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Leveraging keystone agents in extractive industries to advance sustainability

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ABSTRACT

Natural resource extraction has a lasting and dramatic impact on the natural environment as well as far-reaching social effects. As such, public policy and governmental regulation are crucial for a transition to sustainability. However, on their own, these have shown to be insufficient to achieve such transformation. Changing commitment and conduct of the extractives too is important to transit. Firms in the extractives are large and highly international, and their owners are decisive for businesses' conduct. Therefore, it is relevant to determine whom and how to influence to transit towards sustainability. To this extent, we study dominant firms and their owners in the top-10 international extractive industries. We establish that both natural resource markets and ownership of keystone agents are highly concentrated: the three largest companies earn 70% of the revenues in the ten industries studied, and the three largest shareholders in these companies on average have 22% of the shares of the keystone firms. This helps explain why regulation has been rather ineffective so far. We discuss several options to influence keystone agents. We conclude that advancing sustainability in extractives requires leveraging a limited number of keystone agents.

1. Introduction

Extractive industries have negative externalities, as the damage they do to environmental and social systems is not accounted for in their business model (Habert et al., 2020; Manicini and Sala, 2018; Narula, 2018). These externalities witness the tragedy of the commons, which is a defining feature of modern mining industries (Merrie et al., 2014). A major transformation of these industries is required to support societal transition to a more circular and sustainable system (Luckeneder et al., 2021; Ostrom and Garner (1993), RMF, 2020; Northey et al., 2014). So far, he transformation has been very slow as its governance is not effective. This in part is the case because it does not target keystone agents. Keystone agents are dominant agents in a particular economic activity, for example earning most profits or controlling most of the industry. Therefore, we study keystone agents in extractive industries to determine where to put leverage to achieve a transition towards sustainability (see also Prior et al., 2012; Northey et al., 2017; Luckeneder et al., 2021). Furthermore, we discuss how to the influence keystone agents.

With extractives, the focus predominantly has been on the fossil fuel industry, which is the largest source of anthropogenic carbon dioxide emissions, contributing to climate change (Dordi et al., 2022; Heede, 2014). Without doubt, this industry plays a dominant role in the energy system and its overhaul is crucial regarding the management of climate risks (Jaccard et al., 2018; McGlade and Ekins, 2015). However, the fossil fuel industry is not unique concerning the generation of sustainability concerns. Numerous studies establish there is a devastating environmental and/or social impact from other extractives as well. For example, in gold (Papworth et al., 2017; Merrie et al., 014), rare earth metals (Chakmouradian and Wall, 2012), and seabed mining (Dover et al., 2017). Environmental effects include the destruction of natural habitats, loss of biodiversity, soil erosion, land subsidence, water and soil contamination, noise pollution, air blasts, hazardous waste, and threats to protected areas (Dudka and Adriano, 1997; Sonter et al., 2014). Social effects are corruption, modern slavery, tax evasion, armed conflict, and social uncertainty (King and Mutter, 2015; Mancini and Sala, 2016; OECD, 2016; Galaz et al., 2018; Sovacool, 2021). The Responsible Mining Foundation (RMF, 2020) argues that mining companies' reporting on the Sustainable Development Goals (SDGs) is cosmetic and that the vast majority of the companies do not integrate them into their business model. The sustainability transition of these industries is not straightforward, as they are embedded in a broader

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economic, political and social context that faces obduracy and is slow to change (Kivimaa et al., 2021; Van der Schoor, 2020; Safarzyńska and Van den Bergh, 2010; Berkhout, 2002; Geels, 2002).

As capital and capital accumulation is an important driver of the dominant business model, we will focus on the role of capital markets regarding transition and innovation of the extractive industries. This by no means assumes we view capital to be the only driver of change, but focus on the business of keystone firms and owners. Capital is a crucial resource for business both in the short and long-term and is a mechanism that can bring about structural change within firms and industries (Scholtens, 2006). According to Bergek et al. (2015), the analysis of capital and capital markets as a critical context system informs the understanding of their role in resisting and promoting societal transition.

The aim of this study is first to answer two questions regarding the leverage of keystone agents in extractives to advance transition towards sustainability. First, who are the dominant firms in extractives are, i.e., the keystone firms. Second, who owns these dominant firms, i.e., the keystone owners. We find that both natural resource markets and ownership of keystone firms in the extractives are highly concentrated. Based on the answers to these questions, we discuss how keystone agents may be influenced to advance sustainable development. We conclude that advancing sustainability in extractives requires leveraging a limited number of agents.

The article is organized as follows. Section 2 introduces the key concepts of the study. Section 3 details the materials and methods employed. The results are in section 4. Section 5 discusses how keystone agents can be influenced. Section 6 concludes.

2. Background

We investigate keystone agents and their owners – the 'keystones of keystones' – in the ten largest extractives industries to determine where and whom to leverage to achieve a transformation to a more sustainable economic and social system.

The concept of keystone agents derives from keystone species: keystone species have a highly profound and disproportionate effect on ecosystems and communities and they determine their function and structure to a much larger degree than what would be expected based on their appearance alone (Power et al., 1996; Valls et al., 2015). This concept can be used for business systems as well. For example, Ostrom et al. (1993) and Chakravarty et al. (2009) find that individual actors can have a disproportionate and dominant impact on the environment. Heede (2014) studies keystone agents in relation to greenhouse gas emissions and Österblom et al. (2015) do so for the seafood industry. Until now, the focus of attention on keystone agents predominantly has been on firms operating in a single industry (Heede, 2014; Österblom et al., 2015; Dordi et al., 2022). We aim to contribute to this 'keystone research'. In particular, our study expands to a range of related industries to allow for comparison among extractive industries. Furthermore, we want to study both keystone firms and keystone owners and discuss how to influence both.

In our study, we differentiate between the firm (market) and the ownership (finance) perspective. As to the firm perspective, important is to understand that firms combine resources to create products and sell these in markets. However, their production decisions are not separable from externalities; they produce economic goods and 'bads' at the same time (Kitzmueller and Shimshack, 2012). The conventional idea in economics is that there is perfect competition and hence no power of individual firms. Further, it assumes that if there would be some power abuse, the threat of takeover would discipline management (Alchian and Demsetz, 1972). Externalities, i.e., effects that go unpriced, are the realm of public policy. The reality is very different: Corporate power is increasingly concentrated. Grullon et al. (2019) observe that even in the US the relative size of corporations is still rising. This results from the growing market for mergers and acquisitions and a decreasing birth rate of firms. Corporations are large enough to influence and even dominate politics (Moe, 2010; Zingales, 2017). The increase in firms' market power and size results from past investment, economies of scale, network externalities, and government licensing (Porter, 1979; Zingales, 2017; Grullon et al., 2019).

As to ownership, finance plays a crucial role within the firm (Hart and Zingales, 2017). Shareholders provide equity, which becomes part of the own funds of the corporation. In return, the shareholder has the exclusive right to residual profits, the dividend rights. Part of firm profits is handed out to the shareholders as dividend. In addition, shareholders have voting rights. Voting rights imply that the owner has a say in business strategy and key corporate decision-making. Owners can file petitions and vote on these at the annual general meeting of shareholders. The voting right is also at the basis of a less formal way to influence business strategy, namely engagement. Here, an owner can privately discuss their preferences with executive directors or board supervisors of a firm to influence corporate strategy (e.g., Dimson et al., 2015).

Corporations listed on the stock market have thousands, sometimes millions, of shareholders. This suggests diffuse and fractured ownership and the resulting free rider problems (Grossman and Hart, 1980). However, it shows that virtually all corporations have dominant shareholders (La Porta et al., 1998). Edmans and Holderness (2014) find that in the US 96 % of the large listed firms have at least one shareholder with more than 5 % of the shares and observe that such ownership concentration has gradually increased over time. Thus, the 'natural' state of the corporate world is the presence of large investors, i.e., blockholders. Blockholders are endogenous, ubiquitous, and heterogeneous (La Porta et a., 1998; Edmans and Holderness, 2014).

Firms and owners interact. Shareholders can vote on corporate policy and file petitions aimed at maximizing welfare instead of pure profit. The owners control the firm, albeit subject to information and agency problems (Jensen and Meckling, 1976) and, hence, do so in an imperfect manner. This controlling role is connected with the ownership. With other financing types, like bank loans or bonds, the influence is not as direct. Here, financiers may include their preferences in the contract that is written when they provide funding. However, there is limited scope for the financier to include novel preferences in an existing contract.

In the course of time, companies' interests have become vested interests that are highly influential regarding setting and implementing political priorities (Moe, 2010; Zingales, 2017). In addition, regulation usually is based on past conduct, it tends to ignore the de facto situation, and provides scope for firms to use loopholes. This can set in motion a regulatory dialectic, which often leads away from the original purpose of regulation (Kane, 1977). Consequently, the outcome of policy making for society can be far from optimal. Then, next to policy and regulation, addressing the responsibility of the firms and their owners by stakeholders is an alternative mechanism that can be used to discipline the business community (Kitzmueller and Shimshack, 2012). Especially in a global setting it is important to allow for this mechanism as the international regulatory framework required to reign in the irresponsible conduct of multinational enterprises is much too weak to be effective (Galaz et al., 2018; Narula, 2018). Therefore, leveraging keystone agents and their owners seems crucial to arrive at a transition to sustainability (Jouffray et al., 2019).

This paper studies the keystone firms' owners as they directly benefit from firms' operations in financial terms. Ownership of corporate capital is a major factor in socio-technical regimes (Kivimaa et al., 2019) and a driver of system transition (Geddes and Schmidt, 2020). Therefore, we study the role of capital markets as a critical context system. Via its influence on the mobilization and allocation of resources, finance is crucial for business and business strategy. In most of the literature about sustainability transition so far, the focus has been on the redirection of capital away from incumbent regimes to foster transition (e.g., Geddes and Schmidt, 2020). In particular, these studies regard the decarbonisation of economic systems (Nykvist and Maltais, 2022; Plantinga and

Scholtens, 2020). Although this is important, the role of capital is more complicated as it influences business conduct and strategy (Scholtens, 2006). Therefore, next to opposing transition, it can also be an enabler of such transition, and owners are the most important stakeholders in private firms. In this regard, it is important to acknowledge than not all owners have the same priority and focus regarding shareholder value maximization (Hart and Zingales, 2022). Increasingly, non-financial performance plays a role in investment management (Eurosif, 2018). Financial asset owners can engage with the invested companies, vote on the annual general meeting of shareholders, divest, and tilt their portfolios. Such strategies affect firms' risks, returns, and costs of capital (Plantinga and Scholtens, 2020).

Effective public policy and regulation are required for the transition toward sustainability (Folke et al., 2019, 2021). However, especially in the international context, it is important to realize that policy and regulation of extractives are far from sufficient to reign in large corporations: Multinational enterprises can escape jurisdictions and influence the policies they are subjected to (Steenbergen and Saukav, 2023; Nykvist and Maltais, 2022; Moe, 2010). We aim to complement this debate and argue that the role of firms and their owners is material too, as finance plays a crucial role within the highly capital-intense extractives. Hart and Zingales (2022) argue that especially in industries with externalities, the role of owners is decisive regarding the development of the firms in such an industry. The fiduciary duty of investors needs to connect with the Sustainable Development Goals and planetary boundaries to advance the industries' transformation. Then, leveraging extractive companies and their owners is crucial to accelerate sustainability efforts substantially.

3. Materials and methods

3.1. Data

To study the role of keystone agents in the extractives, we 'follow the money' and use market and concentration analysis with both extractive industries and owners. This method is different from and complements most research about the environmental performance of companies, which relies on expert ratings (see Overland et al., 2021), companies' self-reporting (see Berg et al., 2022), or news from the media (Capelle-Blancard and Petit, 2017). Keystone analysis informs where to exert leverage in an efficient manner. We acknowledge that the produce and revenues of extractives are closely connected with demand and interests elsewhere, as the business system is an integrated web of real and financial supply chain relations (Boons et al., 2013). The focus on the supplying firms in the extractives results from the idea that it is more efficient to leverage firms that produce resources rather than all the individual firms and households that demand these (Weisbach et al., 2022).

We use data from the EIKON - Thomson Reuters platform for the analysis. EIKON is proprietary database with economic data. Firms are classified along the industry and sector they operate in, i.e., where the majority of their business revenues is generated (Thomson Reuters Business Classification: TRBC). The focus of the study is on the operations of firms in the extractive industries, but this is not a standard sector or industry: Mining companies belong to different industries and sectors. To allow for sufficient granularity – as otherwise we would have ended up with only "Energy" and "Basis Materials', which both include all kinds of economic activity – we select resource extracting economic activity in top-10 minerals regarding market volume. We choose the largest ten to allow for comparison. There are many more minerals, but data about revenues and ownership is increasingly difficult to find in Eikon for these other extractives. To be specific, we investigate the following industries "Oil and Gas Exploration and Production (TRBC 50102020), Gold Mining (TRBC 5120106011), Iron Mining (TRBC 5120102011), Silver Mining (TRBC 5120101011), Platinum Mining (TRBC 5120101012), Diamond Mining (TRBC 5120101013), Lead Mining (TRBC 5120102011), Zinc Mining (TRBC 5120102014), Copper Mining (TRBC 5120102012), Nickel Mining (TRBC 5120102013), Cement and Concrete Manufacturing (TRBC 5120201012)". We listed all companies of an industry based on revenues. To analyze the revenues of the firms, we use "Total Revenue" from the concurrent fiscal year (FY), which is available with a one-year lag. Hence, we use "Total Revenue FY-1" throughout the analysis, implying that we report about data for 2020. Then, we downloaded the ranked lists for the ten industries. We take care to use data from the same fiscal year (FY −1) for all revenue and asset information, as this provides the most complete data set. The data on ownership structure for the largest companies of each industry (as measured by "Total revenues" or "Total assets", where we use the latter for robustness purposes) is for mid-2020.

3.2. Measuring concentration

To find out about keystone firms and owners, we first analyze the market concentration of the ten largest companies (by Total Revenue) within each industry. We select ten companies as this allows for comparison with other studies (like Dordi et al., 2022). Thus, we calculate the revenues of the company in relation to total revenues within the same industry. We do so for each of the ten extractive industries. After calculating the market concentration that 1, 1 + 2, 1 + 2 + 3 … firms (the ten largest by Total revenue) possess for each industry, we review their ownership structure. To conduct this analysis, we reviewed every firm's EIKON page and used the ownership function to access the available data on which investors make up the firm's ownership structure. For each of the ten largest firms (note: sometimes less than ten firms were active in a particular industry), we ranked the company's investors according to the percentage they own of the company (from highest to lowest). The data does not always allow to find out who actually owns or controls a firm as there can be dual class shares and investment vehicles can be registered in locations that do not require disclosure of ownership. Additionally, we listed the number of investors and which investors own a certain % threshold. For this analysis, we used 10, 20, 30, 40, and 50 percent thresholds. For the thresholds, we always used the smallest number of constituents that are needed to account for the X% threshold. We applied this approach with all ten industries and their ten largest firms (by Total Revenue).

These exercises render numbers of firms and owners, as well as percentages of market and ownership concentration. The latter is calculated as per the "C-X index". Here, X is an integer. For example, with X = 3, C-3 relates to the combined market share of the three largest companies in a particular market; with X = 5, C-5 is the combined market share of the five largest companies. In addition, we calculate the concentration index as per the Herfindahl-Hirschmann Index (HHI), where the HHI is defined as follows:

$$HHI = s_1^2 + s_2^2 + s_3^2 + \ldots s_n^2,$$

where s_n = the market share percentage of firm n expressed as a whole number, not a decimal. As such, we construct an alternative measure of the concentration of firms and owners in the extractives (see also Dordi et al., 2022).

4. Results

4.1. Keystone firms

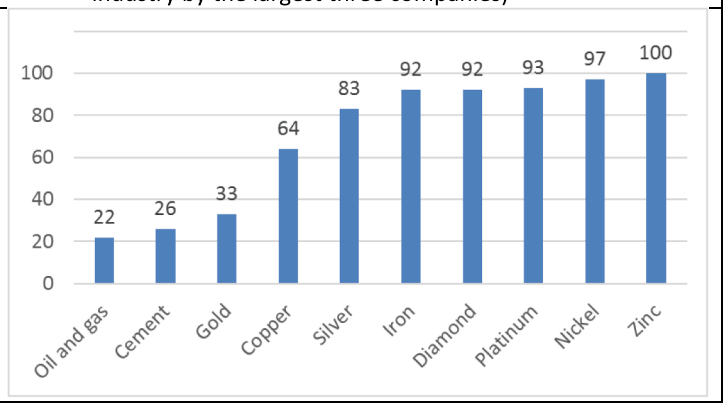
Exhibit 1 provides information about the dominance of keystone firms in the extractives. The right-hand panel shows the C-3 ratio per each of the ten extractive industries, that is, the relative share of the largest three companies in total revenues of this industry. It shows that on average, this C-3 is 68 %. This implies that the largest three companies earn 68 % of all revenues within their industry. C-3 is lowest with oil and gas, namely, 22 %. This means that China Petroleum,

Exhibit 1
Market concentration in the extractive industries (HHI index and C-3 ratio).

a. HHI

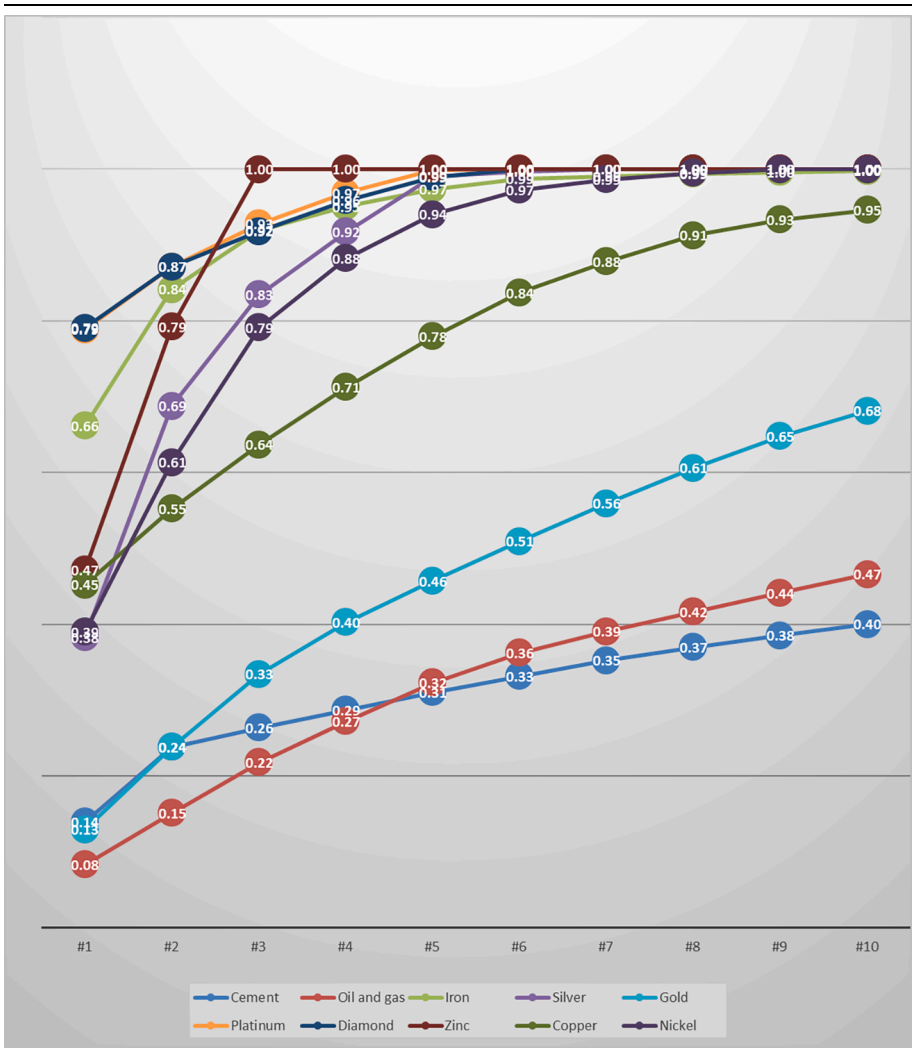
Oil and gas	315
Gold	599
Cement	625
Silver	2390
Nickel	2464
Copper	2725
Zinc	3874
Lead	5083
Iron	5342
Diamond	6391
Platinum	6744

b. C-3 ratio (percentage of total revenues earned within the industry by the largest three companies)



Note: Largest three firms in oil and gas: China Petroleum, PetroChina, Royal Dutch Shell; in cement: Holcim, Anhui, China Resources; in gold: Barrick, Shandong, Newmont; in copper: Jiangzi, Yunnan, Zhejiang; in silver: PanAmerican, Coeur, First Majestic; in iron: Vale, Fortescue, Kumba; in diamond: Alrosa, Petra, Gem; in platinum: Anglo American, Northmam, Zimplats; in nickel: Vale, Pacific Metals, Nickels Asia; in zinc: Yunnan, Zhuzhou, Huludao. Source: Appendix A.

Exhibit 2
Cumulative share of the ten largest companies in total industry revenues.



Source: Appendix A.

PetroChina, and Royal Dutch Shell together have more than one-fifth of all revenues in this industry. C-3 is highest with Zinc, where three companies (Yunnan, Chihong Zhuzhou, Huludao) earned all revenues. The left-hand panel in the exhibit reports the Herfindahl-Hirschman Index (HHI), an alternative measure for concentration. To put these numbers into perspective, Dordi et al. (2022) qualify the situation in the oil and gas business as one that can be characterized by the hegemony of the oil majors. Exhibit 1 suggests that in all other nine extractives, concentration is much higher.

Exhibit 2 shows a more detailed overview of the relevance of keystone firms per industry. It shows the cumulative revenues of the ten largest companies (the individual firms and their specific relevance per industry are reported in Appendix A). For example, in Gold, the largest company (Barrick) earns 13 % of the revenues. The number two (Shandong) earns 10 %, and combined with #1, this is (rounded) 24 %. The five largest firms have 46 % of the revenues in Gold mining, and the top 10 have 68 % of all Gold revenues. Exhibit 2 shows that concentration patterns are not the same within the extractives. In particular, Diamond, Iron, Platinum, and Zinc are extremely concentrated, as three firms earn at least 90 % of their revenues. Market concentration is lowest in Cement, where the largest ten companies earn 40 % of all industry revenues. In general, it shows that the extractives are characterized by very high concentration: in six out of the ten industries, ten firms earn all revenues in the period under consideration. On average, the ten largest companies in an industry earn 85 % of total revenues within their industry.

This implies that there is substantial dominance of keystone firms. Such concentration results from the high capital intensity of the extractive industries and the economies of scale and scope (Shapiro et al., 2018). Zingales (2017) finds that high concentration makes it highly likely that an industry can influence policies that might pertain to its activities. Especially with multinational companies, which is the rule rather than the exception in extractives, dominant market parties are highly influential (Narula, 2018). The result is regulatory capture and vested interests that consolidate the dominant structure of the existing economic system. The symbiotic relationship between dominant firms and policies hinders their transformation to sustainability (Kitzmueller and Shimshack, 2012; Zingales, 2017).

4.2. Keystone owners

We now focus on the role of the owners of the dominant firms, i.e. keystone owners, as a major driving force of potential change as they control firm strategy. As such, this complements the original perspective about keystone agents of Jacquet et al. (2013) and Österblom et al. (2015). Accounting for ownership is relevant, as policy and regulation are far from perfect means to discipline firms. Policies are often impacted by lobbyists and vested interests (Moe, 2010), and powerful companies influence regulation and institutions (Zingales, 2017). Furthermore, especially with these globally operating firms, there is the risk of regulatory arbitrage (Kane, 1977). Companies can (re)organize themselves in such a way that the activities are under the jurisdiction of policy regimes that are most favourable to them (Dam and Scholtens, 2012).

Exhibit 3 provides information about the dominance of keystone owners in the extractives. The right-hand panel shows the C-3 ratio per industry. This C-3 is the share of the largest three owners in traded stock of the largest companies operating in the ten extractive industries. On average, C-3 is 22 %. This implies that the largest three owners have 22 % of the shares of the ten dominant companies. C-3 is lowest with Cement, namely, 6 %. It is highest with Platinum, where three shareholders (Anglo American, Zimplats, Bafokeng) own 55 % of the shares of the dominant firms. The left-hand panel reports the HHI. Almost all authorities who supervise and regulate financial markets require owners disclose their holdings when they hold more than 1, 2, 5, and multiples of 5 percent of a firm's stock, signalling that these thresholds are relevant and material for controlling the firm. Owners of 1, 2, and 5 percent of the stock of a firm are qualified as 'blockholders' (Hart and Zingales, 2017). This signals that in financial markets, such ownership is regarded as highly influential. This contrasts with 'real' market concentration, where regulators usually relate to overall market concentration. It has to be pointed out that the investors can have a highly different background and motivation. Some invest to assure the access to resources ('real firms'), some want to have strategic control (governments, families), some invest for returns (asset managers).

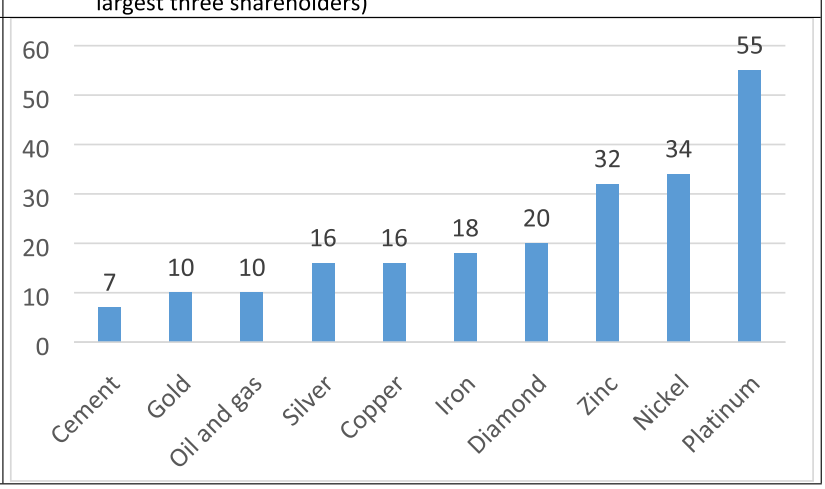
Exhibit 4 displays more detailed ownership concentration in the extractives. It shows the concentration rate in the ten industries of the ten largest investors. Concentration is highest in Platinum, where the ten

Exhibit 3
Ownership concentration within extractives (HHI and C-3 ratio; see Methods).

a. HHI

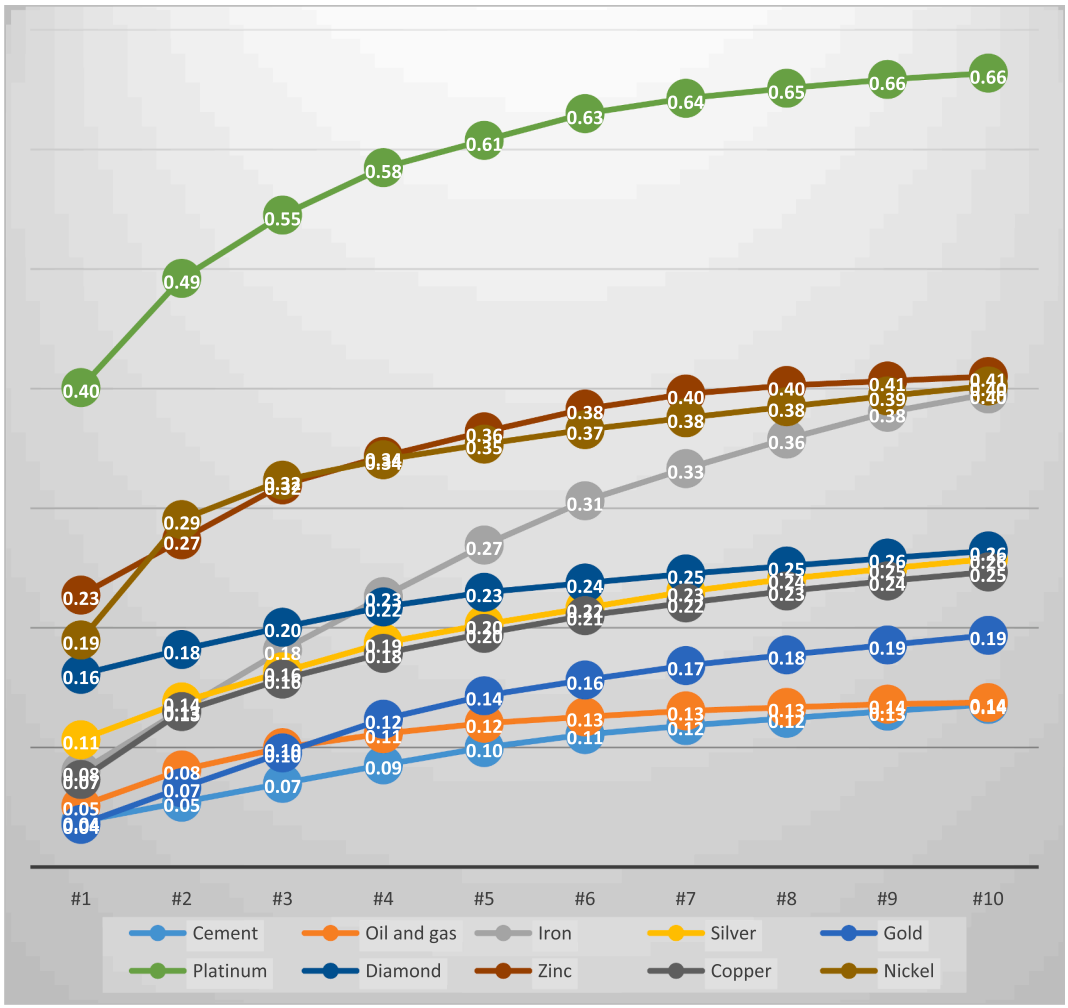
Silver	382
Nickel	841
Diamond	977
Zinc	1017
Gold	1321
Copper	1842
Oil and gas	2189
Cement	2304
Platinum	3125
Iron	3138

b. C-3 ratio (percentage of total shares within the industry owned by the largest three shareholders)



Note: Largest three investors in cement: Anhui, Desmarais, Grupo Inversiones Suramericana; in gold: Blackrock, Vanguard, Van Eck; in oil and gas: China National Petroleum, China Petrochemical, Russian Agency for State Property; in silver: Van Eck, Vanguard, Blackrock; in copper: Jiangxi, Abaroa, Climax Metals; in iron: BNDES, John Forrest, Litel Particiipacoes; in diamond: Federal Government of Russia, Republic of Sakha (Russia), Aberdeen Asset Management; in zinc: Yunnan, Ting Bao Su, Zhuzhou; in nickel: Vale, Sumitomo, Mantra; in platinum: Anglo American, Impala, Bafokeng. Source: Appendix B.

Exhibit 4
Ownership concentration Cumulative share of the ten largest shareholders in industry ownership.



Source: Appendix B.

largest shareholders own 66 % of the industry. With Zinc, Nickel and Iron, the ten largest shareholders own 40 % of the industry. With Silver, Diamond and Copper, this is 25 %. In Gold, the ten largest shareholders combined own 19 % of the industry. With Oil and Gas and Cement, this is 14 %.

Exhibit 4 shows that the single largest shareholder owns between 4 % (China National Petroleum Corporation in Oil & Gas, Anhui in Cement) and 40 % (AngloAmerican in Platinum) of the industry. It also shows that between industries, there are different patterns regarding how much the next largest shareholder owns. Especially the case of Iron is remarkable. Here, the differences between the ten largest owners are relatively small (the tenth largest shareholder still owns 2 % of the complete industry). In Nickel and Platinum, these differences are much more pronounced. Overall, in these extractives, the largest ten shareholders combined own 31 % of the shares of the ten keystone agents (see Appendix C). Such high concentration also implies that there is a vested interest of the owners and that they will exert their power to influence relevant policies (Hart and Zingales, 2017).

To further investigate ownership, Exhibit 5 lists the blockholders in the ten industries, that is the investors who own more than 1 % (as well as 2 % and 5 %) of the shares. It also specifies the type of owner (i.e., high net worth investors, asset managers, government entities or corporates). However, due to differences in legislation between countries, this classification is an indication only, as different types can be labelled differently. Given this limitation, it appears that high net worth investors are blockholders in Cement, Iron, and Zinc. Financial asset managers are blockholders in all industries, as are corporates. Asset managers especially are dominant in Gold and Silver. Furthermore, there is blockholdership of government entities in Copper, Diamond, Gold and Oil & Gas industries.

4.3. International perspective

We now provide an international perspective and organize keystone agents along their domicile. In this regard, we find aggregation of these industries' revenues and ownership is highly informative, as it provides insight into the power structure in the global economic system.

We first analyse the keystone firms' revenues. Appendix D has the data (Appendix D.1) and accompanying treemaps of the aggregated revenues and ownership in the ten industries of the keystone firms based on their domicile. It shows that with these firms, the market is highly skewed (Appendix D.2). Firms from four countries (China, Canada, Australia, and Russia) earn more than 60 % of the revenues in the ten extractives. The keystone firms from China and Canada together earn one quarter of all revenues. This also reflects the globalized nature of the extractives, where there is an imbalance between where the natural resources actually are located and mined, and where the revenues actually land. The international ownership of extractives is shown in Appendix D.3. As with revenues, there is a highly skewed distribution: owners from four countries (US, China, UK, South Africa) control about

Exhibit 5
Ownership concentration (Owners with at least 1% (‡for 2%; *for 5%) ownership in top-10 firms per industry; asset managers in *italics*, high net worth individuals underlined, government entities in **bold**).

Cement	Copper	Diamond	Gold	Iron	Nickel	Oil & gas	Platinum	Silver	Zinc
Anhui#	Jiangxi*	**Russia***	*Blackrk‡*	*BNDES**	Vale*	**CNP***	Anglo*	*Eck**	Yunnan*
Desmarais	Aboroa*	*Aberd.‡*	*Vangrd‡*	Forrest*	Sumi-tomo*	CPC‡	Impala*	*Vangrd‡*	Su‡
Suramer	Climax‡	*Vertigol*	*Eck‡*	*Litel**	Mantr‡	**Russia**	Bafokeng*	*Blackrk‡*	Zhuzhou‡
CRH	**Poland‡**	*Lazard*	*Polyus‡*	DTVM‡	Ni Cap.	*Vangrd*	*Coronat‡*	*Renaissance‡*	*YSheng‡*
Schmid	*Capital*	*M&G*	*Fidelity‡*	Capital‡	*Nonillio*		*PIC‡*	*MStanley*	Huludao‡
Vilat	Yunnan		*Eagle*	Mitsui‡	N Steel		*Allan Gray‡*	Wheaton	*Zhuhai*
	Cerro		**CN Nat.**	*Blackrck‡*			*Medway*	*Dimens.*	*Guohua*
				Anglo‡				*Tocque*	
				India ‡					
				Vanguard					

Source: Appendix B.

60 % of all keystone firms. Especially owners from the US and China control the extractives. The keystone owners from these two countries own almost half of the keystone firms. Furthermore, there are substantial discrepancies between where revenues land with keystone firms and where their keystone owners are located (Appendix D.2 and D.3). In particular, it shows that the US and UK ownership is much higher than their revenues. For Australia and Canada, this is the other way round. For China, there is more of a balance between the revenues owned by their keystone firms and the ownership of their keystone owners. However, it is important to realize that the revenues mostly already are captured by firms headquartered outside the country where the resources actually are mined (Steenbergen and Saurav, 2023).

These aggregate patterns are the result of the combination of the international production and ownership in the ten different industries. For example, with Zinc, all top-10 firms reside in China. With Platinum, 94 % of the top-10 firms' revenues is in South-Africa. 79 % of the revenues in Diamond for top firms are in Russia. 68 % of Copper and 66 % of Iron revenue of top firms is in China and Brazil respectively. For Silver, 61 % of the revenues in these top-10 firms is from Canada. With Cement, Gold, Nickel and Oil & Gas, the revenues are more dispersed internationally. We find that international ownership of keystone firms is more dispersed than their revenues. However, international ownership concentration of the keystone firms differs significantly between the extractive industries. For example, in Zinc, all top firms are owned by Chinese shareholders. With Platinum, 40 % of the owners reside in the UK. With Diamonds, 37 % of the ownership is in Russia. In the case of Silver and Gold, US investors dominate as they own 24 % and 12 % of the top firms respectively. With Nickel and Iron, 19 % and 17 % respectively of ownership is with Brazilian investors.

As discussed in section 4.2 (see also Appendix C), there are different types of owners. It appears that government entities and high worth individuals usually invest in one industry only. However, asset managers and hedge funds seem to invest in most of the industries. These differences are driven by the motivation of the investor. For the government, it predominantly is strategic control. For financial investors, it is investment returns. However, this dimension is hard to specify as we do not have a complete overview of investors' portfolios. Furthermore, a wealthy person might invest (directly) in a listed company while at the same time (indirectly) own stocks in this company via asset management vehicles.

5. Discussion

Traditionally, there is a strong case for government policy to address production externalities (Heal, 2017;). In this regard, there is a range of policy approaches to help enterprises mitigate their impact on the environment. They can be identified as the '5P's': patrolling (monitoring emissions), prescription (laws and regulations), penalties (taxes and fines), payments (incentives and fiscal support), and persuasion (corporate commitment and information) (see Steenbergen and Saurav, 2023). The effectiveness and efficiency of these policies is subject to a long-standing debate and the jury is still out (Heal, 2017). However, it is well-established that multinational enterprises can escape jurisdictions and influence the policies they are subjected to (Nykvist and Maltais, 2022; Moe, 2010; Zingales, 2017). With the international mining companies, policy effectiveness is even more complicated due to their disproportionate share of emissions and pollution, and because of their substantial bargaining power in factor and product markets (Steenbergen and Saurav, 2023). Therefore, it makes sense to look into the potential of other mechanisms to achieve leverage on these firms to advance the transformation towards sustainable development (Folke et al., 2019).

To determine whom to target when aiming to bring about sustainability transition in the extractives, not only the dominant firms, but also their dominant owners need to be addressed, as they design the strategic direction of these firms (Jouffray et al., 2019; Dordi et al., 2022). It shows there is a very high concentration in the extractives: with the ten industries studied, the largest three firms on average earn more than two-thirds of industry revenues. Furthermore, the largest ten earn 85 % of these. As such, keystone firms have an enormous vested interest and require special attention from policy makers and stakeholder groups. However, policy setting for these internationally operating resource companies proves to be highly challenging. At the national level, there is often lack of solid and consistent public governance, as mining operations often occur in countries with challenges regarding enforcement of laws and regulations. International policies and codes are actively promoted, e.g., UN Global Compact, OECD Guidelines for Multinational Enterprises, but also difficult to enforce as individual firms and organizations are not subject to these regulations.

For these keystone firms, it is important to realize that environmental externalities may influence their cost of capital (Xu and Kim, 2022). This is because most financiers will regard them as riskier than companies with less externalities (Chava, 2014; Trinks et al., 2022a). These risks may stem from concerns about future liabilities and more restrictive regulation as well as from exposure to litigation and consumer action (see Friede et al. (2015) for the literature about corporate responsibilities and their financial performance). Therefore, there is economic reason for companies to pay more attention to the external effects of their business.

As a leading agent, proactive international mining companies might gain leverage themselves by imposing sustainability standards or encourage green technology transfers within their supply chain (Thorlakson et al., 2018). Given their size and reach, this could affect millions of producers and accelerate the transition to sustainability. However, this requires that they indeed advance such standards and that there is appropriate information about the emissions from international supply chains (Zhang et al., 2020). Successful examples are from the international fisheries (Österblom et al., 2017; Folke and Kautsky, 2022) and international forestry (Mandle et al., 2019). In this regard, disclosure and reporting policies are important to accompany these initiatives as

there is the risk of greenwashing (Delmas and Burbano, 2011; Marquis et al., 2016). Here, stakeholders and interest groups can stimulate keystone firms to take this leading role (Steenbergen and Saurav, 2023).

Leverage might also be achieved via industry bodies and multi-stakeholder organizations. These can set requirements or standards for company policies and practices. Relevant examples for extractives are Responsible Gold Mining Principles, Voluntary Principles on Security and Human Rights, MAC TSM Protocols and Frameworks, OECD Guidelines for Multinational Enterprises, ICMM Performance Expectations, and EITI Expectations for supporting companies. The RMF (2022) argues that the effectiveness and credibility of these initiatives is limited because of low ambition, narrow scope, or lack of clear requirements to demonstrate compliance. Österblom et al. (2022) are more optimistic and argue that corporations are able to exercise substantial leadership by working alone, together in their sector with peers, or in cooperation with science. Furthermore, they assume a global convention that governs corporations is likely necessary if the sustainable development goals are to be met in time. However, they also observe that the mining industry has shown very little progress in this direction so far.

Thus, given the very high concentration in the ten extractive industries, leveraging the keystone firms by stakeholders and nongovernmental organizations may help bring about transformational change. This is because only few companies need to be targeted.

Another route to leverage is via the financiers of keystone firms, as access to finance is crucial. Ease of access to debt and equity reduces emissions and pollution (Levine et al., 2019; Xu and Kim, 2022). As such, financiers can help to achieve leverage as ownership in the extractives is highly concentrated. Owners themselves can pressure keystone firms towards sustainability, and they themselves can be pressured by stakeholders and interest groups to do so (Steenbergen and Saurav, 2023).

This is in particular feasible with the extractive industries as they are characterized by blockholdership; these owners have a disproportionate say in corporate strategy (Edmans and Holderness, 2014). The three largest shareholders hold on average one-fifth of the shares of keystone agents in extractives, and the ten largest owners hold almost one-third. This implies that dominant owners are prevalent in the extractives. Therefore, it seems relevant to target these owners and to highlight their responsibility (Hart and Zingales, 2017, 2022). Here, investor activism is an important means to bring about change (filing petitions on responsible mining, voting for petitions that acknowledge the importance of environmental and social objectives, engaging with the board on these objectives). However, several keystone owners are privately or state-owned companies. In the case of the former, pressure can be put on them via industry initiatives or nongovernmental organizations. With the latter, given that most states require international financial markets to fund their debts, financial investors remain a critical factor via which leverage can be exercised.

In this regard, there are two mechanisms by which private owners can influence business strategy and conduct: divestment and engagement. However, preliminary is the decision of such owners whether or not to account for externalities and taking responsibility for moving in the direction of more sustainability in the extractives; and it is exactly here where there is scope for influencing the owners. It seems that in the past two decades investors increasingly answer this question in the affirmative. For example, the number of investors who sign up to the Principles for Responsible Investing[1] has steadily increased over time. Their combined assets under management increased from US$ 6 trillion in 2006 to 120 trillion in 2021. This implies that 40 % of all assets under management are somehow in the hands of owners who relate to their responsibility concerning sustainability. This does not mean that this sum already is invested in a way that is sustainable or advances societal transition (Plantinga and Scholtens, 2020). However, such increase is important to achieve momentum, which is material for the economic impact of taking responsibility as it affects the returns of the investment and the cost of capital of the investee firm/organization (Heinkel et al., 2001). Both internal factors and external pressure has contributed to the increase in PRI signatories (Bolton and Kacperczyk, 2022; Eurosif, 2018). Even investors who do not want to take on responsibility appear to use non-financial information regarding firm performance in their fundamental analysis of companies (Van Duuren et al., 2016).

A major hurdle is that the quality of the information provided is highly problematic with the result that investment decisions based thereon are unlikely to be efficient and effective (Berg et al., 2022). In addition, Capelle-Blancard et al. (2021) find that the response of investors to accidents like oil spills, fraud, etc. is economically limited and does not bear a close relationship with the damage done to society and ecosystems. Some studies suggest that investors divest from controversial activities, like alcohol and tobacco. This can be absolute (implying negative screening) or in relation to a benchmark (i.e., underweighting controversial assets) (see Plantinga and Scholtens, 2020; Edmans, 2022). Here, policies regarding disclosure and monitoring of externalities might be useful in complementing stakeholders' and activists' requests and pressure on owners.

As the concentration of ownership in the ten extractives is very high, there is substantial scope to influence their investment decisions and affect the transformation of the industries. These owners' decisions affect the cost of capital and the returns of the investee firms. Targeting the relatively small number of keystone owners in the extractives therefore seems an efficient means to help bring about transformational change.

Sustainability transformation in the extractives requires change with firms and their owners. In this regard, Bolton and Kacperczyk (2022) find that growing fraction of companies globally commit to reduce pollution. The observe that while the companies that make commitments subsequently reduce their emissions, the effect on overall emissions of companies (including those that do not commit) has been small; the companies that commit, and those that make the most ambitious commitments, tend to have lower emissions (Bolton and Kacperczyk, 2022). Trinks et al., (2022b) find that firm commitments are more prevalent in countries where governments have made more ambitious national commitments to reduce emissions.

To achieve a transformation of the extractives industries towards a more circular and sustainable system, major changes are required. So far, policies have not been very successful and the industries themselves are slow to move. Therefore, focus on keystone agents (both firms and owners) is an alternative route that may be used to help bring about transformational change of the industry. Pressure from stakeholders and shareholders on these agents, together with 'persuasion' and 'patrolling' as per government policies, might bring about such change. Important is that the keystone agents come to realize the urgency and their responsibility regarding the transformation of business and society.

6. Conclusion

This study tries to answer two questions regarding the leverage of keystone agents in extractives to advance transition towards sustainability. First is who are the dominant firms in extractives, i.e., the keystone firms. Here, it shows that the keystone firms are mainly based in China, Canada, Australia, and Russia. The markets in extractives are highly concentrated, with the largest three firms on average having 68 % of the revenues in the ten extractive industries. Our second question was who owns these dominant firms, i.e., the keystone owners. It shows that the ownership mainly is with investors from the US, China, the UK, and South Africa. With the ten extractive industries, the largest three owners

[1] The UN sponsored Principles for Responsible Investing aims to help their signatories to understand the investment implications of environmental, social and governance (ESG) factors and to support an international network of investor signatories in incorporating these factors into their investment and ownership decisions.

on average hold 22 % of the shares of the ten dominant firms. As such, ownership too is highly concentrated. We find that the industry studied most, namely Oil and Gas, is not representative for the extractives. Dordi et al. (2022) point out that this industry is dominated by a few hegemons. We find that both the real activities and the financial ownership in most other extractives is even more concentrated. This concentration with firms, owners and countries suggest that there is substantial scope for leverage to bring about transformational change in the extractives.

So far, keystone agents in the extractives are lagging those in other industries when it comes to transiting to a more circular and sustainable business model (Österblom et al., 2022). Therefore, keystone firms should realize that they could be leading the change, as 'doing nothing' is very risky: It is likely to trigger a critical response from society and (international) regulatory bodies as other industries appear to be open to change. Keystone owners can support such a move as they have several strategies to influence corporate strategy: they can tilt their investment portfolios, the can file and vote for petitions at the Annual General Meeting of shareholders, they can engage with board members, they can (threaten to) divest, and they can integrate sustainability objectives in their investment performance management. These strategies can be combined to enhance their effectiveness regarding the transition towards sustainability in extractives.

These findings result in three important recommendations regarding achieving leverage of keystone agents in the extractives. The first is for stakeholders and interest groups, they might concentrate on the keystone firms and owners as these are controlling the ten industries. To achieve sustainability, these need to be targeted and made aware of their responsibility and potential leading role and pressured towards transformational change. The second is for shareholders, where the analysis suggests that there are relatively few firms that dominate the industry as well as a small number of very powerful blockholders. They might use investor activism, where the objective is to change the company's focus from shareholder wealth to shareholder welfare. For ultimate owners, i.e. those who invest with keystone owners, it is important to realize the nonfinancial impact of their investment and the economic, environmental, and societal risks this brings. Participants in pension schemes and mutual funds can require their intermediaries to disclose the impacts and risks in detail and require investee companies to mitigate these risks and align them with SDGs and Planetary Boundaries. The third is for policymakers. Traditional policies like laws, taxes, and fines have been ineffective so far with these multinational enterprises (Steenbergen and Saurav, 2023). However, specific policies for keystone agents might be aligned with more traditional mechanisms, like regulation and supervision, where existing requirements for the keystone agents and owners can be stricter than for other agents. In this regard, there is precedent in financial regulation, where systematically important banks face much more stringent regulation than small and locally operating institutions (Mirzaei and Samet, 2022). However, and more importantly, accommodating policies, especially regarding disclosure and reporting, could help bring about change. In particular, policies to support the information disclosure of the effects of production and monitoring these, as well as trying to get commitment from keystone agents for social and environmental objectives can be helpful. Ideally, this is in tandem with demands from (ultimate) investors and society groups.

An important limitation of the study is that it only investigates the ten largest extractive industries, as information about others was not available in our databases. Concentration of firms and owners might differ in the extractives not studied. Hence, our findings and recommendations cannot be generalized. Furthermore, the study refrains from analysing the illegal mining industry and illegal activity, and cannot inform as to how to govern or leverage these.

In all, the conclusion is that both natural resource markets and ownership of keystone firms in the extractives are highly concentrated. This provides guidance as to whom to target to achieve transition towards sustainability in extractives. There is a smorgasbord of mechanisms to advance societal transition via ownership. This implies that advancing sustainability in extractives requires leveraging a limited number of keystone firms and owners in a small number of countries.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

Industry concentration in the ten extractive industries.

This table presents the keystone firms within each of the ten extractive industries and their share in industry revenues.*

		market share (fraction)	cumulative market share (fraction)
Cement			
1	LafargeHolcim Ltd	0.1394	0.1394
2	Anhui Conch Cement Co Ltd	0.0984	0.2378
3	China Resources Cement Holdings Ltd	0.0254	0.2632
4	Tangshan Jidong Cement Co Ltd	0.0237	0.2868
5	Grupo Argos SA	0.0233	0.3102
6	Huaxin Cement Co Ltd	0.0210	0.3312

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		market share (fraction)	cumulative market share (fraction)
7	Taiwan Cement Corp	0.0207	0.3519
8	Xishui Strong Year Co Ltd Inner Mongolia	0.0177	0.3696
9	Vicat SA	0.0152	0.3849
10	Dangote Cement PLC	0.0151	0.4000
Copper			
1	Jiangxi Copper Co Ltd	0.4521	0.4521
2	Yunnan Copper Co Ltd	0.0998	0.5520
3	Zhejiang Hailiang Co Ltd	0.0846	0.6366
4	KGHM Polska Miedz SA	0.0762	0.7128
5	Antofagasta PLC	0.0669	0.7796
6	First Quantum Minerals Ltd	0.0574	0.8371
7	Sociedad Minera Cerro Verde SAA	0.0408	0.8779
8	Anhui Truchum Advanced Materials and Technology Co Ltd	0.0348	0.9127
9	Hudbay Minerals Inc	0.0208	0.9335
10	Ningbo Boway Alloy Material Co Ltd	0.0128	0.9463
Diamond			
1	AK Alrosa PAO	0.7906	0.7906
2	Petra Diamonds Ltd	0.0808	0.8714
3	Gem Diamonds Ltd	0.0466	0.9180
4	Mountain Province Diamonds Inc	0.0407	0.9588
5	Lucara Diamond Corp	0.0307	0.9895
6	Firestone Diamonds PLC	0.0100	0.9995
7	Diamcor Mining Inc	0.0005	1.0000
Gold			
1	Barrick Gold Corp	0.1294	0.1294
2	Shandong Gold Mining Co Ltd	0.1083	0.2377
3	Newmont Corporation	0.0966	0.3343
4	Zhongjin Gold Corp Ltd	0.0682	0.4025
5	Polyus PAO	0.0544	0.4569
6	AngloGold Ashanti Ltd	0.0525	0.5095
7	Newcrest Mining Ltd	0.0498	0.5593
8	Kinross Gold Corp	0.0466	0.6059
9	Shandong Humon Smelting Co Ltd	0.0422	0.6480
10	Agnico Eagle Mines Ltd	0.0332	0.6813
Iron			
1	Vale SA	0.6614	0.6614
2	Fortescue Metals Group Ltd	0.1802	0.8416
3	Kumba Iron Ore Ltd	0.0775	0.9191
4	NMDC Ltd	0.0316	0.9507
5	Ferrexpo PLC	0.0230	0.9737
6	HBIS Resources Co Ltd	0.0134	0.9871
7	Mount Gibson Iron Ltd	0.0035	0.9907
8	Aowei Holding Ltd	0.0033	0.9939
9	Sandur Manganese and Iron Ores Ltd	0.0018	0.9957
10	Labrador Iron Ore Royalty Corp	0.0018	0.9975
Nickel			
1	Vale Indonesia Tbk PT	0.3896	0.3896
2	Pacific Metals Co Ltd	0.2238	0.6134
3	Nickel Asia Corp	0.1775	0.7909
4	Western Areas Ltd	0.0913	0.8822
5	Sherritt International Corp	0.0579	0.9401
6	Nickel Mines Ltd	0.0326	0.9727
7	Mincor Resources NL	0.0137	0.9864
8	Panoramic Resources Ltd	0.0085	0.9949
9	S Science Co Ltd	0.0050	0.9998
Oil and gas			
1	China Petroleum & Chemical Corp	0.0830	0.0830
2	PetroChina Co Ltd	0.0681	0.1511
3	Royal Dutch Shell PLC	0.0668	0.2179
4	BP PLC	0.0539	0.2718
5	Exxon Mobil Corp	0.0513	0.3231
6	Total SA	0.0388	0.3619
7	Chevron Corp	0.0284	0.3903
8	NK Rosneft' PAO	0.0260	0.4163
9	NK Lukoil PAO	0.0248	0.4411
10	Gazprom PAO	0.0247	0.4658
Platinum			
1	Anglo American Platinum Ltd	0.7883	0.7883
2	Northam Platinum Ltd	0.0829	0.8712
3	Zimplats Holdings Ltd	0.0568	0.9280
4	Tharisa PLC	0.0407	0.9687
5	Royal Bafokeng Platinum Ltd	0.0304	0.9991
6	Jubilee Metals Group PLC	0.0009	1.0000
Silver			
1	Pan American Silver Corp	0.3825	0.3825

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		market share (fraction)	cumulative market share (fraction)
2	Coeur Mining Inc	0.3052	0.6877
3	First Majestic Silver Corp	0.1467	0.8344
4	Silvercorp Metals Inc	0.0831	0.9175
5	Endeavour Silver Corp	0.0734	0.9909
6	Santacruz Silver Mining Ltd	0.0056	0.9965
7	Golden Minerals Co	0.0035	1.0000
Zinc			
1	Yunnan Chihong Zinc & Germanium Co Ltd	0.4713	0.4713
2	Zhuzhou Smelter Group Co Ltd	0.3207	0.7920
3	Huludao Zinc Industry Co Ltd	0.2079	0.9999

*This table presents the ten largest firms within each of the ten extractive industries. Here, size is proxied by revenues. In some case, less than ten firms earn 100 % of the revenues (for example, Zinc, Silver, and Platinum). The first column gives the fraction of each of the (max) ten companies in industry revenues. The second column gives the cumulative fraction.

Appendix B

Ownership concentration in the ten extractive industries.

This table presents the keystone owners within each of the ten extractive industries, their ownership in the industry, as well as the cumulative ownership of the keystone owners.

		ownership in industry (fraction)	cumulative ownership in industry (fraction)
Cement			
1	Anhui Conch Group Co., Ltd.	0.0381	0.0381
2	Desmarais & Frère Families	0.0160	0.0542
3	Grupo de Inversiones Suramericana S.A.	0.0158	0.0699
4	CRH (Cement) Ltd.	0.0155	0.0854
5	Schmidheiny (Thomas)	0.0145	0.0999
6	Merceron-Vicat (Jacques & Family)	0.0109	0.1107
7	Jidong Development Group Co., Ltd.	0.0075	0.1182
8	The Vanguard Group, Inc.	0.0061	0.1243
9	BlackRock Institutional Trust Company, N.A.	0.0059	0.1303
10	Norges Bank Investment Management (NBIM)	0.0057	0.1360
Copper			
1	Jiangxi Copper Corporation Limited	0.0732	0.0732
2	E. Abaroa Foundation	0.0568	0.1300
3	Cyprus Climax Metals Company	0.0272	0.1572
4	State Treasury of the Republic of Poland	0.0215	0.1786
5	Capital Research Global Investors	0.0167	0.1953
6	Yunnan Copper (Group) Company Ltd.	0.0149	0.2102
7	SMM Cerro Verde Netherlands B.V.	0.0107	0.2209
8	Compania de Minas Buenaventura SAA	0.0099	0.2308
9	RBC Global Asset Management (UK) Limited	0.0084	0.2392
10	The Vanguard Group, Inc.	0.0075	0.2467
Diamond			
1	Government of Russia	0.2128	0.1611
2	Ministry of Property Relations of the Republic of Sakha	0.1611	0.1819
3	Aberdeen Asset Investments Limited	0.0208	0.2005
4	Vertigol Unlimited Company	0.0186	0.2175
5	Lazard Asset Management Limited	0.0170	0.2297
6	M & G Investment Management Ltd.	0.0122	0.2375
7	Sustainable Capital Ltd.	0.0078	0.2451
8	The Vanguard Group, Inc.	0.0076	0.2517
9	Norges Bank Investment Management (NBIM)	0.0066	0.2583
10	Alfred Berg Kapitalförvaltning AB	0.0066	0.2643
Gold			
1	BlackRock Advisors (UK) Limited	0.0356	0.0356
2	The Vanguard Group, Inc.	0.0306	0.0663
3	Van Eck Associates Corporation	0.0292	0.0954
4	Polyus Gold International, Ltd.	0.0282	0.1236
5	Fidelity Investments Canada ULC	0.0196	0.1432
6	First Eagle Investment Management, L.L.C.	0.0132	0.1564
7	China National Gold Group Co., Ltd.	0.0120	0.1684
8	Yantai Humon Group Co., Ltd.	0.0090	0.1774
9	Flossbach von Storch AG	0.0083	0.1857
10	State Street Global Advisors (US)	0.0080	0.1937
Iron			
1	BNDES Participações S.A. – BNDESPAR	0.0798	0.0798
2	Forrest (John Andrew Henry)	0.0516	0.1314
3	Litel Participacoes SA	0.0499	0.1813
4	BB Gestão de Recursos - DTVM S.A.	0.0448	0.2261
5	Capital Research Global Investors	0.0431	0.2692

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		ownership in industry (fraction)	cumulative ownership in industry (fraction)
6	Mitsui & Co Ltd	0.0370	0.3062
7	BlackRock Institutional Trust Company, N.A.	0.0269	0.3331
8	Anglo American PLC	0.0247	0.3579
9	Government of India	0.0224	0.3802
10	The Vanguard Group, Inc.	0.0154	0.3956
Nickel			
1	Vale Canada Ltd.	0.1899	0.1899
2	Sumitomo Metal Mining Co Ltd	0.1006	0.2905
3	Mantra Resources Corporation	0.0329	0.3235
4	Ni Capital Corporation	0.0171	0.3405
5	Mitsubishi Corp	0.0131	0.3536
6	Nonillion Holding Corporation	0.0121	0.3657
7	Nippon Steel Stainless Steel Corporation	0.0099	0.3756
8	BlackRock Institutional Trust Company, N.A.	0.0093	0.3849
9	Shanghai Decent Investment (Group) Co. Ltd.	0.0090	0.3939
10	Xu (Yuanyuan)	0.0083	0.4023
Oil and gas			
1	China National Petroleum Corporation	0.0511	0.0511
2	China Petrochemical Corporation	0.0300	0.0812
3	Federal Agency for State Property Management	0.0186	0.0998
4	The Vanguard Group, Inc.	0.0117	0.1115
5	BlackRock Institutional Trust Company, N.A.	0.0087	0.1202
6	Rosneftegaz	0.0053	0.1256
7	State Street Global Advisors (UK) Ltd.	0.0050	0.1306
8	Total Employees	0.0029	0.1335
9	Norges Bank Investment Management (NBIM)	0.0027	0.1361
10	Legal & General Investment Management Ltd.	0.0014	0.1375
Platinum			
1	Anglo American Corporation Of South America	0.4009	0.4009
2	Impala Platinum Holdings Ltd	0.0913	0.4922
3	Royal Bafokeng Platinum Holdings (Pty) Ltd. (RBPH)	0.0529	0.5452
4	Coronation Fund Managers Limited	0.0397	0.5848
5	Public Investment Corporation (SOC) Limited	0.0228	0.6076
6	Allan Gray Proprietary Limited	0.0224	0.6300
7	Medway Developments Ltd.	0.0128	0.6428
8	Kagiso Asset Management (Pty) Limited	0.0084	0.6512
9	The Vanguard Group, Inc.	0.0073	0.6586
10	Fairtree Asset Management (Pty) Ltd	0.0053	0.6639
Silver			
1	Van Eck Associates Corporation	0.1064	0.1064
2	The Vanguard Group, Inc.	0.0316	0.1380
3	BlackRock Institutional Trust Company, N.A.	0.0252	0.1633
4	Renaissance Technologies LLC	0.0241	0.1874
5	Morgan Stanley & Co. LLC	0.0154	0.2028
6	Wheaton Precious Metals Corp	0.0138	0.2166
7	Dimensional Fund Advisors, L.P.	0.0137	0.2303
8	Tocqueville Asset Management LP	0.0107	0.2410
9	Merian Global Investors (UK) Limited	0.0086	0.2496
10	Slate Path Capital LP	0.0081	0.2576
Zinc			
1	Yunnan Metallurgical Group Co., Ltd.	0.2274	0.2274
2	Su (Ting Bao)	0.0463	0.2736
3	Zhuzhou Smelter Group Holding Co., Ltd.	0.0460	0.3196
4	YueSheng No.1 Single Capital Trust	0.0238	0.3434
5	MCC Huludao Nonferrous Metals Group Co., Ltd.	0.0205	0.3639
6	Zhuhai Jinrun Zhongze Investment Center (LP)	0.0191	0.3830
7	Guohua Life Insurance Co., Ltd.	0.0126	0.3955
8	Zheng (Ji Hua)	0.0071	0.4027
9	Hunan Nonferrous Metals Co Ltd	0.0037	0.4064
10	Hunan Economic & Technology Investment Guarantee	0.0037	0.4101

Appendix C

Blockholdership in the ten extractive industries.

This table presents the number of owners who own a relevant fraction of the industry for each of the ten extractive industries.

	HHI	10 %	20 %	30 %	40 %	50 %
Cement	2304	1	2	3	7	12
Copper	1842	1	2	3	8	10
Diamond	977	1	3	5	6	8
Gold	1321	2	3	5	11	20
Iron	3138	1	1	1	2	3
Nickel	841	4	4	4	6	7
Oil and gas	2189	2	7	29	na	na
Platinum	3125	1	1	2	2	3
Silver	382	1	4	6	15	76
Zinc	1017	1	3	4	4	5

HHI is Herfindahl-Hirschman Index; the percentage relate to the various blockholdership thresholds; the number relates to the number of owners. For example, in the gold industry, four owners hold at least 25 % of the stock of the listed companies in this industry.

Appendix D. International perspective

Revenues and ownership of keystone agents in ten extractive industries.

D.1

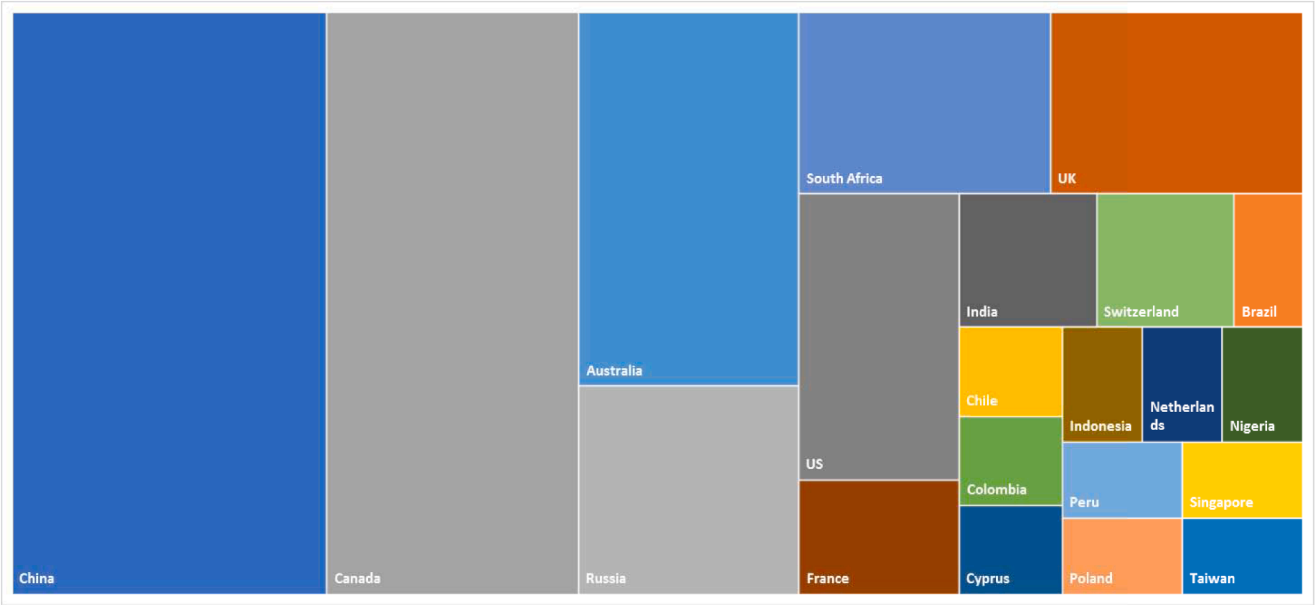
This table gives the percentages revenue (column A) and ownership (column B) of the keystone firms and owners respectively at the country level. The difference between these percentages is in column C and signals whether there is a balance between the geographic location of keystone firms and owners.

Country*	% revenue	% ownership	differential (column A - column B)
	(A)	(B)	(C)
Australia	11.0	1.0	10.0
Brazil	1.2	3.0	−1.8
Canada	19.5	5.0	14.5
China	24.4	21.0	3.4
France	2.4	2.0	0.4
India	2.4	1.0	1.4
Japan	0.0	4.0	−4.0
Liechtenstein	0.0	1.0	−1.0
Norway	0.0	3.0	−3.0
Russia	6.1	5.0	1.1
South Africa	6.1	7.0	−0.9
Switzerland	2.4	1.0	1.4
UK	6.1	9.0	−2.9
US	6.1	25.0	−18.9
Other	12.2	12.0	0.2
Total	100.0	100.0	0.0

*we include only countries when either revenues from keystone firms or ownership from keystone owners is more than 1 %. As a result, we have ‘other’, which covers the revenues and ownership from remaining countries.

Appendix D.2

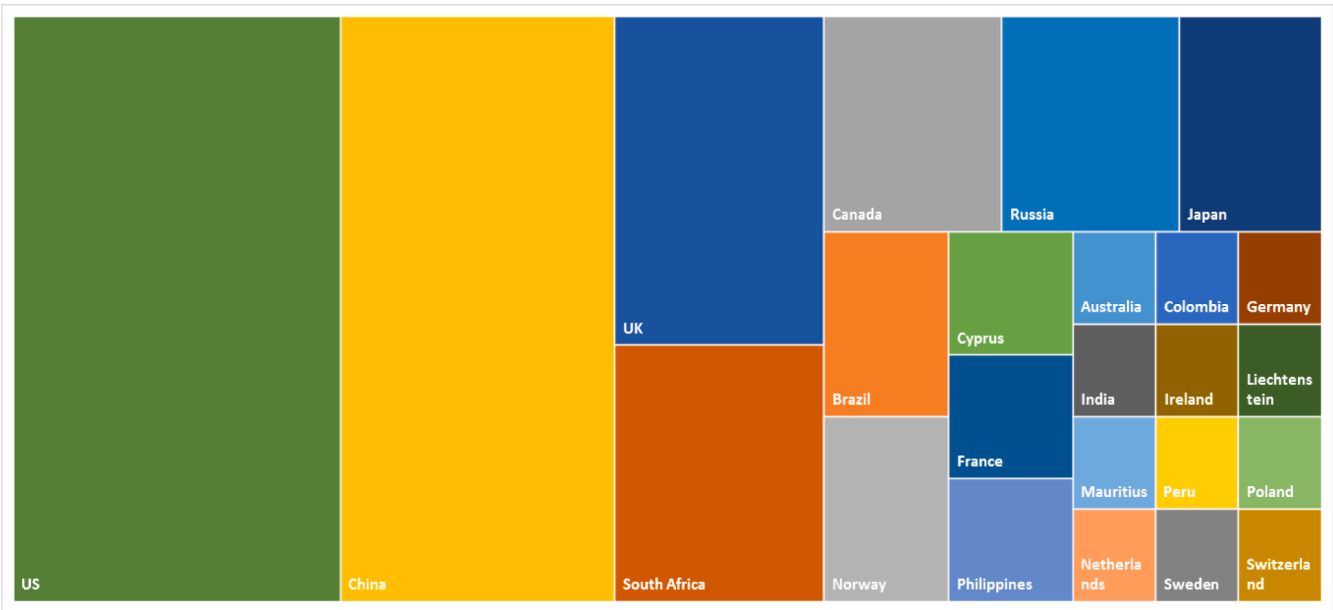
Geographical distribution of keystone firm revenues.



Source: D.1.

D.3

Geographical distribution of keystone firm ownership.



Source: D.1.

References

Alchian, A.A., Demsetz, H., 1972. Production, information costs, and economic organization. Am. Econ. Rev. 62, 777–795.

Berg, F., Rigobon, R., Kölbel, J., 2022. Aggregate Confusion: The Divergence of ESG Ratings. Eur. Finan. Rev. https://doi.org/10.1093/rof/rfac033.

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., Truffer, B., 2015. Technological innovation systems in contexts: conceptualizing contextual structures and interaction dynamics. Environ. Innov. Soc. Trans. 16, 51–64. https://doi.org/10.1016/j.eist.2015.07.003.

Berkhout, F. (2002) Technological regimes, path dependency and the environment. Global Environmental Change 12. 10/1016/S0959-3780(01)00025-5.

Bolton, P., Kacperczyk, M., 2022. Firm Commitments. Columbia Business School Research Paper, New York.

Boons, F., Montalvo, C., Quist, J., Wagner, M., 2013. Sustainable innovation, business models and economic performance: an overview. J. Clean. Prod. 45, 1–8.

Capelle-Blancard, G., Desrozier, A., Scholtens, B., 2021. Shareholders and the environment: A review of four decades of academic research. Environ. Res. Lett. 16, 123005 https://doi.org/10.1088/1748-9326/ac3c6e.

Capelle-Blancard, G., Petit, A., 2017. The weighting of CSR dimensions: One size does not fit all. Bus. Soc. 56, 919–943.

Chakhmouradian, A.R., Wall, F., 2012. Rare earth elements: Minerals, mines, magnets (and more). Elements 8, 333–340.
Chakravarty, S., Chikkatur, A., De Coninck, H., Pacala, S., Socolow, R., Tavoni, M., 2009. Sharing global CO2 emission reductions among one billion high emitters. PNAS 106, 11884–11888.
Dam, L., Scholtens, B., 2012. The curse of the haven: The impact of multinational enterprise on environmental regulation. Ecol. Econ. 78, 148–156.
Delmas, M.A., Burbano, V.C., 2011. The drivers of greenwashing. Calif. Manage. Rev. 54, 64–87. https://doi.org/10.1525/cmr.2011.54.1.64.
Dimson, E., Karakas, O., Li, X., 2015. Active Ownership. Rev. Financ. Stud. 28, 3225–3268.
Dordi, T., Gehrick, S.A., Naef, A., Weber, O., 2022. Ten financial actors can accelerate a transition away from fossil fuels. Environ. Innov. Soc. Trans. 44, 60–78.
Dudka, S., Adriano, D.C., 1997. Environmental impacts of metal ore mining and processing: A review. J. Environ. Qual. 26, 590–602.
Edmans, A., Holderness, C. G. (2014) Blockholders: A Survey of Theory and Evidence. CEPR Discussion Paper DP11442.
Edmans, A., Levit, D., Schneemeier, J. (2022) Socially Responsible Divestment (April 2022). CEPR Discussion Paper No. DP17262, https://ssrn.com/abstract=4121445.
Eurosif., 2018. European SRI Study. Eurosif, Brussels.
Folke, C., Kautsky, N., 2022. Aquaculture and ocean stewardship. Ambio 51, 13–16.
Folke, C., Österblom, H., Jouffray, J.B., et al., 2019. Transnational corporations and the challenge of biosphere stewardship. Nat. Ecol. Evol. https://doi.org/10.1038/s41559-019-0978-z.
Folke, C., Polasky, S., Rockström, J., et al., 2021. Our future in the Anthropocene biosphere. Ambio 50, 834–869.
Responsible Mining Foundation (RMF) (2022) Accelerating responsible mining: spotlight on industry and multistakeholder initiatives. Columbia Center on Sustainable Investment (2022).
Friede, G., Busch, T., Bassen, A., 2015. ESG and financial performance: aggregated evidence from more than 2000 empirical studies. Journal of Sustainable Finance and Investing 5, 210–233. https://doi.org/10.1080/20430795.2015.1118917.
Galaz, V., Crona, B., Dauriach, A., Jouffray, J.B., Österblom, H., Fichtner, J., 2018. Tax havens and global environmental degradation. Nat. Ecol. Evol. 2, 1352–1357.
Geddes, A., Schmidt, T.S., 2020. Integrating finance into the multi-level perspective: technology niche-finance regime interactions and financial policy interventions. Res. Policy 49 (6), 103985. https://doi.org/10.1016/j.respol.2020.103985.
Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study. Res. Policy 31, 8–9. https://doi.org/10.1016/S0048-7333(02)00062-8.
Grossman, S., Hart, O., 1980. Takeover bids, the free-rider problem and the theory of the corporation. Bell J. Econ. 11, 42–64.
Grullon, G., Larkin, Y., Michaely, R., 2019. Are US industries becoming more concentrated? Eur. Finan. Rev. 23, 697–743.
Habert, G., Millar, S.A., John, V.M., et al., 2020. Environmental impacts and decarbonization strategies in the cement and concrete industries. Nature Reviews Earth & Environment 1, 559–573.
Hart, O., Zingales, L. (2022) The New Corporate Governance. ECGI Working Paper Series in Law, 640.
Hart, O., Zingales, L., 2017. Companies should maximize shareholder welfare not market value. Journal of Law, Finance and Accounting 2, 247–274.
Heal, G., 2017. Endangered Economies. Columbia University Press, New York.
Heede, R., 2014. Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. Clim. Change 122, 229–241.
Heinkel, R., Kraus, A., Zechner, J., 2001. The effect of green investment on corporate behavior. J. Financ. Quant. Anal. 36, 431–449.
Jaccard, M., Hoffele, J., Jaccard, T., 2018. Global carbon budgets and the viability of new fossil fuel projects. Clim. Change 150 (1–2), 15–28. https://doi.org/10.1007/s10584-018-2206-2.
Jacquet, J., Frank, D., Schlottmann, C., 2013. Asymmetrical contributions to the tragedy of the commons and some implications for conservation. Sustainability 5, 1036–1048.
Jensen, M.C., Meckling, W.H., 1976. Theory of the firm: Managerial behavior, agency costs and ownership structure. J. Financ. Econ. 3, 305–360.
Jouffray, J. B., Crona, B., Wassénius, E., Bebbington, J., Scholtens, B. (2019) Leverage points in the financial sector for seafood sustainability. Science Advances 5 (10), eaax3324. 10.1126/sciadv.aax33245: eaax3324.
Kane, E., 1977. Good intentions and unintended evil: The case against selective credit allocation. J. Money Credit Bank. 9, 55–69.
King, E., Mutter, J.C., 2015. Natural disasters and violent conflicts. Hazards, Risks and Disasters in Society 11, 181–198.
Kitzmueller, M., Shimshack, J., 2012. Economic perspectives on corporate social responsibility. J. Econ. Lit. 50, 51–84.
Kivimaa, P., Boon, W., Hyysalo, S., Klerkx, L., 2019. Towards a typology of intermediaries in sustainability transitions: a systematic review and research agenda. Res. Policy 48 (4), 1062–1075. https://doi.org/10.1016/j.respol.2018.10.006.
Kivimaa, P., Laakso, S., Lonkila, A., Kaljonen, M., 2021. Moving beyond disruptive innovation: A review of disruption in sustainability transitions. Environ. Innov. Soc. Trans. 38 https://doi.org/10.1016/j.eist.2020.12.001.
La Porta, R., Lopez-de-Silanes, F., Shleifer, A., Vishny, R.W., 1998. Law and finance. J. Polit. Econ. 106, 1113–1155.
Levine, R., Lin, C., Wang, Z., Xie, W., 2019. Finance and pollution: Do credit conditions affect toxic emissions? Working Paper University of California, Berkeley.
Luckeneder, S., Giljum, S., Schaffartzik, A., Maus, V., Tost, M., 2021. Surge in global metal mining threatens vulnerable ecosystem. Glob. Environ. Chang. 69, 102303.
Mancini, L., Sala, S., 2018. Social impact assessment in the mining sector: Review and comparison of indicators frameworks. Res. Policy 57, 98–111.
Mandle, L., Ouyang, Z., Salzman, J., Daily, G.C., 2019. Green Growth That Works: Natural Capital Policy and Finance Mechanisms around the World. Island Press, Washington D.C.
Marquis, C., Toffel, M.W., Zhou, Y., 2016. Scrutiny, norms, and selective disclosure: A global study of greenwashing. Organ. Sci. 7, 483–504. https://doi.org/10.1287/orsc.2015.1039.
McGlade, C., Ekins, P., 2015. The geographical distribution of fossil fuels unused when limiting global warming to 2°C. Nature 517 (7533). https://doi.org/10.1038/nature14016.
Merrie, A., Dunn, D.C., Metian, M., et al., 2014. An ocean of surprises – Trends in human use, unexpected dynamics and governance challenges in areas beyond national jurisdiction. Glob. Environ. Chang. 27, 19–31.
Mirzaei, A., Samet, A., 2022. Effectiveness of macroprudential policies: Do stringent bank regulation and supervision matter? Int. Rev. Econ. Financ. 80, 342–360. https://doi.org/10.1016/j.iref.2022.02.037.
Moe, E., 2010. Energy, industry and politics: Energy, vested interests, and long-term economic growth and development. Energy Policy 35, 1730–1740.
Narula, R., 2018. Multinational firms and the extractive sectors in the 21st century: Can they drive development? J. World Bus. 53, 85–91.
Northey, S.A., Mudd, G.M., Werner, T.T., Jowitt, S.M., Haque, N., Yellishetty, M., Weng, Z., 2017. The exposure of global base metal resources to water criticality, scarcity and climate change. Glob. Environ. Chang. 44, 109–124.
Nykvist, B., Maltais, A., 2022. Too risky – The role of finance as a driver of sustainability transitions. Environ. Innov. Soc. Trans. 42 https://doi.org/10.1016/j.eist.2022.01.001.
Oecd, 2016. Corruption in the extractive value chain: Typology of risks, mitigation measures and incentives. OECD, Paris.
Österblom, H., Jouffray, J.B., Folke, C., Crona, B., Troell, M., Merrie, A., Rockström, J., 2015. Transnational corporations as 'Keystone Actors' in marine ecosystems. PLoS One. https://doi.org/10.1371/journal.pone.0127533.
Österblom, H., Jouffray, J.B., Folke, C., Rockstrom, J., 2017. Emergence of a global science-business initiative for ocean stewardship. PNAS 114 (34), 9038–9043.
Österblom, H., Bebbington, J., Blasiak, R., Sobkowiak, M., Folke, C., 2022. Transnational corporations, biosphere stewardship, sustainable futures. Annu. Rev. Env. Resour. 47, 609–635. https://doi.org/10.1146/annurev-environ-120120-052845.
Ostrom, E., Garner, R., 1993. Coping with asymmetries in the commons: Self-governing irrigation systems can work. J. Econ. Perspect. 7, 93–112.
Overland, I., Bourmistrove, A., Dale, B., et al., 2021. The Arctic Environmental Responsibility Index: A method to rank heterogenous extractive industry companies for governance purposes. Bus. Strateg. Environ. https://doi.org/10.1002/bse.2698.
Papworth, S., Rao, M., Oo, M.M., et al., 2017. The impact of gold mining and agricultural concessions on the tree cover and local communities in northern Myanmar. Sci. Rep. 7, 46594.
Plantinga, A., Scholtens, B., 2020. The financial impact of fossil fuel divestment. Clim. Pol. https://doi.org/10.1080/14693062.2020.1806020.
Porter, M.E., 1979. How competitive forces shape strategy. Harv. Bus. Rev. 57, 137–145.
Power, M.E., Tilman, D., Estes, J.A., et al., 1996. Challenges in the quest for keystones: Identifying keystone species is difficult-but essential to understanding how loss of species will affect ecosystems. Bioscience 46, 609–620.
Prior, T., Giurco, D., Mudd, G., Mason, L., Behrisch, J., 2012. Resource depletion, peak minerals and the implications for sustainable resource management. Glob. Environ. Chang. 22, 577–587.
Responsible Mining Foundation (RMF), 2020. Mining and the SDGs. A 2020 Status Update. Columbia Center on Sustainable Investment.
Safarzyńska, K., van den Bergh, J.C.J.M., 2010. Demand-supply coevolution with multiple increasing returns: policy analysis for unlocking and system transitions. Technol. Forecast. Soc. Chang. 77 (2) https://doi.org/10.1016/j.techfore.2009.07.001.
Scholtens, B., 2006. Finance as a driver of corporate social responsibility. J. Bus. Ethics 68, 19–33.
Shapiro, D., Hobdari, B., Oh, C.H., 2018. Natural resources, multinational enterprises and sustainable development. J. World Bus. 53, 1–14.
Sonter, L.J., Moran, C.J., Barrett, D.J., Soares-Filho, B.S., 2014. Processes of land use change in mining regions. J. Clean. Prod. 84, 494–501.
Sovacool, B.K., 2021. When subterranean slavery supports sustainability transitions? power, patriarchy, and child labor in artisanal Congolese cobalt mining. The Extractives Industries and Society 8, 271–293.
Steenbergen, V., Saurav, A., 2023. The Effect of Multinational Enterprises on Climate Change. Supply Chain Emissions, Green Technology Transfers, and Corporate Commitments. World Bank Group, Washington D.C.
Thorlakson, T., Zegher, J. F. de, Lambin, E. F. (2018) Companies' contribution to sustainability through global supply chains. PNAS 115: 2072-2077. 101073/7ba74100-en.
Trinks, A., Ibikunle, I., Mulder, M., Scholtens, B., 2022a. Carbon intensity and the cost of equity capital. Energy J. https://doi.org/10.5547/01956574.43.2.atri.
Trinks, A., Mulder, M., Scholtens, B., 2022b. External carbon costs and internal carbon pricing. Renew. Sustain. Energy Rev. 168, 112780 https://doi.org/10.1016/j.rser.2022.112780.
Valls, A., Coll, M., Christensen, V., 2015. Keystone species: toward an operational concept for marine biodiversity conservation. Ecol. Monogr. 85, 29–47.
Van der Schoor, T., 2020. Strategies for Energy Reconfigurations. Ipskamp, Groningen, Obduracy, Values and Scripts.
van Dover, C.L., Ardron, J.A., Escobar, E., 2017. Biodiversity loss from deep-sea mining. Nat. Geosci. 10, 464–465.

Van Duuren, E., Plantinga, A., Scholtens, B., 2016. ESG integration and the investment management process: fundamental investing reinvented. J. Bus. Ethics 138, 525–533. https://doi.org/10.1007/s10551-015-2610-8.
Weisbach, D., Kortum, S. S., Wang, M., Yao, Y. (2022) Trade, leakage, and the design of a carbon tax. NBER Working Paper 30244.
Xu, Q., Kim, T., 2022. Financial constraints and corporate environmental policies. Rev. Financ. Stud. 35, 576–632. https://doi.org/10.1093/rfs/hhab056.
Zhang, Z., Guan, D., Wang, R., Meng, J., Zheng, H., Zhu, K., Du, H., 2020. Embodied carbon emissions in the supply chain of multinational enterprises. Nat. Clim. Chang. 10, 1096–1101.
Zingales, L., 2017. Towards a political theory of the firm. J. Econ. Perspect. 31, 113–130.