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Following the Money: Who is Keeping Coal Alive?

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Following the Money: Who is Keeping Coal Alive?*
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ABSTRACT: The 2023 United Nations Climate Change Conference reinforced already existing pressure to transition away from fossil fuels, in particular for the most polluting source, coal. We use a comprehensive dataset on bank loans for coal projects to shed light on which type of banks continue to finance coal and how coal phase-out commitments affect coal financing. We find that coal financing is becoming increasingly concentrated, partly in banks with a very high coal exposure. We also find that many coal loans have maturities much shorter than the remaining lifetime of coal assets, thus exposing equity holders of coal assets to the risk of a more difficult loan rollover. An econometric analysis shows that countries with a strong commitment to coal phase-out, fixed in national law for example, receive less coal financing. Using an instrumental variable, we identify this effect as causal.

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WORKING PAPERS

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1. Introduction

Global coal consumption has increased strongly until 2013 and remains close to that level (IEA 2023a). Looking back at the historic importance of this energy source, it appears to be a safe investment. However, the carbon content of the proven reserves owned by fossil fuel companies is three to four times higher than the remaining budget for the 2°C target (van der Ploeg and Rezai 2020). This means that if the 2°C target is to be respected, most of the reserves need to remain unused (Jakob and Hilaire 2015).

From an economic viewpoint, therefore, the outlook is unfavorable. The political pressure to phase out the most polluting form of energy generation is becoming increasingly strong and has culminated in a strong global agreement to “phase down” the use of unabated coal at the 2021 Conference of the Parties (COP 26) and to “transition away” from fossil fuels at COP 28. In addition, the dramatic cost reduction of renewable energy has made wind and solar cheaper than coal in electricity generation (IRENA 2023). As a result, scenarios for the future energy mix anticipate a quick collapse of coal consumption (Bogdanov et al. 2019; Mercure et al. 2021). Achieving the target of 1.5°C or 2°C global warming requires a very strong reduction of coal use by 2030 and a complete phase-out by 2050 (Luderer et al. 2018).

The ongoing financing of new coal assets may thus in part be motivated by continued political support for the technology in some countries (Dorband, Jakob, and Steckel 2020; Steckel et al. 2020). Even banks that state an awareness of climate change do not commit to reducing the financing of fossil fuels (Elliott and Löfgren 2022). However, many types of coal investments, mines, and power plants in particular, are long-lived, and it is uncertain whether the support enjoyed at the moment will last long enough to make the investments viable. Already several coal companies have experienced increasing caution by banks: Peabody Energy Corporation (in 2019), Sandy Creek Energy Associates (in 2020) and InterGen (in 2021) have been unable to refinance coal-related lending (Moody’s 2021, page 7).

As a result of the large stock of coal assets and the urgency to move out of coal, many investments in coal technology are at risk of becoming stranded. Some assets have already become stranded and are retired early. An example is Germany, which socializes the losses through auctions for coal power plants to shut down early at least cost (Tiedemann and Müller-Hansen 2023). Using a new dataset on bank lending for coal assets, we explore which types of banks are still active in financing coal projects and what determines coal investments at the country level. [1] Identifying the banks still financing coal projects and potential risk clusters is a first step towards understanding potential financial risks from coal investments.

In a descriptive analysis of coal financing, based on the Global Coal Exit List (GCEL), we find that only a limited number of banks is engaging in lending to coal companies. The number has reduced from more than 300 in 2018 to less than 200 in 2020. About 40 percent of coal financing has been received in the Asia Pacific region, and the region also has the largest bank lending for coal assets. At the same time, investments are increasing. Investments into coal supply, that is coal mining, are trending upwards, from 112 billion USD in 2019 to 148 billion USD in 2023 (IEA 2023b). Investments into new powerplants is stable at a low level. These observations indicate a possible concentration of coal financing both geographically and for certain types of banks.
We find that most of the coal power plant capacity is in power plants younger than 20 years. Coal power plants typically operate for about 40 years. Given the large number of young coal power plants and the small size of

[1] The data has been collected from public reports by banks and does not cover other types of investors.

the remaining carbon budget to achieve the Paris Agreement, many coal power plants must retire early. Technological progress alone is expected to cause stranded assets worth 32.6 percent of today's coal assets (Mercure et al. 2018). This includes both coal power plants and coal mines. If climate policy is enacted to limit global warming to 2°C or 1.5°C of global warming, stranded assets are expected to amount to 54.8 percent and 67.5 percent, respectively.

Europe, the Middle East, and Sub-Sahara Africa have a larger proportion of banks that are exposed to coal among banks invested in coal. There is thus a pattern that the region with the largest amount of coal lending, Asia Pacific, also has a lower coal exposure for the average bank than the regions lending less. In Asia Pacific, coal lending is thus common and well diversified. In other regions, there is less coal lending, but the banks that do engage in it are more exposed. Further, we find that banks that are invested in coal assets and are relatively small (assets less than USD 10 billion) or are located in low-income countries, also have a high share of equity in coal.

In a complementary econometric analysis, we identify how membership in the Powering Past Coal Alliance (PPCA) affects coal investments at the country level. In a first step, we evaluate the effect of the strength of the commitment. We measure the strength of the commitment by how strongly the phase-out is anchored legally. We find that countries with a strong commitment to a coal phase-out have received less coal financing but are not less likely to finance coal abroad. By using an instrumental variable for the strength of the commitment, we show that the commitment is causal for the reduction of borrowing for coal projects.

This paper is related to a strand of literature estimating the amount of stranded assets. Mercure et al. (2018) compare the amount of existing coal assets with coal capacity compatible with scenarios in the literature. They find that technology trends alone will cause substantial amounts of stranded assets. The more climate policy is tightened, the more assets will become stranded. Semieniuk et al. (2021) describe that the fossil fuel industry might reevaluate their assets in the light of emerging technology and climate policy trends and abruptly default on debt. (Mercure et al. 2021) find that it will be the fossil fuel producers with the highest production cost that will become uncompetitive and suffer most from stranded assets. von Dulong (2023) estimates that listed owners of fossil fuel assets, mostly located in Europe, the US, and China, may face stranded assets of up to 80 percent of their equity. We complement this literature by describing the regional distribution of the lenders exposed to stranded assets.

A second strand of literature analyzes the financial risk of stranded assets. Battiston et al. (2017) find that the portfolio of investors exposed to climate policy (including assets beyond coal) is of a magnitude comparable to their equity. As a result, a late and abrupt policy change could become a threat to financial stability. Further, there is a risk of contagion of financial instability between banks and investment funds, as they are exposed to the same asset classes (Roncoroni et al. 2021). Sen and von Schickfus (2020) show that investors are aware of the risk of their assets becoming stranded through policy. They price in the risk of stranded assets, but also expect to be compensated by the government. We contribute to this literature by identifying potential weak points for financial stability where banks are particularly exposed to stranded assets.

The remainder of the paper is structured as follows. In Section 2, we discuss the data used for the analysis in this paper. Section 3 provides a descriptive analysis on the distribution of coal financing across banks of different locations, sizes, and types. Section 4 presents an econometric analysis on the effect of coal phase-out pledges on coal financing. Section 5 concludes.

2. Data

Our main data source is the “Global Coal Exit List” (Urgewald 2021) . It contains all publicly available information on financing for coal-related projects for the years 2016 to 2020. This represents 90 percent of the world’s thermal coal production and the world’s coal-fired capacity for generating electricity, which covers 1,000 parent companies and 1,800 subsidiaries along the entire thermal coal value chain. The data thus allows identifying the exposure of financial institutions to the coal sector. The data cover individual financing transaction from banks to coal firms. Since the data are collected from public sources like annual reports, the names of both the coal firms and the banks are listed explicitly. The data provides full transparency and firms which see their activities represented incorrectly can get the data corrected. This provides a high degree of reliability.

Estimates of stranded assets are taken from Mercure et al. (2021). The estimates of stranded assets are based on the value of coal assets estimated in four major scenarios:

- The first estimate is a baseline, which is used by today’s investors as a basis of investment decisions.
- The second estimate is a Technology Diffusion Trajectory (TDT), which means that it considers the technology trajectory. Ongoing technological change is expected to shift electricity generation more strongly from fossil fuels to renewables than in the baseline.
- The third scenario assumes that climate policy will be enforced to limit global warming to 2°C global warming. This implies a reduction of the use of fossil fuels beyond the TDT scenario.
- The fourth scenario assumes that climate policy will be enforced to limit global warming to 1.5°C global warming. In this scenario the use of fossil fuels is limited even more strongly than in the 2°C.

The four scenarios thus have a decreasing use of fossil fuels. As less fossil fuel can be sold, the value of the assets for producing coal decreases proportionally. This decrease in asset value is defined as stranded assets in (Mercure et al. 2021). The data of (Mercure et al. 2021) use the gross sales value of fossil fuels. A more precise measure of the value of stranded assets would be obtained by comparing the net value of fossil fuels (sales value less production cost) between scenarios. However, we are mainly interested in the share of stranded assets in total coal assets. This can be estimated quite closely with the gross value of the fossil fuels. Information on the equity and total assets of the banks with investments in coal is taken from FitchConnect. This data supports the analysis on whether banks have enough capital to absorb losses if coal assets become stranded under different climate change scenarios.

Data on all power plants globally is from the “Global Power Plant Database” (WRI 2021). Data on European settler mortality, which we use as an instrumental variable for the commitment to phase out coal is taken from Acemoglu, Johnson, and Robinson (2001).

Macroeconomic variable used for the regression are from the IMF World Economic Outlook database. Nominal variables have been deflated.

We use data on the membership in the Powering Past Coal Alliance, which we use to test econometrically the effect of membership. The PPCA was launched at COP23 in 2017 and self-describes as “a coalition of national and subnational governments, businesses and organizations working to advance the transition from unabated coal power generation to clean energy”. Data on net direct investment (BFD) and net portfolio investment (BFP) are taken from IMF (2023).

3. Some Stylized Facts about Coal Financing

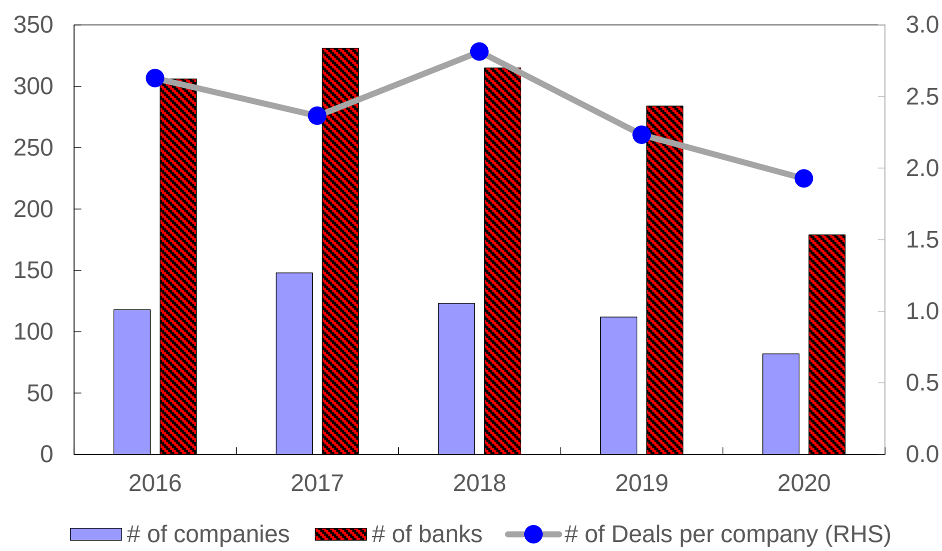
The question of who owns coal assets can be viewed from several different angles. In the first subsection, we cover the number of lenders and their geographic concentration. The second subsection addresses the question of who bears the financial risk of stranded coal assets. As asset lifetimes generally exceed the maturity of financing, equity holders might be disproportionally exposed. The third subsection identifies the types of banks, in terms of geography, size and activity that are most exposed.

The descriptive analysis in this section is intended to identify indications for possible risks to financial stability by identifying patterns in coal asset ownership that might contribute to instability. The analysis is not suited to assess the risk of financial stability. This would require full stress testing as described in Adrian, Morsink, and Schumacher (2020), including a comparison of assets at risks to total assets of each bank and an analysis of the interconnectedness of banks exposed to elevated risk.

3.1 Coal financing and stranded assets

For financial stability it is optimal to spread the financial risk of any type of asset as broadly as possible, so that a shock to the asset type is absorbed by many actors. For coal financing, there might be a strong concentration on a few financial institutions. The data show that the number of banks is surprisingly small for an energy source that provided 33.2 percent of global electricity in 2022 (Figure 1). The production and use of coal requires large-scale operations and the data in Figure 1 show that there are less than three financing deals per year and coal company. This combination of large scale and limited number of financing deals could explain why only few banks are active in the sector. Even though the data covers only a short period, there appears to be a trend of a declining number of banks involved in lending to coal companies. Figure 1 also shows that the number of borrowing coal companies is steadily declining between 2016 and 2020.

Figure 1: Number of coal companies and banks per year



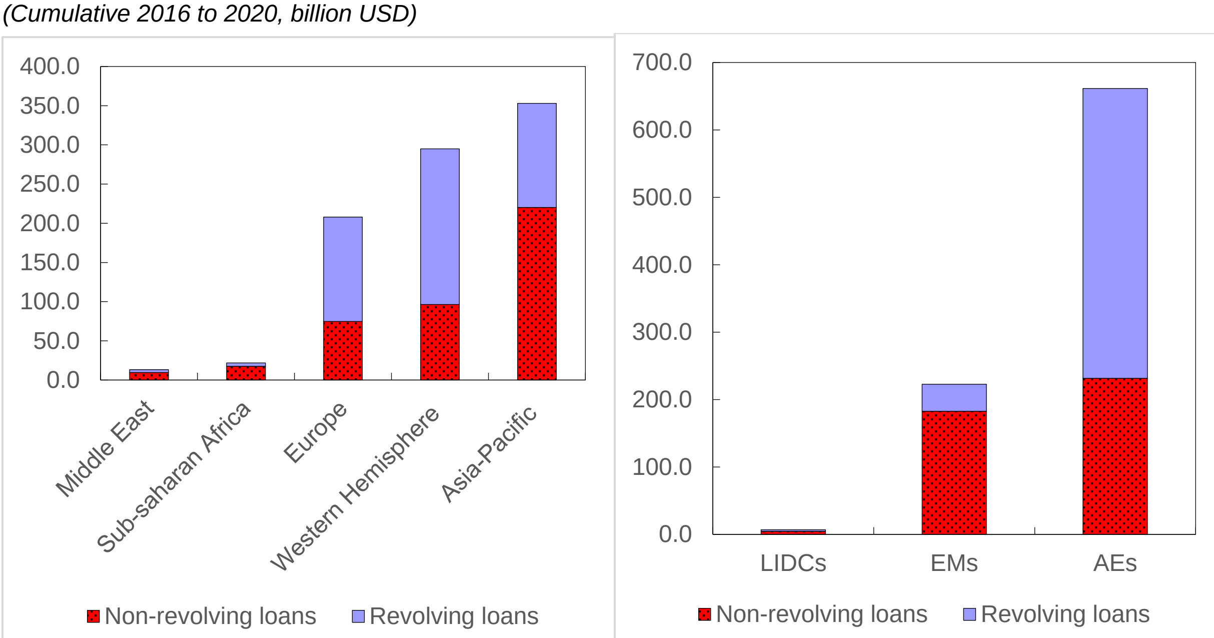
Sources: Urgewald and authors' calculations.
Note: While the data provide information on underwriting as well, this graph considers only loans.

The decreasing trend in the number of banks lending to coal projects corresponds to the trend of divestment from coal (Lipman 2021). At the same time, overall investment in coal assets is not falling. The IEA reports very low levels of investments into electricity generation with coal. However, it also reports an upward trend of investments into coal supply, from 112 billion USD in 2019 to 148 billion USD in 2023 (IEA 2023b). Given that coal investments maintain a high level, a decrease in the number of active banks likely reflects an increasing exposure of these banks to a shock in the coal sector.

If the few banks exposed to the coal sector were to be distributed evenly across the world, the geographic dispersion might support financial stability, as many different countries could deal with their respective threatened banks. Indeed, the countries investing in coal assets are distributed across Europe, the Western Hemisphere and Asia-Pacific, in ascending order (Figure 2, left panel). Over time, these shares are shifting. European lenders are leaving coal financing and are replaced by lending from the coal producers like Australia, Indonesia and South Africa (The Economist 2023). The Middle East as well as Sub-Saharan Africa cover only a small share of the financing.

The right panel of Figure 2 reveals that most of the financing originates in advanced economies (AEs), with a sizeable share coming from emerging markets as well. Overall, the origin of the financing is thus distributed across a large part of the global economy, with Asia-Pacific as the most exposed region. Figure 2 also shows that revolving loans, which allow companies to borrow any amount needed up to a pre-defined limit, are more common in advanced economies. It indicates that in well-developed markets coal companies are trusted sufficiently to be able to borrow without individual project evaluation.

Figure 2: Composition of coal financing by source region, income, and financial instrument
(Cumulative 2016 to 2020, billion USD)



Sources: Urgewald and authors' calculations.

Another indicator for the potential effect of large-scale default of coal assets is the geographic diversification of coal investments. If coal assets default in one country or world region, it would help financial stability if the risk was absorbed through countries across the world.

Table 1 indicates that there is a strong regional-bias, where we define regional-bias as the share of a region's investment that is received by companies within the region. It shows the flow of coal financing, with origin of the funding in columns and destination in rows. Except for the Middle East, all regions direct more than 60 percent of their coal investments to companies within their own region. It implies that the financial risk is concentrated in the region where the coal projects are realized. This data indicates that any policy affecting the profitability of coal projects in a region will be felt mostly by the regional financial sector.

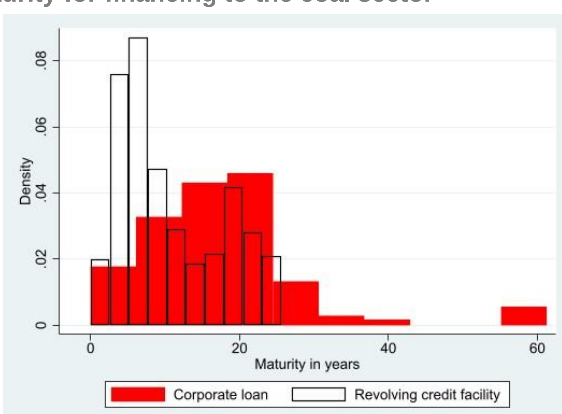
Table 1: Gross financial flows for coal financing between world regions
(Cumulative 2016 to 2020, billion USD)

		Origin					
		Asia-Pacific	**Europe**	**Middle East**	**S.S. Africa**	**W. Hemisphere**	**Total**
Destination	**Asia-Pacific**	305.7	21.2	2.8	0.4	21.1	351.2
	Europe	32.8	139.6	3.1	0.8	28.4	204.7
	Middle East	11.0	0.9	3.1	0.0	0.1	15.1
	S.S. Africa	8.8	4.4	2.2	3.5	2.8	21.7
	W. Hemisphere	38.2	65.2	0.5	0.4	188.2	292.5
	Regional-bias (%)	77.1	60.4	26.5	68.6	78.2	

Sources: Urgewald and authors' calculations.
Note: The origin of the funding is in columns and the destination in rows. For example, Asia-Pacific has lent 8.8 billion USD to Sub-Sahara Africa and received 0.4 billion USD from there. S.S. Africa stands for Sub-Saharan Africa; Middle East includes North Africa and W. Hemisphere stands for Western Hemisphere.

For financial stability, the maturity of financing is relevant as it indicates over which time horizons banks can withdraw from the market. Figure 3 shows that there are important parts of the financing with short time horizons (of less than ten years) and with quite long maturities. As the coal market is expected to shrink substantially by 2030, all maturities beyond ten years are exposed to this expected swing in the market. The maturities of coal financing in Figure 3 can be compared to the long remaining lifetimes of coal capacity in Figure 4. Coal power plants are typically designed for about 40 years. As a lot of coal power plants are quite new, banks providing loans with relatively short maturities will be able to end their exposure, before investments have amortized. In this case the equity owners of coal investments can be expected to bear a large part of the lost value. Indeed, following COP 26, the stock market value of coal-related companies declined substantially (Birindelli et al. 2023).

Figure 3: Distribution of maturity for financing to the coal sector



Sources: Urgewald and authors' calculations.

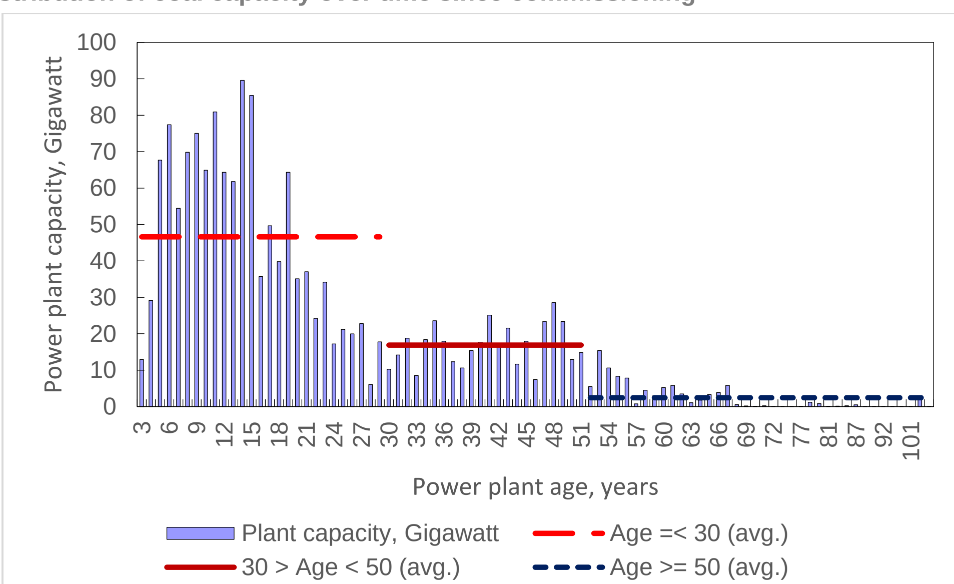
3.2 Coal assets

A counterpart to the financing of coal is an analysis of the stock of coal assets. The 2015 Paris Agreement contained a statement to limit global warming to “well below 2°C”. Since global warming is linked to the concentration of greenhouse gases (GHG) in the atmosphere, it is possible to derive a “carbon budget”, that is the amount of GHG that can be emitted before the warming target is reached. Typically, scientists distinguish the carbon budgets for 1.5°C and 2°C. These carbon budgets can then be allocated to the economic sectors according to historical emission shares.

The lifetime emissions from already constructed assets for the production and consumption of coal exceed the carbon budget for the energy sector (Luderer et al. 2018). If the carbon budgets are to be respected, not all the assets can be used to the end of their economic lifetime. The part of the assets that cannot be used are described as “stranded assets”, which are defined as having “suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities”. Naturally, the amount of stranded assets will be larger if the 1.5°C is to be reached than if the 2°C target is to be reached.

We begin with the assets for coal consumption, that is coal power plants. Figure 4, based on data from the World Resources Institutes (WRI 2021), shows the distribution of capacity over the age of the power plant. It can be expected that older power plants are decommissioned first as they are also the least efficient. If the need to decommission exceeds the stock of old power plants, however, power plants have to “retire early” (Kefford et al. 2018; Fofrich et al. 2020). A considerable amount of coal power capacity is younger than 20 years, so that early retirement is necessary. This implies that debt repayment may not be able to proceed as planned.

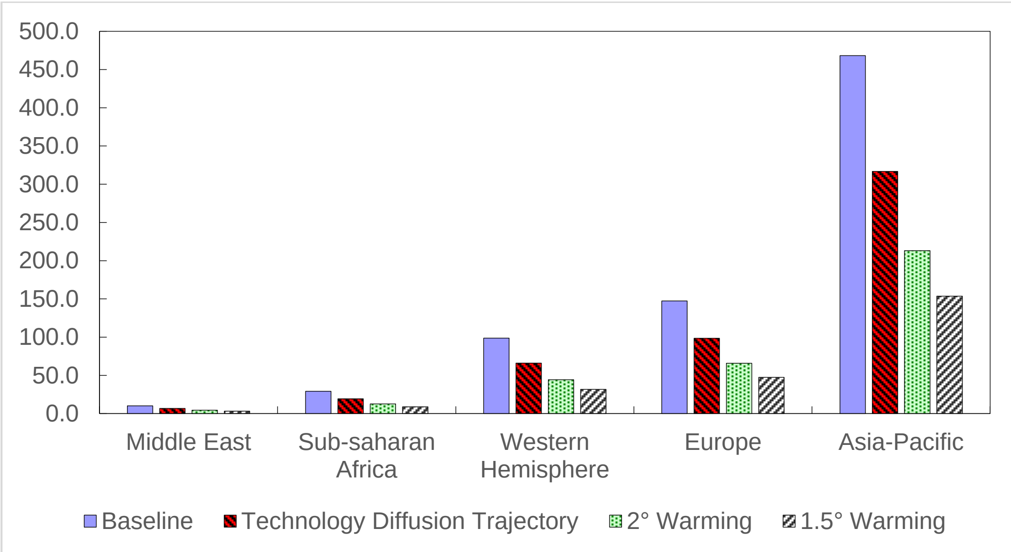
Figure 4: Distribution of coal capacity over time since commissioning



Sources: World Resources Institutes and authors’s calculations.
Notes: The sample contains 1897 coal plants with commssionned year ranging from 1908 to 2018.

On the coal production side, we exploit that the value of coal production assets is given by the profit that can be made with the sale of coal. As described in Section 2, Mercure et al. (2018) estimate stranded assets by comparing the sales value of coal in different scenarios. Figure 5 shows for each of the regions the coal sales value in the four scenarios. Already the TDT scenario, which does not require any climate policy, shows that there will be a considerable amount of stranded assets. The amount increases if climate policy is added to the ongoing progress of technology.

Figure 5: Coal Assets Values Under Different Scenarios
(USD Trillion)



Sources: Mercure et al. 2018 and authors's calculations.

The share of value that gets stranded in each of the scenarios is similar for each world region. The estimates of the value of coal assets are based on a global energy model. The model assumes that each world region must scale back coal production to a similar degree. In other words, the model is neutral regarding the global distribution of stranded assets. In reality, this may turn out differently as some regions might either be politically more ambitious to reduce coal production or as there might be cost differentials in production which force some producers out of the market sooner than others.

3.3 Bank exposure to coal

In Section 3.1, we discussed that the implications of defaults in the coal sector for financial stability depend on how concentrated coal assets are geographically and within individual banks. In Section 3.2, we showed that a considerable amount of coal assets is at risk of being stranded. We now combine these two strands to investigate how strongly banks are exposed to the threat of stranded coal assets.

By using financial data from FitchConnect, we link the exposure of banks to coal projects to the banks' equity. The data below do not include banks which do not have loans for coal projects. An assessment regarding financial stability would need to go beyond the analysis done here and compare the assets managed by banks with coal investments with those of banks without coal investment. We focus on those banks that have at least some coal investments, according to the Urgewald database. Figure 6[2] shows the exposure of banks to coal assets among those banks that have at least some investments in coal.

Well diversified banks are better able to handle default in one type of their assets than less diversified banks. Figure 6 shows the share of banks that are invested with more than 10 percent or 25 percent in coal assets and lists the number of banks with at least some coal investment. The top left panel shows that the average exposure to coal is between 8 percent of equity in the Asia-Pacific region and 21 percent of equity in Europe. There appears to be a pattern that regions with more banks active in coal (like Asia-Pacific) are less exposed per bank, while in regions with a smaller number of active banks (like in Europe), these banks are more exposed. While the Asia-Pacific region thus holds more coal assets in total, individual banks in the region are much less exposed to coal than banks in other regions. The high exposure in Europe could indicate that only a few banks engage in coal, but those which do accept considerable exposure to the sector.

The data can also be used to verify if specific types of banks are particularly exposed to coal, as different types of banks might react to default differently. The top right panel of Figure 6 shows the bank exposure by type of banking activity. Commercial banks hold 49.9 percent of coal investments and on average, around 10 percent of their equity is invested in coal. About twice as exposed, however, are development banks, which on average hold 20 percent of their equity in coal and overall hold 10 percent of coal loans. The World Bank has not made any direct coal investments since 2011 and other development banks have also stopped financing coal. However, Figure 6 covers the period 2016 and 2020, so it contains investments made before some banks made their pledges to stop financing coal. Further, the dataset contains many development banks, including regional and national ones.[3]

The ability of banks to absorb defaults of coal assets might also depend on their size. For smaller banks, an individual coal financing project might cover a considerable share of their equity, while for larger banks it will be easier to stay diversified. The bottom left panel of Figure 6 shows the bank exposure by size. Banks with total assets below USD 10 billion hold 42 percent of coal investments and are most exposed, with coal assets at 13 percent of equity. Medium banks (USD 10 billion to USD 100 billion) hold 37 percent of coal investments and have an average exposure of 6 percent and large banks (above USD 100 billion) are at 2 percent. While this relation between exposure and size does not seem surprising, it does point to a potential stability risk for smaller banks.

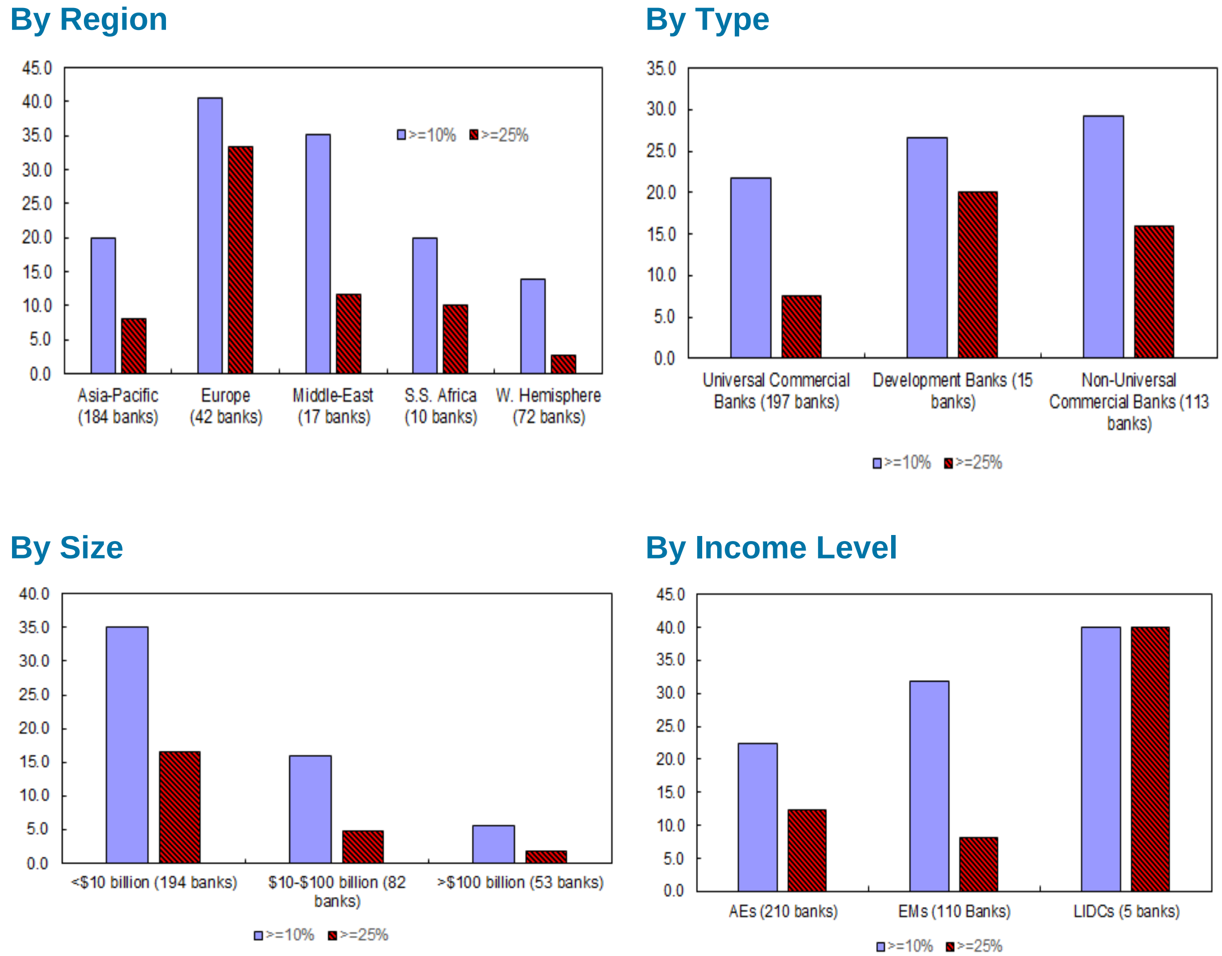
The bottom right panel shows the distribution of exposure to coal by the income level of the bank's country of residence. While AEs have made much more progress in phasing out coal for electricity generation, the chart shows that they have by far the most banks active in coal lending. Just five banks in the database of coal lenders are located in Low-income countries (LICs). The banks in AEs, which are active in coal lending, are less likely to have an exposure to coal of more than 10 percent. Given the relatively high share of exposure in Europe (top left), this indicates that banks in AEs outside Europe are well diversified.

[2] The ratios reported in this section are not comparable to the standard regulatory capital ratios of Basel III. The regulatory capital ratios are based on risk weighted assets. The weights depend on how an asset is considered risky under Basel III from a financial perspective. These weights do not exist yet in the area of climate finance. In addition, this paper focuses only on one type of asset (investment in coal).

[3] Two regional development banks and one national development bank are still over exposed to coal financing with a ratio of coal outstanding loans larger than 10 percent.

Figure 6: Banks' Exposure to Coal Financing by type and size

(Shares of Banks with Outstanding Loans as of end 2020 to Capital Larger than 10 or 25 Percent)



Sources: Urgewald, Fitch Connect, World Economic Outlook, and authors' calculations.

4. Econometric analysis: the Powering Past Coal Alliance

As mentioned above, the PPCA aims to phase out coal to reduce greenhouse gas emissions. To become a member of the PPCA, countries need to commit to a coal phase out date, that is, a year by which they want to cease using coal for electricity generation. Our data covers countries that joined the PPCA between 2017 and 2022 and have phase-out dates between 2030 and 2070 or are already coal free and want to remain so. Further, the data indicates the status of the phase-out, between “in discussion” and “in law”. We use this data to analyze how the target year and the status affect the financing of coal on both sides. Table 2 provides the descriptives statistics of variables used in the regression and Table 3 the list of economies by borrowers and lenders.

4.1 Econometric specification

We use the data of Urgewald on coal financing by banks. We sum up all coal financing of a country's banks and assign it to the country. Similarly, all coal financing received by firms in a country is assigned to the country. This way, we can identify how much coal financing is flowing from an investing country i to a receiving country c. For the economic approach, we follow Rose and Spiegel (2004), who investigate the link between bilateral trade and bilateral lending. Instead of using all bilateral lending, we focus on coal financing.

For the econometric specification, we follow Santos and Tenreyro (2006). We estimate the determinants of bilateral coal finance through a gravity equation. The authors warned against the use of OLS and a log-linearized version of the gravity equation particularly in the presence of heteroskedasticity. They proposed the Poisson pseudo-maximum likelihood (PPML) to estimate the effects on the dependent variable in levels. The traditional Poisson estimator can also be used even if the dependent variable is not an integer. Standard gravity equation variables, like GDP per capita of the trade partners and distance between the trade partners are complemented with PPCA variables:

$$\begin{gathered} C_{ict} = cons + \beta_1 \ln(C_{iit}) + \beta_2 \ln(C_{cct}) + \beta_3 \ln\left(\frac{Y_i}{Pop_i}\right) + \beta_4 \ln\left(\frac{Y_C}{Pop_C}\right) \\ +\beta_5 TS_i + \beta_6 TS_c + \beta_7 TY_i + \beta_8 TY_c \\ +\beta_9 X_{ict} + \beta_{10} X_{cit} + \beta_{11} \ln(D_{ic}) + \beta_{12} cont_{ic} + \beta_{13} Colony_{ic} \\ +\beta_{14} fd_i + \beta_{15} fd_c + \beta_{16} CI_c + \beta_{17} BFD_c + \beta_{18} BFP_c + \beta_{18} r \end{gathered} \tag{1}$$

The variables are defined as

- C_{ict} denotes the amount of coal lending from i to c at time t
- $cons$ is a constant
- Y is real GDP
- Pop is population
- TS is the target status of the coal pledge
- TY refers to the target year
- X_{ic} are exports from country i to country c
- D_{ic} is the distance between country i and country c
- $cont_{ic}$ is a binary variable that is unity if i and c share a land border
- $Colony_{ic}$ is a binary variable that is unity if i ever colonized c or vice versa
- fd is the IMF Financial Development Index
- BFD is net direct investment of all types (not only coal)
- BFP is net portfolio investment of all types (not only coal)

The variables of target status and target year are based on the data of the PPCA. The target status is coded as ‘’no commitment’’=0, “in discussion” =1, “only pledge” = 2, “in policy document” = 3, “in law” = 4. This means, countries with a more credible target have a higher number assigned. The target year is coded as a 0 for countries that are coal free (and intend to stay coal free), 1 if the country aims to phase out coal by 2040, 2 for 2041 to 2050, 3 for 2051 to 2060, 4 for 2061 to 2070 and 5 for after the year 2070. This means that smaller numbers are assigned to more ambitious phase-out plans.

The first line in equation 1 contains controls which capture basic characteristics of the trading countries. The second line in equation 2 contains the PPCA variables, which are the main variables of interest. If countries are sincere in their engagement with the Powering Past Coal Alliance, we would expect the following effects: Countries with a more serious engagement, that is a higher value in the target status, should invest less in coal and receive less coal financing. Further, countries with an earlier phase-out year, that is with a higher value in target year, should invest less in coal or receive less coal financing. The third line in equation 1 represents those variables that have been identified in previous literature as explaining the amount of lending or trading between countries: trade in each direction, distance, a shared land border and a joint colonial history. The fourth line of equation 1 contains variables reflecting financial development.

4.2 Results

We begin with a simplified variant of equation 1 to establish some baseline results, see column 1 in Table 2. The first step leaves out the variables related to the PPCA and the self-financing variables. The lender's GDP per capita has a negative significant coefficient. More developed countries have lower cost of moving out of coal and more resources to manage the transition (Jewell et al. 2019). Of the variables in the third line, sharing a land border and a joint colonial history do not have a significant effect. Of the financial variables, the IMF Financial Development Index for both the investing and receiving country have a positive and significant effect. This is plausible as more financially developed countries can be expected to be more involved in international lending. Net direct investment of the borrower has a negative and significant effect. This suggests that direct investment and borrowing are substitutes.

The effect of GDP, added in column 2 of Table 2, is positive for lenders and borrowers, which simply reflects that larger countries can borrow and lend more. In column 3, we report the self-financing (domestic lending of coal assets) of both borrower and lender (and leave out GDP again). The self-financing has positive and significant effects for lenders and borrowers. This is plausible, as domestic lending and borrowing can be expected to be complementary to international borrowing and lending in the coal sector. The complementarity results from portfolio diversification, that is a domestic bank can diversify by lending to domestic and foreign coal companies. In column 4, we control for both GDP and self-financing, for both borrowers and lenders. In this specification, GDP and self-financing lose significance. It is very plausible that these two variables are highly correlated. All variables which were significant in the first column remain significant in all four specifications. We take the plausible and robust results on these control variables as confirmation that both the data and the methodology are reliable.

In Table 3, we implement the full equation 1, including the target status and the target year. Regarding the target status, the coefficient is negative and significant. This means that countries with a firmer commitment to phase out coal borrow less for financing coal than less committed countries. The lender's status is not significant. This means that the amount of lending is not affected by the commitment of the country to phase out coal. It reflects that joining the PPCA only covers the *use* of coal, not the financing.[4] The results are robust to different specifications regarding GDP and self-financing (columns 2 to 4).

The results for the borrower's target year are negative and significant. This is a counter-intuitive result. We would expect that an earlier phase-out reduces demand more strongly and hence investment into the sector. However, a potential explanation could be the green paradox theory. According to this theory, fossil fuel use is accelerated in the near future if its use is expected to be prohibited further on. It means that coal firms bring investments forward to fully exploit the remaining time before the phase-out. The green paradox has been observed under some circumstances (Norman and Schlenker 2024). The combined results imply that countries with a strong commitment, fixed in national law for example, reduce more their demand for coal financing

[4] The PPCA self describes as "The Powering Past Coal Alliance (PPCA) is a coalition of national and subnational governments, businesses and organizations working to advance the transition from unabated coal power generation to clean energy." It does not cover coal mining, export, or financing.

compared to countries with a less binding commitment but the reduction is less frontloaded when the target year for the phaseout is relatively closer, potentially reflecting the green paradox effect.

A loophole in the PPCA might reduce the risk for investors who are frontloading coal investments. It precludes the use of coal for electricity generation, but not the use in other sectors (Bi, Bauer, and Jewell 2023). When the use of coal for electricity is phased out, the coal price is expected to fall sufficiently to make the use of coal in other sectors profitable. If the loophole is not closed, the phase-out in electricity might cause intersectoral leakage. For example, it is possible to convert coal into a liquid fuel and use it in transportation. Private investors might thus not consider a coal phase-out as definite as the PPCA makes it appear.

The lender's target year is again insignificant. It means that countries making coal pledges do not ensure that their financial institutions stop financing coal abroad. Such a regulation of the financial sector is not required by the PPCA, but it might be expected from consistent policymaking to align actions abroad with those implemented domestically. Again, the results are robust across specifications (columns 2 to 4).
Column 5 of Table 3 contains an additional robustness check. The dramatic decrease in renewable costs may not only influence a country's willingness to join the PPCA and establish coal phase-out targets, but these could also impact the decision to use coal. We therefore use data on the cost of renewable energy and fossil fuels from (Way et al. 2022) and add the relative price as a control to avoid any potential bias. Lower relative price of renewable energy is associated with lower coal financing, but the other results still hold.

Countries that are not coal-intensive but who joined the PPCA may not be highly ambitious because meeting their commitment may not be challenging. As another robustness check, we focus on countries that are coal-dependent—defined as those for which the share of coal in the electricity mix is at least 25 percent. Table 4 shows that the overall results hold or are even stronger when not coal-intensive countries are excluded from the sample. This result implies that coal-dependent countries who credibly commit to phase-out coal are both ambitious and credible by reducing their coal borrowing.

In Table 3, we are using the borrower's target status as an independent variable. However, the borrower's target status is likely to be endogenous to the amount of borrowing. A country borrowing large amounts to finance coal projects might be hesitant to commit formally to phasing out. A less formal commitment makes it easier to backtrack if a phase-out appears inconvenient later. We thus instrument the borrower's target status with European settler mortality, an instrumental variable proposed by Acemoglu, Johnson, and Robinson (2001). These authors show that lower mortality rates allowed for the development of better institutions. Countries with better institutions, in turn, are more likely to be able to commit to a coal phase-out. We find that results with the instrument are still significant (Table 5). With this, we can infer that countries willing to commit more firmly to a coal phase-out subsequently increase their efforts to phase out coal and borrow less for coal investments. The IV approach shows that the correlation in Table 3 is not driven by a choice of commitment based on existing borrowing for coal projects.

Table 2: Baseline estimation

	(1) PPML	(2) PPML	(3) Poisson	(4) Poisson
Log borrower's GDP per capita	-0.1437	0.1367	0.0868	0.2418
	(0.1627)	(0.1882)	(0.1893)	(0.1691)
Log lender's GDP per capita	-0.7274***	-0.3155*	-0.6891***	-0.4790***
	(0.1623)	(0.1857)	(0.1687)	(0.1796)
Log borrower's GDP		0.3484***		0.2272
		(0.0992)		(0.1490)
Log lender's GDP		0.4874***		0.4149***
		(0.1039)		(0.1080)
Exports from borrower to lender	-0.0681	-0.2360***	-0.0029	-0.1418*
	(0.0870)	(0.0908)	(0.0700)	(0.0774)
Exports from lender to borrower	0.1652	-0.0291	-0.0039	-0.1118
	(0.1272)	(0.1211)	(0.1065)	(0.0963)
Log of distance	-0.1744	-0.4623***	-0.2756**	-0.4457***
	(0.1062)	(0.1230)	(0.1203)	(0.1149)
Dummy equal to 1 if countries are contiguous	0.1801	0.1864	0.0983	0.1568
	(0.2338)	(0.2567)	(0.2030)	(0.1982)
Borrower's financial development index	1.6060***	1.5812***	1.3670***	1.4676***
	(0.4558)	(0.4547)	(0.5281)	(0.5389)
Lender's financial development index	4.3896***	3.5880***	4.8553***	4.6304***
	(0.8692)	(0.9531)	(0.7695)	(0.8531)
Net Direct Investment for borrower	-0.0029***	-0.0029***	-0.0026***	-0.0028***
	(0.0007)	(0.0007)	(0.0006)	(0.0007)
Net Portfolio Investment for lender	-0.0001	0.0004	-0.0001	0.0006
	(0.0007)	(0.0006)	(0.0006)	(0.0006)
1 if pair ever was in colonial or dependency	-0.0130	-0.1414	0.1549	0.0357
relationship	(0.2802)	(0.2732)	(0.2021)	(0.1890)
Borrower self-financing			0.1421***	0.1359
			(0.0497)	(0.0948)
Lender self-financing			0.0650**	0.0233
			(0.0312)	(0.0310)
Constant	13.1443***	-12.1625**	10.2439***	-8.3308
	(3.0619)	(6.0309)	(2.7301)	(5.2716)
Pseudo R2	0.2977	0.3449	0.3234	0.3517
Observations	821	821	556	556

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Determinants of Coal Financing

	(1) PPML	(2) PPML	(3) Poisson	(4) Poisson	(5) Poisson
Log borrower's GDP per capita	-0.4367***	-0.1592	-0.2534	-0.1019	-0.0286
	(0.1495)	(0.1628)	(0.1589)	(0.1498)	(0.1471)
Log lender's GDP per capita	-0.6948***	-0.2939	-0.6493***	-0.4243*	-0.4157*
	(0.2047)	(0.2501)	(0.1979)	(0.2455)	(0.2490)
Log borrower's GDP		0.3653***		0.2194	0.2785*
		(0.0966)		(0.1510)	(0.1513)
Log lender's GDP		0.4601***		0.3584***	0.3570***
		(0.1189)		(0.1185)	(0.1146)
Exports from borrower to lender	-0.0172	-0.1775**	0.0146	-0.0995	-0.1168
	(0.0845)	(0.0885)	(0.0709)	(0.0819)	(0.0836)
Exports from lender to borrower	0.1730	-0.0322	0.0280	-0.0823	-0.0850
	(0.1229)	(0.1195)	(0.0916)	(0.0876)	(0.0855)
Log of distance	-0.1051	-0.4030***	-0.2426**	-0.4097***	-0.4410***
	(0.1036)	(0.1292)	(0.1046)	(0.1064)	(0.1084)
Dummy equal to 1 if countries are	0.1889	0.2021	0.0454	0.0830	0.0183
contiguous	(0.2078)	(0.2170)	(0.1844)	(0.1813)	(0.1866)
Borrower's financial development index	2.8856***	2.8282***	2.9743***	3.0447***	2.8510***
	(0.6487)	(0.5741)	(0.5543)	(0.5722)	(0.5638)
Lender's financial development index	4.0286***	3.1497***	4.0296***	3.8349***	3.8409***
	(0.8406)	(0.9424)	(0.7862)	(0.8856)	(0.9126)
Net Direct Investment for borrower	-0.0024***	-0.0023***	-0.0019***	-0.0019***	-0.0018***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Net Portfolio Investment for lender	-0.0002	0.0002	-0.0003	0.0003	0.0000
	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0006)
1 if pair ever was in colonial or	0.0408	-0.1164	0.2016	0.1077	0.0948
dependency relationship	(0.2642)	(0.2658)	(0.1929)	(0.1785)	(0.1657)
Borrower self-financing			0.1514***	0.1409	0.1235
			(0.0551)	(0.1017)	(0.0974)
Lender self-financing			0.0702**	0.0380	0.0514*
			(0.0302)	(0.0310)	(0.0271)
Borrower's target status	-0.2694**	-0.2862**	-0.4079***	-0.4209***	-0.4365***
	(0.1281)	(0.1269)	(0.1179)	(0.1133)	(0.1134)
Lender's target status	0.1258	0.1543	0.2410**	0.2093*	0.2299*
	(0.1199)	(0.1357)	(0.1215)	(0.1244)	(0.1223)
Borrower's target year	-0.4597***	-0.4374***	-0.5418***	-0.5058***	-0.5138***
	(0.1452)	(0.1358)	(0.1204)	(0.1187)	(0.1165)
Lender's target year	0.0228	0.0500	0.0107	0.0487	-0.0307
	(0.1693)	(0.1724)	(0.1657)	(0.1904)	(0.1913)
Ratio of fossil prices to renewable					-1.8653***
energy prices					(0.5016)
Constant	15.7006***	-9.1064	14.1406***	-2.9218	-2.9597
	(3.1345)	(6.8681)	(2.9040)	(6.8230)	(6.6346)
Pseudo R2	0.3442	0.3852	0.3888	0.4075	0.4338
Observations	821	821	556	556	556

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Robustness test with coal-intensive countries

	(1) PPML	(2) Poisson	(3) Poisson
Log of borrower's GDP per capita	-0.5224***	-0.5128***	-0.4247**
	(0.2020)	(0.1936)	(0.1908)
Log of lender's GDP per capita	-0.6800*	-0.3732	-0.3691
	(0.3779)	(0.4045)	(0.4083)
Log borrower's GDP	0.1776	0.3106	0.3480
	(0.1703)	(0.2743)	(0.2787)
Log lender's GDP	0.3015	0.3741*	0.3700*
	(0.1967)	(0.1989)	(0.1963)
Exports from borrower to lender	-0.0250	0.0036	-0.0139
	(0.1805)	(0.1479)	(0.1521)
Exports from lender to borrower	0.1349	0.0266	0.0043
	(0.1429)	(0.1487)	(0.1456)
Log of distance	-0.2647	-0.3801**	-0.4168**
	(0.2468)	(0.1865)	(0.1928)
Dummy equal to 1 if countries are contiguous	0.1508	-0.0444	-0.1048
	(0.2832)	(0.2496)	(0.2515)
Borrower's financial development index	5.5199***	5.8617***	5.8146***
	(0.9368)	(0.8029)	(0.8054)
Lender's financial development index	5.2353***	4.9884***	4.9889***
	(1.2135)	(1.1121)	(1.1470)
Net direct investment for borrower	-0.0009	-0.0008	-0.0007
	(0.0006)	(0.0005)	(0.0005)
Net portfolio investment for lender	0.0004	0.0010	0.0006
	(0.0008)	(0.0009)	(0.0008)
1 if pair ever was in colonial or dependency relationship	-0.1094	0.0604	0.0270
	(0.3683)	(0.2409)	(0.2155)
Borrower self-financing		-0.0051	-0.0167
		(0.1070)	(0.1062)
Lender self-financing		0.0369	0.0507
		(0.0508)	(0.0412)
Borrower's target status	-0.7411***	-0.7816***	-0.8043***
	(0.1490)	(0.1464)	(0.1423)
Lender's target status	-0.0585	0.0494	0.0760
	(0.1579)	(0.1962)	(0.1898)
Borrower's target year	-0.3869**	-0.3687**	-0.3635**
	(0.1784)	(0.1610)	(0.1706)
Lender's target year	-0.4042	-0.1240	-0.2078
	(0.2695)	(0.3357)	(0.3336)
Ratio of fossil prices to renewable energy prices			-1.7702***
			(0.5217)
Constant	5.3617	-3.4085	-2.9516
	(9.9181)	(12.4928)	(12.2840)
Pseudo R2	0.5455	0.5622	0.5846
Observations	461	317	317

Table 5: Determinants of coal financing - IV approach

	Poisson (1)	GMM (2)	Poisson (3)	GMM (4)
Log of borrower's GDP per capita	-0.0984***	-1.5157	-0.0244***	-1.4233
	(0.0058)	(0.9284)	(0.0058)	(0.9917)
Log of lender's GDP per capita	-0.4218***	-1.0384**	-0.4125***	-1.0683**
	(0.0093)	(0.4839)	(0.0095)	(0.5321)
Log borrower's GDP	0.2203***	0.6624	0.2796***	0.6752
	(0.0039)	(0.5388)	(0.0039)	(0.5587)
Log lender's GDP	0.3608***	0.6655*	0.3599***	0.7376*
	(0.0036)	(0.3573)	(0.0036)	(0.3832)
Exports from borrower to lender	-0.1008***	-0.0199	-0.1183***	-0.0495
	(0.0032)	(0.1592)	(0.0032)	(0.1770)
Exports from lender to borrower	-0.0835***	-0.3477	-0.0866***	-0.4629
	(0.0032)	(0.2913)	(0.0032)	(0.3186)
Log of distance	-0.4112***	-1.0476*	-0.4427***	-1.2443**
	(0.0034)	(0.5472)	(0.0035)	(0.6257)
Dummy equal to 1 if countries are contiguous	0.0840***	-0.7147	0.0196***	-0.9764
	(0.0072)	(0.7062)	(0.0073)	(0.8021)
Borrower's financial development index	3.0465***	13.5225**	2.8536***	14.3968**
	(0.0220)	(5.7859)	(0.0219)	(6.4096)
Lender's financial development index	3.8317***	6.3173***	3.8368***	6.6696***
	(0.0335)	(2.0182)	(0.0343)	(2.2577)
Net direct investment for borrower	-0.0019***	-0.0003	-0.0018***	-0.0001
	(0.0000)	(0.0007)	(0.0000)	(0.0008)
Net portfolio investment for lender	0.0003***	0.0014	0.0000	0.0009
	(0.0000)	(0.0012)	(0.0000)	(0.0011)
1 if pair ever was in colonial or dependency relationship	0.1074***	0.2966	0.0944***	0.2176
	(0.0066)	(0.2632)	(0.0066)	(0.2656)
Borrower self-financing	0.1421***	0.1093	0.1250***	0.1979
	(0.0021)	(0.2007)	(0.0020)	(0.2402)
Lender self-financing	0.0378***	0.0592	0.0512***	0.0822
	(0.0010)	(0.0611)	(0.0010)	(0.0515)
Borrower's target status	-0.4228***	-2.4097**	-0.4387***	-2.6812**
	(0.0035)	(1.0257)	(0.0036)	(1.1776)
Lender's target status	0.2081***	-0.0357	0.2284***	-0.0249
	(0.0046)	(0.2729)	(0.0046)	(0.2749)
Borrower's target year	-0.5059***	-1.4832***	-0.5140***	-1.5294***
	(0.0032)	(0.4661)	(0.0032)	(0.4874)
Lender's target year	0.0496***	-0.2202	-0.0294***	-0.2961
	(0.0068)	(0.2650)	(0.0069)	(0.2850)
Ratio of fossil prices to renewable energy prices			-1.8629***	-2.5554***
			(0.0157)	(0.9447)
Constant	-3.0515***	7.4082	-3.1203***	9.0341
	(0.2178)	(10.9011)	(0.2176)	(11.4628)
Pseudo R2	0.408		0.4342	
Observations	557	352	557	352

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Since the underlying methodology of the IV is based on GMM, there is no first stage. However, the correlation between the log of mortality and the borrower's target status is about negative 49 percent (the regression of borrower's target status on the log of mortality gives a coefficient of -0.05 with a T-Student of -13.1). This means higher the log of mortality, the higher the chance to not legislate and enforce PPCA commitment.

5. Conclusion

Previous research estimates that coal assets will become stranded through technological process alone. The more climate policy is enacted, the more stranded coal assets must be expected. From the perspective of financial stability, it is important to understand how coal asset ownership is distributed. In addition, identifying effective measures to avoid additional coal investments could help addressing the challenge.
We find indications that some patterns warrant a closer look from the point of view of financial stability. Coal assets are increasingly concentrated among a smaller number of banks. A large part of coal assets is owned in the Asia-Pacific region, Europe, and the Western Hemisphere. Among the banks lending to coal companies, banks in Europe, the Middle East and Sub-Sahara Africa have a ratio of outstanding loans to coal companies to equity of more than 15 percent. The exposure to coal is also high among small banks and banks in low-income countries.

Banks with a high exposure to coal are at risk of stranded assets in the coal sector, especially for loans with maturities beyond 10 years. We also find that many loans have maturities below ten years, while the majority of coal power plants are less than half into the standard power plant lifetime of 40 years. Should deteriorating prospects for coal power plants make loan rollover difficult in coming years, equity holders of coal assets are at risk of losing their investment. At the same time, a stronger engagement with the Powering Past Coal Alliance (PPCA) is correlated with receiving less coal financing. Further, countries provide less coal financing after joining the PPCA.

For policymakers, it might thus be useful to monitor the exposure to coal assets to ensure that the risks of this asset type are assessed correctly and that systemic risks are avoided. The PPCA seems to be at least partly successful in communicating and reinforcing a commitment to phase out coal. This seems to serve as a signal to investors to become more cautious. Joining the PPCA might thus be a good way for governments to wind down the coal sector in an orderly and timely manner, because it sets clear expectations well in advance of the end of the business model of coal.

Our results underline the need for future research on the financial stability implications of coal financing. Such an analysis could simulate what a coal phase-out as required for the 2°C or 1.5°C targets would mean for banks, and if some banks might be so exposed that they could not handle the amount of stranded assets expected in these scenarios. If banks threatened by stranded assets are concentrated geographically, there could be a systemic impact on financial stability. Depending on the timing of the coal phase-out and the length of maturities for coal lending, there is also a possibility that banks can avoid much of the risk by not rolling over the debt. This would imply that equity holders of coal assets would have to expect a loss in value of their equity.

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Appendix: Tables

Table 6: List of Economies

Borrowers		Lenders	
United Arab Emirates	Japan	United Arab Emirates	Israel
Australia	Kazakhstan	Australia	Italy
Bangladesh	Kenya	Austria	Jordan
Bulgaria	Korea	Burundi	Japan
Bosnia and Herzegovina	Luxembourg	Belgium	Korea
Brazil	North Macedonia	Bangladesh	Kuwait
Canada	Malaysia	Bahrain	Luxembourg
Switzerland	Pakistan	Brazil	Mauritius
Chile	Phillipines	Barbados	Malaysia
China	Poland	Canada	Netherlands
Columbia	Russia	Switzerland	Norway
Czech Republic	Singapore	Chile	Pakistan
Germany	Serbia	China'	Philippines
Finland	Thailand	Cote d'Voire	Poland
France	Türkiye	Cyprus	Portugal
Great Britain	Taiwan, POC	Germany	Qatar
Grece	United States	Denmark	Russia
Hong Kong, SAR	Vietnam	Egypt	Saudi Arabia
Hungary	South Africa	Spain	Singapore
India	Zambia	Finland	Sweden
Indonesia	Zimbabwe	France	Thailand
Italy		Great Britain	Taiwan, POC
		Hong Kong, SAR	United States
		Hungary	Vietnam
		India	South Africa
		Indonesia	Zimbabwe
		Irland	

Note: SAR stands for Special Administrative Region and POC stands for Province of China

Table 7: Descriptive Statistics

Variable	Observations	Mean	Std. dev.	Minimun	Maximum
Coal financing	972	462.724	911.503	2.444	10343.68
Log of borrower's GDP per capita	972	10.357	0.82	7.745	11.678
Log of lender's GDP per capita	972	10.611	0.61	6.633	11.68
Log borrower's GDP	972	28.312	1.403	24.23096	30.84
Log lender's GDP	972	28.491	1.328	22.212	30.84
Log of exports from borrower to lender	966	2.103	1.832	-12.572	6.358
Log of exports from lender to borrower	945	2.099	1.986	-18.238	6.358
Log of distance	972	15.227	1.045	12.283	16.687
Contiguity dummy	972	0.102881	0.303	0	1
Net direct investment for borrower	853	0.672	0.216	0.156	0.966
Net direct investment for lender	838	0.759	0.156	0.133	0.966
Net portfolio investment for borrower	972	-11.702	80.703	-345.437	218.864
Net portfolio investment for lender	972	-4.398	123.824	-540.195	301.91
Ratio of fossil to renewable prices	863	0.829	0.123	0.525	1.032
Borrower's target status	972	2.802	1.093	0	4
Lender's target status	972	3.388	0.884	0	4
Borrower's target year	972	3.146	1.019	1	6
Lender's target year	972	3.074	0.789	1	6