Energy Monitor Wiki that provides background information on coal plant closures.

This article cannot provide detailed case studies but aims for an initial exploratory analysis to establish a conceptual differentiation of coal phaseout strategies. Such an approach allows only limited generalization: More in-depth studies and comparative work on premature phaseout decisions are needed in the future. To elicit the major political strategies involved in premature coal phaseout, we applied an exploratory and inductive coding strategy informed by both conceptual considerations from the literature on strategic state capacity and desk research of available information on premature coal phaseouts. We started the analysis by gathering the main reasons and justifications for the premature closure of all 46 units or plants (> 100 MW, < 30 years, based on the Global Energy Monitor Wiki; see the Supplementary Material for more details). Where the Wiki did not provide sufficient details, we extended the desk research to media reporting, announcements by companies, and policy documents. In a next step, we identified key patterns in commonalities and differences in strategies to phase out coal across the findings and—informed by Meckling and Nahm's terminology on strategic state

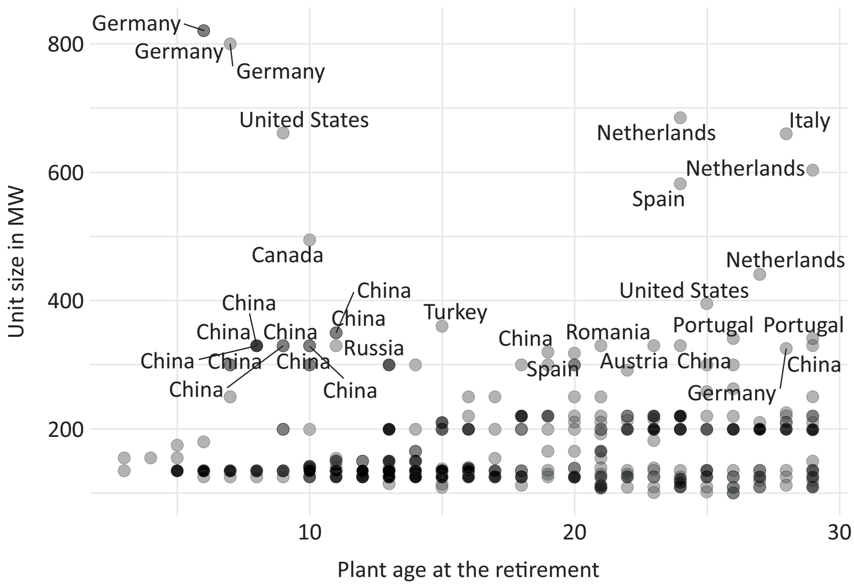

Figure 4. Cases of premature coal power plant retirements based on the data from the Global Energy Monitor (2022). Here we highlight cases where plants larger than 100 MW were retired.

capacity (2021)—developed a conceptual differentiation of strategies we found. After identifying three different illustrative strategies, we did a second round of coding to associate every premature closure with one of the general patterns (see Figure 5, which summarizes all the steps in the process).

Based on our review of 46 prematurely retired units (for a full overview see Supplementary Material, Table S4) we find the following three illustrative political strategies: (a) *rein-in* through top-down regulatory enforcement of environmental, climate, or other regulations that affect the operating license of coal plants; (b) *buy-out* by providing compensation to companies and regions to appease vested interests; and (c) *crowd-out* by accelerating and underpinning existing market and price dynamics in the power sector that crowd out coal. These strategies represent a continuum ranging from top-down direct state intervention to implicit governance of premature phaseout (see Figure 6 for a conceptual overview). The three illustrative patterns do, of course, overlap and should not be thought of as mutually exclusive. Furthermore, it is important to highlight that the strategies are being implemented in complex political and economic environments and that their success depends on many context-specific factors. This exploratory analysis helps to provide a first overview of political strategies and point to relevant questions for future research.

Rein-in is a key strategy for early decommissioning of coal-fired power plants or units. In general, we have observed two distinct sets of regulatory enforcement. First, cases in which operating permits are revoked in the form of administrative decisions by agencies or other government entities due to violations of pollution or other environmental regulations. An example of this is the Weiquiao plant in China where, after a pollution scandal, four units of 1,320 MW were retired after just eight years in operation (Global Energy Monitor, 2021). Another example from China is the Chentangzhuang power station, a seven-year-old coal plant with 600 MW that had to switch to gas because the Tianjin Municipal Government was trying to expand the urban area and improve living conditions (Baidu, 2021). We also found examples of regulatory enforcement of premature coal phaseout in European countries, for example, in the Netherlands, where the government decided to close the Maasvlakte power station (age: 29 years; 603 MW). Although the decision was later revoked by the Dutch consumer and market authority, the company closed the power plant in 2017 due to the issue of new energy efficiency standards with which it was unable to comply (Beall, 2014).

A second pattern we have observed is governments being actively engaged in *buying-out* to appease the interests of companies owning and operating the plants as well as political constituents linked to coal mining. One of the most prominent compensation schemes is being implemented in Germany. Companies received an average compensation per MW of €66.259 (Bundesnetzagentur, 2022). In a newly established auction framework, companies can apply for their plants to be decommissioned. In the first round, two of the youngest coal plants were among the successful bidders (Moorburg, age: 6; 820 MW; and Westfalen, age: 7; 800 MW). German climate and energy politics has long been seen as a frontrunner in deploying renewables while continuing to burn coal; "targeted compensation politics" (Meckling & Nahm, 2021) have now managed to overcome well established vested interests. Compensation has also been paid in the Netherlands for the Hembweg coal plant (age: 25; 685 MW). Following a court ruling (the "Urgenda target"), the Dutch government paid €52.5 million to Vattenfall in exchange for early retirement of the plant (European Commission, 2020; Karagiannopoulos, 2019).

Finally, we identified strategies aiming to instigate and accelerate market dynamics that are increasingly crowding coal out of the power market. Due to the plummeting prices of renewables, many coal plants

Figure 5. Overview of inductive coding strategy and desk research for qualitative analysis of sample of closed coal power plants.

Figure 6. Strategies for premature coal power plant retirement.

are struggling to remain profitable, and companies are deciding to ditch or switch their existing coal infrastructure (Diluiso et al., 2021). Among these early retirements, many plants are being switched over to gas production, and some are being used to burn biomass. In some cases, these developments are being accelerated and supported by government decisions. For example, the Spanish operator of the Litoral de Almer plant (age: 24; 582 MW) made the case that the plant was no longer competitive because of the high cost of CO_2 rights (Edwardes-Evans & Baratti, 2019). The closure was accompanied by Just Transition agreements to "cushion the social consequences of this measure" which the state is involved in (Endesa, 2021). Another example of accelerating market dynamics is the Keephills power station in Canada (age: 10; 495 MW). The owner, TransAlta, decided to switch the plant to gas due to its limited economic viability in the oversupplied Alberta power market and the low power price environment. This decision was taken in the context of regulations to phase out traditional coal-fired electricity by 2030, eliminating all emissions from the power sector by 2035 and an annually increasing federal carbon tax (Climate Action Tracker, 2021).

All of the examples mentioned here would qualify for a detailed case study to analyze the political strategies and economic dynamics in more detail. This cannot be done in this article. Nevertheless, the exploratory analysis of the coal-fired power plants that were closed prematurely shows that different strategies exist to promote the coal phaseout. More detailed research on each of these three illustrative strategies could, in the future, show the extent to which they are context-specific and which aspects are transferable to other countries; this would help further improve the knowledge about the enabling conditions for an early coal phaseout.

4. Conclusion

The phasing out of coal is one of the politically and economically challenging elements in the envisaged societal transformation toward deep decarbonization. The premature retirement of existing coal power plants, as a key element of achieving net zero emissions targets by mid-century, will face substantial obstacles and will be problematic for policymakers—even more so in the context of surging gas prices. The research carried out for this article, based on a mixed-methods approach, contributes to a better understanding of the enabling conditions and political strategies behind premature coal phaseout.

Our analysis makes a number of innovative contributions to the ongoing debates. We show that a general measure of state capacity that goes beyond GDP per capita is a robust predictor for both total and prematurely retired share of coal capacity across a wide variation of political systems and levels of development. Given that China and India both have a relatively high score in terms of state capacity and that recent developments in those countries are following an upward trend, the hope that they will develop and implement goals of downsizing or phasing out coal is a tangible one. The importance of state capacity additionally implies that this is a key contextual factor that needs to be taken into account when strategies from success stories are considered for replication elsewhere.

Our other key contribution pertains to the application of the concept of "strategic state capacity" (Meckling & Nahm, 2021), namely, to strategies concerned with how vested interests can be overcome, with the political challenge of phasing out coal plants prematurely. The inductive approach taken in this research to finding patterns among existing cases of prematurely retired coal power plants shows how important it is to explain not only *why* countries retire power plants but also *how*. The continuum of political strategies from top-down state intervention to implicit and more indirect forms of governing coal phaseouts indicates the variety and context-sensitivity of successful political strategies. Future research should explore questions about which political strategy fits which context, what factors for success can be identified, and what forms of international cooperation help facilitate premature coal phaseout. The very different starting positions with regard to coal phaseout among many developed economies and growing economies such as China and India point to the importance of equity debates. It is to be expected that coal phaseout could, from the political point of view, turn into a highly contested symbol for discussions about historic emissions and current mitigation obligations. These political circumstances will affect the political strategies deployed to phase out coal, and new strategies could emerge. Equity, however, is relevant not only in the context of international climate negotiations and global mitigation efforts under the UNFCCC, but also at the national level. We observe that some countries use elaborate schemes under the heading of "just transition" to pay off companies, political constituencies, and workers, while in other countries, market mechanisms are more prevalent and the state does not become involved. To build further support for climate mitigation across a wide range of actors, it will be crucial to understand which strategies create the least costs for the public and the economy, while being politically robust and effective in achieving premature coal phaseout.

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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