Brown Capital (Re)Allocation*

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Abstract

This paper studies capital reallocation in the fossil fuel industry by investigating who owns coal power plants – the largest single source of global greenhouse gas emissions. We build a bottom-up measure of the ownership of these brown assets by merging asset-level data on firms' plant ownership (real capital) in Europe with firms' shareholder data (financial capital). We document a sharp increase in private firms' coal ownership since 2015, accompanied by a large decline in public equity ownership. A formal decomposition shows that the large decline in public equity ownership was however not due to *capital reallocation* ("exit") but to *capital utilization*: these investors scaled down plants, not sold them. Instead, state investors played a crucial role: they sold to private firms, while being the slowest at scaling down their plants. We illustrate the economics of brown capital allocation by calibrating a model in which asset owners vary in how they value externalities. The possibility of nationalization of coal plants by state investors that value social factors (e.g. jobs, "energy security") is an important limit to the ability of "green finance" to decrease aggregate emissions, in line with recent episodes in Germany and Poland.

Keywords: Energy transition, capital reallocation, exit vs. voice, state ownership, climate finance, energy security, private equity

JEL codes: G32, G11, E440, H54, Q40

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1 Introduction

A "green transition" is sure to have dramatic effects on capital allocation across the globe. Any significant reduction in greenhouse gas emissions would imply a large-scale transformation of many key sectors of the economy. In particular, it not only calls for scaling up "green", low-carbon, capital but crucially also scaling down "brown," carbon-intensive capital as well. An absolutely central sector is power production, in which traditional fossil fuels are progressively being challenged by renewable energy sources. In particular, phasing out coal power plants is seen as an absolute priority in any scenario projecting a reduction in brown capital and emissions, given that burning coal is by far the most carbon-intensive way to produce energy. That makes coal the single largest source of carbon emissions globally[1] and the United Nations Secretary General has dubbed a coal phase-out the "single most important step" in addressing climate change.[2] In Western economies, recent years have witnessed the multiplication of announcements of government commitments to end coal and the rise of competition from renewables. Coal has also become a major red flag in the rising "green finance" movement.

In spite of this declining trend, there are nevertheless still plenty of active coal plants in Western economies. This paper asks: Who then owns this (very) brown capital? This is important since owners (i.e. equity investors) have the largest say in how plants are run.[3] There is widespread concern that climate-conscious investors might stop at selling brown capital, instead of scaling it down, i.e. choosing "exit" over "voice." The concern is that simply reallocating brown capital across investors might lead to a limited reduction in aggregate carbon emissions.

In the first part of the paper, we unpack the dynamics of coal ownership by merging asset-level data on firms' plant ownership (real capital) with firms' shareholder data (financial capital) for the universe of coal power plants in the European Union since 2015. Equipped

[1]Source: "It's critical to tackle coal emissions," *International Energy Agency* , October 8, 2021, Link.

[2]Source: "Statement by the Secretary-General on the announcements by the United States and China on climate action," *United Nations*, September 21, 2021, Link

[3]They are also the most exposed to long-run risk in asset valuation (i.e. "stranded assets").

with this bottom-up ownership measure, we document changes in ownership shares of these brown assets across three investor groups: public equity investors, private investors, and state investors. In spite of a sharp increase in the private ownership of coal, we introduce a formal decomposition to show that the large decline in public equity ownership was not due to *capital reallocation* ("exit") but to *capital utilization*: these investors scaled down plants, not sold them. Instead, state investors played a crucial role: they sold to private firms, while being the slowest at scaling down their plants. In the second part of the paper, we illustrate the economics of brown capital reallocation by calibrating a model that incorporates production externalities. Investors (private, public, states) differ in how they value externalities and trade is subject to financial frictions. We argue that the possibility of nationalization of brown assets by state investors that value social factors (e.g. jobs, "energy security") is an important limit to the ability of "green finance" to decrease aggregate emissions, in line with recent episodes in Germany and Poland.

We focus on European coal power plants for two reasons. First, Europe is a large historical coal power producer but also at the forefront of the green transition, at least since the Paris Agreement in 2015. The European Union has witnessed the most ambitious commitments to emission reduction targets across both governments and the private sector, with many explicit references to a coal phase-out. This region experienced the largest decline in coal power capacity since 2015, of about 25%. Second, there is a wide range of firm ownership patterns in Europe and all main types of investors play an important role, including publicly listed firms, private firms, and states and local governments. The reallocation dynamics at play in Europe are thus particularly informative.[4]

We build a bottom-up measure of coal power plant ownership by combining two levels of micro-data. We first gather data on which firms own plants using an asset-level database constructed by Beyond Fossil Fuels. For the period 2015-2022 and for all European coal

[4]In a global context, North America is the only other region with declining coal capacity. The ownership patterns in Europe also contrast with China and other emerging economies, as well as with the U.S., which are dominated by state-owned enterprises and publicly listed firms, respectively.

power plants, we observe its location, generation capacity, and crucially the name of the firm(s) owning it. We also observe a measure of scale via plant-level verified CO2 emissions that come from the European carbon market (the ETS). We merge this plant-level data with firm-level shareholder data. For publicly traded firms, we use detailed data on equity investors from S&P Capital IQ. For other firms, which are either state-owned or private, we manually collect shareholder information from annual reports and other sources. We classify investors as belonging to one of three investor groups: (i) public equity investors, (ii) private equity, and (iii) state investors. Some of our analysis will nevertheless be more granular and we will study heterogeneity within these groups.

We first document aggregate ownership dynamics. There is a large rise in private ownership of 12 percentage points, doubling its share during our sample period. This rise is the sum of a large decline in the share of public equity investors of 9 percentage points and a smaller decline of state ownership of 3 percentage points. The aggregate trends however mask the origin of these dynamics.

To this end, we introduce a formal decomposition of ownership changes that distinguishes between *capital reallocation* and *capital utilization*. Indeed, an investor can reduce its coal ownership by selling assets, or by scaling down its plants, or both. This empirical decomposition aims to relate to the conceptual distinction between "exit" (divestment) vs. "voice" (action).[5] This is one of the great advantage of our asset-level data: this distinction is difficult to make with firm-level data only.

This decomposition reveals that aggregate trends mask striking patterns. Perhaps surprisingly, the decline in public equity investors' ownership was entirely driven by a quick decline in utilization, not reallocation. In other words, these investors have been closing or scaling down plants faster than other investors, and not selling to them. There is thus little evidence of "exit" of public equity investors in coal. Instead, the decomposition makes it clear that state investors played a crucial role: they were the ones that sold to private firms and were

[5] The decomposition is exact once we account for a covariance term, which is typically small.

also the slowest in scaling down their plants. In that sense, states (as investors) seemed to have slowed down the transition.[6] For robustness, we confirm that these findings are not purely driven by composition effects across investors, due to for instance to differences in technological obsolescence (age) or location (country) of their initial capital.

Moreover, we find striking differences between domestic and foreign state investors. We define a state investor as domestic if it is affiliated with a local or state government in the same country as the plant it owns. Over our sample period, foreign states have massively decreased their ownership share by 10 percentage points, from 15% to 5%, while domestic states have increased their ownership share by 7 percentage points, from 31% to 38%. Our decomposition reveals what led to these diverging paths. Foreign state investors decreased their ownership purely via reallocation: they sold plants to private firms. The massive sale of German plants owned by Swedish utility Vattenfall to private firm EPH was the most prominent example. Domestic state investors in contrast were the slowest to scale down their existing plants, implying a large rise in their ownership share.

To understand the economics of brown capital reallocation, we present a model that differs from traditional models of capital reallocation in one key aspect: the presence of externalities in production, which will generate new insights. Capital owners differ in how they value externalities, which implies dispersion in asset valuation and incentives to trade. We introduce two important ingredients related to finance and governance. First, there are financial frictions in the acquisition of new capital. Second, we take the structure of socially responsible "investment mandates" seriously [Oehmke and Opp, 2022]. Beyond caring about climate externalities, it crucially matters *how* investors care. Investors with "narrow" mandates only internalize externalities of the capital they currently hold (a micro perspective). On the other hand, investors with broader mandates internalize the effects of their capital allocation on

[6] We can also use our data to formally quantify the relative contribution of real reallocation versus financial reallocation to capital reallocation, i.e. how much of investors' sale of assets is from trading plants vs. trading shares. There were diverging patterns of real versus financial reallocation across investors. Private firms bought plants from states, while until 2022 public equity investors bought shares from states. We discuss the 2022 reversal in more detail below in the context of (re)nationalizing brown assets.

aggregate emissions (a macro perspective). Narrow mandates give strong incentives to choose "exit" and sell plants instead of scaling them down.

We calibrate the model using our micro-data and moments from our formal decomposition. We find reasonable values for model parameters that can rationalize the key facts in ownership dynamics documented above. There has been a large aggregate decline in profitability of coal since 2015. The valuation of climate externalities is large relative to profitability, and financial constraints are binding. Public equity investors have broad mandates, explaining why they preferred to scale down rather than sell to private firms. States seem to have a much higher valuation of brown capital, consistent with the existence of social and political considerations, such as stable electricity supply ("energy security") that other investors might not value as highly. Our data suggests that these potential social factors are almost large enough to fully offset climate externalities.[7] That can explain why these investors scaled down less than public equity investors. Domestic states have a broad mandate while foreign states have a "narrow mandate", meaning states highly internalize externalities but only within their jurisdiction. That can explain why foreign states sold more to private firms and scaled down less than other investors.

We use the calibrated model to illustrate some of the key economic implications of brown capital reallocation. In particular, we focus on the effects of the rise of "green finance," understood broadly as the increased attention paid by financial institutions to the carbon content of their capital allocation. We argue that, while "green finance" can decrease aggregate emissions, the existence of states as investors is an important limit.

Through the lens of the model, the first effect of a more climate-conscious financial sector is to tighten financial constraints for potential buyers. Interestingly, unlike in traditional models driven by productivity dispersion, trade is not necessarily (socially) efficient if driven by externalities. Retiring units instead of selling them is necessary to decrease aggregate emissions. In that sense, impediments to trade, such as financial frictions, might improve

[7] Note however that we do not want to imply that states always behave as benevolent social planners.

capital allocation, instead of reducing it. This has the flavor of theories of the second-best. Moreover, a second effect is a larger share of investors with broad mandates. Both effects reduce aggregate emissions, but quantitatively investment mandates appear to be the most important. In the counterfactual in which public equity investors have mandates as narrow as foreign states, aggregate emissions are 3pp higher, relative to less than 1pp higher in the counterfactual without financial frictions. Intuitively, financial frictions matter much less when investment mandates are sufficiently broad.

Importantly, we argue that "green finance" not only affects firms' decisions, but also the state's incentives to intervene. While "green finance" can help correct climate externalities and substitute for government intervention to retire plants, we point out that it might also increase incentives to intervene because of social factors. When the state values social factors such as "energy security" relatively more than other investors, that introduces the possibility of nationalization: the state might want to purchases a unit that another owner plans to retire. Through the lens of our model, the incentives to nationalize are the largest when: (i) the value of social factors are large relative to pecuniary profits; as well as (ii) financial frictions are tight; and (iii) firms' mandate are broad, such that firms' incentives to scale down are large. In our calibration, we find that these effects are substantial. As much as a fifth of units retired by public equity investors are potential targets for nationalization (representing about 11% of initial emissions). However, incentives to intervene are dramatically smaller in the counterfactual with no financial frictions and narrow mandates: in that case the number of targets is two times smaller.

The state has incentives to undo some of the effects of climate-conscious investors if it believes climate-conscious investors do not sufficiently value some social factors. This is consistent with the recent nationalization in Poland, a country heavily reliant on coal in its energy mix. In 2023, the government announced that it will purchase all coal power plants held by publicly traded companies in order to release the market pressure to close them, spending close to \$4 billion of taxpayer money on brown assets.[8] At a macroeconomic level, it is thus important that capital leaving brown sectors actually funds alternative locally, in order to mitigate incentives for states to intervene in this way.

Related Literature: This paper contributes to several strands of an emerging literature studying how the green transition affects the real economy and capital markets.

First, our empirical analysis sheds light on some new key insights from the theory of socially responsible capital. Broccardo et al. [2022] argue that "exit" (divestment and boycott) can often lead to worse outcomes than "voice" (engagement) investment strategies in a world where companies generate externalities (see also Berk and Van Binsbergen [2021]). We also take the structure of socially responsible investment seriously: Oehmke and Opp [2022] and Green and Roth [2021] show that socially responsible investors that only consider externalities in their own portfolio allocate their capital inefficiently from the perspective of generating impact. Hartzmark and Shue [2023] provide evidence that directing capital away from brown firms and toward green firms may be counterproductive, while Kahn et al. [2023] find that engagement by shareholders can be more effective to reduce carbon emissions by firms than divestment.

Distinguishing between reallocation ("exit") and utilization is difficult with firm-level data alone. In that way, we complement recent work that also uses asset-level data by Duchin et al. [2022] and Andonov and Rauh [2022]. Asset-level data allows us to study the widespread concern that publicly traded firms might respond to environmental pressure by only selling assets. In contrast to Duchin et al. [2022] that studies the asset market for pollutive plants, we find that this is generally not the case for coal plants, in line with Andonov and Rauh [2022]'s study of fossil-fuel power plants in the U.S. This is possibly due to coal investment being explicitly "enemy number 1" for many stakeholders and as such particularly scrutinized. While the goal of this paper is not to explicitly explain the origins of environmental pressure, we relate more generally to works studying how the rise of "green finance" has affected different

[8] Source: "Poland's PGE, Enea, Tauron, Energa get state offers for coal assets", Reuters, July 15, 2023; Link.

investors and stakeholders. Within the coal sector, Green and Vallee [2022] and Sastry et al. [2023] study for example the role of bank lenders.[9]

Second, we uncover a key role of states as investors in fossil fuels. Indeed, another advantage of asset-level data is that it is not restricted to particular firms (say listed firms) or investors (say mutual funds investing in equities). In the data, we find that state ownership is large and has been rising in recent years, in part due to a wave of re-nationalization of coal power plants observed in Germany and Poland. Given that we often associate states with emissions targets, renewable energy subsidies or carbon markets, is there a "paradox" of state ownership? We argue that it is crucial to understand the role of (short-run, local) social considerations, such as jobs and energy security, that states often balance with (long-run, global) climate externalities. While growth in renewable power infrastructure can generate substantial welfare gains [Arkolakis and Walsh, 2023], it is capital intensive and takes significant time to build. Blonz et al. [2023] and Du and Karolyi [2023] document how the energy transition away from fossil fuels caused broad-based negative impacts on communities historically built around these industries. In a global context, countries that are expanding coal capacity, like China and emerging markets, tend to have many state-owned enterprises. Insights gleaned from our European evidence might thus be relevant more generally.

Third, we reveal new insights by incorporating production externalities in classical models of capital reallocation, surveyed in Eisfeldt and Shi [2018]. This allows us to study equilibrium interactions between profit-maximizing, socially responsible investors, and state investors. We also highlight how financial frictions can reduce aggregate emissions and complement Lanteri and Rampini [2023] that focuses on the adoption of clean technology in the presence of financial constraints.

[9] Briere et al. [2023] and Brière et al. [2018] study how large institutional investors vote on shareholder resolutions aimed at mitigating climate externalities. There is also many works investigating how ESG concerns have affected public equity markets [Koijen et al., 2020, Baker et al., 2022, Giglio et al., 2023, Van der Beck, 2021] and bank lending [Kacperczyk and Peydró, 2022, Ivanov et al., 2023, Giannetti et al., 2023].

2 Background and Data

2.1 Coal and the Green Transition

Coal combustion is currently the most carbon-intensive way to produce power. Even compared to other fossil fuels, coal power plants produce significantly more greenhouse gas emissions per unit of output. The International Energy Agency estimates that coal is the single largest source of emissions globally, responsible for as much as a fifth of the total.[10] For example, in the European Union, all top ten largest emitters in 2022 were coal power plants.[11]

For this reason, coal has been at the center of the “green transition,” i.e. efforts to reduce carbon emissions by transforming key sectors of the economy. Phasing out coal power plants is seen as an absolute priority in any scenario projecting a reduction in aggregate emissions. The United Nations Secretary General has dubbed a coal phase-out the "single most important step" in addressing climate change.[12] In Western economics, recent years have also witnessed the multiplication of announcements of government commitments to end coal, in conjunction with increased subsidies for competing renewable energy sources. Coal has also become a major red flag in the rising “green finance” movement after the 2015 Paris Agreement, playing a key role in ESG ratings for instance. As such, many private sector firms made explicit commitments against coal.

In spite of this declining trend, there are nevertheless still many active coal plants in Western economies. This paper investigates who are the ultimate owners of these brown assets (i.e. equity investors) since they have the most say in how plants are run.[13] They are also the most exposed to long-run risk in asset valuation (“stranded assets”). A widespread concern is that some investors might stop at selling brown capital, instead of scaling it down.

[10]Source: "It’s critical to tackle coal emissions," *International Energy Agency*, October 8, 2021, Link.

[11]Source: "Repeat offenders: coal power plants top the EU emitters list," *Ember Climate*, May 23, 2023, Link.

[12]Source: "Statement by the Secretary-General on the announcements by the United States and China on climate action," *United Nations*, September 21, 2021, Link.

[13]Shareholders may engage with firm decision-making through shareholder voting, and also through private communication [Dimson et al., 2015, Azar et al., 2021, Kahn et al., 2023].

This echoes the conceptual distinction between investors choosing to "exit" rather than exercise their "voice." The concern is that exit might only lead to reallocating brown capital across investors and would achieve a limited reduction in aggregate carbon emissions.[14]

We mainly focus on European coal power plants for three reasons.[15] First, Europe is a large historical coal power producer. Second, the European Union is however also at the forefront of the green transition, at least since the Paris Agreement in 2015. The EU has witnessed the most ambitious commitments to emission reduction targets. As a group, the EU announced the "Green Deal" in 2019, followed by the "Fit for 55" initiative which aims to significantly reduce emissions by 2030. All EU governments have an explicit timeline for a coal phase-out. Second, there is a wide range of firm ownership patterns in Europe and all main types of investors play an important role. Many coal power producers are publicly traded, with a mixed ownership composition that include retail, institutional and state investors. There are also an important number of private firms active in the energy sector, backed by private equity investors and wealthy individuals. The reallocation dynamics at play in Europe are thus particularly informative.

We illustrate these points in a global context to situate the EU relative to other countries using data from the Global Energy Monitor. In 2016, the EU was the fourth largest region in terms of coal capacity.[16] It was the region that experienced the largest decline in coal capacity since then, at about -25%, as shown in Figure IA.2 in the Internet Appendix. North America was the only other region that experienced a decline. Moreover, the distribution of coal firms' ownership in the EU is also particularly interesting. Table IA.1 in the Internet Appendix shows the average share of state investors' ownership for the ten largest coal power producers in four regions: the United States, the EU, China, and India. While the US has a low average state investor share (10%), it is much higher in China (80%). Interestingly, Europe sits in

[14]More generally, this relates to concerns over "greenwashing", i.e. when words are not followed by the appropriate actions.

[15]Section 3.2.1 provides some results for the United States.

[16]The top 4 were: China 50%, US and Canada: 15%, India: 10%, EU and UK: 8.2%, according to GEM data.

the middle with about 30%. Table IA.2 in the Internet Appendix also shows that Europe has a much more varied ownership structure relative to the United States or China. The US is dominated by publicly traded companies with virtually no state ownership, while China is dominated by state-owned enterprises. In contrast, large coal power producers in the EU include a mix of publicly traded firms with low and high state ownership shares, as well as multiple private firms. India has a comparable mix of ownership structure to the EU.

2.2 Data

2.2.1 Coal Power Plants

The primary dataset on coal power plants used in this paper is the coal plant database from Beyond Fossil Fuels ("BFF data"), which tracks coal power plants in the EU (including UK) from 2015-2022. In the Internet Appendix, we also rely on coal power plant data from the Global Energy Monitor (GEM) for summary statistics on coal plants outside the EU. While GEM also tracks coal plants in the EU, the BFF data provides greater quality detail on plant ownership and data on actual CO2 emissions for plants in the EU.

The BFF data contain information such as the location, generation capacity, operational status, announced retirement year, owner names, and realized CO2 emissions for each coal plant. Coal plants may contain one or more coal units that contribute to the generation capacity of the plant. In total, the database tracks 356 plants and contains 2,837 plant-year observations. A total of 136 firms who have ownership stakes in coal plants are represented in the data. The NGO Beyond Fossil Fuels researches each individual data point, collecting information from a wide variety of sources, including but not limited to government publications and news articles. In the BFF data, the plant generation capacity represents the amount of electricity the plant can produce at maximum power, while the CO2 emissions produced by the plant provides a measure of the actual utilization of the plant. The CO2 emissions reported in the BFF data are annual realized CO2 emissions for each coal plant, which are sourced from the European Union Emissions Trading System (EU ETS).[17] CO2 emissions data from the EU ETS are subject to monitoring and verification.[18]

2.2.2 Firm-Level Shareholder Data

For firms that are publicly-traded, we collect detailed data from S&P Capital IQ on their equity investors, from 2015-2022.[19] The investor data from Capital IQ include the shareholder's name, percentage of total shares outstanding owned, shareholder type, and whether the shareholder has an active or passive investment style. The shareholder type distinguishes whether the shareholder is a state investor or (non-state) institutional investor.[20] State investors may be state or local governments, or entities owned by state or local governments. The residual investors that are not listed in Capital IQ are assumed to be retail investors. For firms that are not publicly traded, we manually collect information on the percentage of shares that are privately held or state-owned using sources such as annual reports or press releases.

This process allows us to classify investors for each firm at calendar year-end from 2015-2022 into three investor groups: (i) public equity investors, (ii) private equity, and (iii) state investors. Public equity investors include retail or institutional investors in publicly traded firms. State investors include state-owned shares in both publicly traded firms and non-

[17] In the BFF data, values for CO2 emissions for the most recent year of 2022 are incomplete. We use EU power plant emissions data from EMBER to supplement the CO2 emissions data in 2022. EMBER data is also derived from the EU ETS.

[18] Source: "Monitoring, reporting and verification of EU ETS emissions," *European Union Directorate-General for Climate Action*; Link

[19] We will make two comments here. First, some publicly traded firms may have other firms as a large shareholder. For example, E.ON owned 46.65 % of Uniper in 2017. When this occurs, we treat the shareholders of the investing firm as shareholders of the focal firm. The shareholder percentage is determined by multiplying the proportion of shares held by the investing firm in the focal firm with the proportion of shares held by the shareholder in the investing firm. Second, if a firm is acquired, the BFF data continues to associate the target firm with its pre-acquisition plants. For example, the Polish state-controlled power company PGNiG was acquired by another Polish power company Orlen before the end of 2022; the two coal plants originally owned by PGNiG continue to be recorded as owned by PGNiG at the end of 2022. Post-acquisition, we assign the shareholder structure of the acquiring company (Orlen in this example) to the target company (PGNiG). Thus, we treat acquisitions are events of financial reallocation (trading shares), rather than real reallocation (trading plants across firms).

[20] There is a small percentage of investors who are classified as "individual/insiders" or whose type is unclassified by Capital IQ. For large unclassified investors, we manually assign them to be a state or institutional investor. The remaining unclassified shareholders and individual/insiders, who together own $< 0.1\%$ of annual aggregate CO2 emissions, are collectively categorized into the institutional investors category.

publicly traded firms.

In all cases where a shareholder is a state investor, we manually code the country of location of the state or local government investor. This, combined with the location of a coal plant, allows us to classify state-owned shares as domestic or foreign. Domestic state investors are defined as state or local governments who are located in the same country as the coal plant they own. We also use Capital IQ's classification of passive investment style to explore heterogeneity within the public equity investor group. A portion of institutional investors do not have an active or passive classification. These investors are generally non-traditional investment managers such as charitable foundations or private corporations and represent ownership of around 3% of annual aggregate CO2 emissions.

The coal power plant data gives us each firm's percentage ownership in each plant (real-side), and the firm-level shareholder data gives us the percentage ownership of each investor category in each firm (financial-side). Combining the two datasets provides us with a bottom-up measure of percentage ownership of each investor category in coal plants. It allows us to determine the percentage of CO2 emissions and coal capacity associated to and owned by each investor category, based on their ownership in these coal plants.[21]

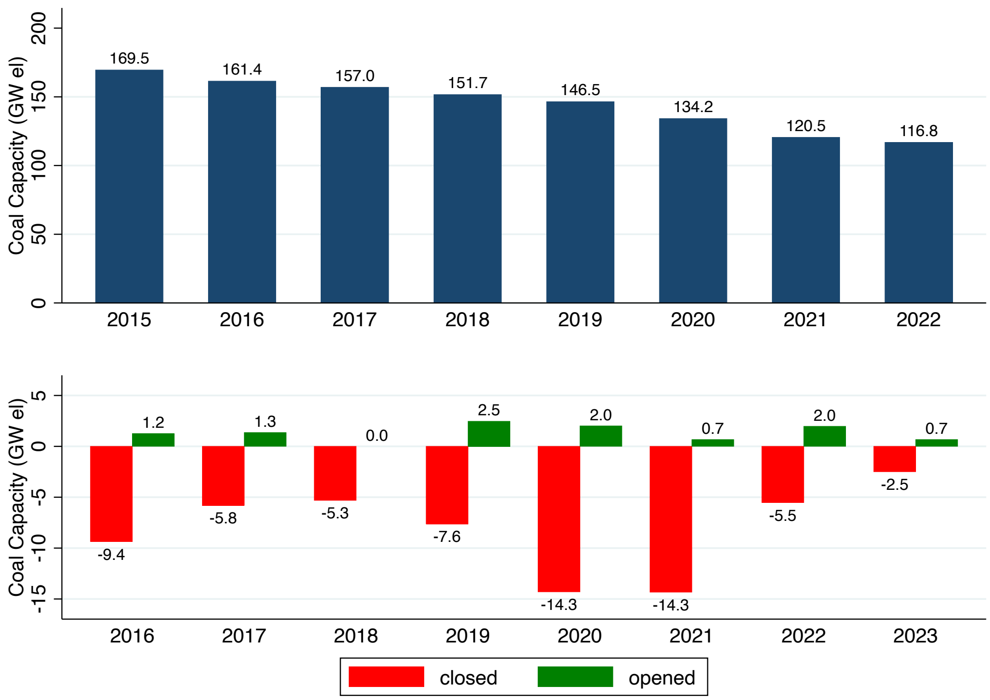
2.3 Coal in Europe

To motivate the main analysis, we present a few stylized facts about coal in Europe through the lens of our micro-data. Figure 1 illustrates the decline in aggregate coal power capacity driven by many power plant closures during our sample period.[22] Figure IA.4 and IA.5 in the Internet Appendix break down emissions in 2021 across countries and firms, respectively. Plants in Germany and Poland represent almost 75% of all EU coal emissions, followed by the Czech Republic. As a motivation for looking at ownership dynamics across investor groups, it is interesting to look at the three largest firms: PGE (Polish), RWE (German), and EPH

[21] Select consolidated versions of the data used in this study are made available online [Link].

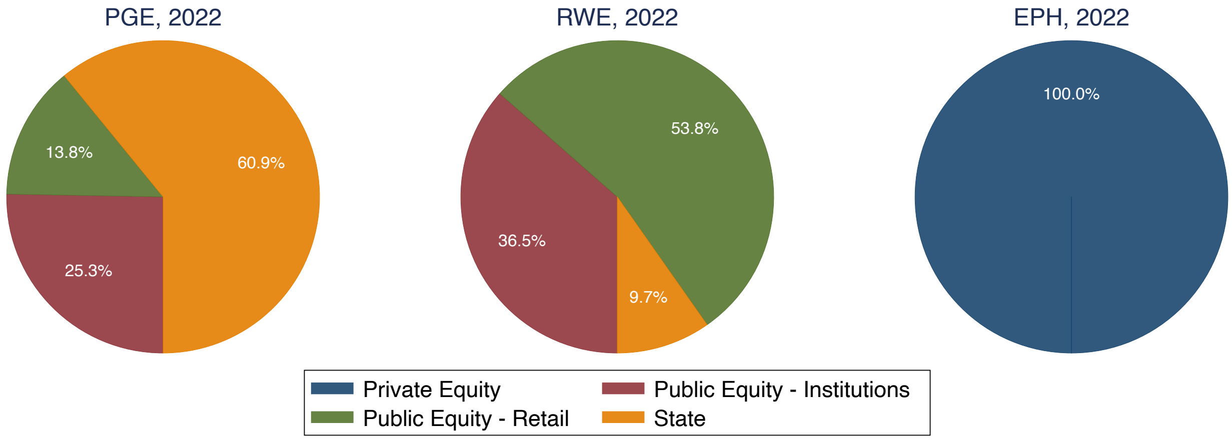
[22] Figure IA.3 in the Internet Appendix shows that the ownership of coal capacity changed very little in European countries outside of the EU. Power producers are all either private or state-owned, with virtually no change in coal ownership share between these groups.

Figure 1: Coal Capacity of Open Plants in the EU, 2015-2022



The top panel shows the aggregate coal capacity across all open coal plants in the EU and UK, as recorded at the end of each year from 2015 to 2022 in the BFF data. The bottom panel shows increases or decreases in aggregate coal capacity in each year, which may result from the opening or closure of entire coal plants or operational units within coal plants. The aggregate coal capacity for year t is equivalent to the aggregate coal capacity for year $t-1$, adding any coal capacity opened in year t and subtracting any coal capacity closed in year t.

Figure 2: Investor Composition for PGE, RWE, and EPH, 2022



Shares of the four investor categories are based on the investor composition of each firm as of December 31, 2022. PGE and RWE are publicly-traded firms, whose shareholder information are from Capital IQ. EPH is entirely privately-owned.

(Czech). Figure 2 shows that they have very different ownership structures. PGE is a publicly traded company but is 61% owned by the Polish state. In contrast, RWE is publicly traded but is only 10% owned by state investors. EPH differs from both, being 100% private.[23] Figure IA.6 in the Internet Appendix also shows that these three firms experienced very different trajectories in their carbon emissions over our sample period: RWE has reduced its emissions significantly more than PGE, while EPH's emissions have increased in contrast.

3 Coal Ownership Dynamics

3.1 Aggregate Dynamics: 2015-2022

We start by documenting aggregate dynamics across three main categories. We classify each investor as belonging to one of three investor groups: (i) public equity investors, (ii) private equity, and (iii) state investors. Later tests use more granular categories and study heterogeneity within these groups. For investor group g, define their coal ownership share across all

[23] EPH is almost entirely owned by Czech billionaire Daniel Kretiznky.

plants i:

$$\text{Ownership share}_t^g = \frac{\text{aggregate group-owned emissions}_t}{\text{aggregate emissions}_t} = \sum_i \omega_{i,t}^g \frac{e_{i,t}}{E_t} \qquad (1)$$

In this formula, $e_{i,t}$ is the emissions of plant i at date t, which is a measure of scale of operations, with aggregate emissions being $E_t = \sum_i e_{i,t}$. $\omega_{i,t}^g$ is investor g's ownership share of plant i at date t, which is the product of the firm share of the plant times the investor share of the firm.

Figure 3 illustrates aggregate ownership dynamics. There is a large rise in private equity ownership of 12 percentage points, more than doubling its share during our sample period from 9% to 21%. This rise is matched with a decline in other investor groups ownership shares. In particular, there is a large decline in the share of public equity investors of 9 percentage points, from 45% to 36%. There is also a smaller decline in state ownership of 4 percentage points, from 46% to 43%.[24]

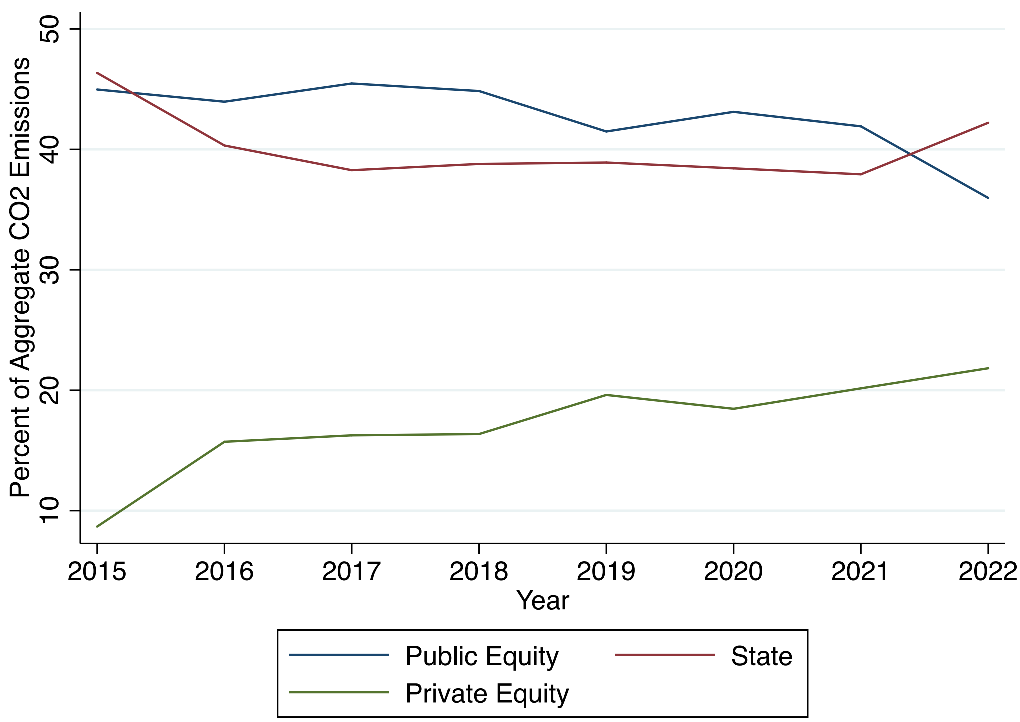
The aggregate trends however mask the origin of these dynamics. For instance, did public equity investors sell to private firms or did they scale down their plants faster than other investors? To answer this question, we next introduce a decomposition that will be at the heart of our empirical analysis.

3.2 Decomposition: Capital Reallocation vs. Capital Utilization

We introduce a formal decomposition of ownership changes that distinguishes between *capital reallocation* and *capital utilization*. Indeed, an investor can reduce its coal ownership by selling assets, or by scaling down its plants, or both. There is an analogy between this empirical decomposition and the conceptual distinction between investors choosing between "exit" and "voice." Choosing to exit implies divestment, i.e. selling brown assets to another party. Exercising one's voice implies taking action to change firm behavior, i.e. scaling down

[24] We discuss the recent rebound in state ownership in Section 4.

Figure 3: Ownership of CO2 Emissions in the EU, 2015-2022



This figure shows the share of annual aggregate CO2 emissions in the EU owned by each of three main investor categories. Coal plant data are from Beyond Fossil Fuels. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research.

existing plants.

Formally, the ownership share of investor group g can change between t_0 and t because ω_i^g (plant ownership) changes and/or e_i (plant scale) changes:

$$\Delta_{t_0 \to t}\text{Ownership share} = \sum_i \omega_{i,t}^g \frac{e_{i,t}}{E_t} - \omega_{i,t_0}^g \frac{e_{i,t_0}}{E_{t_0}} \tag{2}$$

$$= \sum_i (\omega_{i,t}^g - \omega_{i,t_0}^g)\frac{e_{i,t_0}}{E_{t_0}} + \sum_i \omega_{i,t_0}^g (\frac{e_{i,t}}{E_t} - \frac{e_{i,t_0}}{E_{t_0}}) + \sum_i (\omega_{i,t}^g - \omega_{i,t_0}^g)(\frac{e_{i,t}}{E_t} - \frac{e_{i,t_0}}{E_{t_0}})$$

This is an exact decomposition of change in ownership share that includes three terms:[25]

1. **Capital reallocation** $\sum_i (\omega_{i,t}^g - \omega_{i,t_0}^g)\frac{e_{i,t_0}}{E_{t_0}}$**:** Keeping plant scale constant, how much did changes in plant ownership contribute to the change in ownership share?

2. **Capital utilization** $\sum_i \omega_{i,t_0}^g (\frac{e_{i,t}}{E_t} - \frac{e_{i,t_0}}{E_{t_0}})$**:** Keeping plant ownership constant, how much did changes in plant scale contribute to change in ownership share?

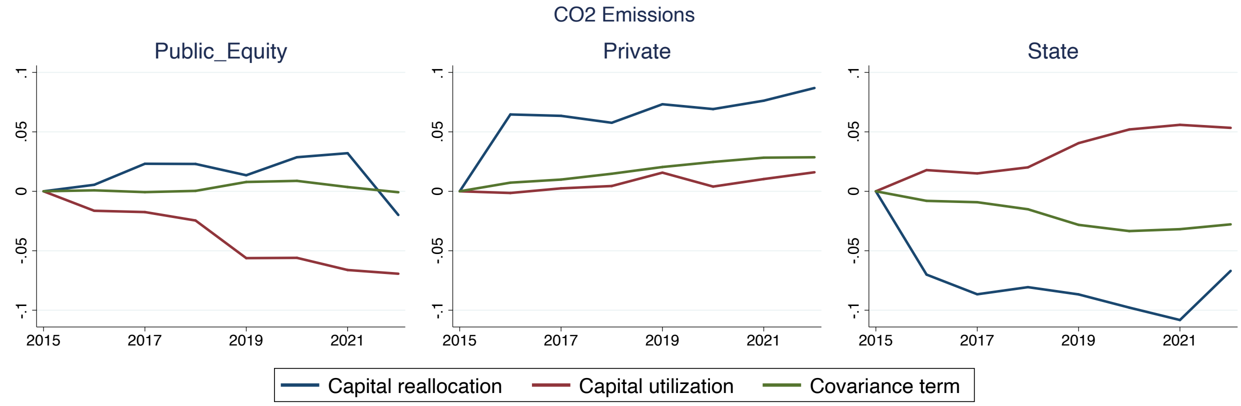
3. **Covariance term** $\sum_i (\omega_{i,t}^g - \omega_{i,t_0}^g)(\frac{e_{i,t}}{E_t} - \frac{e_{i,t_0}}{E_{t_0}})$**:** The effect of changing ownership exactly at plants that changed scale. This is often the smallest term empirically.

This decomposition reveals that aggregate trends mask striking patterns, as illustrated in Figure 4. Perhaps surprisingly, the left panel shows that the decline in public equity investors' ownership was entirely driven by a quick decline in utilization, not reallocation, i.e. the capital reallocation term is not negative. In other words, these investors have been closing or scaling down plants faster than other investors, and not selling to them. There is thus little evidence of "exit" of public equity investors in coal. (We discuss in detail the 2022 drop in public ownership share in a later section – we will see it differs from traditional "exit").

This evidence sheds light on the widespread concern that firms, especially listed corporations, might respond to environmental pressure by only selling assets. We find that, in the

[25]The decomposition requires a balanced panel of units. For units that closed before the end of our sample, we set their owners at the time of closure to be their owners in subsequent periods and set their emissions to zero. For units that were created after the beginning of our sample, we set their owners at the time of creation to be their owners in prior periods and set their emissions to zero.

Figure 4: Capital Reallocation versus Capital Utilization



Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in the EU over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

case of coal, this is generally not the case: public equity investors are the group of coal owners that most aggressively scaled down since the Paris Agreement. This contrasts with the evidence on pollutive manufacturing plants in Duchin et al. [2022]. This is possibly due to the nature of coal being explicitly "enemy number 1" for many stakeholders and as such particularly scrutinized. Indeed, many NGOs publish lists of institutions active in coal, such as the "Global Coal Exit List" regularly updated by Urgewald and its forty partner organizations. Our evidence is consistent with the case of fossil fuel plants in the United States [Andonov and Rauh, 2022].

Instead, the decomposition makes it clear that state investors played a crucial role in the rise of private ownership. The right panel first shows that they have a very large negative reallocation term, indicating that they sold coal assets during this time. This is comparable to the very large positive reallocation term for private firms in the center panel. This implies that state investors were the ones that sold to private firms and choosing to "exit." The right panel also shows a very large positive capital utilization term, which means that state investors have been the slowest group to scale down their plants. Both of the facts suggest that states (as investors) have contributed to slowing down the transition away from brown capital.

This figure also makes clear how much aggregate dynamics masks the underlying patterns. In particular, we can estimate how ownership dynamics would have evolved in the absence of asset sales to other investors, i.e. without brown capital reallocation. This corresponds to the red lines of capital utilization. The private equity share would have increased by only 1pp instead of doubling. The share of public equity investors would have still fallen by 7pp but at the expense of an almost equal *rise* in state investor share, entirely driven by a failure of states to scale down plants as fast as public equity investors.

3.2.1 Additional Results

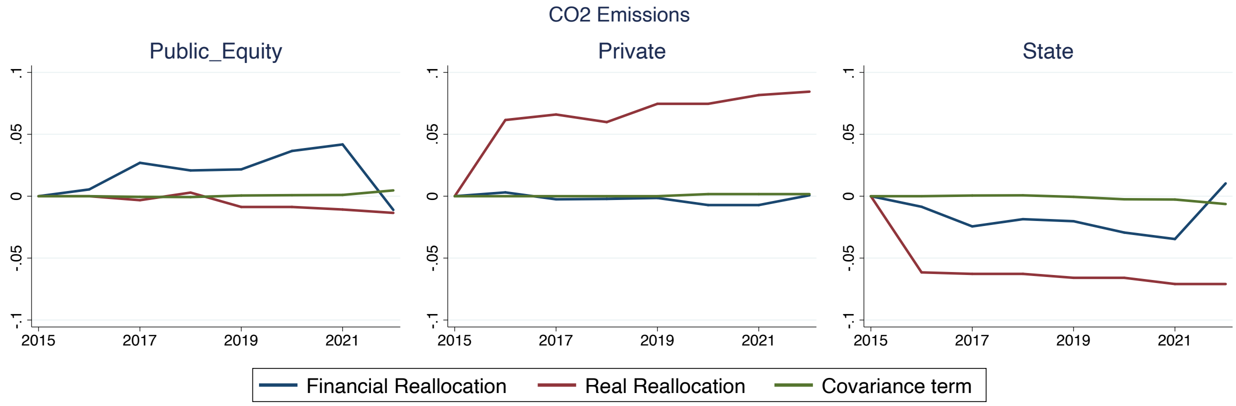
Plant age: One potential concern is that differences between investors only reflects differences in technological obsolescence of their initial capital.[26] To address this concern, we repeat the decomposition separately for sub-samples of units of similar age in Figures IA.8, IA.9, and IA.10 in the Internet Appendix. We confirm that our key facts are not purely driven by composition effects across investors. There is nevertheless some intuitive heterogeneity across plants of different age: there is less reallocation among old units (which are more likely to be retired), and less difference in utilization across young units (which are less likely to be retired).

Real vs. Financial Capital Reallocation: We can also use our data to quantify the relative contribution of real reallocation versus financial reallocation to capital reallocation, i.e. how much of investors' sale of assets comes from trading plants vs. trading shares. Formally, investor group g ownership of plant i is the product of ownership of firm f and firm f's ownership of plant i: $\omega^g_{i,t} = \sum_f \omega^g_{f,t}\omega^f_{i,t}$.

We can thus further decompose the capital reallocation term between financial reallocation

[26] Figure IA.7 in the Internet Appendix shows unit age across investor groups.

Figure 5: Financial Reallocation versus Real Reallocation



Each panel shows the three terms in the decomposition in equation (3) for a given investor group, across all plants in the EU over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

(across investors) and real reallocation (across firms), plus a covariance term:

$$\sum_i (\omega^g_{i,t} - \omega^g_{i,t_0}) \frac{e_{i,t_0}}{E_{t_0}} = \underbrace{\sum_i \sum_f (\omega^g_{f,t} - \omega^g_{f,t_0}) \omega^f_{i,t_0} \frac{e_{i,t_0}}{E_{t_0}}}_{\text{financial reallocation (trade shares across investors)}} + \underbrace{\sum_i \sum_f \omega^g_{f,t_0} (\omega^f_{i,t} - \omega^f_{i,t_0}) \frac{e_{i,t_0}}{E_{t_0}}}_{\text{real reallocation (trade plants across firms)}} + \underbrace{\sum_i \sum_f (\omega^g_{f,t} - \omega^g_{f,t_0})(\omega^f_{i,t} - \omega^f_{i,t_0}) \frac{e_{i,t_0}}{E_{t_0}}}_{\text{covariance term}} \tag{3}$$

Figure 5 reveals that there were diverging patterns of real versus financial reallocation across investors. Private firms bought plants from states, while until 2022 public equity investors bought shares from states. We discuss the 2022 reversal in more detail below in the context of (re)nationalizing brown assets.

Permanent versus temporary closure: Emissions of a plant can decrease either because of (i) permanent closure (a decline in generation capacity) and/or (ii) temporary scaling down (a decline in the emission rate per unit of open capacity). In the aggregate, it is clear that both channels matter, since emissions declines by about 50% but capacity only decreased by about 25%. Figure IA.13 in the Internet Appendix shows that is generally true for investors groups that decreased their emissions.[27] There is a rebound in emissions post-2020 that we discuss in more detail below.

Across Countries: To investigate geographical differences, we separately look at ownership dynamics in three regions: Germany, Poland (the two largest emitters of CO2), and the rest of the EU. Figures IA.14, IA.15 and IA.16 in the Internet Appendix illustrate the results. We find that virtually all reallocation in Europe, whether of plants or shares, occurred for German plants. Moreover, unlike in Poland, public equity investors in German plants did not scale down faster than other investors. The largest decline in public equity ownership is observed in the rest of the EU, with a decline of almost 20 percentage points, almost entirely driven by a decline in utilization.

Heterogeneity Within Public Equity Investors: We can also look at ownership dynamics within public equity investors, since they have experienced a striking decline in their ownership share. In particular, large passive investors like Blackrock and Vanguard have faced significant and repeated pressure in the past decade to account for carbon emissions in their portfolios. One might expect that such "universal" investors might have played a large role, in part because they often claim to use their voice to influence corporate management

[27] For this, we decompose the capital utilization term in three further terms, with the modification that we measure plant scale by the level of its emission ($e_{i,t}$) rather than its share relative to the total ($e_{i,t}/E_{i,t}$). Formally, the emissions of plant i are the product of its capacity k (driven by closure/opening of units) and emission rate r (how much CO2 per unit of capacity): $e_{i,t} = k_{i,t} r_{i,t}$. The capital utilization term can thus itself be divided into an exact sum of three terms:

$$\sum_i \omega^s_{i,t_0}(e_{i,t} - e_{i,t_0}) = \underbrace{\sum_i \omega^s_{i,t_0}(k_{i,t} - k_{i,t_0}) r_{i,t_0}}_{\text{capacity changes}} + \underbrace{\sum_i \omega^s_{i,t_0} k_{i,t_0}(r_{i,t} - r_{i,t_0})}_{\text{emission rate changes}} + \underbrace{\sum_i \omega^s_{i,t_0}(k_{i,t} - k_{i,t_0})(r_{i,t} - r_{i,t_0})}_{\text{covariance term}} \tag{4}$$

due to a lesser ability to re-allocate their equity portfolio (making "exit" difficult).

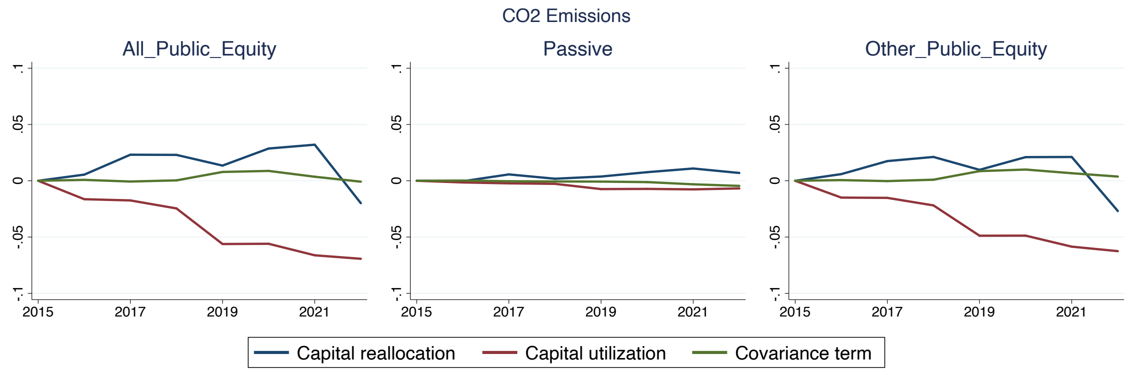
To investigate this question, we separate the public equity investor group between passive institutional investors and the rest, using investor classifications from Capital IQ. Applying our decomposition to these subgroups, we see that the decline in utilization is not in fact more pronounced for passive institutional investors. Figure 6 illustrates this heterogeneity: passive investors do not drive the negative capital utilization term over our sample period. In terms of aggregate ownership, Figure IA.17 in the Internet Appendix confirms that the share of passive investors has been extremely stable at 5% over the entire period. The aggregate decline in public equity ownership of 9 percentage points is *entirely* driven by other equity investors, whose share has fallen by from 40% to 31%. While large passive investors generally tend to vote in favor of managing climate externalities in firms they invest in [Briere et al., 2023], our evidence revealed that this had no noticeable effect on the coal power production industry, the most carbon-intensive sector in the world. The rise of large "universal investors" over the past decades might thus not have accelerated the phase-out of brown capital.[28]

Debt vs. Equity: This paper focuses on equity ownership, but we provide a brief analysis of capital structure by including micro-data on firms' debt. We collect data on debt structure from Capital IQ for firms in our sample and divide financial liabilities into four groups: (i) equity (ii) bank debt (iii) bonds (iv) other debt.[29] We apply our decomposition to these four groups as shown in Figure IA.18 in the Internet Appendix. We see that over time there have been a de-leveraging of coal assets, with a rise in equity relative to debt. The decline is debt is entirely due to a fall in bond financing from capital markets. In fact, bank debt has been

[28]In recent years, BlackRock and especially Vanguard seem to have stepped back their environmental commitment. Vanguard for instance left the Net Zero Asset Managers initiative in December 2022. Both firms also reported a substantial increase in rejections of ESG shareholders proposals. Source: "BlackRock and Vanguard were once ESG's biggest proponents–now they seem to be reversing course", Fortune, September 13th, 2023; Link.

[29]The value of bank debt includes the value of revolving credit, term loans, lease liabilities, trust preferred securities, general and other borrowings. The value of bond debt includes the value of commercial paper, senior bonds and notes, and subordinated bonds and notes. The value of other debt includes the value of debt whose category is unknown, firms for which we do not have data on their debt structure, and adjustments to debt. The ownership percentage of each group is determined based on the group's value, with the value of equity determined by market prices for publicly listed firms and book equity for other firms.

Figure 6: Capital Reallocation versus Capital Utilization: Public Equity Investors



Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in the EU over the period 2015-2022. The *Passive* category and reflects investors whose investment style is labeled by Capital IQ as passive, respectively. The *Other Public Equity* category reflects public equity investors that are not labeled by Capital IQ as passive. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

rising moderately during this time. This shift in debt structure is consistent with some of the findings of Walz [2022] and Luneva and Sarkisyan [2022].

Comparison with the U.S.: While the focus of this paper is on Europe, we provide a brief comparison with the U.S.[30] Overall, we find dynamics that are in line with the EU, but with significantly smaller magnitudes, as shown in Figure IA.20 and IA.21 in the Internet Appendix. Public equity ownership has declined by about 5pp, while ownership by private firms, governments, and cooperatives increased slightly. Our decomposition shows that there was no "exit" by public equity investors: capital utilization explains the decline. On the other hand, governments and cooperatives were also slower at scaling down their plants. The key difference with Europe is the absence of significant capital reallocation and private ownership has barely increased, in line with the evidence of Andonov and Rauh [2022]. Note that there is no obvious U.S. analog to prone-to-exit foreign state investors.

[30]We collect data on the universe of coal power plants, as well as their CO2 emissions and owners from the EIA's Form EIA-860 and the EPA's Greenhouse Gas Reporting Program (GHGRP). We use the same procedure as in Europe to match firms to their investors using Capital IQ. For reference, Figure IA.19 in the Internet Appendix show that between 2014 and 2022 aggregate U.S. coal capacity and emissions have declined by 36% and 47%, respectively.

4 State Ownership of Brown Capital

4.1 Foreign vs. State Investors

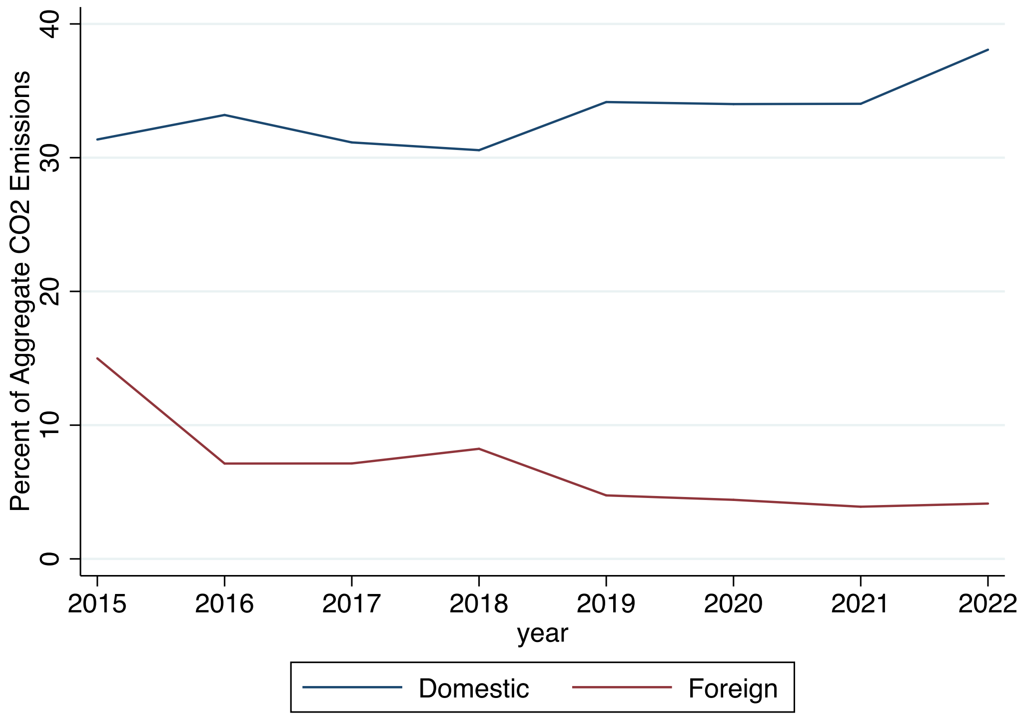
States are strikingly large investors in coal and it is crucial to understand what drives their behavior. To this end, this section investigates the behavior of state investors and find striking differences between domestic and foreign state investors. We define a state investor as domestic if it is affiliated with a local or state government in the same country as the plant it owns. For example, if Swedish state-owned utility Vattenfall owns a plant in Germany, its ownership would count toward the foreign state investor share, but if it owns a plant in Sweden, it would count toward the domestic state investor share.[31]

Figure 7 shows foreign states have massively decreased their ownership share over our sample period. It fell by as much as 10 percentage points, from 15% to 5%, dividing their ownership share by three. In contrast, domestic states have massively increased their ownership share. It increased by 6 percentage points, from 31% to 38%. The relatively stability in the aggregate state investor share masks these sharp differences.

Our decomposition reveals what led to these diverging paths. Figure 8 shows that foreign state investors decreased their ownership purely via reallocation: they sold assets to private firms. Domestic state investors in contrast were the slowest to scale down their existing plants, implying a large rise in their ownership share. In fact, their aggregate ownership generally underestimates this effect since they have been selling assets to public equity investors at the same time (with a partial reversal in 2022). Absent reallocation, their ownership share would have increased much more rapidly. Figure IA.12 in the Internet Appendix unpacks the role of real vs financial reallocation: foreign states sold plants to private firms, while domestic states sold shares to public equity investors.

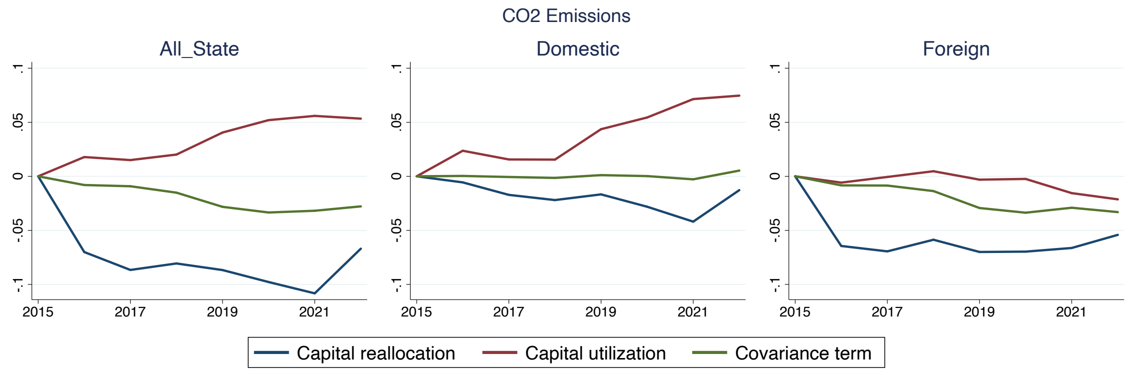
[31] Figure IA.11 in the Internet Appendix lists the largest foreign state investments in firms in our sample.

Figure 7: Ownership of CO_2 Emissions by Foreign and Domestic States in the EU, 2015-2022



This figure shows the annual percentage of aggregate CO_2 emissions that is owned by foreign and domestic state investors. A state investor in a plant is considered domestic if it is affiliated with a local or state government that is located in the same country as the plant it owns. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure 8: Capital Reallocation versus Capital Utilization: State Investors



Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in the EU over the period 2015-2022. The *All State* category reflects all state investors. The *Domestic* category reflects only domestic state investors. A state investor in a plant is considered domestic if it is affiliated with a local or state government that is located in the same country as the plant it owns. The *Foreign* category reflects only foreign state investors. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

4.2 Key Episodes

States are large investors and have been involved in a number of key transactions since 2016. Delving deeper in these episodes is extremely informative about the underlying economics, which we formalize in a model in the next section.

The E.ON-Uniper Asset Split: In 2016, Germany energy giant E.ON finalized an asset split between its renewable and distribution services on the one hand and fossil fuel power generation on the other. All fossil fuel plants were transferred to a large new entity called Uniper, with a market capitalization of $11B in 2017. E.ON executives argued the split would make both companies more "agile" in "dramatically altered energy markets". E.ON CEO said: "This liberates us from continually having to make compromises."[32]

Who purchased Uniper once it became listed as an independent public firm? Fortum, a state-controlled Finnish utility, eventually acquired a full controlling stake after a takeover bid

[32]Source: "E.ON completes split of fossil fuel and renewable operations", The Guardian, January 4th, 2016; Link.

was accepted in 2018. It initially purchased 50% of Uniper's stock, a share that increased to 75% in 2020.[33] Figure IA.22 in the Internet Appendix shows the ownership dynamics of each firm. Soon after the 2016 split, the two firms started to diverge sharply: the state ownership of Uniper increased fast, while it stayed very low in E.ON. By 2022, Uniper is in fact fully state-owned, after a separate episode we describe in more detail below.

The Vattenfall Sale to EPH: While cross-border state investments in coal were historically large in Europe (Fortum being a key example), they have shrunk considerably in recent years.[34] Conceptually, this evidence is informative about how state investors seem to value brown capital. By far the most striking case is Vattenfall, a Swedish state-owned utility. Vattenfall was the largest foreign state investor in coal in 2015, with notably a very large presence in Germany, accounting for nearly 10% of German coal emissions alone. In 2016, Vattenfall announced the sale of the vast majority of its German plants to the Czech private firm EPH. Vattenfall cited a willingness to improve its "corporate CO2 profile" and was gradually divesting from fossil fuels in accordance with a corporate commitment to CO2 neutrality by 2050. Nevertheless, the sale generated some backlash from commentators:

Asked whether greening Vattenfall's CO2 balance sheet would have any positive impact on the climate if it was achieved by simply selling its portfolio of lignite coal-fired power plants to another corporation, [CEO] Müller said the operation of coal-fired power plants was a matter of political policy and not within Vattenfall's bailiwick.[35]

This seems to suggest that state investors put some (negative) value on climate externalities generated by brown assets, but only at home. In the parlance of Oehmke and Opp [2022], they seem to have a "narrow" mandate. For states, it is not difficult to imagine that their accountability lies mainly within the limits of their jurisdiction.

[33]Source: "Finland's Fortum to gain control of Uniper in $2.5 billion deal", Reuters, October 8th, 2019; Link.

[34]Figures IA.23, IA.24, and IA.25 in the Internet Appendix visualizes this decline with a heat map: off-diagonal foreign state investment has fallen over time.

[35]Source: "Vattenfall sells German coal business", DW, April 18, 2016; Link.

The 2021-2022 Energy Crisis: From the post-COVID recovery, electricity prices started to increase, with rising gas prices making coal more competitive. Gas generation decreased 5% across the EU in 2021 with coal increasing by 20%.[36] The energy sector entered a fully-fledged crisis in 2022 in Europe with the Ukrainian conflict and the drastic decline of Russian gas imports. The switch to coal that ensued led to an *absolute increase* in coal emissions after years of steady decline, as shown in Figure IA.26 in the Internet Appendix. This implies an increase in aggregate capital utilization during this period.[37] The rebound occurred in all regions and for all investor groups.

Which investors increased utilization the most? Our decomposition is helpful to purge the effect of reallocation, and Figure IA.27 in the Internet Appendix finds the sharpest increase in utilization for domestic states. This suggests that the supply of alternatives is a key driver of brown capital phase-out. A shortage accelerates state ownership. The next section shows that beyond utilization, increased reallocation also contributed to rising state ownership during this period.

Recent Wave of Re-Nationalization: 2022 and 2023 witnessed some dramatic episodes of coal (re)nationalization. First, Uniper, which was spun off from E.ON, went bankrupt in 2022 after it could no longer afford to pay for Russian gas imports. It was rescued by the German government in order to keep it operating, it what eventually became the largest corporate bailout in German history. This wiped out many public equity investors in Uniper, explaining part of the reversal observed in 2022. Eventually, it was announced that Uniper would be fully nationalized, costing 8B€ to the German taxpayer, decades after the original state-owned utility was listed on the stock market.[38] "Energy security" was cited as the primary motive for nationalization.

Germany also reverted some of its previous policies in favor of a coal phase-out. Strikingly,

[36] Source: Ember Electricity Review 2022; Link.

[37] Figure 1 shows that aggregate capacity has been declining throughout, so the rebound is driven by an increase in emission rates rather than new capacity additions.

[38] Source: "German Government Nationalizes Uniper in Move to Secure Energy Supply", New York Times, September 22, 2022; Link.

it mandated the re-opening of plants it had previously subsidised to retire early.[39] For example, Uniper was asked to extend the operations of its Heyden 4 plant with capacity of 875 MW in order to secure enough energy supply. The Heyden 4 plant had ceased operations after receiving a subsidy in a government tender in 2020.[40]

More recently, the Polish government announced in 2023 that it will purchase all coal power plants held by publicly traded companies in Poland. This amounts to spending close to $4 billion of taxpayer money on brown assets, in order to release the market pressure to close them.[41] The role of financial pressure was clear, with the government stating that "financial institutions have been limiting their involvement in financing entities with coal assets" and the CEO of PGE, the largest owner of coal plants in Europe, saying that the nationalization would help his firm with "obtaining financing for investments." The Polish government justification was to avoid a decrease in local energy supply: "[The new public institution owning coal assets] will guarantee energy security."[42]

Takeaways: Typically, we tend to think of the role of states in the green transition (at least in the EU) through the lens of emissions targets or the introduction of renewable energy subsidies and carbon markets, i.e. a role that tends to reduce brown capital. Is there thus a "paradox" of rising domestic state ownership?

We argue that these episodes make it clear that it is crucial to understand the role of (short-run, local) social factors that states often balance with (long-run, global) climate externalities. These potential social factors include a desire to keep energy prices low ("energy security"), but also local jobs and income. Indeed, there is evidence that a transition away from fossil fuels can cause broad-based negative impacts on local communities historically built around these industries [Blonz et al., 2023, Du and Karolyi, 2023]. This will be an important ingredient in

[39]Source: "Germany Reopens Coal Plants Because Of Reduced Russian Energy", Forbes, July 8, 2022; Link.

[40]Source: "Uniper extends market operation of Heyden 4 and Staudinger 5 hard coal-fired power plants", Uniper, December 22, 2022; Link.

[41]Source: "Poland's PGE, Enea, Tauron, Energa get state offers for coal assets", Reuters, July 15, 2023; Link.

[42]Source: "Polish government outlines offer to buy coal assets from state energy firms", Notes from Poland, July 17, 2023; Link.

our model below. Note however that we do not necessarily want to imply that states always behave as benevolent social planners.

Moreover, states are also less affected by financial pressure relative to corporations, as they have deeper pockets with an ability to tax and borrow in their name. They might also be less concerned about the risk of tighter future regulation or taxes since they can make or influence the legislation. It is also worth noting that, in a global context, countries that are expanding coal capacity, such as China and other emerging economies, tend to have many state-owned enterprises. On the other hand, the two regions with declining coal capacity, the EU and North America, have a much lower share of state ownership. At a global level, it is thus clear that the state ownership of coal assets is on the rise. Insights gleaned from our European evidence might thus be relevant more generally.

5 The Economics of Brown Capital (Re)Allocation

5.1 Overview

To understand the economics of brown capital reallocation, we develop a parsimonious model with one key difference with traditional models: externalities in production. The presence of externalities will generate a number of new insights. We then calibrate the model to the data and conduct some counterfactual analysis to draw implications for the rise of "green finance" and how it interacts with government intervention, in particular nationalization.

Our model has three main ingredients, informed by the evidence above. First, owners differ in how they value externalities associated with brown capital. Typical models instead focus on differences in productivity: some owners are better at operating a unit of capital. Our baseline model assumes away such productivity differences to focus on the role of externalities. Dispersion in asset valuation generates incentives to trade (regardless of whether they originate in productivity or externalities).

Second, there are financial frictions in the acquisition of new capital. While this is a common impediment to trade in traditional models, their effects are particularly interesting in the presence of externalities. Indeed, trade is not necessarily (socially) efficient if driven by externalities. Retiring units instead of selling them is necessary to decrease brown emissions. In that sense, impediments to trade, such as financial frictions, might improve capital allocation, instead of reducing it. This has the flavor of theories of the second-best.

Third, we take the structure of socially responsible investing seriously. [Oehmke and Opp, 2022] have stressed the importance of the exact "mandate" of investors that value externalities. Investors with "narrow" mandates only care about externalities of the capital they currently hold (a micro perspective). On the other hand, "impact" investors care about the effects of their capital allocation on aggregate externalities (a macro perspective). We will model the breadth of an owner' mandate directly through a specific parameter.

5.2 Setup

For tractability, we divide initial coal emissions into individual units (say 1MT of CO2) and model the decision of their owner to keep, sell or retire each of them individually over our sample period. For simplicity, we do not distinguish between hard retirements (closure) and soft retirement (leaving unit idle).[43] Units might differ in their profitability, with each unit i generating emissions $\pi^i \sim F$. To focus on the role of externalities, we assume in the baseline model that all owners have the same profitability π^i for unit i.

Consider the problem of an owner (investor) endowed with a particular unit of brown capital. They can (i) keep operating it, (ii) sell it to a private buyer, or (iii) retire it. The owner's valuation of the asset is the sum of pecuniary profits and non-pecuniary externalities.

Pecuniary profits: The pecuniary profits from operating one unit are given by π^i. This represents productivity and cost of operating brown capital. Importantly, this includes any cost of carbon that is internalized, such as carbon pricing, competition from renewables, etc. Selling the unit to a private buyer (whose demand is derived below) generates a price P^i,

[43] In the data, the decline in utilization comes from a mix of both.

which the owner takes as given. Retiring a unit yields zero profits.

Externalities: We augment the model to incorporate externalities. We first focus on (negative) climate externalities of operating brown capital. We assume that a private buyer does not value these externalities, while other owners incur a cost of $-\epsilon$ when operating a unit. Retiring the unit removes this cost. We interpret this potential valuation "wedge" for brown capital as resulting from stakeholder pressure (active shareholders, creditors, consumers, etc.) faced by public firms relative to private firms.[44] On the other hand, the impact of selling crucially depends on the owner's mandate. Selling generates a negative payoff of $-\theta\epsilon$, with $\theta \in [0, 1]$. The parameter θ governs how *broad* the owner's mandate is [Oehmke and Opp, 2022]. If $\theta = 0$, they do not value externalities associated with assets they sell ("narrow mandate"). If $\theta > 0$, they have an "impact mandate:" they value (negatively) externalities from assets they sold and did not retire.

State investors differ from other investors in three important ways, but we defer the details of the state problem to a later section below.

Financial frictions: We assume private firms face financial frictions in acquiring brown capital. A competitive private owner purchasing unit i of brown capital at price P^i receives a payoff:

$$\pi^i - P^i$$

Absent financial constraints, the market clearing price is given by $P^{i*} = \pi^i$, a value that ignores externalities. However, we assume that the buyer has no cash on hand and must raise fund on capital markets. They can only pledge a fraction $\xi \leq 1$ of future profits to financiers, who ask for an expected return of $r \geq 1$. The unit can thus only be purchased if:

$$\xi\pi^i \geq rP^i \iff P^i \leq \frac{\xi}{r}\pi^i$$

The ratio ξ/r measures how loose financial frictions are. A lower ratio implies tighter

[44] One example of stakeholders include creditors. Green and Vallee [2022] argue that banks' environmental commitments can cause closures of coal power plants.

constraints and an equilibrium price below π^i. As $\xi/r \to 1$, the price converges to its unconstrained value.

5.3 Equilibrium: Baseline

In this section we described the equilibrium allocation of brown capital in the presence of different investors. For ease of exposition, we first focus on public equity investors and financially constrained private firms. We incorporate state investors in the next section.

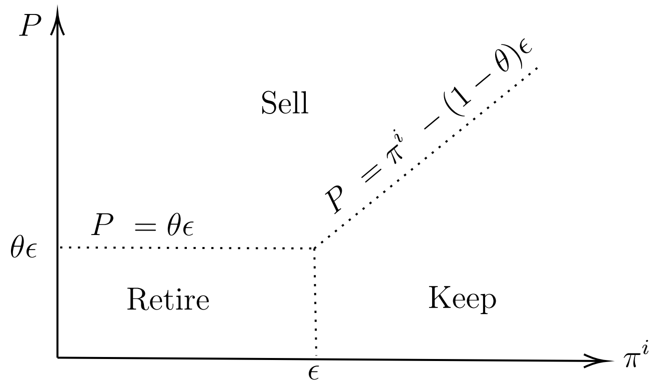
5.3.1 Public equity investors

Consider a public firm owning some units with different profitability $\{\pi^i\}_i$. The decision of keep, sell or retire a unit will depend on two crucial parameters: (i) the market price P^i (ii) the breadth of its mandate θ. The payoff for each unit is given by:

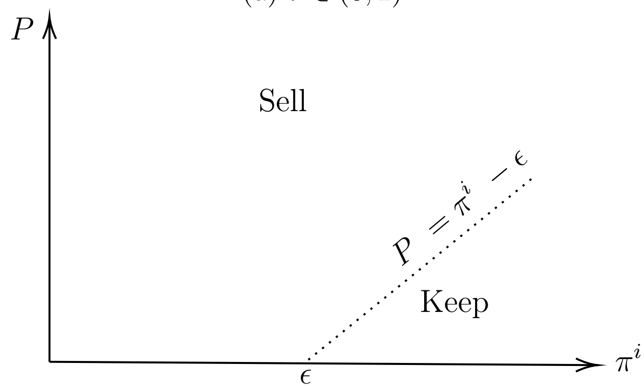
- *Keep:* $\pi^i - \epsilon$
- *Retire:* 0
- *Sell:* $P^i - \theta\epsilon$

We first illustrate the key role played by investment mandates. Figure 9a shows the choice made by an owner with a mandate $0 < \theta < 1$. That means they (partially) internalize the externalities of units that they sell. In that case, they only keep units that are sufficiently profitable (π^i is high) when their price P is low enough. If the price is high enough, they prefer selling, and if the unit is not very profitable, they prefer to retire it.

Contrast this with the choices made by an owner with a narrow mandate $\theta = 0$. To be clear, this investor can strongly dislike emissions, but only for units that it keeps. Figure 9b shows that such an owner *never retires* units. When the market price is high relative to profitability, it sells these units to private firms. Intuitively, retiring gives a payoff of zero, while selling yields a non-negative price. When the price is low, that dissuades them from



(a) $\theta \in (0, 1)$



(b) Narrow mandate: $\theta = 0$

Figure 9: Capital choice

selling, but does not incentivize them to retire any units: they now prefer to keep some of the high-profitability units because the price is lower, but they still prefer selling low-profitability units. Even in the limit, they would rather sell these units for a penny rather than retire them. Narrow mandates thus only lead to pure reallocation and aggregate emissions do not fall. This is a key point: it is not enough that investors care about climate externalities, it crucially matters *how* they care.

5.3.2 Market equilibrium and the effects of financial frictions

We illustrate the market equilibrium for trading brown capital graphically in Figure 10. The demand curve from private firms is driven by financial frictions, while the supply curve is driven by investment mandates, as described previously.

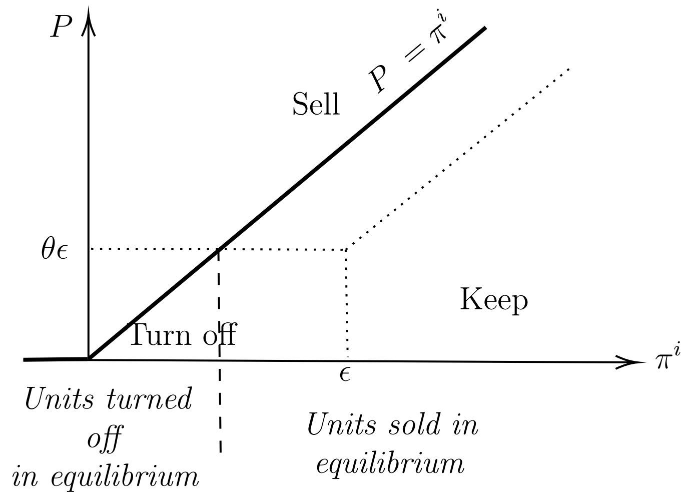
This highlights the key role played by financial frictions. To this end, consider first the case in which they are absent. The top panel of Figure 10 shows the case of no financial frictions ($\xi/r = 1$). In that case, the market price is at its highest possible value for each unit $P^i = \pi^i$, and the private firms' demand is the 45 degree line. As a result, owners do not keep any units in equilibrium. Units are sold to a private buyer, with the exception of units with very low profitability which are retired. Most of the units are sold because the private buyer does not value externalities and has the highest valuation for the asset; there are thus large incentives to trade. The only limit to trade is the breadth of the owner's mandate. If $\theta > 0$, there is penalty incurred for selling brown capital instead of retiring it. This penalty is large enough only for units with low profitability.

The presence of financial frictions reduces selling and increase retirements. The bottom panel of Figure 10 shows that the price is lower than its unconstrained value of π^i, the owner now keeps some units with high profitability since selling is less attractive. But importantly, aggregate emissions also fall: the owner also retires more low-profitability units, as the price is no longer high enough to justify incurring a selling penalty. If financial constraints are strong enough, the price falls so much that the owner stops selling altogether and even more units are retired. Interestingly, note also that with narrow mandates ($\theta = 0$), tighter financial constraints have no effect on aggregate emissions, as they only redistribute ownership.

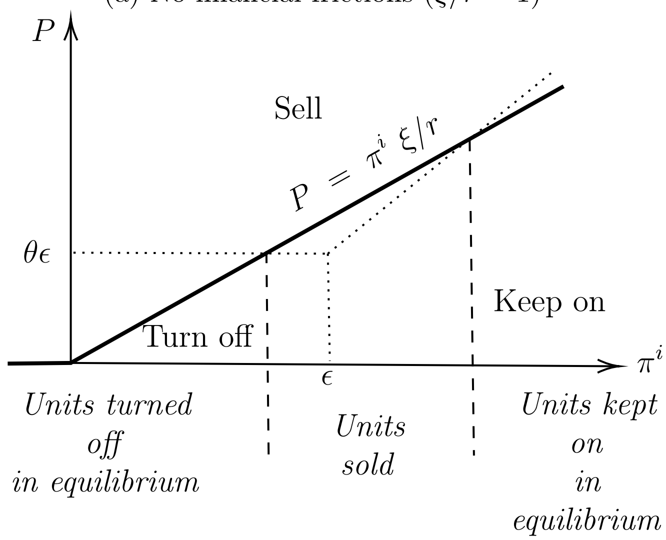
5.4 State ownership

States are large owners of coal power plants. We introduce states into our equilibrium model in such a way to rationalize two key facts: (i) domestic states scaled down less than public equity investors, (ii) foreign states sold more to private firms and scaled down less than other investors.

We assume states deviate from other owners in three important ways. First, they positively value social factors that are not valued as highly by other owners. Keeping a domestic unit open generates an additional payoff of $s > 0$ to the state. We interpret this potential valuation



(a) No financial frictions ($\xi/r = 1$)



(b) High financial frictions ($\xi/r < 1$)

Figure 10: Equilibrium for different levels of financial frictions ξ/r

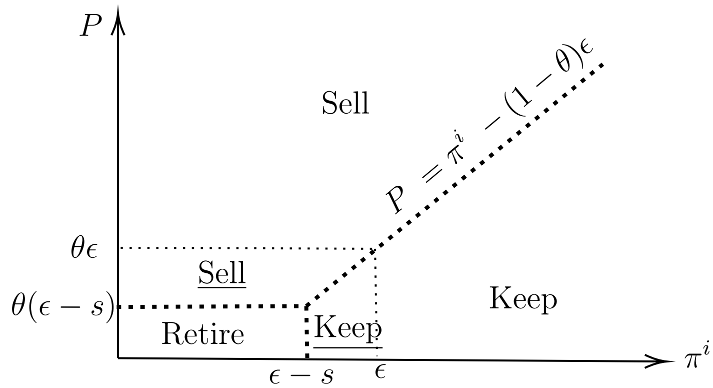


Figure 11: Capital choice for state investor with $s > 0$

"wedge" for brown capital as driven by jobs and local activity associated with plants, but also stable energy prices for the rest of the economy ("energy security"). These could potentially be positive externalities under-valued by the private sector, but note that we do not want to imply that states necessarily act as a benevolent social planner. The framework allows for such social factors to be potentially mis-valued due perhaps to regulatory capture or other political considerations from the government, and we will recover the overall magnitude of s from state investors' behavior in that data.

Second, states only internalize climate externalities in their own country. That means that foreign states have a low θ, while domestic states have a high θ. Moreover, they value externalities of domestic units they do not own. This gives them potential incentives to buy units from other owners. Third, the state has "deep pockets" and we assume that financial constraints are not binding should it want to buy a plant from another owner.

These assumptions make it easy to rationalize the two facts above. The first assumption can explain why domestic states scaled down less than public equity investors. Valuing social factors reduces the payoff of retiring a plant. Figure 11 shows capital choice changes in the case of $s > 0$. The larger s, the more units are kept. Moreover, the second assumption can explain why foreign states sold more to private firms and scaled down less than other investors. As discussed above, an owner with a low θ has a high propensity to sell rather than retire units.

	Parameter	Moment	Estimate
1	Average profitability of units $\bar{\pi}$	Share of emissions retired by private firms	0.18
2	Cost of climate externalities ϵ	Share of emissions retired by public equity investors	0.47
3	Benefit of social factors s	Share of emissions kept by domestic state investors	0.32
4	Mandate of public equity investors θ^P	Share of emissions sold by public equity investors	0.81
5	Mandate of domestic state investors θ^{DS}	Share of emissions retired by domestic state investors	0.75
6	Mandate of foreign state investors θ^{FS}	Share of emissions kept by foreign state investors	0.42
7	Financial frictions ξ/r	Share of emissions retired by foreign state investors	0.81

Table 1: Model calibration

5.5 Model calibration

We calibrate the model using our micro-data. Our decomposition of ownership dynamics can be used to identify the key parameters. To take the model to the data, we make the following additional assumptions. Profitability is normally distributed $\pi^i \sim N(\bar{\pi}, 1)$. Since payoffs are unit-less, there is one degree of freedom and we normalize the standard deviation of profitability to unity.[45] We allow for different breadth θ of mandates across public equity investors, domestic state investors, and foreign state investors. To reduce the effects of different technologies across plants, we only include data for plants between the 10th and 90th percentile of plant age.[46] In the baseline, we only use data up to 2020 before the energy crisis, but we include the reversal in the extension below.

Table 1 summarizes the baseline model calibration. There are seven parameters to estimate, which are identified by seven moments from our decomposition. The Internet Appendix describes the underlying estimating equations and mapping to the model in more details, including proofs that the model parameters are identified.[47]

We find reasonable values for model parameters, reported in the last column. There has been a large aggregate decline in profitability of coal since 2015, implying that 43% of initial capital is no longer profitable. The cross-sectional distribution of profitability is close to a

[45]The model can be easily extended such that the mean profitability depends on the age of the plant.

[46]Table IA.3 in the Internet Appendix shows robustness to using a more homogeneous sample of plants with age between the 33th and 66th percentiles. Estimated parameters are very similar to our baseline sample. Recall also that Figure IA.9 in the Internet Appendix shows that applying our decomposition in that sample yield very similar results than on the entire sample.

[47]Note that an investor mandate θ is only set-identified if that investor does not sell any units in equilibrium. Hence in the current calibration we only recover a lower bound for θ^P.

standard normal. The valuation ϵ of climate externalities is large (about half of the standard deviation of profitability). Domestic states however strongly value social factors, with s being in fact almost as high as climate externalities ϵ. Financial constraints are binding, with the ratio ξ/r being below unity. The magnitudes of investor mandates θ are also intuitive. Domestic states and public equity investors have broad mandates (θ close to 1), while foreign state investors on the other hand have a narrow mandate with $\theta^{FS} = 0.42$, much lower than other investors.

Extension: We complement the baseline calibration with an extension that investigates some of the (admittedly limited) cross-country and time variation in the data. Specifically, we extend the calibration along two dimensions. First, we allow heterogeneity among domestic state investors and re-calibrate θ and s separately for Poland, Germany, and the rest of the EU. Second, we include the reversal due to the the energy crisis by comparing the estimates when the sample ends in 2022 versus 2020.

Table IA.4 in the Internet Appendix summarizes the results. First, we find important cross-sectional differences across state investors. In the pre-energy crisis sample, s is strikingly large in Poland, being twice as large as climate externalities (0.95 vs. 0.47). In comparison, s is actually negative for Germany and Other EU countries, consistent with these countries actively implementing energy policies that favors alternatives to coal (Russian gas, nuclear, renewables). Strikingly, however we observe a drastic increase in s for all states once we include data up to 2022. The case of Germany is particularly striking, with s increasing from *negative* 0.29 to *positive* 0.35. Germany's plan to rely on Russian gas to replace nuclear and coal power generation was severely disrupted with the start of the Ukrainian-Russian conflict in 2022. We also find that the profitability of coal is dramatically higher in this sample. Overall, these parameter values are consistent with a reduction in the supply of alternatives to coal and salient "energy security" concerns in recent years. We view this extension as additional evidence supporting the underlying economics of the model.

6 Implications

In this section, we use the baseline calibration of the model to illustrate some of the key economic implications of brown capital reallocation. In particular, we focus on the effects of the rise of "green finance," understood broadly as the increased attention paid by financial institutions to the carbon content of their capital allocation. We argue that, while "green finance" can decrease aggregate emissions, the existence of states as investors is an important limit.

6.1 The rise of "green finance"

Through the lens of the model, a more climate-conscious financial sector has two effects. First, it tightens financial constraints for potential buyers. As more financial institutions are conscious of the emissions of their portfolio, it becomes increasingly difficult to finance brown assets. This would lower the ratio ξ/r, either by increasing the financiers' expected rate of return and/or reducing the pledgeability of brown assets (i.e. worse collateral). Second, it can also increase the share of investors with broad mandates, which take a macro perspective. Indeed, they have been many campaigns to convince investors not to sell assets to reduce their carbon footprint but instead actually scale down (exercise "voice" over "exit").[48]

In equilibrium, we have seen how tighter financial constraints reduce aggregate emissions because they depress the market price of brown capital, making selling less attractive relative to scaling down a plant. Broad mandates have similar effects of making selling less appealing. In that sense, the rise of "green finance" can reduce aggregate emissions.

Quantitatively, investment mandates appear to be the most important. Indeed, in our calibration, removing financial frictions ($\xi/r = 1$) increases aggregate emission by 2.2 percentage point. This effect is relatively small because public equity and domestic state investors have a broad mandate, and foreign states are already selling a lot even in the presence of financial

[48] For instance, the NGO Beyond Fossil Fuels calls for pushing "fossil fuel companies [...] towards a rapid and just energy transition that includes commitments to close **(not sell)** coal plants by 2030." Source: https://beyondfossilfuels.org/finance-and-corporates/. Emphasis added.

frictions. On the other hand, having narrow mandates has larger effects. In the counterfactual in which public equity investors have mandates as narrow as foreign states ($\theta = 0.42$), aggregate emissions are 4.1pp higher. Including both effects lead to only 5.6pp, as they partially crowd out each other. Intuitively, when mandates are very narrow, financial frictions have limited effects: investors are willing to sell even for a very low price.

6.2 Government intervention and nationalization

Importantly, we argue that "green finance" not only affects firms' decisions, but also the state's incentives to intervene. In our model, there are two reasons why the state might potentially want to step in: climate externalities and social factors, both of which are potentially undervalued by the private sector. We consider each in turn.

Climate externalities: The state might prefer to have some units retired rather than being sold to private buyers, for example by subsidizing plant closure. The economics of the model shows that incentives to intervene are largest when three conditions are met. First, climate externalities are large relative to social factors ($s << \epsilon$), such that there are many units that the state would prefer to retire. Second, financial frictions are low (ξ/r is close to one). Third, owners do not internalize climate externalities when they sell (θ is low). In these cases, the incentives for firms to "exit" are the largest. Intuitively, the rise of "green finance" can thus help correct climate externalities and substitute for government intervention to retire plants.

In our calibration, we actually find no units that the state would like to close due to climate externalities. This is due to two factors. First, states highly value social factors, by almost the same magnitude as climate externalities. Second, financial frictions are low and public equity investors have a broad enough mandate, such that they often prefer to retire units rather than selling them to private firms.

Social factors: Interestingly, the picture looks very different when considering potential social factors. When the state values aspects such as "energy security" relatively more than other investors, that introduces the possibility of nationalization: the state might want to purchases a unit that another owner plans to retire. Interestingly, in our model nationalization tend to be cheaper than subsidies to keep units open.[49]

Through the lens of our model, the incentives to nationalize are the largest when: (i) social factors are highly valued relative to pecuniary profits; as well as (ii) financial frictions are tight; and (iii) firms' mandate are broad, such that firms' incentives to retire are large. In that sense, the rise of "green finance" can actually increase the incentives to intervene because of social factors.

In our calibration, we find that these effects are substantial. A fifth of units retired by public equity investors are potential targets for nationalization (representing about 12% of initial emissions). However, incentives to intervene are significantly smaller in the counterfactual with no financial frictions and narrow mandates: in that case the number of targets is a third smaller.[50]

The existence of state investors is thus an important limit to the ability of "green finance" to reduce aggregate emissions. Indeed, the state has incentives to undo some of the effects of climate-conscious investors if it believes they do not sufficiently value social factors. This is consistent with the narrative of the recent nationalization in Poland.[51] This suggests that quantifying the value of these social factors and whether states are appropriately valuing them

[49]Subsidies tend to be more expensive than nationalization as long as owners do not fully internalize climate externalities ($\theta^O < 1$). Intuitively, in that case an owner requires less compensation to sell a unit rather than keep operating it. To see this, a subsidy $\Delta > 0$ convinces an owner to keep a unit open if $\pi^i - \epsilon^O + \Delta > 0$ (taking the subsidy must also be more attractive than selling, but this constraint is slack for the type of units that would be retired absent subsidies). The lowest subsidies that can be offered is thus $\Delta = \epsilon^O - \pi^i$, which is positive since the owner would retire it without subsidies. The cost to the state is thus $\Delta = \epsilon^O - \pi^i$, which is greater than the net cost of buying a unit (at price $\hat{P} = \theta^O \epsilon^O$) of $\theta^O \epsilon^O - \pi^i$. This can potentially explain why the recent wave of nationalization was not implemented as new subsidies. In our calibration, subsidies would be 34% more expensive than nationalization for the median target.

[50]Note also that the state must pay a premium over the market price P^i. Indeed, a price higher than the market is necessary to convince an owner wanting to retire to change its mind. Assuming that the state can make a take-it-or-leave-it offer to its owner, the minimum price that must be offered is $\hat{P^i} = \theta\epsilon$. In our calibration, the premium of the medium target is 51% of its market price. The premium is high because public equity investors both highly dislike climate externalities and have a broad mandate, making them reluctant to sell. However, when financial frictions are tight, the market price is low to begin with.

[51]Note again that we do not want to imply that the Polish government is a benevolent social planner, but rather that it values factors that climate-conscious private investors might value less.

is an important avenue for future research. More generally, more work is needed to understand how state ownership interacts with traditional Pigouvian motives and tools.

Permanent vs. temporary closure: What if firms have the possibility to only temporary scale down their units, preserving the option value of turning them back on later? Section IA.1 in the Internet Appendix shows that this reduces, but crucially does not eliminate, incentives for the state to nationalize plants. This is because the private sector has still some incentives to permanently retire units. Intuitively, for the least profitable plants, the option value is not large enough to outweigh the costs of temporarily turning off a plant, whether they are pecuniary cost (i.e. fixed operating cost) and non-pecuniary (i.e. the possibility of future emissions). A larger cost of climate externalities ϵ exacerbates these incentives to permanently retire units.

6.3 Alternatives to brown capital

A key aspect of the phase-out of coal is the existence of alternatives. In our model, the development of alternatives to coal (or lack thereof) is crucial to brown capital reallocation, not only because it influences firms but also *states*.

Through the lens of our model, the role of alternatives on brown capital reallocation can be understood through their effects on profitability π and s *jointly*. For instance, consider growth in renewable power generation that competes with existing coal plants. This implies a declining trend in both the profitability of coal and the social value of brown capital. This decreases incentives for firms to keep operating or sell units, but also crucially for the state to intervene to prevent retirements. In a counterfactual in which average profitability and s both decline by 50% , aggregate emissions falls by another 5pp (relative to 50% in the data). In addition, the effects on reducing incentives to nationalize are equally large: the share of potential targets would be cut in half (about 6% of 2015 emissions).[52]

In contrast, a sudden decline in profitability without significant change in s, has dramatically different effects. For example, a sharp rise in carbon pricing is likely to reduce the profitability of coal without alternatives growing equally fast, as clean power investment takes time to build. While it increases incentives for firms to quickly retire units, it would also preserves incentives for the state to intervene to prevent retirements. In our calibration, decreasing average profitability by 50% without changing s leads a 3pp reduction in emissions, but no incentives to nationalize fewer units. This is perhaps part of the rationale for "gradualism" in clean energy policies.

An important implication is thus that is it crucial that any capital leaving brown sectors actually fund alternatives locally. Otherwise, states have incentives to "get in the way" with the looming threat of nationalization. This is especially salient in times and regions in which the risk of energy shortages is high, as experienced by many parts of the world in recent years. Whether capital diverted by "green finance" away from fossil fuels actually funds renewable alternatives locally is an important question for future research.

7 Conclusion

This paper investigates who owns coal power plants by merging micro-level data on firms' plant ownership in Europe with firms' shareholder data. In spite of a sharp increase in the private ownership of coal, we find no evidence for public equity investors exercising "exit" over "voice". Instead, the large decline in their coal ownership since 2015 is due to them retiring plants, not selling them. In contrast, we highlight the crucial role played by a third, large investor group: states and local governments. Foreign states were the ones that sold to private

[52]This is the mirror image of an "energy crisis." A sudden reduction in alternatives to coal (i.e. ending gas imports) would likely have two effects. First, an increase in electricity prices would increase the profitability of coal π, reducing incentives for firms to retire units. Second, an increase in s would also increase incentives for the state to both stop paying to retire units and for nationalizing more units. This is consistent with the experience of Germany in 2022 described above. In our calibration, increasing average profitability and s by 30% would increase aggregate emissions by 3.1pp, and the share of potential targets for nationalization would increase by 7pp (or about 3.9% of 2015 emissions).

firms, while domestic states were the slowest at scaling down their plants.

We illustrate the economics of brown capital reallocation through a model that incorporates production externalities. We find that the rise of "green finance" can decrease aggregate emissions, but that the existence of states as investors that care about other social factors (i.e. "energy security") is an important limit. A more thorough understanding of the drivers of capital reallocation across brown and green sectors and the role of the state is an important avenue for future research.

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Internet Appendix for Brown Capital (Re)Allocation

IA.1 Model extension: Permanent vs. Temporary Closure

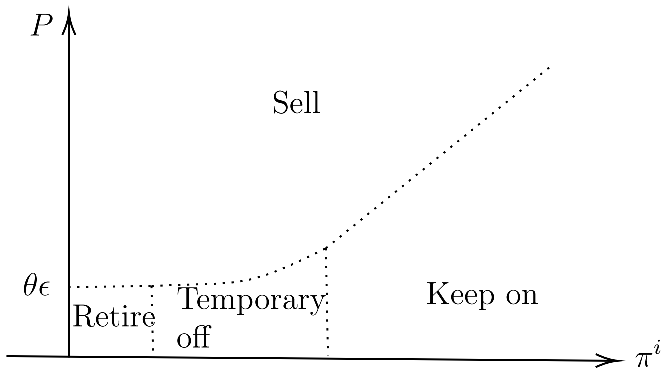
We extend the model and assume that firms have four options for each of their units. In addition to keeping them on and selling them, they can now choose to either temporarily turn them off or permanently retire them. Temporarily turning off an unit, without retiring it, preserves the option value of turning it on later. If a firms does so, it must still pay an operating fixed cost $f > 0$.

- Keep on: $\pi^i - \epsilon - f$
- Sell: $P - \theta\epsilon$
- Temporarily off: $q(v(\pi^i) - \epsilon) - f$
- Retire: 0

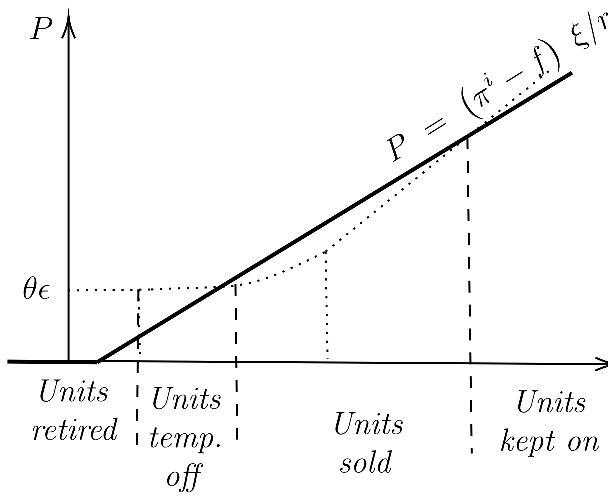
The payoff to temporarily turning off a unit can be interpreted in the following way. The benefit relative to permanently retiring the unit is the option value of turning it on later when its more profitable. We assume that the unit will be turned on again in the future with probability q (also capturing potential time discounting), in a state of the world in which its profitability is $v(\pi^i)$. We assume that this option value is always positive and increasing in the current profitability π^i.[53] On the other hand, there are two potential costs relative to retiring the unit: (i) an operating fixed cost $f > 0$, and (ii) the probability of future climate externalities $q\epsilon$. From the state perspective, we make the assumption that s is only foregone if the unit is retired, but not if it is temporarily turned off.

Figure IA.1 illustrates the capital choices in equilibrium with this additional option. Like in the data, we see that units are both temporarily turned off and retired in equilibrium. Intuitively, for the least profitable plants, the option value is not large enough to outweighs

[53] Formally, assume that $v' > 0$, $\lim_{\pi^i \to -\infty} v(\pi^i) = 0$ and $\lim_{\pi^i \to +\infty} v(\pi^i)/\pi^i = 1^-$.



(a) Firm capital choice



(b) Equilibrium with financial frictions

Figure IA.1: Extension: Full retirement vs. Turning off

the pecuniary and non-pecuniary costs of temporarily turning a plant off. This implies that the state still has incentives to nationalize some units that the private sector would prefer to retire. A larger cost of climate externalities ϵ exacerbates these incentives.

IA.2 Model calibration and identification

There are seven parameters to estimate:

1. The average profitability of units $\bar{\pi}$.

2. The cost of climate externalities ϵ.

3. The benefit of social factors s.

4. The mandate of public equity investors θ^P.

5. The mandate of domestic state investors θ^{DS}.

6. The mandate of foreign state investors θ^{FS}.

7. The strength of financial frictions ξ/r (only the ratio is identified).

We use seven moments to identify these parameters:

1. The share of emissions retired by private firms.

2. The share of emissions sold by public equity investors.

3. The share of emissions retired by public equity investors.

4. The share of emissions kept by foreign state investors.

5. The share of emissions retired by foreign state investors.

6. The share of emissions kept by domestic state investors.

7. The share of emissions retired by domestic state investors.

For each investor group $g = \{\text{private, public equity, domestic state, foreign state}\}$, we denote the empirical moments as $\{R^g, K^g, S^g\}$. R^g is the share of initial emissions of group g that were retired over 2015-2020. K^g is the share of initial emissions of group g that were kept over 2015-2020. S^g is the share of initial emissions of group g that were kept over 2015-2020. The three shares adds to 100% for each group ($R^g + K^g + S^g = 1$, $\forall g$). We use seven of these for identifying the seven model parameters.

Moment 1: The share of emissions retired by private firms. The private firms' valuation of climate externalities is normalized to zero. In the model, the share of emissions retired is given by:

$$R^{private} = \mathbf{P}(\pi^i < 0) = \Phi(-\bar{\pi})$$

This moment identifies average profitability $-\bar{\pi}$.

Closed-form equation:

$$\bar{\pi} = -\Phi^{-1}(R^{private})$$

Moment 2: The share of emissions sold by public equity investors. In the data, public equity investors do not sell any emissions ($S^{public} = 0$).[54] In the model, this can only happen if their mandates is large enough. This moment provides set identification for θ^P:

$$\theta^P \geq \xi/r$$

(We will see below that ξ/r is point identified from other moments.)

Moment 3: The share of emissions retired by public equity investors. Given that they do not sell units, the share of emissions retired is given by:

$$R^{public} = \mathbf{P}(\pi^i < \epsilon) = \Phi(\epsilon - \bar{\pi})$$

Given that $\bar{\pi}$ is already identified, this moment identifies the cost of climate externalities ϵ.

Closed-form equation:

$$\epsilon = \bar{\pi} + \Phi^{-1}(R^{public})$$

Moment 4: The share of emissions kept by foreign state investors. In the model, the share of emissions kept is given by:

$$K^{FS} = \mathbf{P}(\pi^i > \frac{1-\theta^{FS}}{1-\xi/r}\epsilon) = \Phi(\bar{\pi} - \frac{1-\theta^{FS}}{1-\xi/r}\epsilon)$$

Moment 5: The share of emissions retired by foreign state investors. In the

[54] To be precise, they actually purchased small amounts in some time periods. We make the simplification that they did not sell nor purchase any capital.

model, the share of emissions retired is given by:

$$R^{FS} = \mathbf{P}(\pi^i < \frac{\theta^{FS}}{\xi/r}\epsilon) = \Phi(\frac{\theta^{FS}}{\xi/r}\epsilon - \bar{\pi})$$

Given that $\bar{\pi}$ and ϵ are already identified, these last two moments jointly identify the mandate θ^{FS} and the strength of financial frictions ξ/r.

Closed-form equations:

$$\xi/r = \frac{\Phi^{-1}(K^{FS}) - \bar{\pi} + \epsilon}{\Phi^{-1}(K^{FS}) + \Phi^{-1}(R^{FS})}$$

$$\theta^{FS} = \frac{\xi/r}{\epsilon}(\bar{\pi} + \Phi^{-1}(R^{FS}))$$

Moment 6: The share of emissions kept by domestic state investors. In the model, the share of emissions kept is given by:

$$K^{DS} = \mathbf{P}(\pi^i > \frac{1-\theta^{DS}}{1-\xi/r}(\epsilon - s)) = \Phi(\bar{\pi} - \frac{1-\theta^{DS}}{1-\xi/r}(\epsilon - s))$$

Moment 7: The share of emissions retired by domestic state investors. In the model, the share of emissions retired is given by:

$$R^{DS} = \mathbf{P}(\pi^i < \frac{\theta^{DS}}{\xi/r}(\epsilon - s)) = \Phi(\frac{\theta^{DS}}{\xi/r}(\epsilon - s) - \bar{\pi})$$

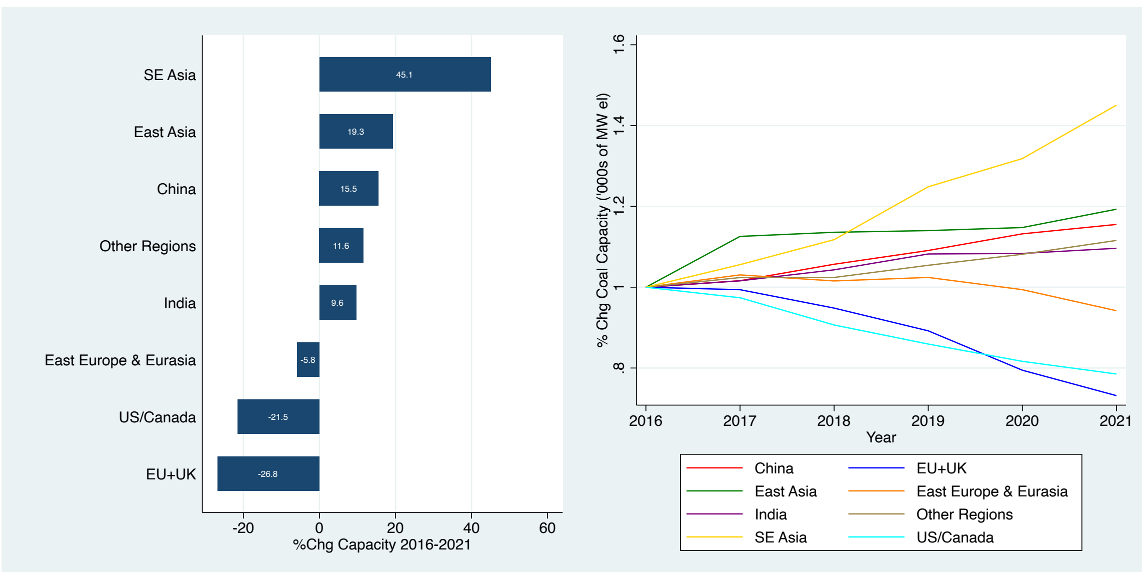
Given that $\bar{\pi}$, ϵ and ξ/r are already identified, these two moments jointly identifies the mandate of domestic state θ^{DS} and the benefit of social factors s.

Closed-form equation:

$$\theta^{DS} = 1/(1 + \frac{\bar{\pi} - \Phi^{-1}(K^{DS})}{\bar{\pi} + \Phi^{-1}(R^{DS})}\frac{1-\xi/r}{\xi/r})$$

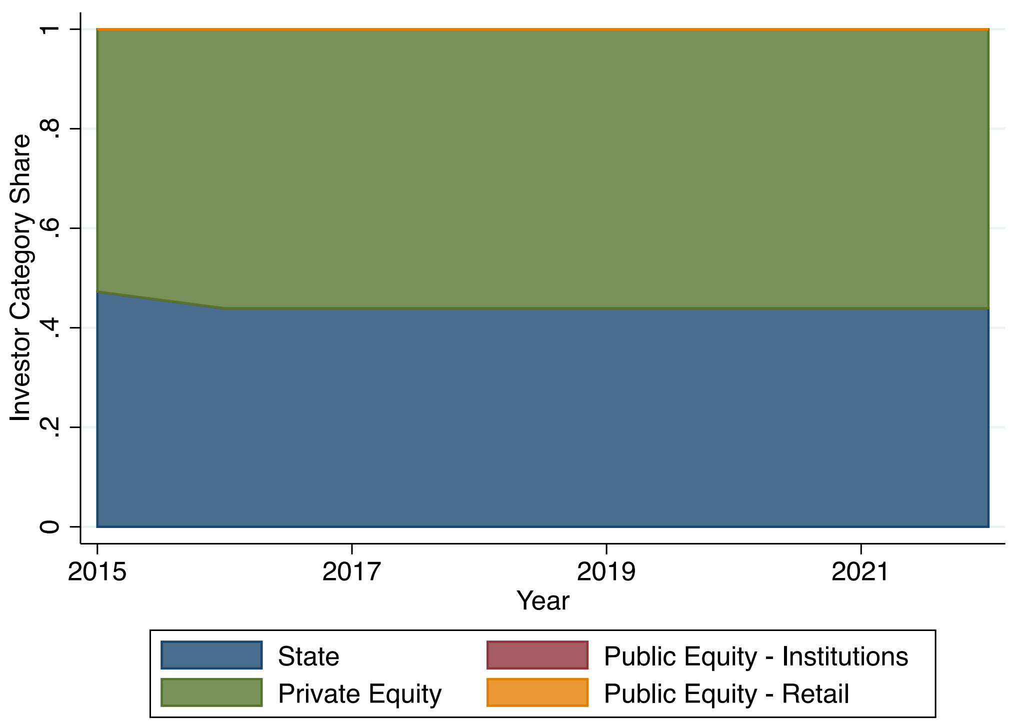
$$s = \epsilon - (\bar{\pi} + \Phi^{-1}(R^{DS}))\frac{\xi/r}{\theta^{DS}}$$

Figure IA.2: Change in Coal Capacity across Regions: 2016-2021



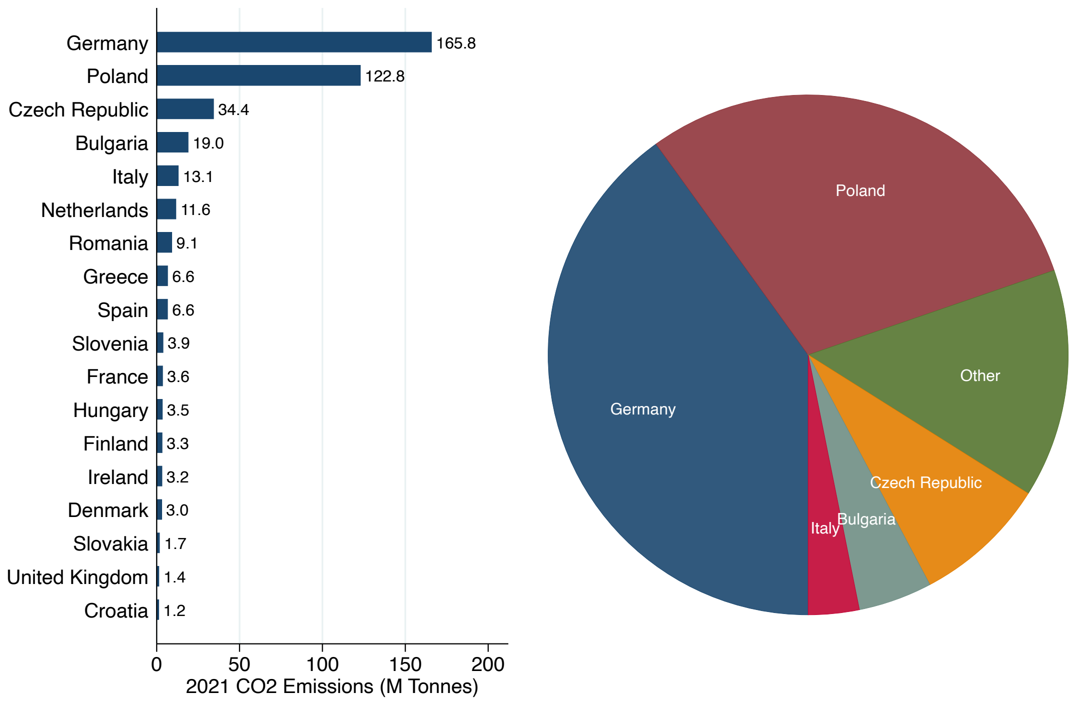
This figure shows the change in coal capacity in different regions of the world. The data comes the Global Energy Monitor coal power plant tracker.

Figure IA.3: Ownership of Coal Capacity Outside of the EU, 2015-2022



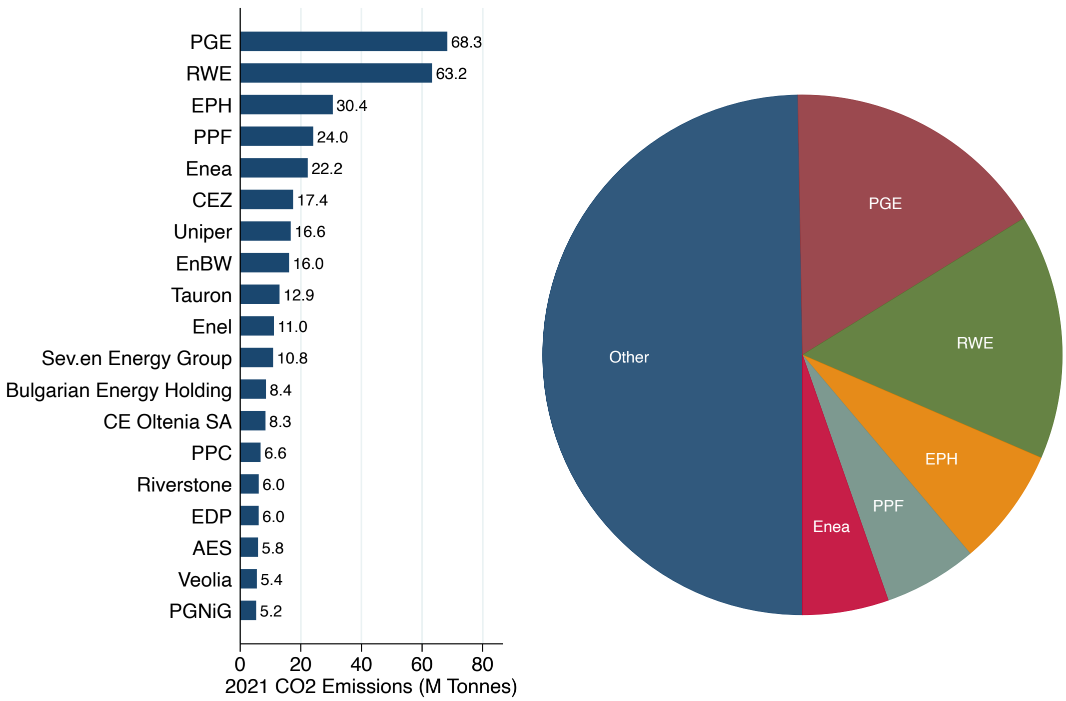
This figure shows the share of aggregate coal capacity owned by the different investor categories outside of the EU by other coal plants present in the BFF data. These plants are mainly located in Turkey, with plants also in Bosnia & Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia.

Figure IA.4: Country-Level CO2 Emissions from Coal Plants, 2021



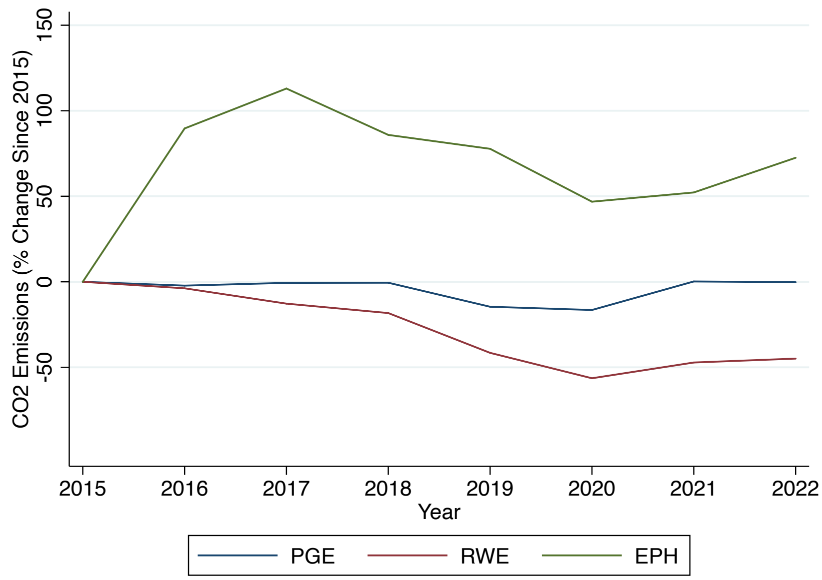
The bar chart on the left shows CO2 emissions in 2021 at the country level from the BFF data, for countries in the EU and UK for which open coal plants emitted more than 1 Million Tonnes of CO2. The pie chart on the right shows the share of CO2 emissions for coal plants top 5 highest-emitting countries. An "Other" category is also included that represents the remaining share of CO2 emissions not covered by the top 5. Note the "Other" category may include countries that are not present in the bar chart on the left.

Figure IA.5: Firm-Level CO2 Emissions from Coal Plants, 2021



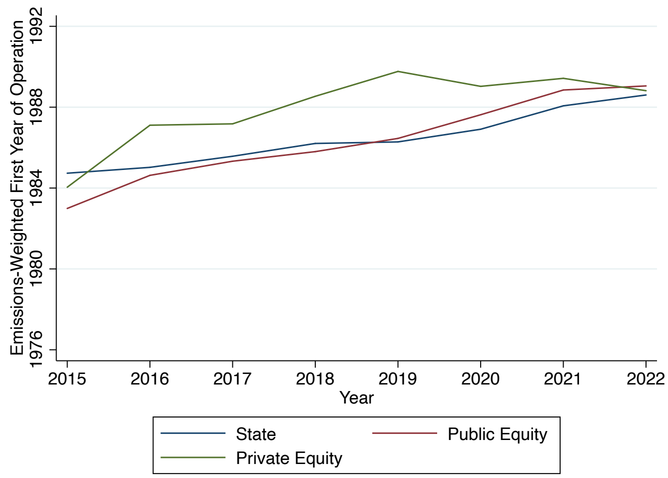
The bar chart on the left shows CO2 emissions in 2021 at the firm level from the BFF data, for the top 19 highest-emitting firms who owned open coal plants in the EU. The pie chart on the right shows the share of CO2 emissions attributable to the top 5 highest-emitting firms. An "Other" category is also included that represents the remaining share of CO2 emissions not covered by the top 5. Note the "Other" category may include firms that are not present in the bar chart on the left.

Figure IA.6: Dynamics of CO2 Emissions by PGE, RWE, and EPH, 2015-2022



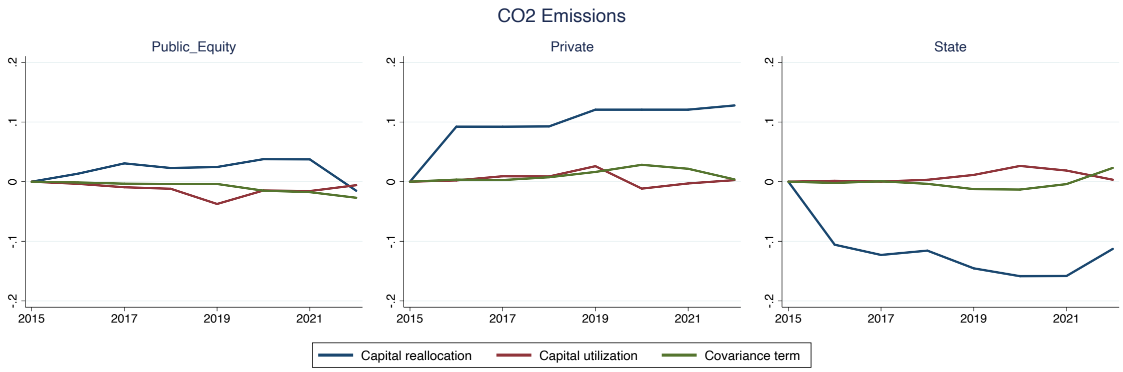
This figure shows the annual percentage change in CO2 emissions relative to 2015 produced by plants owned by PGE, RWE, and EPH. Coal plant data are from Beyond Fossil Fuels.

Figure IA.7: Emissions-Weighted First Year of Operation by Investor Group



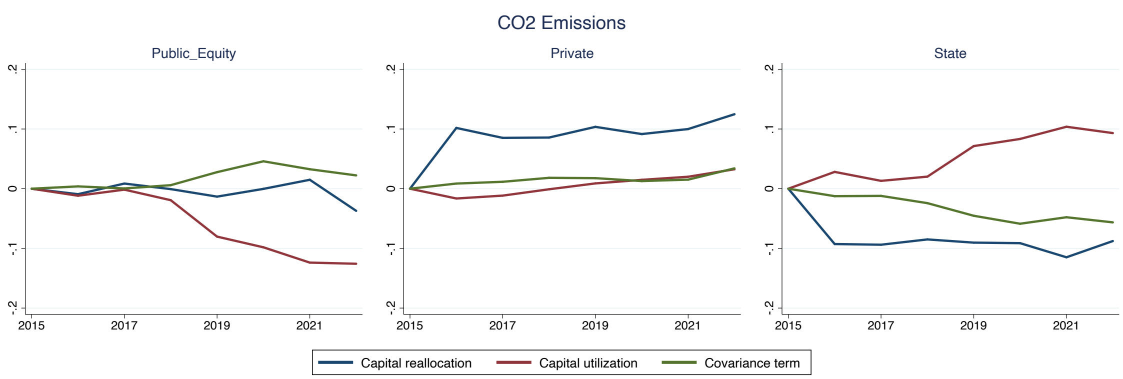
The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. For a investor group j, we define Emissions-Weighted First Year of Operation$_{j,t}$ $= \sum_i \frac{CO2_{ij,t}}{\sum_{i'} CO2_{i'j,t}}$First Year of Operation$_{i,t}$, where the i subscript indexes electricity generation units. $CO2_{ij,t}$ is the level of $CO2$ emissions attributable to investor group j for unit i.

Figure IA.8: Decomposition: Young Units



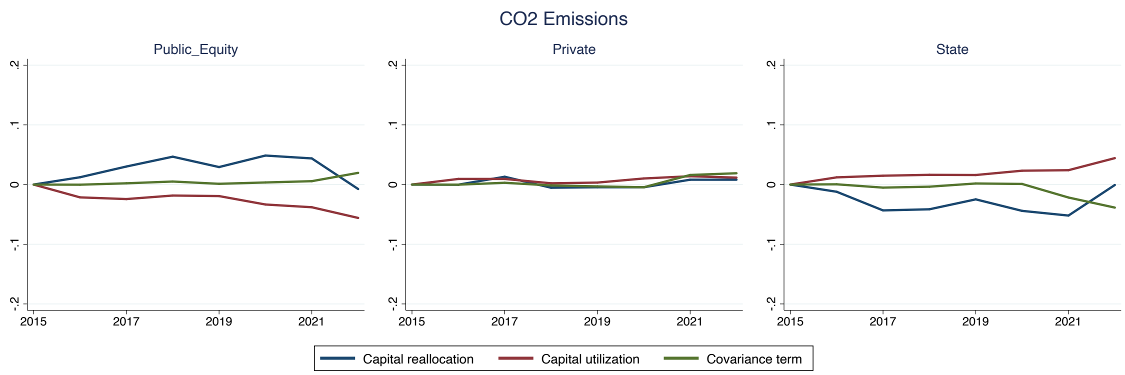
Operational coal units are divided into three age groups (*Young, Middle-Aged, and Old)* based on emissions-weighted terciles, so that each group captures approximately one-third of aggregate CO2 emissions. Operational coal units are classified based on their age and CO2 emissions as of 2015. CO2 emissions are available at the plant level, but allocated to units based on the coal capacity of each unit. Each panel in the figure shows the three terms in the decomposition in equation (2) for a given investor group, using the coal unit as the level of observation across units in the lowest age tercile over the period 2015-2022. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.9: Decomposition: Middle-Aged Units



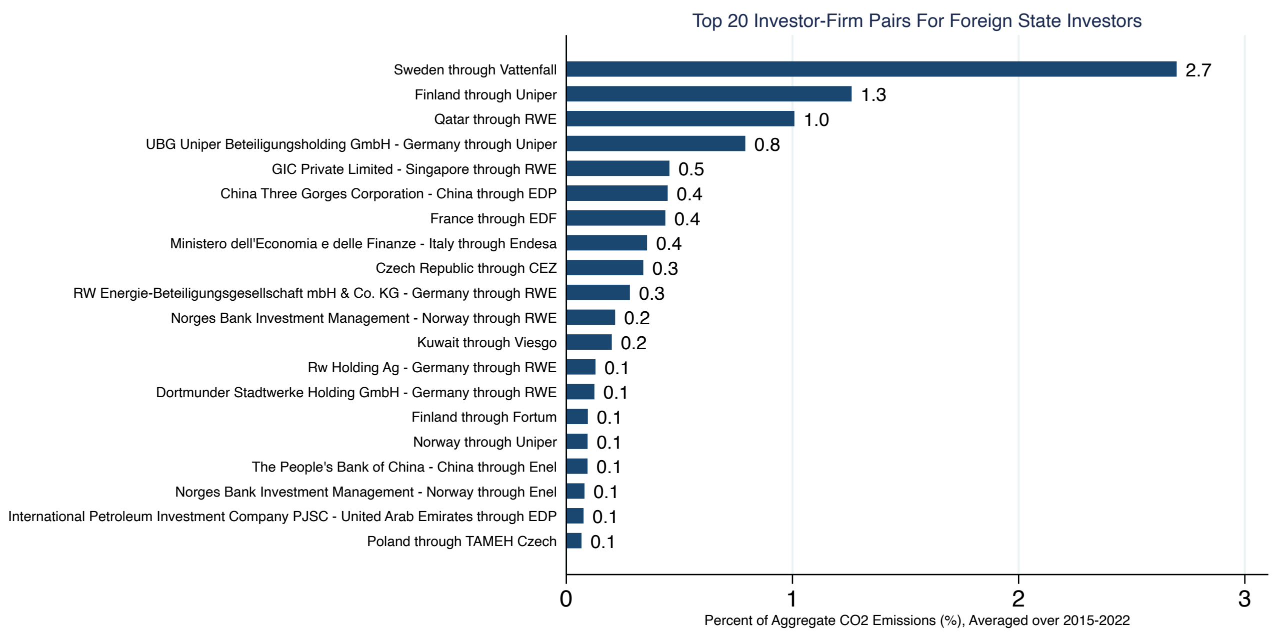
Operational coal units are divided into three age groups (*Young, Middle-Aged, and Old)* based on emissions-weighted terciles, so that each group captures approximately one-third of aggregate CO2 emissions. Operational coal units are classified based on their age and CO2 emissions as of 2015. CO2 emissions are available at the plant level, but allocated to units based on the coal capacity of each unit. Each panel in the figure shows the three terms in the decomposition in equation (2) for a given investor group, using the coal unit as the level of observation across units in the middle age tercile over the period 2015-2022. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.10: Decomposition: Old Units



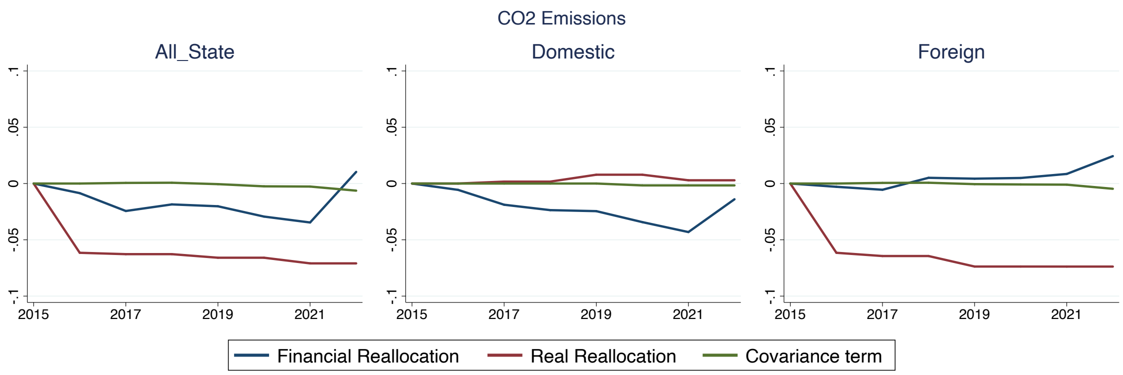
Operational coal units are divided into three age groups (*Young, Middle-Aged, and Old)* based on emissions-weighted terciles, so that each group captures approximately one-third of aggregate CO2 emissions. Operational coal units are classified based on their age and CO2 emissions as of 2015. CO2 emissions are available at the plant level, but allocated to units based on the coal capacity of each unit. Each panel in the figure shows the three terms in the decomposition in equation (2) for a given investor group, using the coal unit as the level of observation across units in the highest age tercile over the period 2015-2022. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.11: Top Foreign State Investors



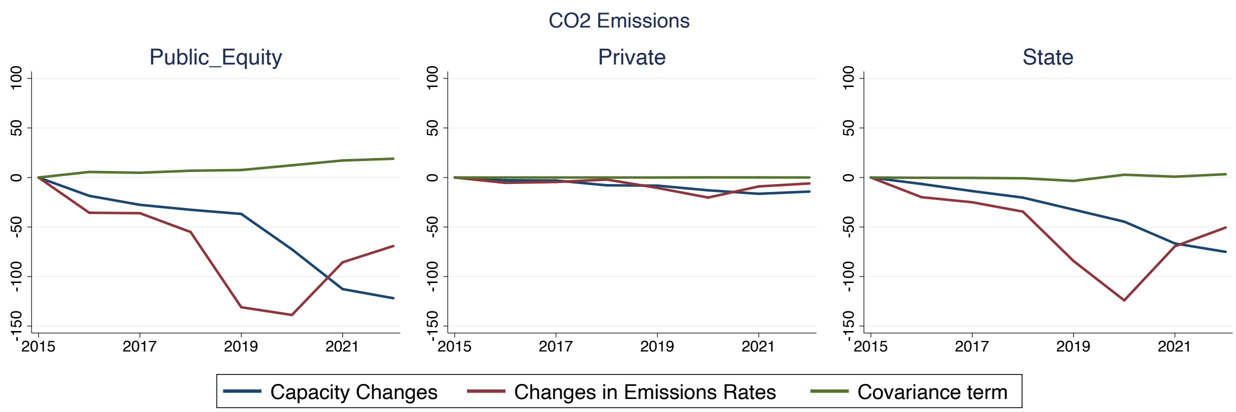
This figure shows the top 20 investor-firm pairs where the investor is a state who owned coal plants in a foreign country through the given firm. For example, the top entry reflects the fact that Sweden owns 100% of Vattenfall, who owned coal plants in Germany and Netherlands. The x-axis shows the percent of aggregate CO2 emissions owned in foreign countries by the investor through the particular firm, averaged over the 2015-2022 period. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.12: Financial Reallocation versus Real Reallocation: State Investors



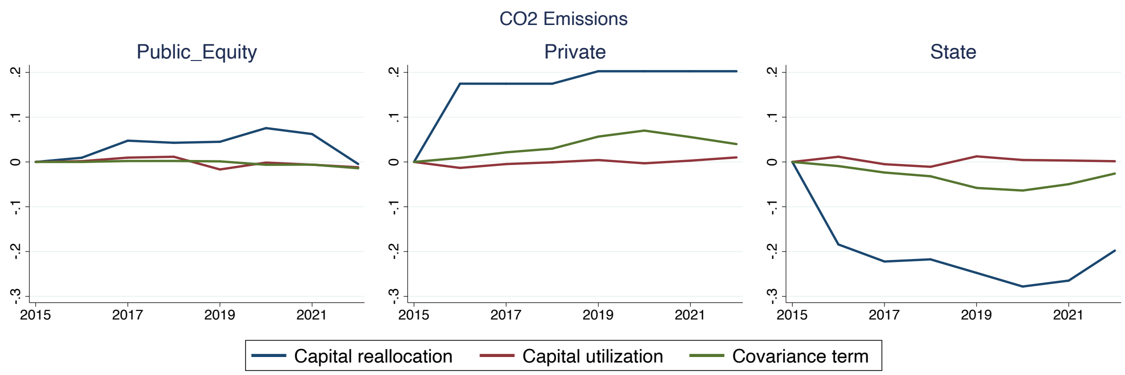
Each panel shows the three terms in the decomposition in equation (3) for a given investor group, across all plants in the EU over the period 2015-2022. The *All State* category reflects all state investors. The *Domestic* category reflects only domestic state investors. A state investor in a plant is considered domestic if it is affiliated with a local or state government that is located in the same country as the plant it owns. The *Foreign* category reflects only foreign state investors. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.13: Decomposing Capital Utilization



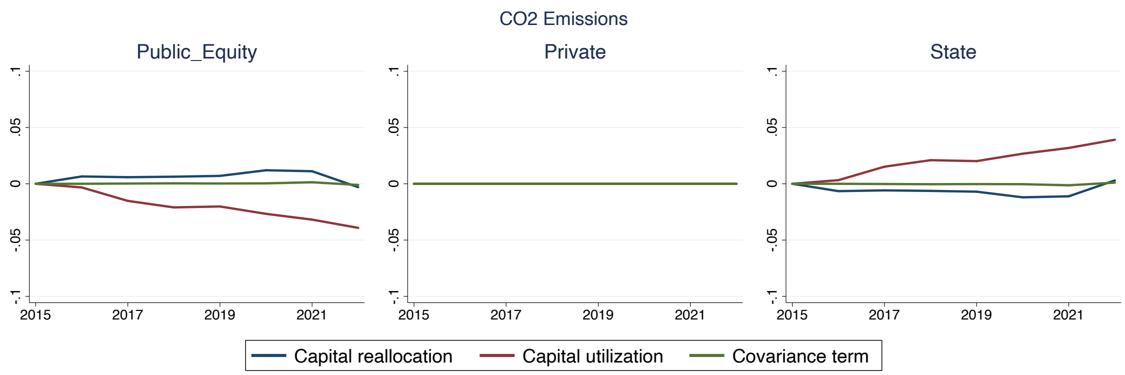
Each panel shows the three terms in the decomposition in equation (4) for a given investor group, across all plants in the EU over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.14: Capital Reallocation versus Capital Utilization: Germany



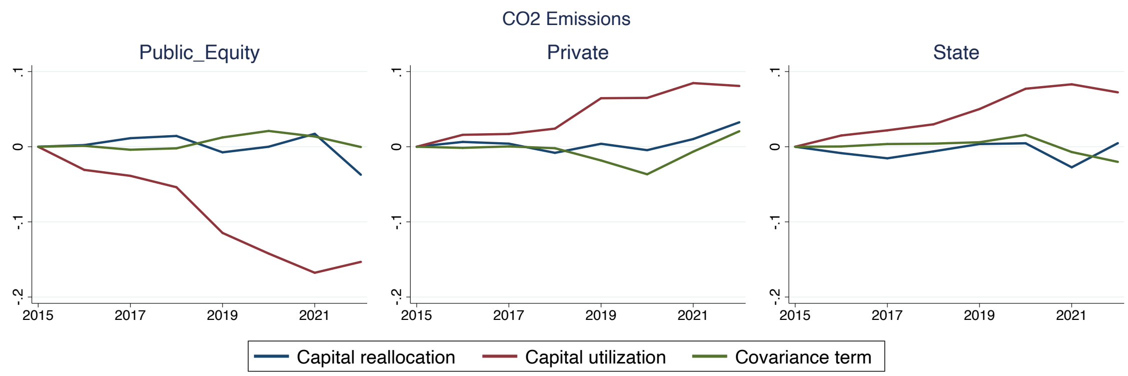
Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in Germany over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.15: Capital Reallocation versus Capital Utilization: Poland



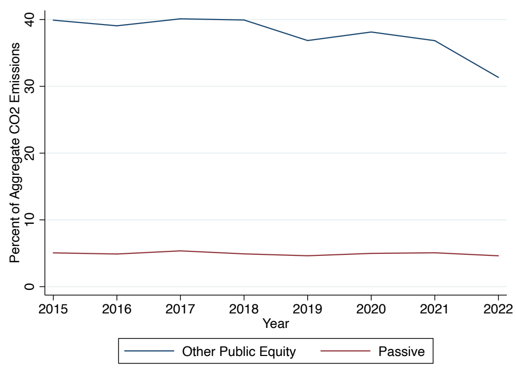
Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in Poland over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.16: Capital Reallocation versus Capital Utilization: EU excluding Germany and Poland



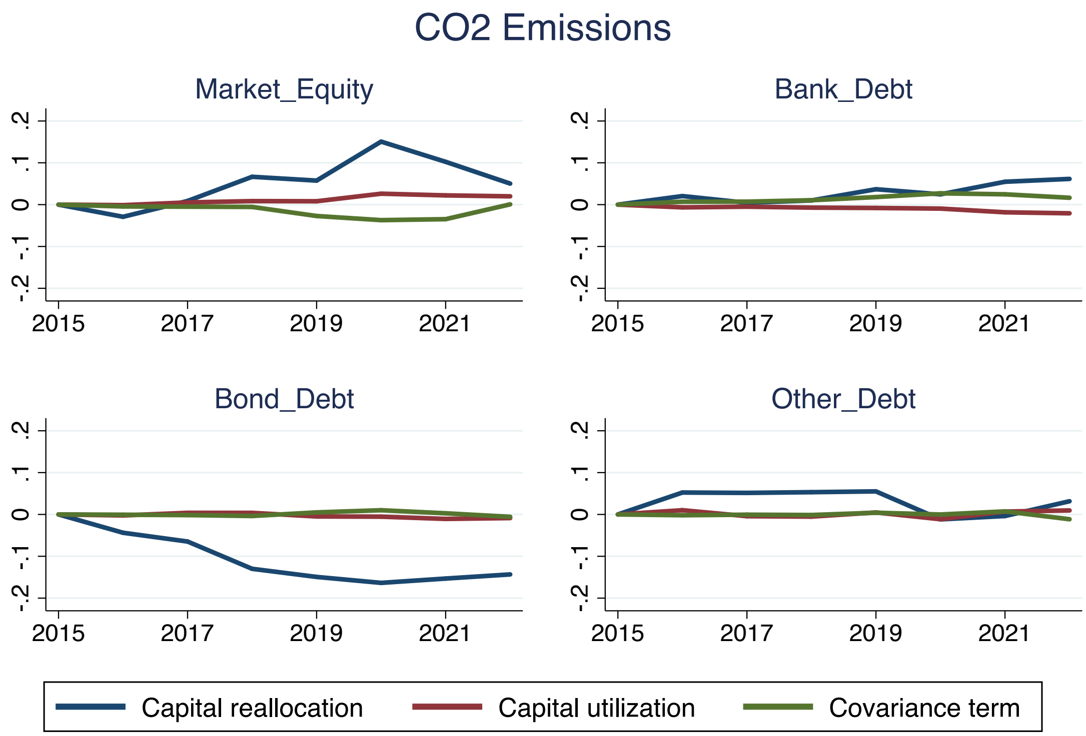
Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in the EU, excluding Germany and Poland over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.17: CO2 Emissions (EU + UK) by Institutional Investor Categories

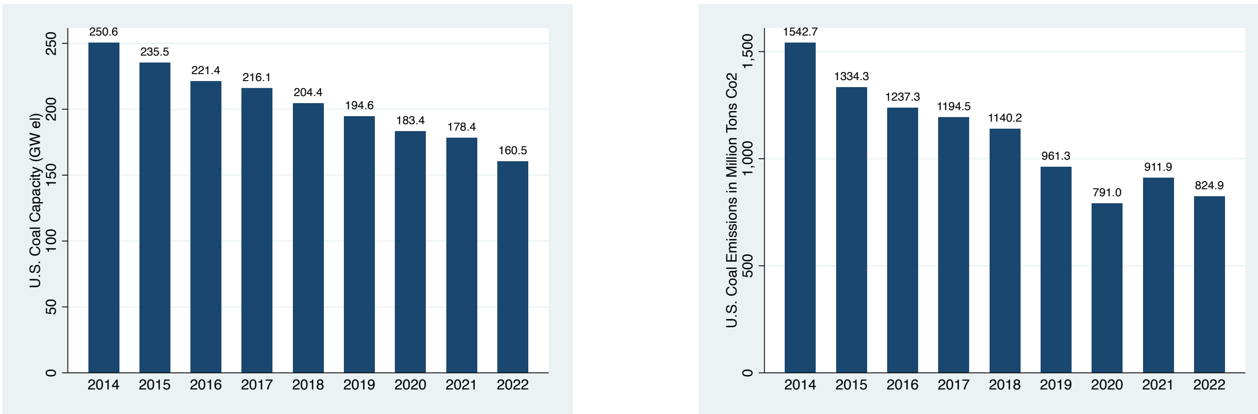


This figure shows the share of annual aggregate CO2 emissions in the EU owned by passive investors and other equity investors. Coal plant data are from Beyond Fossil Fuels. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research.

Figure IA.18: Decomposition: Bank and Bond Debt



Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in the EU over the period 2015-2022. The *Market Equity* category reflects equity investors. The *Bank Debt* category reflects debt holders that are banks. The *Bond Debt* category reflects bond investors. The *Other Debt* category reflects the portion of firm debt that is unknown, firms' whose debt structure is not observed in the data, and adjustments to debt. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.



(a) Generating capacity

(b) CO2 emissions

Figure IA.19: Aggregate Coal Power Generation in the U.S.

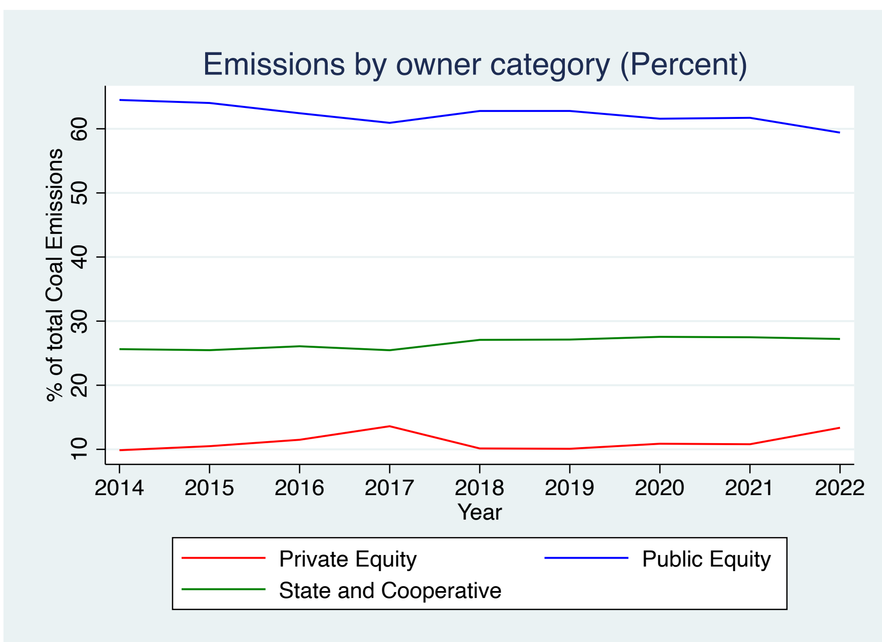


Figure IA.20: Ownership of CO2 Emissions in the US, 2014-2022

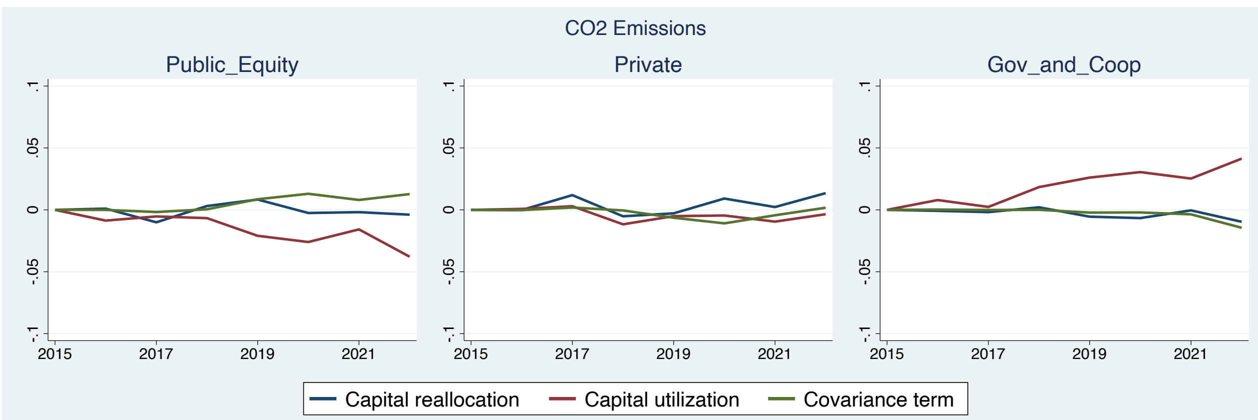
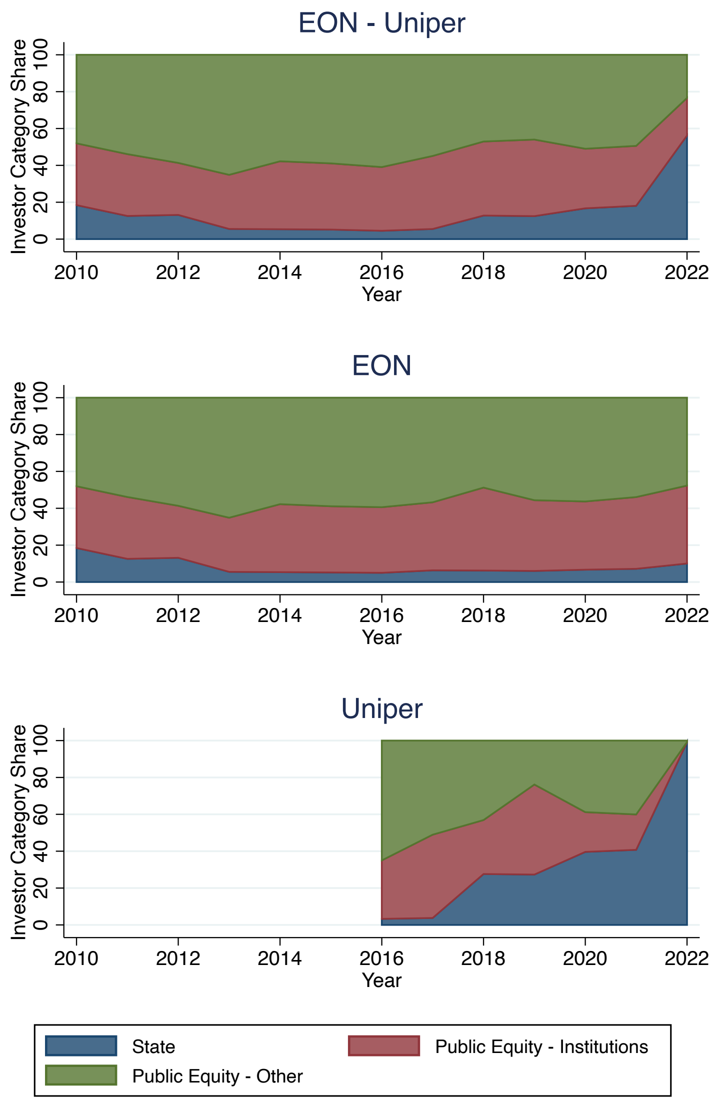


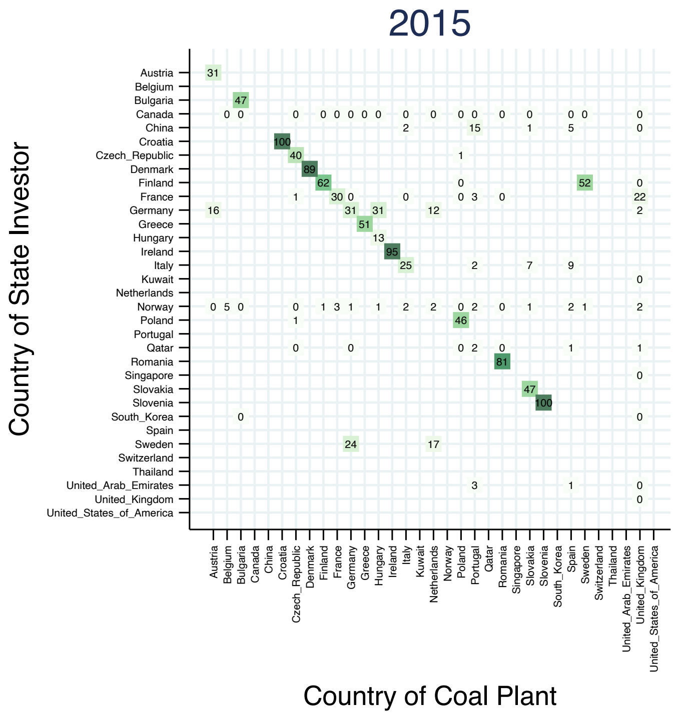
Figure IA.21: Capital Reallocation versus Capital Utilization: U.S.

Figure IA.22: Ownership dynamics: the E.ON -Uniper Asset Split



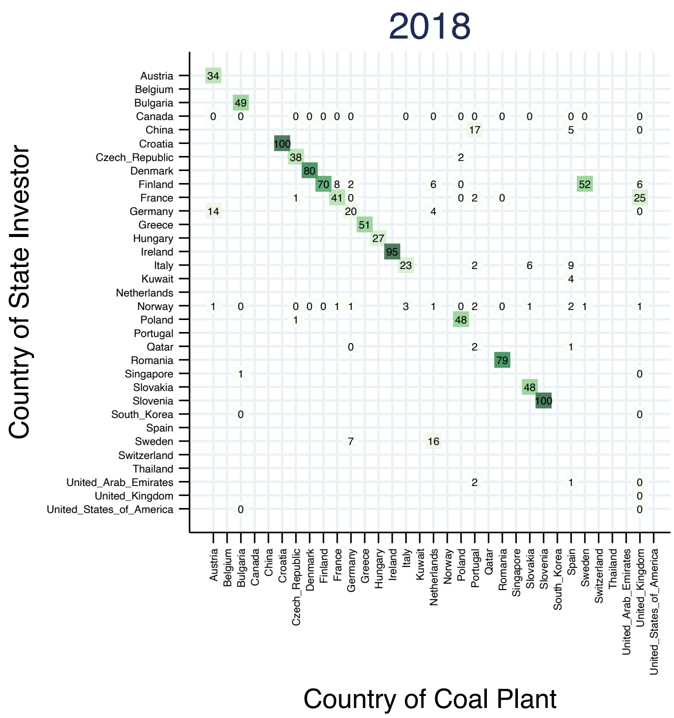
The top panel *EON-Uniper* plots the shares by investor group for E.ON through 2015. After and including 2016, the top panel represents the weighted-average of shares held by investor groups for Uniper and E.ON, with each company's share weighted by its respective market capitalization. The middle panel *EON* plots the shares by investor group for E.ON, and the bottom panel *Uniper* plots the shares by investor group for Uniper. Uniper was spun off from E.ON in 2016. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research.

Figure IA.23: State Ownership of Coal Plants, by Country of Coal Plant and Country of State Investor, 2015



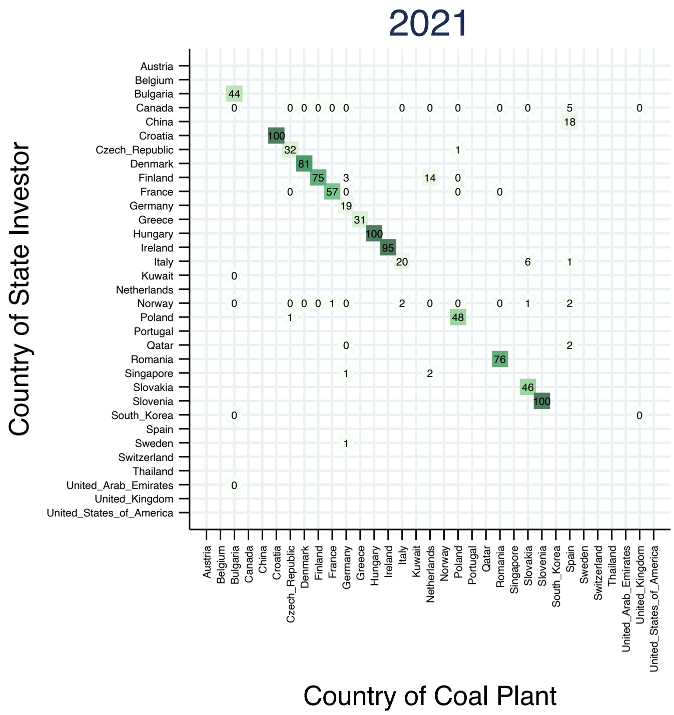
This figure shows for each country on the x-axis, the percentage ownership of CO2 emissions in the x-axis country owned by state investors located in the country on the y-axis in 2015. A value of "0" indicates a non-zero ownership share that is less than 0.5%. Diagonal values represent domestic state ownership, and off-diagonal values represent foreign state ownership. Note that there are non-EU firms on the x-axis. State investors from these non-EU countries own coal plants in the EU, but this figure does not show ownership of any coal plants located in these non-EU countries. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.24: State Ownership of Coal Plants, by Country of Coal Plant and Country of State Investor, 2018



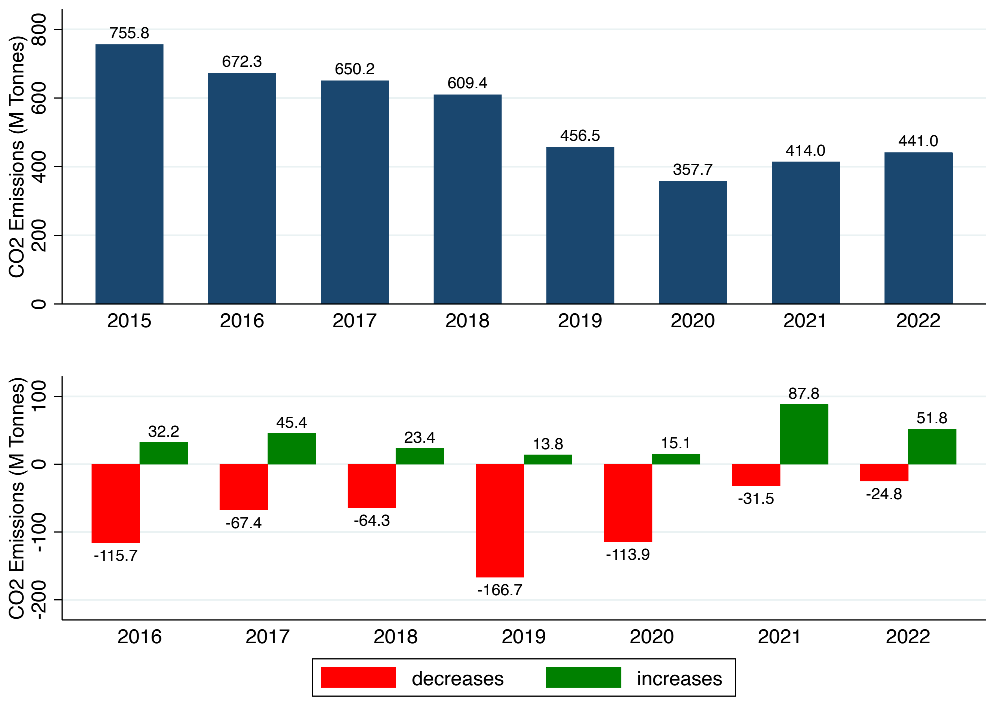
This figure shows for each country on the x-axis, the percentage ownership of CO2 emissions in the x-axis country owned by state investors located in the country on the y-axis in 2018. A value of "0" indicates a non-zero ownership share that is less than 0.5%. Diagonal values represent domestic state ownership, and off-diagonal values represent foreign state ownership. Note that there are non-EU firms on the x-axis. State investors from these non-EU countries own coal plants in the EU, but this figure does not show ownership of any coal plants located in these non-EU countries. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.25: State Ownership of Coal Plants, by Country of Coal Plant and Country of State Investor, 2021



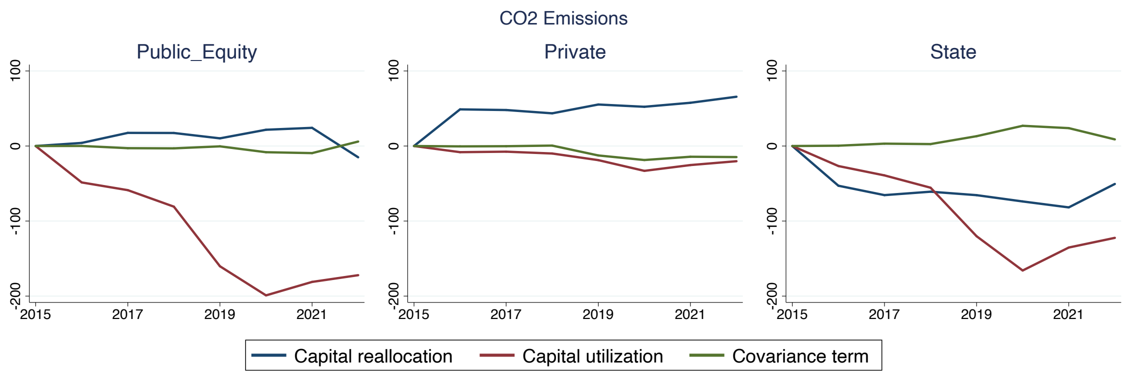
This figure shows for each country on the x-axis, the percentage ownership of CO2 emissions in the x-axis country owned by state investors located in the country on the y-axis in 2021. A value of "0" indicates a non-zero ownership share that is less than 0.5%. Diagonal values represent domestic state ownership, and off-diagonal values represent foreign state ownership. Note that there are non-EU firms on the x-axis. State investors from these non-EU countries own coal plants in the EU, but this figure does not show ownership of any coal plants located in these non-EU countries. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Figure IA.26: Aggregate Coal Emissions in the EU



The top panel shows aggregate CO2 emissions across all open coal plants in the EU and UK, from 2015 to 2022. The bottom panel shows changes in CO2 emissions across coal units that exhibited increases in emissions and units that exhibited decreases in emissions. Aggregate CO2 emissions for year t is equivalent to aggregate CO2 emissions for year $t-1$, adding any emission increases by units in year t and subtracting any emission decreases by units in year t. Coal plant data are from Beyond Fossil Fuels.

Figure IA.27: Decomposition: Levels of Emissions



Each panel shows the three terms in the decomposition in equation (2) for a given investor group, across all plants in the EU, using levels of emissions to measure plant scale instead of emissions as a proportion of aggregate emissions, over the period 2015-2022. The *Public Equity* category reflects retail or (non-state) institutional investors in publicly traded companies. The *Private* category reflects non-state owners of private companies. The *State* category reflects state-owned shares in both public and private companies. Firm shareholder information and classifications are determined using a combination of data from Capital IQ and manual research. Coal plant data are from Beyond Fossil Fuels.

Table IA.1: Top 10 Largest Coal Power Producers in Selected Regions, 2021

	USA	EU/UK	China	India
Av. State Investor Share (%)	10.6	30.8	84.6	45.2
State-owned enterprises (%)	10	0	80	40
Capacity (MW'000)	108.4	84.9	309.8	122.1

Average State Investor Share refers to the average percentage of equity held in the top 10 firms of each region by state institutions. For USA, China and India this percentage only refers to the percentage held by domestic institutions, for reasons of data limitations. For the EU/UK, any shareholder government is considered. A company is classified as a *state-owned enterprise* if 100% of the equity is held by a government institution. The data comes the Global Energy Monitor coal power plant tracker.

Table IA.2: Ownership and Capacity for Largest Coal Power-Producing Energy Firms for Selected Regions, 2021

Name	Type	% State Investor	Capacity (MW'000)
	China		
China Huaneng	State-owned	100	73.0
National Energy Investment Group	State-owned	100	55.6
China Huadian	State-owned	100	50.3
China Datang	State-owned	100	41.1
State Power Investment Corporation	State-owned	100	32.0
China Resources	State-owned	100	17.8
Shandong Weiqiao Group	Private	0	17.5
Henan Investment Group	State-owned	100	8.2
Beijing Energy Group	Publicly traded	45.59	7.2
Datong Coal Mining Group	State-owned	100	7.2
	United States		
Duke Energy	Publicly traded	0	18.5
NRG Energy	Publicly traded	0	14.4
Southern Company	Publicly traded	0	13.6
American Electric Power	Publicly traded	0	13.6
Berkshire Hathaway	Publicly traded	0	11.0
Vistra	Publicly traded	6.23	8.4
Tennessee Valley Authority	State-owned	100	8.1
Xcel Energy	Publicly traded	0	7.9
Evergy	Publicly traded	0	6.5
DTE Energy	Publicly traded	0	6.4
	India		
NTPC	Publicly traded	51.12	52.7
Adani Group	Private	0	11.8
MAHAGENCO	State-owned	100	9.8
Vedanta Resources	Private	0	8.3
Rajasthan RV Utpadan Nigam	State-owned	100	7.8
Damodar Valley Corporation	State-owned	100	7.1
Jindal Group	Publicly traded	0.80	6.4
Reliance Group	Publicly traded	0.60	6.3
Tata Group	Publicly traded	0	6.3
UPRVUNL	State-owned	100	5.5
	EU/UK		
PGE	Publicly traded	57.52	14.0
RWE	Publicly traded	3.03	13.5
EPH	Private	0	11.4
PPF	Private	0	8.3
Uniper	Publicly traded	40.73	7.7
EnBW	Publicly traded	96.48	7.5
Enea	Publicly traded	51.50	5.8
Enel	Publicly traded	25.59	5.8
Tauron	Publicly traded	33.51	5.4
Steag	Private	0	5.4

The variable *% State Investor* refers to the share of equity held by a government institution. For the USA, China and India, this share only refers to domestic institutions, for reasons of data limitations. A company is classified as *state-owned* if 100% of the equity is held by a government institution. The data comes the Global Energy Monitor coal power plant tracker.

	Parameter	Moment	Estimate
1	Average profitability of units $\bar{\pi}$	Share of emissions retired by private firms	0.05
2	Cost of climate externalities ϵ	Share of emissions retired by public equity investors	0.41
3	Benefit of social externalities s	Share of emissions kept by domestic state investors	0.39
4	Mandate of public equity investors θ^P	Share of emissions sold by public equity investors	0.79
5	Mandate of domestic state investors θ^{DS}	Share of emissions retired by domestic state investors	0.96
6	Mandate of foreign state investors θ^{FS}	Share of emissions kept by foreign state investors	0.19
7	Financial frictions ξ/r (only ratio is identified)	Share of emissions retired by foreign state investors	0.79

Table IA.3: Model calibration: Robustness

Parameter	Estimate - up to 2020	Estimate - up to 2022
Average profitability of units $\bar{\pi}$	0.18	0.62
Cost of climate externalities ϵ	0.47	0.78
Financial frictions ξ/r	0.81	0.82
Mandate of public equity investors θ^P	0.81	0.82
Mandate of foreign state investors θ^{FS}	0.42	0.60
Benefit of social factors s		
Poland	0.95	1.42
Germany	-0.29	0.35
Other EU	-0.68	0.003
Mandate of domestic state investors θ^{DS}		
Poland	0.80	0.82
Germany	0.86	1.02
Other EU	1.15	1.18

Table IA.4: Model calibration: Extension