Ten Financial Actors Can Accelerate a Transition Away from Fossil Fuels

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ABSTRACT

Investors have a central role to play in the sustainability transition, due to their inordinate influence on the governance of the fossil fuel extraction industry. Using network analyses, this paper links fossil fuel firms to equity owners, by distinguishing spatial, sensitivity, and ownership characteristics of top shareholders and establishing a ranked list of the most prevalent shareholders based on emissions potential and network centrality. Our study reveals that among the most prevalent owners, are government signatories of the Paris accord and prominent American investment managers. We conclude that a concentrated number of investors have the potential to influence the strategic direction and governance of these firms and should consequently be held accountable for financing the economic activities that contribute to climate instability. This paper directly contributes to the fragmented body of academic research on financial systems, supply-side climate solutions, and sustainability transitions.

[1] The views expressed in this paper do not represent the opinion of the Banque de France or the Eurosystem.

1. INTRODUCTION

The burning of fossil fuels is the single largest source of global greenhouse gas emissions (Heede & Oreskes, 2016), but most fossil fuel extraction is concentrated to a small number of companies (Ekwurzel et al., 2017). Just 200 companies, the Carbon Underground 200 (CU200), currently own 98 percent of global fossil reserves in the form of oil, gas, or coal (Fossil Free Funds, 2020). If these reserves are burned, it is estimated that it would generate 674 gigatons of carbon emissions; 20 times greater than fossil emissions in 2019 and three times greater than our global carbon budget (Matthews et al., 2021). Consequently, we cannot achieve a sustainable transition without addressing the CU200.

One of the most powerful stakeholder groups that can influence the business strategy of fossil fuel companies, and therefore contribute to or stall a sustainable transition are capital markets. Inspired by Naidoo (2020), we contend that climate action requires grand-scale responses, and grand-scale responses require finance. Indeed, capital markets have historically been foundational in supporting economic transitions (Perez, 2002) and will be vital in supporting the sustainability transition as well. Though the study of sustainable finance has burgeoned in recent years, literature on the nexus of finance and sustainable transitions research remains fragmented (Naidoo, 2020).

Perhaps even more overt is the gap in knowledge around finance, sustainable transitions, and the fossil fuel industry. Though fossil fuel production is the leading cause of anthropogenic climate change (Ekwurzel et al., 2017; Frumhoff et al., 2015), most research in this space focuses on reducing demand for carbon (Erickson et al., 2018; Kemp & Van Lente, 2011; Piggot et al., 2018). However, effective climate solutions will require ‘cutting with both arms of the scissors’ (Green & Denniss, 2018), that is, also curtailing fossil fuel supply.

Through engagement and divestment, capital markets are able to influence business strategy and curtail fossil fuel extraction (Hunt & Weber, 2018). However, the potential influence of each independent shareholder will differ based on the shareholder characteristics, and consequently, successful points of intervention will also differ. Interventions from an investment management firm with many small holdings will, for instance, differ from a government with few large holdings. To effectively target solutions, we must first ask, who owns these 200 companies?

In this paper, we do not take a position on what these major owners should do (divest, investor activism, writing off fossil fuel reserves, or nothing at all). We simply map the market structure of equity ownership in the CU200 and identify shareholders who have the greatest potential influence on the corporate governance of these firms. Financial actors continue to invest both debt and equity to propel the fossil fuel industry (Fichtner et al., 2017; Louche et al., 2019); yet, the influence of financial actors in propping industries attributed to climate instability has largely been ignored (Galaz et al., 2018).

We find that the ten owners with the most influence on the future use of fossil fuel reserves are Investment Managers (Blackrock, Vanguard, State Street, Dimensional, Life insurance Corp, FMR, and Capital Group) as well as Governments (India, Saudi Arabia, and Norway). These ten actors have the greatest potential to influence equity markets and the trajectory for a sustainable transition in the fossil fuel industry.

We conclude that decisions by these major actors will influence future global emissions potential and, therefore, climate stability. Given the recent trend of pledges by investment managers to adopt responsible investment approaches as well as pledges by governments to reduce their carbon emissions, we extrapolate that equity markets may place increasingly higher pressure on their

investees to align their business practices with the investors' carbon reduction strategies. These efforts could result in the systemic restructuring of the fossil fuel industry in line with a sustainable transition. Consequently, the study contributes to the research gap on capital markets, market structure, and sustainable transition, as well as to the burgeoning body of supply-side literature (Jaccard et al., 2018; Strauch et al., 2020) by analyzing the structures of capital markets in the fossil fuel industry as a catalyst in driving supply-side constraints.

2. FINANCE AND SUSTAINABILITY TRANSITIONS

Fossil fuel production is the leading cause of anthropogenic climate change. The activity is primarily concentrated to the world's largest fossil fuel producers. Ekwurzel et al. (2017) calculate that nearly two-thirds of total carbon emissions can be traced to just 90 major carbon producers, raising attention to the industry's contribution to and responsibility for climate instability. Production and emissions are also concentrated to few major carbon producers; Heede (2014) estimates that just 78 private and government-run carbon majors produced 63 percent of the world's fossil fuels from 1750 to 2010. The production of remaining reserves held by these 78 firms would surpass the remaining global carbon budget by 160 percent (Heede & Oreskes, 2016). Based on updated estimates for our global carbon budget (Matthews et al., 2021), we calculate that the combined 647 gigatonnes of potential emissions held by the CU200 nearly triples the 230 gigatonne carbon budget that remains in order to safely stay within 1.5-degrees of warming. Consequently, the emissions potential of the CU200, examined in this study, is substantial.

Though fossil fuel production is agreed to be the leading source of anthropogenic climate change, policy discourse remains dominated by demand-side (as opposed to supply-side) solutions like

carbon pricing, energy retrofits, and electrification (Green & Denniss, 2018; Kemp & Van Lente, 2011; Piggot et al., 2018). Supply-side policies are defined as policies that limit the exploration, extraction or transportation of fossil fuels. These policies can come in the form of economic instruments like production taxes or revoked subsidies, regulatory approaches like prohibitions or quotas, or through government provisions that restrict public financing or compensate, leaving reserves underground (Lazarus & van Asselt, 2018). These policies may be more effective as well; Erickson et al. (2018) estimate that simply stopping the issuance of new oil well permits could reduce 2030 oil production by about 70 percent. Supply-side policies would slow investment in fossil fuel production, limiting carbon lock-in and reducing stranded asset risk; however, the potential of supply-side financing is often forgotten in policy solutions.

Much like the supply-side policy solutions above, access to capital markets plays a key role in sustaining or restricting economic activities that coordinate or stall transformative processes. Divesting from and limiting future investments in unsustainable industries such as fossil fuels can play a role in restricting unsustainable economic activities (Naidoo, 2020); however, the technical and societal challenges of a sustainable transition (Horne, 2013) alongside policy uncertainty and short-termism (Hafner et al., 2020) have resulted in continued investments in fossil fuels.

Markets have begun to respond to and reallocate capital toward emissions reduction solutions through, for example, reducing the carbon exposure of their portfolio through divestment or investing in renewable energy, energy efficiency, and low-carbon alternatives (Strauch et al., 2020). However, reduction of carbon exposure without reduction in production is simply not enough to mitigate the climate crisis (Steffen et al., 2018). Sustainability transitions will struggle to materialize without the active engagement of financial systems that shift economic activity

toward sustainability (Naidoo, 2020). Consequently, financing that perpetuates the exploration, extraction, or transportation of fossil fuels should be held responsible for the climate instability caused by said production (Galaz et al., 2018; Urban & Wójcik, 2019).

We assert that financial markets play a central role in curtailing supply-side fossil fuel production; however, it is unknown who exactly these key financial actors are in the fossil fuel industry. Thus, the identification of key financial actors that contribute to climate instability is important. Financiers may allocate capital to the fossil fuel industry through a combination of debt and equity financing. Debt financiers can withhold capital from select firms that may not align with the financier's mandate or build incentives into the debt covenants. Equity owners, in contrast, can vote on the future strategic direction and governance of the firm. As equity ownership determines the influence of an investor over future corporate strategy (Appel et al., 2016), equity holders may be most effective in driving supply-side climate policy from within the organization. Recent analyses linking equity holdings to climate stability provide tools to directly link financial actors to their contribution of emissions attributed to their investments (Galaz et al., 2018; Naef, 2020). Our paper goes further by looking at the ownership structures of the fossil fuel industry – a gap in current equity ownership research.

Equity markets can exert influence on the fossil fuel industry through one of three mechanisms – exit, voice, and loyalty (Hirschman, 1970). Shareholders show loyalty by holding shares and express discontent by voicing their positions or divesting their holdings. There is a sizable body of literature that has emerged in the past decade on divestment as a means to reduce carbon exposure in a portfolio, depress stock valuation, and limit access to capital (Arbuthnott & Dolter, 2013; Dordi & Weber, 2019; Henriques & Sadorsky, 2018; Hunt & Weber, 2018; Trinks et al.,

2018). However, the literature on active ownership and climate-related engagement is less established (Bajo et al., 2020; Dimson et al., 2015). Through the lens of agency theory, large owners or collectives can influence corporate governance through active ownership (Fichtner et al., 2017; Gillan & Starks, 2000); however, intervention through active ownership has traditionally been used to increase corporate value, not curtail production as would be needed in the fossil fuel industry. With the heightened risk of asset stranding in the fossil fuel industry, there is a financial case to intervene in the industry to mitigate the financial risks associated with climate change. In practice, the efficacy of engagement varies; while some investors have taken positive steps to engage with the industry, others continue to vote against climate-related shareholder proposals (Martin et al., 2020). Consequently, equity owners that maintain holdings in fossil fuel firms must be held accountable for their continued and unabated contribution to fossil fuel production and, ergo, to climate instability.

3. RESEARCH QUESTIONS AND CONTRIBUTION

Our study asks three overarching questions. First, what are the characteristics of equity owners that invest in the CU200? To answer this question, we present a descriptive analysis of firms and shareholders. We analyze their spatiality, sensitivity, and ownership distribution. Second, we ask, how much influence do different types of equity owners have over the governance of the industry. We answer this through exploratory analysis, presenting a collection of bipartite network models and examining their structures to quantitatively compare how central and influential different shareholder types might be in affecting corporate governance. Finally, we explore which individual shareholders have the greatest potential impact on the governance of fossil fuel firms.

Based on their carbon exposure and network centrality, we rank shareholders against their peers. We list which governments, corporations, investors, and individuals are both most responsible for and most able to influence economic activities that impact climate stability.

4. DATA AND METHOD

We adopt a network analysis to uncover the structures of ownership in the fossil fuel industry. Data on the 200 most prevalent fossil fuel firms are collected from the CU200. Complementary shareholder data is collected through Bloomberg. The analysis begins with an overarching description of the firms and shareholders in the sample, including aspects of economic geography, sensitivity to shareholders, and ownership distribution. We then present a collection of network models, comparing the dynamics of bipartite structures across shareholder types. We conclude with an exposé of the most influential shareholders, based on a novel score calculation.

4.1 Data

We rely on two sources of data. Data on fossil fuel firms and their related emissions potential is given by the CU200 database, hosted by Fossil Free Funds. This database provides 100 coal and 100 oil and gas companies with the largest reserves of fossil fuels (Fossil Free Funds, 2020). Collectively, these 200 firms account for 98 percent of proven coal reserves, 98 percent of reported proven gas reserves, and 97 percent of proven oil reserves held by publicly listed companies. Based on the held reserves from Q4 2019, the emissions potential of firms ranges from 106 GT Co2 (Saudi Aramco) to 0.097 GT Co2 (Centennial Resource Development Inc).

Ownership data of these 200 companies is collected from Bloomberg. Bloomberg lists owners of most firms and provides a list of owners by the percentage of shares outstanding which they own.

One methodological consideration concerns firms with multiple listings (for example, in Hong Kong and Shanghai or London and Amsterdam). For these companies, we adopt the following procedure. In instances where a Chinese firm is traded in both Hong Kong and China, we select the Hong Kong traded stock for greater international access. In instances where a firm has dual listings in the same region, the larger listing (based on market capitalization) is selected. Finally, in instances where a firm has multiple international tickers, the country of registration is selected. Only holdings greater than one percent, as a delineation of material influence, are included in this analysis. The data analysis from Bloomberg was done in February 2021 and reflected the ownership structure at that point in time.

We complement this data with a second layer of ownership analysis, where we further identify owners of corporations, holding companies, trusts, venture capital, and shareholders that are listed as other or unclassified. Other shareholder types such as banks, governments, hedge fund managers, investment advisors, high net worth individuals (HNWI), and sovereign wealth funds were identified as final owners. Our exploration of indirect owners through the second layer of ownership found that many owners were HNWI. Of the 146 shareholders we investigated for indirect ownership, only 19 percent had additional ownership data. Among the rest, 51 percent had no additional information listed on Bloomberg (for example, HNWIs), 23 percent were owned by private companies which do generally not disclose ownership, and 6 percent were owned by another CU200 listed firm. We applied the same procedure for managing multiple listings, as delineated in the direct ownership method above for the second layer ownership.

4.2 Method

Our opening descriptive analysis presents the sample characteristics of the firms and shareholders. By firm, we indicate which firms are included in the sample and some characteristics like the location of headquarters, stock exchange they are traded on, and range of emissions potential. By shareholder, we indicate what types of shareholders are most prevalent, location of headquarters, and proportion of holdings. We next adopt Wojcik et al.'s (2019) typology of economic geography to present the regional distributions between shareholders and the firm. We briefly speak to the nature of carbon leakage, whereby financiers' export' production capacities to other, less stringent geographies. This typology is complemented with a sensitivity analysis by region, inspired by Galaz et al. (2018), where we use the debt to capital ratio and Herfindahl-Hirschman Index (HHI) to evaluate whether select regions are more susceptible to shareholder influence than others. We finally conclude the descriptive analysis with a stepwise ownership distribution table (Galaz et al., 2018) that presents how ownership type changes as the proportion of equity ownership rises.

We next turn to the network analysis. We present the bipartite network graphs (Bajo et al., 2020) for first layer (direct) ownership and second layer (direct and indirect) ownership. Network analyses can be used to understand the structure and the dynamics of real networks, such as social networks, by adopting a quantitative approach based on relational data to characterize a group of people or a set of organizations (Rowley, 1997). Notably, social network analyses have been used in the context of stakeholder influence in corporations (Cundill et al., 2018; Giurca & Metz, 2018; Yang et al., 2018) and in sustainability transitions research (Brugger & Henry, 2021; Schanz et al., 2019). Centrality metrics are used to measure the relative importance of a node (a shareholder of a firm) within the graph. The metrics can inform, for example, how influential a shareholder is in the network or how influenceable a fossil fuel firm is in the network. We calculate two centrality

236 measures, degree centrality and betweenness centrality, due to their efficacy in addressing the
237 research question (Das et al., 2018). Degree centrality (Equation 1) is a metric of the connectedness
238 of a node, namely, how many firms a shareholder is connected to and how many shareholders have
239 holdings in a firm. A higher degree centrality score for a shareholder may indicate that the
240 shareholder is more deeply connected with numerous fossil fuel firms and may consequently be
241 able to exert influence on a larger proportion of the industry. One notable shortcoming of the
242 degree centrality measure, however, is that it weighs all connections equally; a holding of one
243 percent and fifty percent would be weighed the same.

244 $$Equation\ 1\text{: } C_D(v) = \deg(v)$$

245 Consequently, the degree centrality is complemented with a betweenness centrality measure. The
246 betweenness centrality measures how important a node is to the flow of information through a
247 network (Equation 2). It does so by measuring the sum of instances whereby the shortest distance
248 (σ) between two nodes (s and t) passes through a select vertex (v). A higher betweenness centrality
249 score for a shareholder may indicate that the shareholder is an important bridge that connects many
250 nodes in a network, which quantifies the shareholders' control in communicating information
251 between other shareholders and firms. Other centrality measures like closeness centrality were not
252 included in this analysis, as they prove to be ineffective for disconnected networks.

253 $$Equation\ 2\text{: } C_{B(v)} = \sum_{\{s \neq v \neq t \in V\}} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

254 Our analysis further extrapolates how centrality differs between shareholder types by comparing
255 degree and betweenness measures between public shareholders (governments and sovereign
256 wealth funds), corporations, investment advisors, banks, pension funds, and high net worth

individuals. We compare these scores against a benchmark of the complete network. This informs us about the potential influence each shareholder type may have within a network. For example, investment advisors with many small holdings in multiple firms may adopt a different engagement strategy than governments with large holdings in one or few firms.

We conclude with an exposé of the most influential owners that we identify using a combination of their degree measure and the proportion of emissions held within the sample (Equation 3). The calculation is comprised of two parts. First, we sum the proportion of emissions potential shareholder *j* holds in a fossil fuel firm *i* across all firms. In and of itself, this metric has some limitations. First, firms may have multiple listings with different holders. Thus, we do not infer that any one shareholder 'owns' an exact proportion of a firm's potential emissions. Second, the emissions calculation does not incorporate the shareholders' ability to influence the industry. Thus, the held emissions are multiplied by a degree score. Firms with more connections receive a higher score for their ability to influence numerous firms and, consequently, the industry as a whole. This calculation allows for us to rank equity owners without allocating specific emissions amounts.

$$Equation\ 3: Score_j = \sum (Emissions\ Potential_i \times Percent\ Holding_i) \times \frac{Degree_j}{\max_j Degree_j}$$

5. RESULTS

5.1 Descriptive Analysis

Our data collection for ownership data found valid useable data for 182 of the 200 CU200 companies. This discrepancy arises from 13 firms that do not provide holders greater than one

277 percent, four firms that are listed on both the top 100 coal and top 100 oil and gas list, and one that
278 could not be identified (Encana, now Ovintiv).

279 We identify 918 distinct shareholders with greater than 1% ownership in at least one of the fossil
280 fuel firms in our sample. These are direct and indirect owners of the CU200. Within these owners,
281 by type, 232 are investment advisors, followed by high net worth individuals (101), corporations
282 (90), hedge fund managers (60), governments (55), and holding companies (50). Among the most
283 prevalent shareholders (defined as the number of firms the shareholder has greater than 1%
284 ownership in) is Vanguard (109), Blackrock (105), Norges Bank (46), Dimensional Fund (45),
285 State Street (45), and Fidelity (38). Governments are among the most influential stakeholder,
286 holding on average 24.6 percent of shares in the companies they invest in. This is followed by
287 corporations (18.2 percent), private equity firms (11.7 percent), and holding companies (11.3
288 percent). Investment advisors like Blackrock, Vanguard, and Fidelity, on average, hold 3.9 percent
289 of the firms they invest in.

290 ***5.1.1 Geographic Analysis***

291 The CU200 list is a global registry of fossil fuel majors. By region, 60 firms on the CU200 are
292 registered in the United States, followed by China, Canada, Russia, Australia, and India. These
293 firms may trade on a different stock exchange than the country in which they are registered. By
294 stock exchange, 61 companies are traded on a United States stock exchange, followed by China,
295 Canada, Australia, Hong Kong, and Russia. In contrast, ownership distribution is heavily skewed
296 toward the United States, with 213 of the 918 owners based out of the United States. Table 1 below
297 presents the top firms, stock exchanges, and owners by region.

298

Table 1 Here

Regional Distribution of Firm, Stock Exchange, and Owner

To understand the spatial relations between owners and firms, we adopt Wojcik's (2019) typology to present four groupings, based on the country of registration of the firm and shareholder in relation to the stock exchange. If, for example, a Canadian shareholder owns equity in a Canadian fossil fuel firm, which is traded on a Canadian exchange, this constitutes a domestic activity. In contrast, if an American firm owns equity of a Canadian fossil fuel firm traded on a Canadian exchange, this constitutes an import activity. This typology is visualized in Figure 1 below. Excluding firms and shareholders with unclassified locations, 1,709 holdings (52.2 percent) are classified as domestic activities. 51.3 percent of those holdings are within the United States. Consequently, over a quarter of holdings in the sample are between American fossil fuel firms and American shareholders, traded on an American exchange. By import activity, American shareholders are seen to invest frequently in Canadian, Australian, Russian, Japanese, Indian, and Chinese fossil fuel firms. By platform activity, American shareholders often invest in Chinese fossil fuel firms on foreign exchanges, such as the Hong Kong stock exchange. Finally, export activities, whereby a domestic shareholder holds domestically traded shares in a foreign firm, are less common. This visualization highlights the fact that wealthy nations, such as the United States, are investing in pollution abroad, which ties closely with the carbon leakage concept.

The exportation of carbon emissions by oil-exporting nations is an active point of discourse in climate policy literature (Khan et al., 2020). Through international trade, exports of fossil fuel

resources offset national consumption-based carbon emissions in oil-producing nations while profiting off the production of carbon resources. Literature on carbon leakage attests that global trade of resources transfer pollution to other countries with less stringent climate policy, while wealthy economies gain from production without the associated emissions (Hasanov et al., 2018; Liddle, 2018). The spatial aspects of capital and carbon leakage remain relatively underdeveloped (Liu et al., 2018). Through cross-border investment activity, shareholders can prop and profit off fossil fuel production and emissions outside of federal jurisdiction.

Figure 1 Here

Geographic distribution of shareholders and firms

5.1.2 Sensitivity Analysis

We complement Wojcik et al.'s (2019) typology with a sensitivity analysis by region, which examines how reactive a firm is to shareholder influence. In line with Galaz et al. (2018), we use the debt to equity ratio and Herfindahl-Hirschman Index (HHI) to evaluate whether select regions are more susceptible to shareholder influence than others. The HHI is a measure of market concentration, presenting whether a firm's ownership is competitive or monopolistic. As highlighted to the left of Table 2 (Panels A and B), countries with a high HHI indicate monopolistic ownership and countries with a low HHI indicate a competitive market. Conversely, to the right of Table 2 (Panels C and D), countries with a high debt to equity ratio indicate how heavily a firm relies on debt financing and, consequently, how sensitive the firm is to external financing.

Table 2 Here

Country-Level Herfindahl-Hirschman Index and Debt to Capital Ratio for CU200

5.1.3 Stepwise Reduction of Ownership

We conclude the descriptive analysis with a stepwise ownership distribution table that presents how ownership type changes as the proportion of equity ownership rise. Table 3 and Figure 2 below present the stepwise distribution by ownership type. The question here is, do certain shareholder types own larger shares of companies they are invested in? Though the majority of holdings greater than 1 percent are by investment advisors (53.8 percent), they often hold a smaller proportion of the fossil fuel firms. That is not to say investment advisors cannot influence the firm; at 5 percent (typically denoted as block holding), investment advisors still comprise 48 percent of owners. At 10 percent, investment advisors comprise 34.0 percent. Owners with greater than 20 percent holding in any one firm (denoted as a minority interest shareholder), however, are largely comprised of governments and corporations, who collectively account for 64.3 percent of owners. At the 50 percent mark (denoted as majority shareholders) – owners that hold over half of equity holdings in a firm – governments account for 53.5 percent of owners. 23 of the 195 firms in our sample have a government entity as the controlling shareholder.

Table 3 Here

Stepwise Reduction in Ownership by Shareholder Type

Figure 2 Here

Stepwise Reduction in Ownership by Shareholder Type

5.2 Network Analysis

Our bipartite network examines the interrelation between the CU200 firms and their shareholders based on equity holdings. The connectedness of the graph informs the influence shareholders may have in the corporate governance of these firms. Figure 3 below depicts the complete ownership network, comprised of 913 nodes and 1,691 edges. Fossil fuel firms are denoted as red dots, while shareholders are denoted as black dots. Several inferences can be made from the visualization. First, the disconnected networks along the edges of the network attest to instances where a fossil fuel firm is held by unique owners, those that do not hold shares in any of the other CU200 firms. Saudi Aramco, for instance, has one controlling shareholder, the Kingdom of Saudi Arabia, with 98.18 percent ownership. Along the edges of the connected network are firms that have a combination of unique shareholders (nodes with one edge) as well as shareholders that invest in one or more firms. Yanzhou Coal Mining, for example, has one interest shareholder – a Chinese government entity with 23.95 percent ownership – but is also held by BNP Paribas, Blackrock, Vanguard, and Dimensional Fund. Finally, to the center of the connected network are firms that are more broadly and equally held by many investors with smaller ownership stakes. Here, we see firms like BP, Chevron, and Royal Dutch Shell, who have several shared owners and no one shareholder with greater than 10 percent ownership. Consequently, firms along the edges of the network compared to those to the center will warrant different forms of shareholder engagement.

Table 3 Here

Direct Ownership Network

We extrapolate further that network structures vary considerably across shareholder types (Figure 4). We elucidate early on that investment advisors may have more and less substantial ownership in multiple firms where governments may have large holdings in a few firms. Our network analysis below corroborates this finding across six groupings of shareholders. In addition to the network graph, we highlight some nodes of interest based on the degree of holders and firms. We highlight the shareholder node and firm node with the greatest number of edges. In instances where more than one node has the same number of max edges, all nodes are listed. Norges bank, for example, plays a central role in the public network, with (smaller) holdings in 46 firms. However, Blackrock is not included as the top Investor because Vanguard Group has more edges. Vanguard Group owns the most companies in our sample.

Figure 4 Here

Ownership Networks by Shareholder Type

Centrality measures of the sub-networks allow for quantifiable comparisons between graphs relative to the direct and indirect network benchmark, presented in Table 4. Several inferences can be made from this table. First, some subgraphs (like public, corporation, pension fund, and HNWI) have fewer edges than nodes. This infers that, on average, nodes in those networks have fewer than

two edges. Saudi Aramco, for example, only has one edge connected to the Kingdom of Saudi Arabia. This relation is confirmed in the degree centrality measure, with all four subsample network graphs having a degree centrality score of under 2. Conversely, the investor subsample graph (panel c above) has a higher degree centrality than both the complete direct and indirect network, inferring that investors in this subsample have holdings in many firms. Finally, the betweenness score indicates that shareholders play a notable informational role in those networks and may consequently be able to influence corporate governance with greater ease than corporations, pension funds, and HNWI. However, collective action may be even more impactful than any specific shareholder type.

Table 4 Here

Network Dynamics by Shareholder Type

5.3 Influential Shareholders

In so far, we have presented collective equity ownership dynamics. However, shareholders are not equal. We score and rank each stakeholder independently, using a combination of their degree measure and the proportion of emissions held within the sample (see Equation 3 above). Recognizing some of the limitations of each metric independently (as discussed in section 3), the purpose of Table 5 below is not to allocate emissions to any one stakeholder, rather identify which stakeholders can collectively have the greatest impact through a combination of their influence and their collective holdings. Ten of the top 20 owners are investment advisors like Blackrock, Vanguard, and State Street. Generally, investment advisors have a higher degree score (indicating

that they are more central to the network through their numerous holdings) but lower cumulative emissions. Sovereign Wealth Funds (Norges Bank and China Investment Corporation) and banks (Bank of New York Mellon) similarly have higher degree measures but lower emission measures. Governments in contrast, often have few but large holdings in the CU200. Consequently, their emissions measures are high, but their degree measures are low. Ten of the top 20 owners are also located in the United States, nine of which are investment advisors.

Furthermore, the top ten owners (Blackrock, Vanguard, the Government of India, State Street, the Kingdom of Saudi Arabia, Dimensional Fund Advisors, Life insurance Corporation, Norges Bank, Fidelity Investments, and Capital Group) have notable influence over the trajectory of the fossil fuel industry. Collectively, these ten shareholders own 49.5 percent of the emissions potential from the CU200 (the left side of equation 3). The top ten are also more central to the network, with an average degree centrality of 43.9 compared to 2.4 across the remainder of the shareholders (the right side of equation 3). This indicates that not only do these ten shareholders account for a sizable share of emissions potential, they also have greater potential influence on the trajectory of the industry.

Table 5 Here

Top Influential Shareholders in the CU200

In addition to listing the top shareholders in the network, we also list the top shareholders in each subsample in Table 6. The degree and emissions columns are included to inform the reader about which of the two factors have a greater influence on the final score[2].

Table 6 Here

Top Influential Shareholders Collectively and by Shareholder Type

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6. CONCLUSION

This study identified the structures of equity ownership in the CU200, the leading fossil fuels firms with the greatest potential (by carbon reserves) to contribute to anthropogenic climate instability. Acknowledging potential emissions held by the CU200 would overshoot the global carbon budget three times over, production must be severely curtailed to keep warming under a safe threshold. Supply-side policy solutions such as restricted public financing have gained prevalence in academic literature; however, supply-side constraints through private finance mechanisms have yet to be explored. This opens several opportunities for future research on private-finance-driven policy interventions, with notable value for research and practice. In order to effectively design policy solutions, however, we must first know who the most influential financial actors are.

[2] The Emissions data reflects an estimate of the emissions held through the investment in Carbon Underground 200 companies by the owner. However, this estimate has several drawbacks as sometimes the ownership data does not allow us to estimate the total ownership in a company and the owner may also hold more emissions in investments outside of the carbon underground 200 companies.

Our study found that the ten investors with the most influence on the future use of fossil fuel reserves are investment managers (Blackrock, Vanguard, State Street, Dimensional, Life insurance Corp, FMR and Capital Group) as well as Government entities (India, Saudi Arabia and Norway). These ten actors have the greatest potential impact on the future usage of most of the world's carbon reserves, based on the number and size of ownership and the related emissions potential of the firms.

Our analysis presents a means by which to understand the structure of capital markets in fossil fuel firms and identify the key financial actors that could play a central role in curtailing fossil fuel production. We conclude that the decisions by these financial actors have the potential to influence future carbon emissions and, therefore, climate instability. Could shareholders adopt measures to curtail fossil fuel production? Traditionally, agency theory would posit that shareholders would only exert influence on a corporation to increase shareholder returns. However, as investors and governments begin to commit to net-zero emissions, these owners may be increasingly motivated to align their investments with their own carbon reduction strategy. Nevertheless, Blackrock, amidst all their arguments on climate risk and the need to transition away from fossil fuels, remains on top of our 'worst in class' ranking due to numerous and sizable holdings in the CU200.

Our results corroborate the positions of Fichtner et al. (2017) and Gillan and Starks (2000), who state that large equity owners can influence corporate governance through active ownership. By examining equity ownership in the CU200, this study is the first of its kind to examine equity ownership through the lens of future-looking supply-side solutions. By exposing the most prominent shareholders in the sphere, we raise a call to action, to align their holdings with a sustainable transition, or to be held accountable for propagating climate instability.

We offer several novel and pragmatic insights into capital markets and sustainability transitions. First, supply-side constraints through private finance mechanisms can be championed by a relatively small group of influential shareholders. However, the network structures will warrant different forms of policy solutions. Minority and majority shareholders like governments can directly influence one or few firms, while blockholders with many smaller holdings can have overarching reach across the industry.

Second, the findings expose shareholders with the greatest potential to influence major fossil fuel companies to pressure them to adopt more aggressive supply-side interventions. They might reduce their investment and consequently limit access to capital for the fossil fuel companies or might influence corporate decisions through active ownership. However, that might hold if there is a risk of stranded assets (Mercure et al., 2018) that can be avoided by both divestment and engagement, or if a change in the business strategy away from fossil fuel production will increase the long-term value of a fossil fuel company. Organizational stakeholder pressure may also motivate financiers to adopt proactive approaches to supply-side interventions.

We reiterate that reduction of emissions exposure without reductions in production is simply not enough to mitigate the climate crisis. Thus, we put forth a call for sustainable finance scholars to give even greater merit to research on how financial actors contribute to climate instability and their role in furthering supply-side constraints on carbon emissions. Future opportunities to expand on this research include incorporating a time horizon, allocating quantifiable emissions to shareholders, and incorporating statistical analyses to identify how emissions correlate to shareholder dynamics. We maintain that financing that perpetuates carbon emissions should be held responsible for the climate instability caused by those emissions.

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Figure 1: Geographic distribution of shareholders and firms

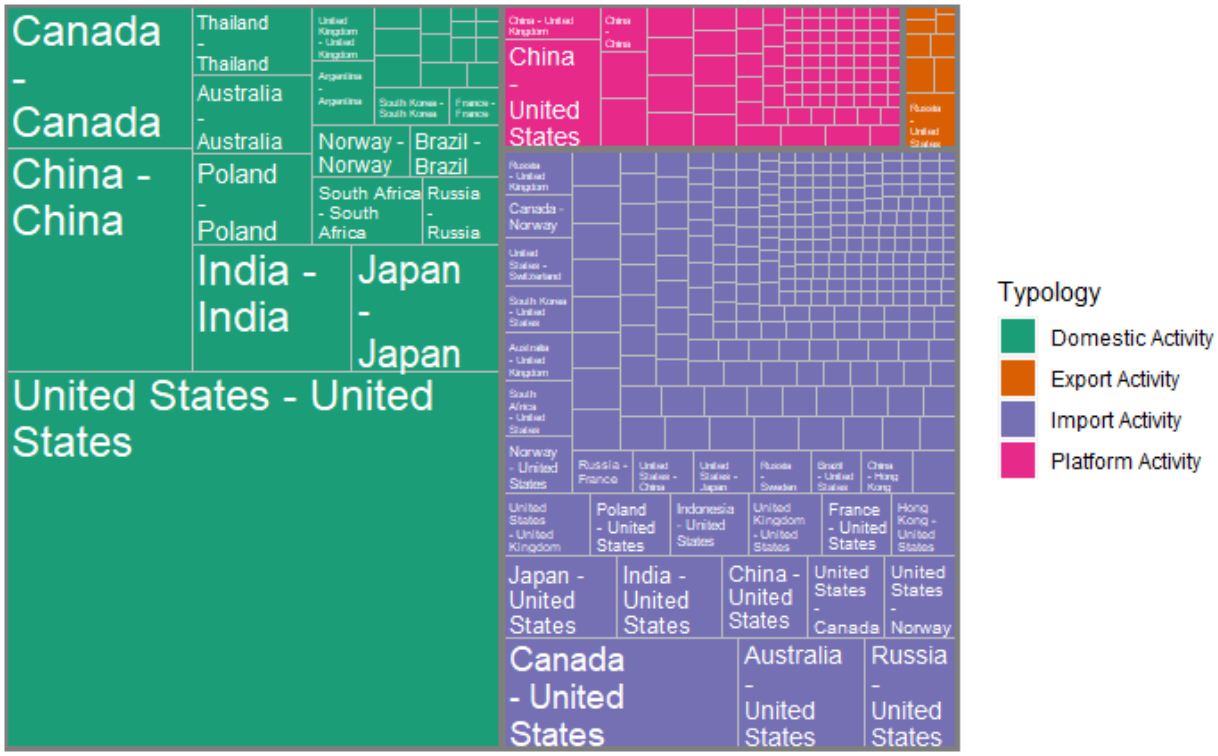


Figure 2: Stepwise Reduction in Ownership by Shareholder Type

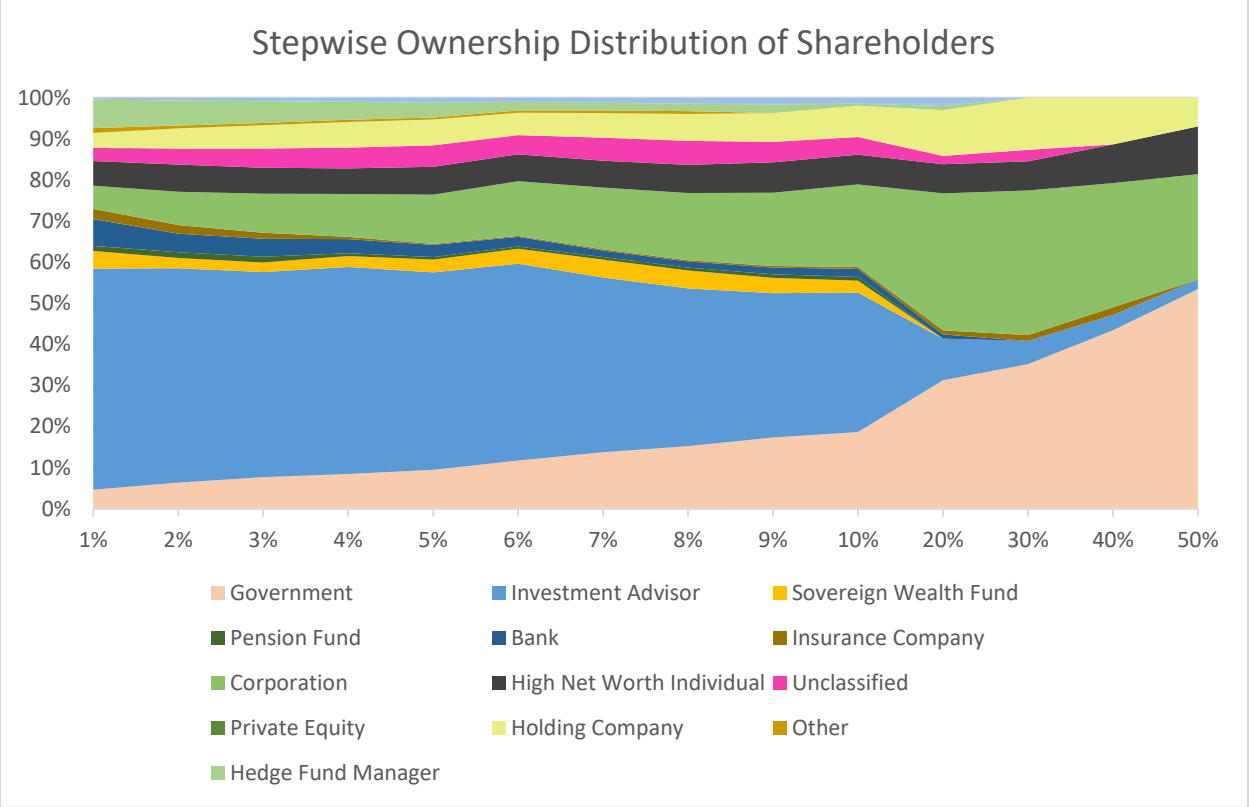


Figure 3: Direct Ownership Network

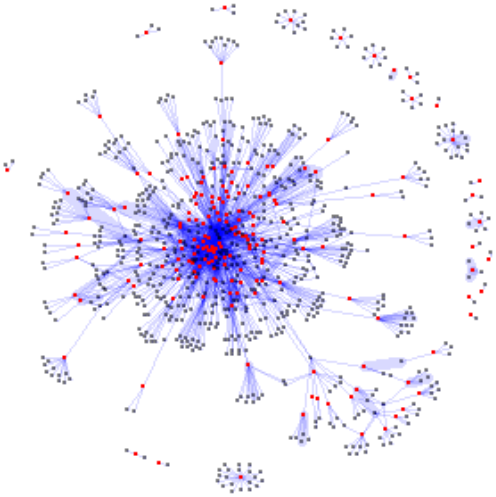
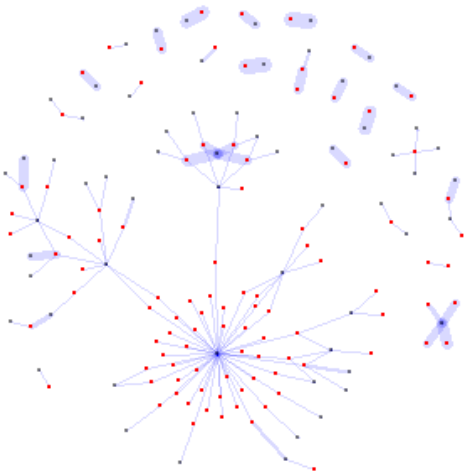


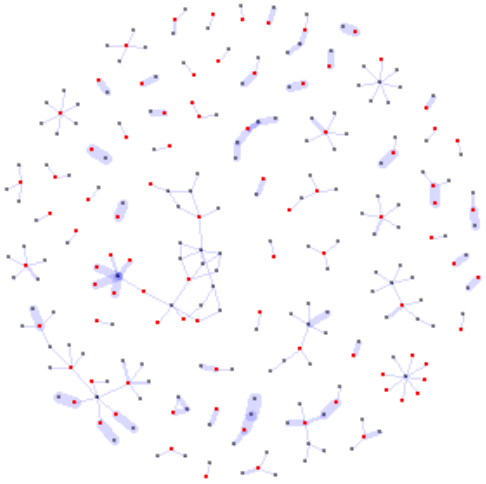
Figure 4: Ownership Networks by Shareholder Type

a) Public (Government + Sovereign Wealth Fund)



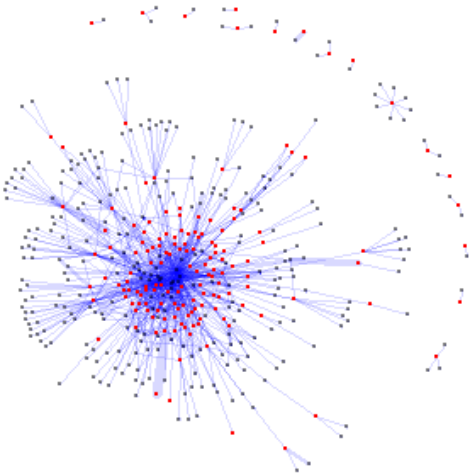
Top Holder(s): Norges Bank (46)
Top firm (s): Bayan Resources, Eni, NLC India, Oil India, ONGC, Shanxi Coking (4**)**

b) Corporation (Corporation + Holding Company)



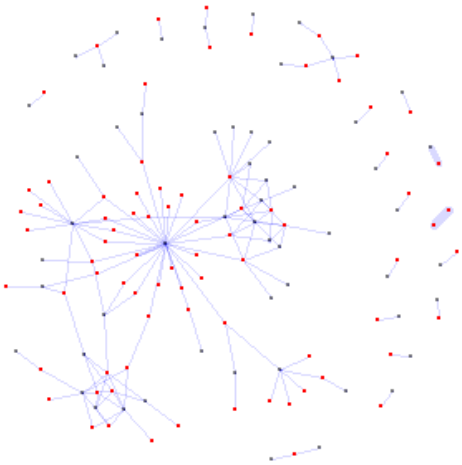
Top holder (s): Power Corp of Canada (7)
Top firm (s): Nava Bharat Ventures, SACYR SA (6)

c) Investor (Investment Advisor + Hedge Fund Manager + Private Equity)



Top Holder(s): Vanguard Group (106)
Top Firm(s): Arch Coal (29)

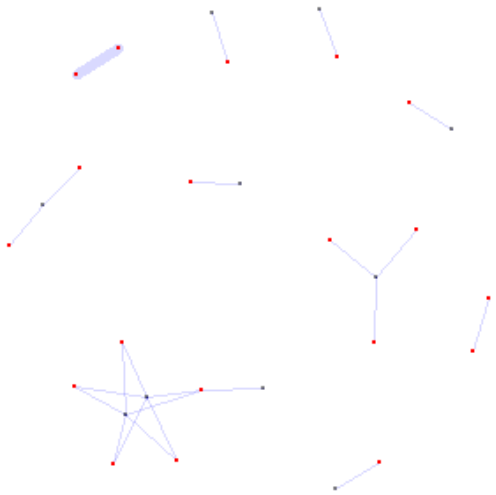
d) Bank (Bank + Insurance Company)



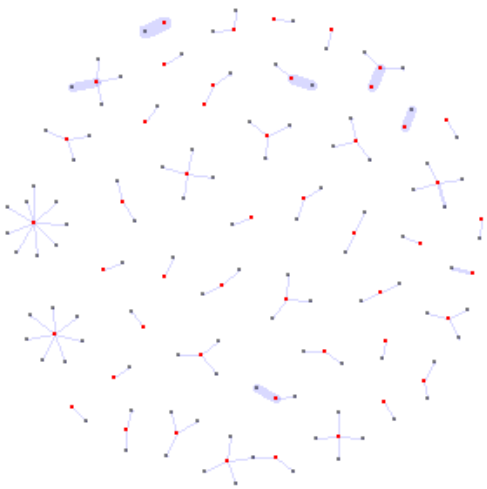
Top holder (s): Bank of New York Mellon (28)
Top firm (s): Itochu (10)

e) Pension Fund

f) High Net Worth Individuals



Top Holder(s): Nationale-Nederlande (5), Powszechny Zakład Ubezpieczeń Spółka Akcyjna (PZU) (5)
Top Firm(s): PGE (3)



Top holder (s): Todd Thomas (2)
Top firm (s): Nava Bharat Ventures (9)

Table 1: Regional Distribution of Firm, Stock Exchange, and Owner

CU200 firm Distribution by Region		**CU200 firm Distribution by Stock Exchange**		**Owner Distribution by Region**	
United States	60	United States	61	United States	213
China	23	China	19	China	73
Canada	17	Canada	16	Japan	60
Russia	13	Australia	13	India	59
Australia	12	Hong Kong	13	United Kingdom	36
India	10	Russia	12	Canada	30

The regional distribution table presents the top countries in the sample based on the headquarters of firms in the Carbon Underground 200 (CU200), the stock exchanges in which the firms are traded, and the registered location of the equity owner.

Table 2: Country-Level Herfindahl-Hirschman Index and Debt to Capital Ratio for CU200

Herfindahl-Hirschman Index aggregated by Region		**Debt-to-Equity Ratio aggregated by region**	
Panel A: Top 10 Countries		Panel C: Top 10 Countries	
Saudi Arabia	9639.32	United States	658.25
Czech Republic	4873.23	United Kingdom	185.08
Poland	3431.82	Norway	145.20
Indonesia	3076.74	Greece	132.03
Norway	3026.06	Thailand	127.60
Argentina	2693.03	Portugal	117.88
India	2436.54	Switzerland	108.94
China	2298.59	Argentina	106.03
British Virgin Islands	2169.21	Japan	104.45
Russia	1722.70	France	92.58
Panel B: Bottom 10 Countries		Panel D: Bottom 10 Countries	
Japan	267.19	Papua New Guinea	59.36
South Africa	266.58	South Africa	51.91
Brazil	246.16	Bermuda	43.64
United Kingdom	210.26	Australia	43.60
Papua New Guinea	152.64	Hong Kong	39.20
Spain	117.71	Cayman Islands	33.79
Germany	108.51	Germany	32.12
Hong Kong	106.37	Luxembourg	30.62
Colombia	71.23	Poland	27.45
Italy	67.08	Saudi Arabia	16.78

The Herfindahl-Hirschman Index (HHI) and debt-to-equity ratio are calculated at the firm level for each of the CU200 firms in the sample and aggregated by averaging the scores by region. Panels A and B present the countries with the highest and lowest average HHI scores respectively. Panels C and D present the countries with the highest and lowest average debt-to-equity ratios respectively.

Table 3: Stepwise Reduction in Ownership by Shareholder Type

	Government	Investment Advisor	Sovereign Wealth Fund	Pension Fund	Bank	Insurance Company	Corporation	High Net Worth Individual	Unclassified	Private Equity	Holding Company	Other	Hedge Fund Manager	Private Equity	Total
1%	80	923	74	21	112	43	97	103	54	1	62	20	119	8	1717
2%	63	515	25	14	44	21	80	65	38	1	48	7	60	7	988
3%	54	351	16	10	31	10	67	44	33	0	40	4	37	6	703
4%	49	290	15	4	20	3	60	36	29	0	36	3	25	6	576
5%	45	228	15	3	14	1	57	32	25	0	30	2	17	6	475
6%	45	184	14	2	9	1	51	25	18	0	21	2	8	4	384
7%	44	136	14	2	5	1	48	21	18	0	19	2	6	4	320
8%	42	106	12	2	4	1	45	19	16	0	18	2	5	4	276
9%	42	85	9	2	4	1	43	18	12	0	17	0	5	4	242
10%	39	71	6	2	4	1	42	15	9	0	16	0	1	3	209
20%	31	10	0	0	1	1	33	7	2	0	11	0	1	2	99
30%	25	4	0	0	0	1	25	5	2	0	9	0	0	0	71
40%	23	2	0	0	0	1	16	5	0	0	6	0	0	0	53
50%	23	1	0	0	0	0	11	5	0	0	3	0	0	0	43

The stepwise reduction table presents the number of owners by shareholder type that have at least a certain percent of ownership in the CU200. We delineate owners with greater than 5 percent as block holders, owners with greater than 20 percent as minority shareholders, and owners with greater than 50 percent as majority shareholders.

Table 4: Network Dynamics by Shareholder Type

Network Model	Nodes	Edges	Degree	Betweenness
Direct Network	913	1,691	3.73	1236.85
Indirect Network	1,098	2,097	3.81	1634.39
Public	159	149	1.87	109.54
Corporation	255	202	1.58	8.13
Investor	454	1042	4.59	475.36
Bank	135	153	2.27	83.38
Pension Fund	29	23	1.59	0.86
HNWI	149	104	1.40	0.95

The network statistics depict the number of nodes and edges within each subsample network as well as the average degree centrality (Equation 1) and betweenness centrality (Equation 2) of each network. The direct network includes direct ownership in the CU200. The indirect network includes second order ownership. Subsample networks are presented by shareholder type.

Table 5: Top Influential Shareholders in the CU200

Target	Type	Country	Degree	Emissions	Score
Blackrock	Investment Advisor	United States	0.97	10.14	9.85
Vanguard Group	Investment Advisor	United States	1.00	8.86	8.86
Government of India	Government	India	0.04	68.23	2.57
State Street Corp	Investment Advisor	United States	0.45	2.25	1.02
Kingdom of Saudi Arabia	Government	Saudi Arabia	0.01	104.21	0.98
Dimensional Fund Advisors	Investment Advisor	United States	0.43	1.94	0.84
Life Insurance Corporation	Government	India	0.06	11.60	0.66
Norges Bank	Sovereign Wealth Fund	Norway	0.54	1.14	0.61
Fidelity Investments	Investment Advisor	United States	0.41	1.46	0.59
Capital Group Company	Investment Advisor	United States	0.24	1.99	0.47
Bank of New York Mellon	Bank	United States	0.26	1.44	0.38
JPMorgan Chase & Co.	Investment Advisor	United States	0.34	0.76	0.26
Russian Federation	Government	Russia	0.01	19.38	0.18
Shaanxi Coal & Chemical	Government	China	0.01	17.57	0.17
Adani, Gautam S.	High Net Worth Individual	India	0.01	15.65	0.15
Citigroup Inc.	Investment Advisor	United States	0.05	3.10	0.15
HDFC Asset Management	Investment Advisor	India	0.04	3.93	0.15
China Investment Corporation	Sovereign Wealth Fund	China	0.08	1.65	0.14
Geode Capital Management	Investment Advisor	United States	0.28	0.50	0.14

The top influential shareholders are measured using a combination of their degree measure and the proportion of emissions held within the sample. The top 20 influential shareholders are presented based on their score as presented in Equation 3. Degree and Emissions values are included for the reader to distinguish which factor has greater influence on the final score.

Table 6: Top Influential Shareholders Collectively and by Shareholder Type

Target	Type	Country	Degree	Emissions	Score
Panel B: Public Sector Owners					
Government of India	Government	India	0.04	68.23	2.57
Kingdom of Saudi Arabia	Government	Saudi Arabia	0.01	104.21	0.98
Life Insurance Corporation	Government	India	0.06	11.6	0.66
Norges Bank	Sovereign Wealth Fund	Norway	0.54	1.14	0.61
Russian Federation	Government	Russia	0.01	19.38	0.18
Shaanxi Coal & Chemical	Government	China	0.01	17.57	0.17
China Investment Corporation	Sovereign Wealth Fund	China	0.08	1.65	0.14
Poland State Treasury	Government	Poland	0.04	2.19	0.08
China National Petroleum	Government	China	0.01	7.13	0.07
China Securities Finance	Government	China	0.06	0.8	0.05
Panel C: Corporations					
Berkshire Hathaway	Holding company	United states	0.11	0.49	0.06
Kailuan Group	Corporation	China	0.01	6.22	0.06
Hong Kong securities	Corporation	Hong Kong	0.06	0.90	0.05
Enea SA	Corporation	Poland	0.10	0.38	0.04
PT Indonesia Asahan Aluminium	Corporation	Indonesia	0.01	3.30	0.03
Shanxi Lu'an Mining Industry	Corporation	China	0.01	3.22	0.03
African Rainbow Mine	Corporation	South Africa	0.12	0.14	0.02
Beijing Energy Investment	Corporation	China	0.02	1.22	0.02
Bradespar SA	Holding company	Brazil	0.17	0.11	0.02
Erdos Cashmere Group	Corporation	China	0.01	1.70	0.02
Panel D: Investors					
Blackrock	Investment Advisor	United States	0.97	10.14	9.85
Vanguard Group	Investment Advisor	United States	1.00	8.86	8.86
State Street Corp	Investment Advisor	United States	0.45	2.25	1.02
Dimensional Fund Advisors	Investment Advisor	United States	0.43	1.94	0.84
Fidelity Investments	Investment Advisor	United States	0.41	1.46	0.59
Capital Group Company	Investment Advisor	United States	0.24	1.99	0.47
JPMorgan Chase & Co.	Investment Advisor	United States	0.34	0.76	0.26
Citigroup Inc.	Investment Advisor	United States	0.05	3.10	0.15
HDFC Asset Management	Investment Advisor	India	0.04	3.93	0.15
Geode Capital Management	Investment Advisor	United States	0.28	0.50	0.14
Panel E: Banks					
Bank Of New York Mellon	Bank	United States	0.26	1.44	0.38
Sino Life Insurance	Insurance Company	China	0.01	5.04	0.05
Charles Schwab Corporation	Bank	United States	0.11	0.34	0.04
Mitsubishi UFJ Financial Group	Bank	Japan	0.07	0.41	0.03
Credit Agricole Group	Bank	France	0.04	0.41	0.02
Royal Bank of Canada	Bank	Canada	0.08	0.25	0.02
Sumitomo Mitsui Trust	Bank	Japan	0.06	0.32	0.02
Afro Asia Industries Ltd.	Insurance Company	Nigeria	0.01	0.75	0.01
Aviva Group	Insurance Company	United States	0.06	0.21	0.01
Huaxia Life Insurance	Insurance Company	China	0.01	1.00	0.01
Panel F: Pension Funds					
Nationale-Nederlande	Pension Fund	Netherlands	0.05	0.17	0.01
Aegon OFE	Pension Fund	Poland	0.03	0.01	0.00
AustralianSuper	Pension Fund	Australia	0.01	0.04	0.00
Canada Pension Plan	Pension Fund	Canada	0.02	0.08	0.00
Folketrygdfondet	Pension Fund	Norway	0.03	0.10	0.00
NPS Trust	Pension Fund	India	0.01	0.03	0.00

Oregon Public Employment	Pension Fund	United States	0.01	0.01	0.00
Porvenir Moderado	Pension Fund	Colombia	0.01	0.01	0.00
Powszechny Zakład Ubezpieczeń	Pension Fund	Poland	0.05	0.11	0.00
Stanbic IBTC Pension Managers	Pension Fund	Nigeria	0.01	0.00	0.00
Panel G: Individuals					
Adani Gautam S	HNWI	Unclassified	0.01	15.65	0.15
Abramov Alexander	HNWI	Unclassified	0.01	0.62	0.01
Abramovich Roman	HNWI	Unclassified	0.01	0.92	0.01
Craft Joseph W	HNWI	Unclassified	0.01	0.55	0.01
Glasenberg Ivan	HNWI	Unclassified	0.01	0.75	0.01
Low Tuck Kwong	HNWI	Unclassified	0.01	0.62	0.01
Alekperov Vagit	HNWI	Unclassified	0.01	0.20	0.00
Share Andrew L	HNWI	United States	0.01	0.02	0.00
Atkins Randall W	HNWI	Unclassified	0.01	0.04	0.00
Sihono Bambang	HNWI	Unclassified	0.01	0.29	0.00

The top influential shareholders by shareholder type are measured using a combination of their degree measure and the proportion of emissions held within the sample. The top 10 influential shareholders per shareholder type are presented based on their score as presented in Equation 3. Degree and Emissions values are included for the reader to distinguish which factor has greater influence on the final score.