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Original article

The criticality of lithium and the finance-sustainability nexus: Supply-demand perceptions, state policies, production networks, and financial actors

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ABSTRACT

Current sustainability transformations render certain minerals, such as lithium, 'critical'. We argue that criticality is actively produced, involving demand, supply and price perceptions, policies linked to green extractivism, and underlying narratives around the role of commodities for sustainable development. Criticality affects, in turn, the geographical and organizational forms of as well as firm strategies in global production networks (GPNs). We highlight the impact of financial actors and interests in these processes, as they enable the expansion of lithium extraction, by assessing three channels through which financial actors impact producer strategies and GPNs – price-setting, equity and debt financing. Driven by criticality, financial actors mobilize green investment stories along the 'finance-sustainability nexus'. This enables the shifting of resource frontiers through funding new projects and creates variable price-setting regimes linked to derivative markets. Financial interests introduce an additional speculative momentum to lithium extraction, contributing to accelerating boom-bust patterns, volatility and short-termism. Methodologically, the paper draws on sector data, industry and company reports, as well as semi-structured interviews with lithium sector and financial actors specifically in London, Switzerland, Chile and Zimbabwe.

1. Introduction

Since 2020, pronouncements of a new commodity super-cycle have been on the rise. This is linked to policies around 'sustainability transformations', as many countries in the Global North and South have pledged large-scale decarbonization efforts and, to achieve this, there are high hopes placed on green technologies. Particularly ambitious pledges have been made concerning electro-mobility. During COP26, over 100 countries, cities, financial institutions and transnational corporations agreed on a 100% zero-emission vehicles target by 2040, and by 2035 in 'leading markets', which was followed by the creation of the Accelerating to Zero Coalition (A2Z) at COP27.[1]

Such ambitions and related policies have rendered certain technologies linked to decarbonization and electrification - such as electric vehicles (EVs) and stationary forms of energy storage for renewable wind or solar energy and the battery systems underlying them - as crucial ingredients of green futures (Bridge and Faigen 2022; Riofrancos 2022). Transformations relying on these technologies are changing the commodity-mix demanded and reinvent specific minerals such as lithium, cobalt, nickel, copper and graphite as critical (Voskoboynik and Andreucci, 2022). Particularly lithium has become the 'super-commodity', frequently referred to as 'white gold' or 'white oil'.

The criticality of lithium – and other minerals - allows collapsing economic, political, social and environmental parameters into a single concern "operational at the political level" (Machacek 2017, 371), risking obscuring the extractive element of lithium production and side-lining negative outcomes related to resource extraction and use (Dorn, Hafner, and Plank 2022; Riofrancos 2022). These contradictions around current sustainability transformations have been the focus of an increasing literature on green extractivism, arguing that sustainability transformations, largely driven by countries of the Global North, re-create uneven development outcomes by externalizing negative

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[1] https://impact.economist.com/sustainability/net-zero-and-energy/progress-on-cop26-pledges-zero-emission-vehicles; https://acceleratingtozero.org/accelerating-to-zero-a2z-coalition-launches-at-cop27-to-drive-global-transition-to-zero-emission-vehicles/

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economic, social and environmental consequences of resource extraction, this time under green banners, to the Global South (Claar 2022; Dorn, Hafner, and Plank 2022; Zografos 2022).

We build on this literature arguing that criticality is made by articulations of (i) supply, demand and price perceptions, which are not objective or readily read off from 'markets', but emerge in a highly uncertain context; (ii) geo-politically- and environmentally-motivated policies at different levels of lithium-battery-EV global production networks (GPNs) in the Global North and South and (iii) underlying narratives around the role of commodities for sustainable development. The making of criticality along these three levels influences strategies of firms as well as geographical and organizational forms of the lithium GPN, but is also shaped by them. Yet, an important, and often overlooked, role in the making of criticality is played by financial actors who, given mining's capital-heavy, long-term and high-risk nature, drive extractivism and have a strong interest to profit from financing and investment activities around booming green commodities.

We analyze how financial interests are mobilized through the criticality of resources and assess three channels through which financial actors shape producer strategies and GPNs – price-setting, equity and debt financing. Building on Franz and McNelly's (2023) finance-extraction-transitions nexus, we argue that financial actors mobilize green investment stories along the 'finance-sustainability nexus' based on the portrayed necessity of (green) finance for critical resourse extraction, focusing on how financial actors and interests interact with GPNs. The nexus is grounded in, and reinforces, the perception of financial actors as enablers of sustainability transformations, side-lining the speculative logics and potentially destabilizing and detrimental outcomes of (global) finance. Financial actors' interests in the lithium GPN enable the expansion of extractive capacities and the shifting of resource frontiers, providing funding also to high-risk projects, as well as create a push towards variable price-setting that allows shareholders greater exposure to lithium price movements. These influences, however, contribute to the acceleration of boom-bust patterns, volatility and short-termism.

In Section 2, we develop our conceptual argument on criticality and the finance-sustainability nexus, which is followed by a methodological Section 3. Section 4 substantiates our argument with empirical insights on the criticality of lithium, focusing on key policies, new frontiers and changing GPN constellations. Section 5 assesses the role of finance through price-setting, equity and debt financing and their interrelations. The last section concludes.

2. The making of criticality and the finance-sustainability nexus

As Zimmermann and Erich (1933) and others who argue that "resources are not; they become" (Bos and Forget, 2021, 3), we view resources as actively made in socio-technological processes. Also criticality is produced, as Machacek (2017, 368) writes, "in a 'bureaucratic practice of classification', (where) 'key materials' are turned into 'critical materials'". Riofrancos (2022, 5) adds that "'criticality' is less a stable condition than an emergent outcome of interacting variables: the discovery of deposits, the development of new extraction methods, government promotion of EVs, evolving battery chemistries, and recycling capacity, among others." Discussions on resource criticality have been interlinked with a resource security discourse as e.g., Bridge (2015) points towards the political dimension of security narratives, which are constructed and mobilized to serve specific political functions. Machacek (2017, 369) extends this logic to investigate how criticality is produced and writes that "the assessments of criticality, when put to work […] pervade government and society and enable operationalization, as attention of policy makers is drawn to specific issues, making new links between the governance of resources, economic development, energy technologies, and national security […]." Overall, the focus of debates around criticality has been on the important role of state policies in rendering certain minerals as critical given their role for green technologies and how criticality of minerals has been mobilized as a geopolitical tool grounded in security discourses.

We build on this literature and identify three interrelated levels in the making of criticality, as depicted in Fig. 1: (i) supply, demand and price perceptions that are mediated by technology; (ii) geo-politically- and environmentally-motivated policies at different levels and (iii) the underlying narratives around the role of commodities for sustainable development. First, supply, demand and price forecasts are the basis of determining the 'risk of disruption' in the availability of materials in the market at acceptable prices (Machacek 2017, 369). However, establishing predictions on resource availability is not a merely technical or objective process. Changing resource frontiers, the entrance of new actors and technological and institutional developments make it difficult to project supply, demand and prices and 'sector specialists' have their own interests and subscribe to certain narratives around desirable industry development trajectories. Second, states and their regulations and policies play a key role in the making of criticality. Policies on sustainability transformations center specific materials as key components of sustainability transformations and create demand in the first place. Importantly, policies also secure the conditions for capital accumulation in GPNs from extraction to battery production to EV manufacturing (Dorn, Hafner, and Plank 2022; Svampa 2015; Riofrancos 2022). Hence, established or new mineral producer countries create an 'enabling environment' (via de-risking, PPPs, tax incentives) to attract investment. Third, these policies enacted by states, are linked to and based on broader narratives around the role of commodities for sustainable development (Voskoboynik and Andreucci 2022). Dorn, Hafner, and Plank (2022) see a shift to the 'climate change consensus', which centers technology as a means of climate protection, justifying and legitimizing extractive activities as imperative and green, denying possibilities for other meanings of development.

While the role of state actors in criticality debates has been widely discussed (Machacek 2017; Riofrancos 2022), less attention has been paid to how criticality is operationalized and enabled by strategies of firms in GPNs and their geographical and organizational forms and, importantly, the role of finance and financial markets in these processes. The latter echoes a broader lacuna pertaining to the role of financial interests and actors in debates on (green) extractivism in general (for exceptions, see Bowman 2018; de los Reyes, 2022; 2017; Franz and McNelly 2023; Parker et al., 2018). Yet, we argue financial interests and actors play a key role in enabling green extractivism through investments in different instruments related to critical minerals, provision of financing to firms in GPNs and engagement in price-setting of minerals (Wojewska et al., 2023). As such, critical mineral sectors are dependent "upon the mediations of a complex network of financial actors, practices and instruments" (Arboleda 2020, 122) that drive and shape green extractivism, and are interrelated with, mineral firm strategies and state policies.

The rise of green finance and the shift in the perception of finance as an enabler of sustainability transformations has transformed and expanded funding for extractivism. To our knowledge, only Franz and McNelly (2023) explicitly focus on how finance is shaping new forms of extractivism and green energy transitions, by centring on "how extractivism is enabled by finance in the name of transition" (10) and "the different ways in which financialization is shaping energy transitions" (22). We develop the analysis around finance and mineral GPNs, linking it to criticality, and focus on three channels through which financial actors and interests influence strategies of firms in mineral sectors, as well as outcomes in producer countries – (i) price-setting; (ii) equity markets; and (iii) debt and bonds markets. In doing so, we aim to break down the monolithic representations of finance and focus on the specific ways in which (green) finance strategies interact with other interests in GPNs.

We argue that these three channels constitute the 'finance-sustainability nexus' as they enable and drive outcomes of green extractivism. This nexus relates to criticality in two ways. First, criticality prioritizes

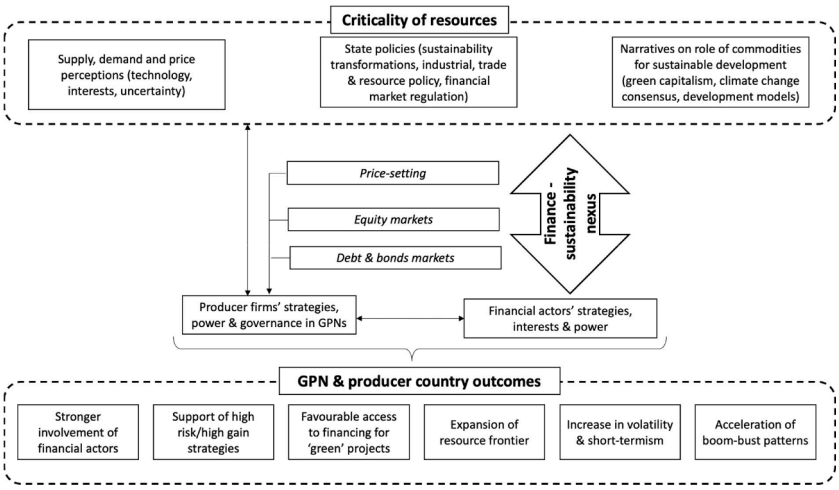

Fig. 1. Criticality of resources and the finance-sustainability nexus.
Source: Own elaboration.

and enables steering finance into industries that are considered strategic for sustainability transformations by policy-makers. In this way, through criticality, finance and greenness or sustainability become closely linked, as in this rhetoric the involvement of financial actors is necessary to close the so-called green financing gap. Second, financial actors in turn leverage criticality to develop 'green investment stories' to create new products and investment channels related to critical minerals or green technologies. Thus, greenness is used by financial actors to develop new modes of accumulation. Both of these links reinforce the perception on finance as an enabler of sustainability transformations, but also have material impacts in terms of shifting resource frontiers and changing dynamics in critical mineral GPNs with potentially detrimental, unsustainable and destabilizing outcomes on mineral GPNs and producer countries as depicted in Fiure 1.

3. Methodology

This paper analyses processes in the lithium GPN based on multi-sited research, which involves a focus on (connected) *sites* where global processes materialize rather than on exemplary *cases* of dynamics or categories to compare (Riofrancos 2022). The aim is to give a macro-level overview of key dynamics and changes in the lithium GPN linked to the finance-sustainability nexus, as they play out in interdependent sites (points of extraction, processing, trade and financial hubs). Methodologically, the paper is based on production, trade and financial data; industry and company reports; and semi-structured interviews. On an industry-level, we used production data from World Mining Data and trade data from the UN Comtrade database to assess global shifts in extraction. Price data was shared by the price reporting agency (PRA) Benchmark Mineral Intelligence (BMI) and analysed regarding levels and volatlity. Data on trading activities on derivative markets from the exchanges London Metal Exchange (LME) and Chicago Mercantile Exchange (CME) was used to assess the role of and actors on derivative markets, and data on initial and secondary listings of lithium producers from the Australian Stock Exchange (ASX) was analysed with respect to the number of listings and the value of capital raised.

The document analysis was conducted at three levels. At the industry level, articles from metal industry and financial news outlets as well as documents and announcements by industry initiatives and associations were analysed as well as publications by the LME and PRAs describing historical and current practices of price-setting. At the firm level, financial statements and other available company information (e.g., strategic reports, press releases) for relevant companies were assessed. Lastly, we focused on certain regions and countries to substantiate the industry-level dynamics with examples and, for these cases, we conducted selective document analysis at the regional (the EU for assessing key consumer country policies) and state levels (Chile and Zimbabwe for assessing key producer country policies), analysing reports describing recent changes in sustainability- and mining-related policies.

Site selection in this multi-sited research requires a focus on locales where macro processes 'touch down', and so can be observable and are of relevance to the site, but also to the GPN as a whole. Hence, interviews focused on actors in central metal trading and financing hubs – Switzerland and London - to be able to analyze such macro industry-level dynamics. Switzerland is an important global mineral trading hub, with headquarters of the largest commodity trading houses (e.g., Glencore, Trafigura) located there, who pursue both physical trade, but also financial activities. London is a key financial trading hub with the London Stock Exchnage (LSE), Alternative Investment Market (AIM) and importantly the LME commodity derivative market. Further, financial investors and PRAs have offices or headquarters in London. While interviews were conducted in person during field research in London (November 2021), they were conducted online in Switzerland (December 2021 and January 2022) due to Covid-19 restrictions.

We further conducted interviews in two selected producer countries to add examples to industry-level dynamics - one established (Chile, 2nd largest in 2020) and one emerging Global South producer country (Zimbabwe, 7th largest in 2020).[2] Chile's lithium sector has experienced steady growth since the early 2000s (Ebensperger, Maxwell, and Moscoso 2005). While in Zimbabwe lithium containing ores has been mined since the 1950s (Maguwu 2017), the industry remained small until the 2022/23 boom in lithium mining projects, making it an important resource frontier. We conducted field research in Chile in May 2022 and in Zimbabwe in January 2023. Further, beyond the specific sites, global industry experts were interviewed through online interviews. Interviews were conducted with metal sector actors (mining companies, international traders, industry associations and experts) and financial actors (LME, PRAs, financial investors and experts) as well as institutional actors (Ministries and other state institutions, sector associations, industry experts, NGOs). Altogether, 35 interviews were conducted in the lithium sector between 2021 and 2023.

[2] World Mining Data 2022 (https://www.world-mining-data.info/wmd/downloads/PDF/WMD2022.pdf)

4. The lithium GPN in the context of criticality

In this section, we discuss key policies in lithium consumer and producer countries that are linked to narratives on lithium's role for sustainable development using the example of the EU as well as Chile and Zimbabwe respectively; developments regarding lithium supply and resource frontiers that are interwoven with demand and technology; and changes in GPN constellations and governance with new actors entering lithium production linked to the criticality of lithium. In Section 5, the key role of finance in these developments is analyzed.

We identify four policy levels through which the criticality of lithium is established giving examples from the EU. First, many countries have issued policies around sustainability and mobility in particular. The key policy in the EU is the EU Green Deal of 2019 that sets the overarching goal of climate neutrality by 2050 and, aims, among other goals, for a drastically less polluting transport sector by advancing EVs. Most important in this regard is the legislative proposal 'Fit for 55' of 2021, which demands that all new cars registered in the EU are zero-emission by 2035. Second, there are policies specifically supporting national battery production. In the EU, the Renewed Industrial Strategy (2017, renewed 2021) underlies the strategic importance of battery investments, and the 2018 Strategic Action Plan for Batteries sets out measures to support all aspects of the battery value chain. This also includes two Important Projects of Common European Interest (IPCEI), which enable access to public funding - the 2019 IPCEI on Batteries and the 2021 IPCEI on European Battery Innovation. Third, policies target global access to and domestic extraction of raw materials. The EU Raw Materials Initiative focuses on access to global raw materials, production in the EU (onshoring) and recycling (Küblböck 2013; Riofrancos 2022). Since 2011 the European Commission has published a list of critical raw materials, which currently includes lithium (added in 2020) alongside 33 other materials. The EU also distinguishes 16 strategic raw materials (including lithium), based on their relevance for five strategic EU sectors[3].

Fourth, sustainability projects are supported through finance instruments and public de-risking of private investments. In 2019, together with other states, the EU inaugurated the International Platform on Sustainable Finance (IPSF) whose primary aim is to enhance the deployment of private capital for environmentally sustainable investments. The European Commission established the EU Battery Alliance already in 2017 to allocate public funds to private entities. In 2019 and 2021, it approved over $7 billion (6.4 billion euro) in member state funding for building the battery supply chain, including raw material extraction and processing (Riofrancos 2022). Via the EIT InnoEnergy Acceleration Fund, the EU has also directly invested in the pilot stages of lithium mines.[4] The proposed EU Critical Raw Materials Act aims to provide favorable financing conditions for extractive projects of strategic minerals such as lithium (Küblböck 2023). Moreover, the EU facilities green finance through new legal frameworks, for instance, the European Green Bond (EuGB) standard for 'environmentally sustainable bonds'. This standard is based on a provisional agreement announced in 2023 by the Council and the European Parliament, but it is only voluntary.[5] The 2020 EU taxonomy for sustainable activities underlying the EuGBs includes the manufacturing of batteries and EVs as sustainable, but the status of mining of critical minerals remains to be clarified.

The EU policies discussed, firmly establish the region as a key source of global demand for lithium but extractive investments also need producer countries' states to create conditions for capital accumulation. Producer countries have engaged in policy-making that range from deregulation and (foreign) investment attraction to regulations aimed at increasing development outcomes in the context of 'resource nationalism' that are articulated to different degrees in diverse institutional contexts in established and emerging producer countries. In Chile, the lithium sector is considered as strategic and hence highly regulated by the state at the national and local level. This is demonstrated by the revision of existing contracts with the two existing lithium producers – Albemarle and SQM – in 2017 and 2018 respectively, including new extraction quotas, higher royalties, social and environmental criteria and minimum values in contracts with local communities in the Salar de Atacama, where extraction takes place. Also, a savings fund was announced in 2023 as a part of the National Lithium Strategy in order to capture the high revenues from lithium mining to finance social, technological and industrial investment, as well as the creation of a National Lithium Company which will "coordinate future public-private partnerships, increasing Chile's lithium production, attracting new players, and expanding the industry through joint ventures."[6] Zimbabwe has opened doors for especially Chinese investors, creating special economic zones with various fiscal and trade incentives such as zero corporate taxes over five years, exemptions on non-residents withholding taxes on dividends, royalties and customs duty rebates on machinery, equipment and raw material imports.[7] However, the government has also issued policies to assert local control over resources and build up local processing industries. The Minister of Mines and Mining Development in 2022 passed a Statutory Instrument banning export of raw lithium ores[8] with the aim to expand local processing of lithium and hence value addition, but there are exemptions that can be granted to selected firms.

Given these policies and related high expectations of increased demand linked to the criticality of lithium, a large number of new extractive projects is emerging (Voskoboynik and Andreucci 2022). A PRA representative interviewed described the lithium market as follows: "it's this kind of structural lack that is causing prices to increase that much and leads to a scramble for any sort of material, regardless even of its quality or the type of material."[9] Similar sentiments are also presented in market analyses, e.g., the 2022 S&P Global Commodity Insights predicted that by 2029 the current lithium capacities will not be able to meet demand, even if all planned projects enter production.[10] But demand and supply forecasting is difficult given high uncertainties typical to the mining industry (unstable jurisdictions such as DRC and Mali, contestations by local communities e.g., in Portugal and Serbia, issues around budgeting, delays and actual quantity and quality of resources, etc.) and also technology, with the latter being particularly pronounced for lithium given the rather recent developments connected to the EV sector.

Related to technology, first, two main extractive methods are currently used - in South America's lithium triangle (Argentina, Bolivia, Chile), lithium is largely extracted from brines (through evaporation processes), whereas in Australia, Brazil and Zimbabwe lithium bearing ores (such as spodumene) are mined. But, new extractive technologies like direct lithium extraction (DLE) or extracting lithium from clay or seawater, if successful, will add new lithium supply and open up new sites along the resource frontier. Second, new battery technologies have important impacts on how much and what specifications of lithium are demanded. For example, solid-state batteries, which use sodium in place

[3] The strategic industries are: renewable energy, e-mobility, energy-intensive industry, information, communication and digital technologies (ICT), aerospace and defense.

[4] https://www.eib.org/en/press/all/2023-270-eib-to-support-green-deal-industrial-plan-with-eur45-billion-in-additional-financing

[5] https://www.consilium.europa.eu/en/press/press-releases/2023/10/24/european-green-bonds-council-adopts-new-regulation-to-promote-sustainable-finance/

[6] Chile's National Lithium Strategy 2023 (https://bitly.ws/32Ize)

[7] https://zidainvest.com/sez/

[8] https://www.reuters.com/world/africa/zimxbabwe-bans-raw-lithium-exports-curb-artisanal-mining-2022-12-21/

[9] Senior data officer at PRA(1), May 2022, London (online)

[10] https://www.spglobal.com/marketintelligence/en/news-insights/research/lithium-ma-involving-assets-with-resources-h221-to-h122

of lithium are being tested (Bajolle, Lagadic, and Louvet 2022). Third, even though currently only a small percent of batteries is recycled, in 2030 lithium from secondary sources is suggested to constitute 6% of total lithium supply.[11] One expert even states: "[r]ecycling will become very important. So, it could be that fifteen years from now, you will not need to develop additional lithium mines […] If you are not there [in the next years] you better not go to the party."[12]

Fig. 2 shows actual growth in global lithium production which started in 2017 and has been concentrated geographically, with 89% of lithium coming from just three countries in 2020 – Australia, Chile and China. Other key producers include Argentina, Brazil, the USA and Zimbabwe.[13] But outlooks on a supply gap have led to many new projects and new actors entering the extraction stage, expanding lithium frontiers. In 2022, approximately 25 lithium mines/salt brines were operational, while an estimated 104 projects were planned or under development (Fitch Solutions 2022). As shown in Fig. 3, 16 new countries are now likely to also become lithium-producing countries, in addition to the seven indicated in Fig. 2.

The lithium boom and new frontiers have also led to changing GPN constellations, with new actors (major mining and refining companies active in other sectors, junior producers, automakers, battery producers, international traders) entering which transforms power relations in the GPN. In 2017, only four lithium producers (i.e., mining and extracting firms;Talison (now Tianqi Lithium), SQM, Albemarle, FMC (now Livent)) dominated the lithium market. Today, the largest so-called major lithium producers are SQM (Chile), Tianqi Lithium (China), Albemarle (US), Ganfeng (China), Livent (US), and Pilbara (Australia) that are often integrated downstream and are therefore mostly classified as chemical companies. Fitch Solutions (2022) reported however 129 active and prospective operations which are held by 105 firms, from which 87 control (defined as minimum of 50% ownership) only a single project. Many of such small firms can be classified as junior producers, which are frequently looking for new lithium sources. Therefore juniors are often more explorers and developers than miners, many pursuing a strategy of selling the projects when successfulto major lithium producers that engage in actual production (Nunez-Picado, Martinus, and Sigler 2022).

Automakers and battery producers had to pay higher prices for lithium inputs and struggled to secure supplies and hence have beein increasingly investing into upstream activities.[14] This involvement takes place through joint ventures with mining or refining companies (e.g., BYD, EVE), off-take contracts with refining companies (e.g., BMW, Tesla, LG Energy Solutions), or equity or large-scale debt financing of new projects (e.g., General Motors, Stellantis, CATL). Less pronounced, international traders have also become increasingly active in the lithium market, such as Traxys, Glencore and Trafigura.[15] Increased demand paired with a move towards variable, short-term price-setting have created opportunities for these traders, who make profits by connecting different actors and taking on associated price (and other) risks. However, they also attempt to gain influence through investments in processing and recycling.[16] Overall, traditional producers' power in the GPN has generally declined as compared to their historical dominance, while the power of end-users (automakers, battery producers) has grown (Bridge and Faigen, 2022). Through junior producers and international traders, new speculative interests have entered the lithium GPN, and this is also related to the sphere of finance.

5. Finance and the criticality of lithium

Financial actors are essential to finance the capital-intensive expansion of minerals extraction, particularly through equity, but also bank loans and other debt instruments (Adams et al., 2019). The criticality of lithium has increased expectations of financial actors to benefit from growing demand for lithium and higher lithium prices. The growing interest of financial actors, including banks, hedge funds and asset managers, to provide capital allowed major lithium producers to gain enhanced access to funding for extraction projects through equity and debt markets and junior producers to raise equity capital to finance projects, also in new frontiers. The latter includes high-risk, short-term oriented projects, driven by speculative investment strategies of junior producers and their shareholders. Moreover, through access to green bonds and more favorable ESG ratings, major lithium producers can benefit from more favorable financing conditions (e.g., lower interest rates) and tap into green investment stories. The boom in equity financing is closely related to changes in price-setting in the lithium GPN. The emergence of spot market-based short-term price reporting contributed to an upward trend in lithium prices. This made the market more attractive especially for financial actors, who could become exposed to growing prices through investments in major and junior producers at a time where no (liquid) derivative markets existed to allow for direct exposure to lithium price movements.

5.1. Price-setting

The boom in lithium extraction has been accompanied by rising prices. The lines in Fig. 4 show lithium carbonate prices as traded in China, reported by the PRA BMI, which are often reported as benchmark prices. These prices increased significantly in 2017 and 2018 as the EV market started expanding. Lithium producers responded, tipping the market into oversupply which led to falling prices in 2018 throughout 2020, exacerbated by the Covid-19 pandemic and supply disruptions. Prices surged again in 2021 and 2022, with an all-time high of approximately $80,000 per ton in October-November 2022, contrasted with prices of around $8,000 per ton just two years earlier. The prices crashed, however, in the first half of 2023, to as low as $25,000 per ton in May 2023 due to the fear of lower than expected growth in EV sales[17], and despite short-term peaks remained on an overall downward trend.

It is however difficult to define what the world lithium price actually is, as there is not yet a single benchmark that dominates the industry. In the EV-linked history of lithium, we can differentiate three price-setting modes as shown in Fig. 4 – i) long-term, fixed-price contracts, ii) emergence of spot markets, and iii) long-term variable price contracts linked to benchmarks. Prior to late 2021, the majority of transactions were conducted based on multi-year fixed-price contracts tailored to individual battery-maker specifications linked to the quasi-commodity nature of lithium that makes standardization difficult. In these contracts, prices were largely set by producers, giving them security and price-setting power. As one interviewee explained: "They [large producers] love the market being fragmented and opaque. They can go to Tesla and dictate the terms."[18]

As supply became increasingly squeezed due to the criticality of lithium, spot markets for immediate delivery emerged in 2017/18. The development of spot markets generated more frequent transactions. Spot

[11] https://www.mckinsey.com/industries/metals-and-mining/our-insights/lithium-mining-how-new-production-technologies-could-fuel-the-global-ev-revolution

[12] Partner at a lithium business consulting firm, December 2021, Santiago (online)

[13] World Mining Data 2022 (https://www.world-mining-data.info/wmd/downloads/PDF/WMD2022.pdf)

[14] https://www.reuters.com/markets/commodities/automakers-go-back-future-secure-battery-metals-2022-04-27/

[15] https://www.mining.com/web/the-lithium-market-is-hotter-than-ever-and-traders-are-moving-in/

[16] https://www.fastmarkets.com/insights/opportunity-knocks-for-traders-with-the-surge-in-lithium-prices

[17] https://www.reuters.com/markets/commodities/lithium-slump-puts-chinas-spot-price-under-spotlight-andy-home-2023-05-19/

[18] Financial instiution director, November 2021, London

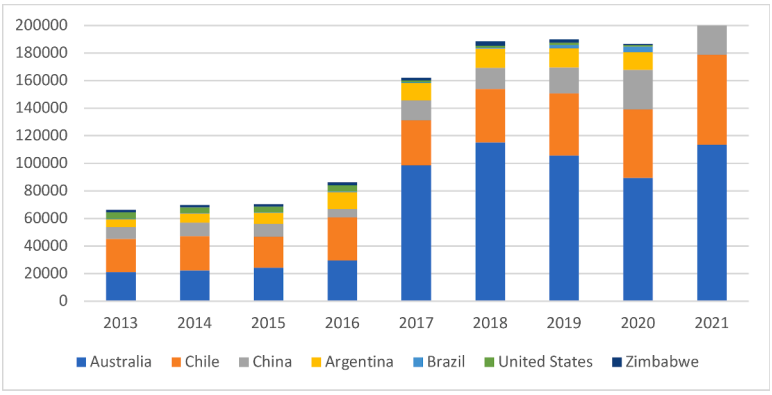

Fig. 2. World production of lithium.
Notes: Lithium reported as lithium oxide (Li_2O) content; in metric tons; Bolivia, Nigeria, Namibia, Canada and Portugal have been reported to produce marginal volumes of lithium, yet not at commercial scale and hence they are not included in the figure.
Source: World Mining Data 2023, 2018, 2016 (https://www.world-mining-data.info)

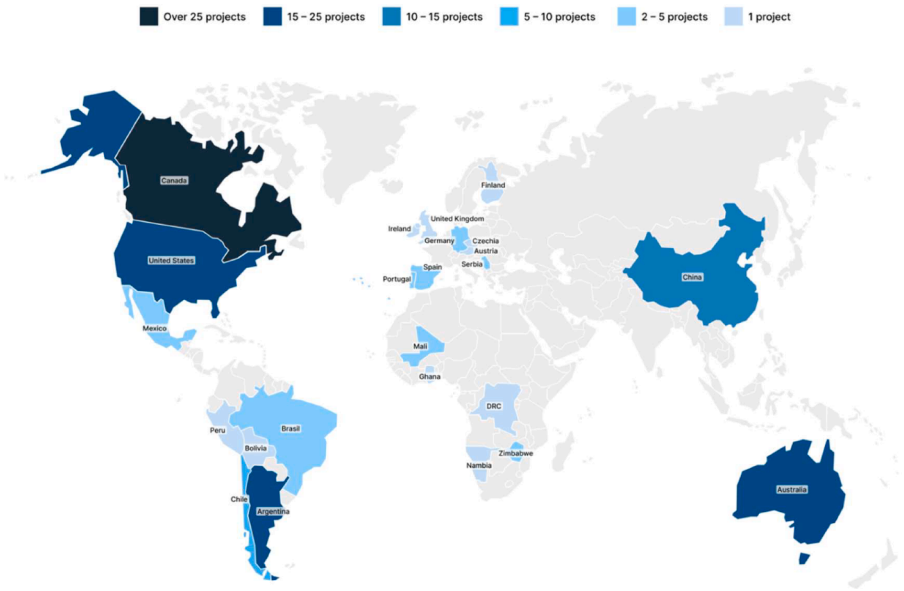

Fig. 3. Active and new lithium production projects in 2022.
Note: For a tabular version see Table A1 in the Appendix.
Source: Own compilation on the basis of Fitch Solutions (2022).

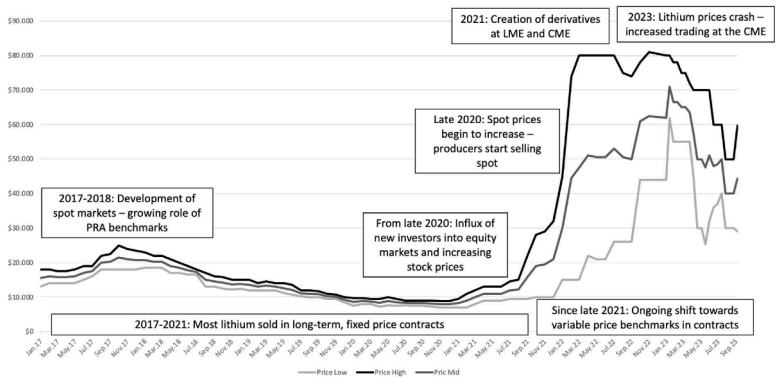

Fig. 4. Lithium price developments (in USD per tonne).
Note: Lithium Carbonate CIF Asia, USD per ton, up until November 2022 data reported monthly later bi-weekly, based on spot prices and prices from contracts lasting up to 12 months.
Source: Own elaboration based on BMI data.

prices differ in every transaction, and so are more volatile, reflective of immediate perceptions of demand and supply, short-term shifts in (geo) political relations and strategies of GPN actors. These changes are reflected in Fig. 4 in the growing differential between "Price High" and "Price Low" indicators. As a rule of thumb, the "Price High" line are spot prices and the "Price Low" line are long-term contract prices, showing that from 2021 prices on spot markets were significantly higher. Hence, lithium producers, and international traders that increasingly entered the lithium market, were interested in making profits from selling part of their products on the spot market and not in long-term fixed-price contracts.

However, major lithium producers do not only sell on spot markets, as it is linked to a high degree of price risk exposure. They still prefer using long-term contracts, but since late 2021 they have shifted away from fixed prices towards variable, short-term prices in these contracts. This was only possible because of the emergence of short-term price benchmarks that could be used as a reference point in contracts. Specifically, the increase in frequency of transactions created an opportunity for PRAs to produce benchmark prices based on expanding spot markets. PRAs usually describe themselves as media companies and employ journalists who - based on data from various market participants and using proprietary methodologies - produce price benchmarks on a (bi-)weekly or even daily basis. These price benchmarks are available on the PRAs' websites to customers on subscription basis.

Initially, these benchmarks and specifically their frequency have been critiqued, as not representing physical trade. As an interviewee stated in 2021, when the benchmarks were gaining popularity: "[t]hat's just not how the [lithium] market works. These are not yet liquid spot markets… There were days and probably weeks when things just wouldn't trade. So where is that number coming from?"[19] However, the existence of these benchmarks enabled producers, or more accurately their shareholders who aimed for exposure to lithium price movements, to demand variable and short-term price-setting in contracts, in order to take advantage of higher prices on spot markets.[20] For instance, Albemarle states in its 2022 annual report "we have renegotiated certain of our long-term agreements to include higher pricing that is more reflective of current market conditions. In other cases, we have moved from our previous fixed-price, long-term agreements toward index-referenced and variable-priced contracts. As a result, our lithium business is more aligned with changes in market and index pricing than it has been in the past."[21]Also SQM link a large share of their contracts (85%) to price indices[22], while some producers still use fixed-price annual contracts such as Livent in 70% of its 2023 sales.[23] Thus, the move towards benchmark pricing is still ongoing as no single PRA provides a dominant benchmark and major producers pursue mixed strategies in their contracts.

In many mineral and metal markets derivative markets play a key role in price-setting based on trade in physically-settled futures.[24] Lithium's material properties (limited standardization and storability of specific products) and relatively small market size make it unsuitable to be priced through physical-settled futures and led to PRAs becoming key institutions for benchmarks. Derivative markets however still had a strong interest to benefit from booming critical minerals, increase trading volumes and tap into green investment stories. For example, LME sees itself as "powering all our futures" as "the EV revolution is key to a more sustainable future and we [the LME] are here to help drive the transition."[25] Hence, derivative markets offered cash-settled futures contracts as shown in Fig. 5, which do not require involvement in physical commodities but the transfer of cash equal to the difference between spot and futures prices at maturity. They rely however on short-term price indicators and these came from PRAs. In 2021 LME and CME and in 2022 Singapore Exchange (SGX) introduced cash-settled lithium contracts. They all rely on benchmark prices provided by the PRA Fastmarkets, reinforcing the role of this PRA. What derivative markets added in addition to PRAs' benchmarks are the possibility to trade lithium futures and hence engage in price risk management through hedging or in speculation on lithium price developments. For hedging to be effective, physical actors must use the same price benchmark in their contracts as underlying the cash-settled futures, leading to a close link between PRA benchmark/futures prices and prices in physical trade (Wojewska et al., 2023).

Cash-settled futures are especially favored by financial investors, who encouraged their creation, as they do not carry the risk of delivery or withdrawal of metal to/from warehouses. Hence, financial investors can gain direct exposure to lithium price developments without holding the physical commodity or shares of firms engaged in physical lithium extraction. When it comes to trading on derivative markets, so far mostly financial actors but also new actors (automakers, battery producers, international traders) were early adopters. In 2021 one interviewee explained risks associated with trade of then new lithium derivatives "[the lithium futures market] isn't liquid […] it's really open to manipulation certainly at this time when it's small […]. You could move that market quite quickly, because it isn't tied to the value of the underlying fundamental, there is no physical delivery."[26] For international traders, trading on derivative markets for hedging and speculative purposes is key in their business strategy (Staritz et al. 2018; 2022; Baines and Hager 2021). For new EV-actors, entry barriers to hedging are low, as they frequently hedge across various metals used in manufacturing, and so have technical capacities. Major lithium producers initially contested derivative markets, but their sentiment partly changed. This is firstly explained by increased volatility of prices since 2021 and hence the need for price risk management and secondly to satisfy financial needs as banks were more cautious when providing credit without financial hedging of price risks. An interviewee at a financial instiution said "[t]hey (i.e., physical actors) can't raise any capital. They can't convince their bankers that there is any certainty over the future price, because there is no futures market. Then they come running to the LME and saying 'actually it would be very nice if the market was a bit more transparent'".[27] However, access to equity capital became easier again in the high price phases of 2021 and 2022 as discussed below and so hedging activity remained limited. Nevertheless, during the recent price crash, where spot prices dropped by 70% between November 2022 and April 2023, the more financial actors-friendly CME saw an uptake in trading, with both hedging and speculation playing a role.[28] Activities on derivative markets are likely to increase, but this depends on the strategies of major producers and EV-actors, who might seek hedging given the high volatility of lithium

[19] Senior data officer at PRA(1), November 2021, London

[20] https://lme-poweringallourfutures.com/2021/09/27/lithium-roars-back-from-3-year-slump/

[21] Albemarle 2022 Annual Report, page 17 (https://bitly.ws/32Jdi)

[22] SQM 2Q2023 Results Presentation (https://bitly.ws/32JhI)

[23] https://www.reuters.com/markets/commodities/lithium-slump-puts-chinas-spot-price-under-spotlight-andy-home-2023-05-19/

[24] Physical-settled futures require the delivery of a physical commodity at warehouses at maturity (if contracts are not closed before). Commodities suitable for physical settlement are characterized by standardization, substitutability for most users, storability (e.g., do not corrode or deteriorate) and transportability (Radetzki and Wårell 2020)

[25] https://www.lme.com/en/Metals/EV

[26] Senior data officer at PRA(1), November 2021, London

[27] Financial instiution director, November 2021, London. See also: https://www.reuters.com/markets/commodities/lithium-still-super-charged-supply-chases-after-demand-2022-12-15/

[28] https://www.reuters.com/markets/commodities/lithium-slump-puts-chinas-spot-price-under-spotlight-andy-home-2023-05-19/ and https://www.fastmarkets.com/insights/spot-price-volatility-drives-record-volumes-cme-lithium-contract

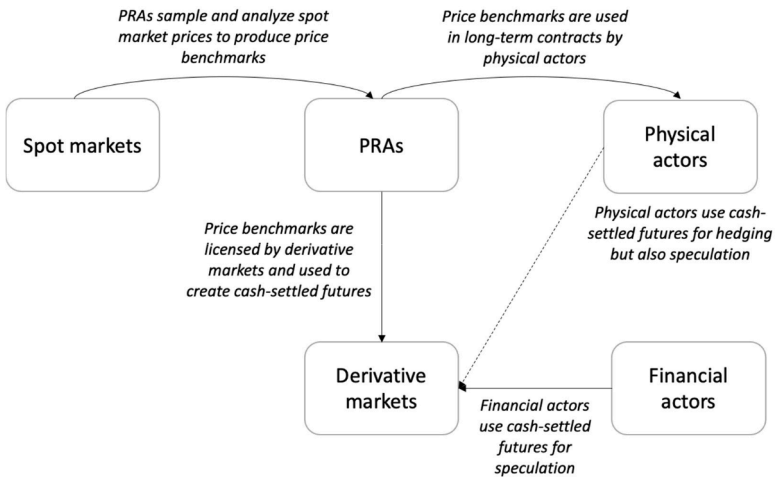

Fig. 5. Relation between spot markets, PRA benchmarks and cash-settled futures.
Source: Own elaboration.

prices. Moreover, financial actors could prioritize lithium investments through derivative markets instead of equity investments once a certain liquidity is reached on these markets.

These changes in price-setting are strongly related to lithium's criticality and have important outcomes. As lithium became more frequently traded, spot markets emerged and with them short-term benchmark prices by PRAs. This changed the strategies of major lithium producers, who started trading on spot markets but, more importantly, using these benchmarks in their long-term contracts. This shift contributed to growing price volatility and short-termism. Hence, short-term price reporting is not only caused by, but also contributes to a market becoming more dynamic and volatile. To manage this increased volatility, producers became more favorable towards lithium derivative markets but also financing through banks required futures prices and price risk management. New actors (automakers, battery producers, international traders) and financial actors supported lithium derivative markets to be able to hedge and speculate on lithium price movements. The large entry of financial actors, which has not taken place yet in lithium derivatives, brings in their short-term and speculative trading strategies, often disconnected from fundamentals, which is likely to accelerate volatility, as seen for other metals, and exacerbate boom-bust patterns (Gilbert 2018). The shift towards benchmark pricing linked to PRAs and derivative markets also has governance impacts, as price-setting processes now take place outside of jurisdictions of producer countries, reducing their states' ability to control and regulate price-setting.

5.2. Equity financing

The criticality of lithium has led to high interest in the lithium industry starting in late 2020, with both major and junior producers looking to expand their operations and financial actors increasing their engagement in the sector. At that time, in the absence of liquid derivative markets which would enable direct exposure to lithium price movements, holding equity became a key way to invest in lithium and profit from high prices. Such investments came from banks but also actors such as asset management companies, hedge funds and venture capital companies. A interviewee at a financial instiution in 2021 explained "a lot of people today, if they are expressing a bullish view on growth of the lithium market, they have to buy, for example, Albemarle shares […] But if they can buy lithium futures themselves, that would be a more direct way of expressing that view."[29] Hence, criticality led to large speculative flows to equity markets, reflected in rapid increases in stock prices of major lithium producers. Altogether, the inflow led to an almost tripling of the lithium stock index between 2020 and 2022 (own elaboration based on Solactive Lithium Index[30]). Rising stock prices (as a result of flows to equity markets) further stimulate initial and secondary equity issues (Hovakimian, Opler, and Titman 2001). This growth of lithium-related equity offerings enabled the highest exploration spending in the lithium sector on record in 2022.[31] The influx of large investors (such as hedge funds, mutual funds, banks) as shareholders and concurrent increases in spot prices throughout 2021 also resulted in pressure on lithium producers to shift to variable prices in contracts, which allows fuller exposure to lithium price movements for investors.

The world's most important exchanges for lithium (and other minerals and metals) companies are the Toronto Stock Exchange (TSX), the ASX in Sydney, AIM (part of LSE) in London. All major lithium producers are listed on these stock exchanges and many (such as Albemarle, SQM and Livent) have risen equity capital through secondary offerings, particularly in 2020 and 2021 for the expansion of extraction and processing. The two existing lithium producers in Chile for example, SQM and Albemarle, raised USD 1.1 billion and USD 1.5 billion, respectively, through the sale of stocks to finance the expansion of lithium carbonate and hydroxide projects.[32] These investments would more than triple Chilean lithium output by 2027 as compared to 2020 (own calculations based on company data and World Mining Data 2022[33]).

In contrast to other minerals, lithium exploration is particularly driven by junior producers, which account for over two-thirds of the sector's activity.[34] For them, equity financing is particularly important as they have only limited access to bank loans and debt capital markets due to lacking revenues and regular cash flow from mining operations (Tilton and Guzmán, 2016). Instead, junior producers seek high-risk financial capital from equity markets, as their performance depends on the risky processes of exploring and developing new mining projects as well as changes in commodity prices. The high exploration spending in the lithium sector was particularly financed by a boom of initial

[29] Financial instiution director, November 2021, London.

[30] https://www.solactive.com/indices

[31] https://www.spglobal.com/marketintelligence/en/campaigns/pdac2023

[32] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/albemarle-prices-1-3b-stock-offering-62476187; https://www.mining.com/sqm-shareholders-approve-1-1-billion-capital-increase/

[33] World Mining Data 2022 (https://www.world-mining-data.info/wmd/downloads/PDF/WMD2022.pdf)

[34] https://www.spglobal.com/marketintelligence/en/campaigns/pdac2023

public offerings (IPOs) of junior mining companies in 2021 and 2022 on the ASX and the TSX.[35] On the ASX, for instance, the number of new listings of all junior mining companies jumped from 29 in 2020, to 107 in 2021 and 58 in 2022, but slowed down in the first three quarters of 2023 to 17 new listings. As shown in Fig. 6, 48% of these newly listed mining companies from 2020 to 2023 are engaged in lithium projects and captured half of the total equity financing of all junior producers (own elaboration based on ASX data).[36]

Junior lithium producers often seek new projects in emerging producer countries. They have therefore a direct impact on the geographies of the lithium GPN through their exploration of prospective sites and the discovery and valorization of lithium deposits. When successful, junior miners usually sell their discoveries to larger operators with the scale and expertise to exploit a deposit, payout the profits as cash dividends and explore new projects (Williams 2012). The major lithium projects in Africa, for instance, are all explored and developed through junior lithium producers listed on the ASX, TSX or AIM.[37] This includes the Arcadia Lithium Mine Project in Zimbabwe, which is considered one of the world's largest hard rock lithium resources. The junior explorer Prospect Resources, which got listed at the ASX in 2009, explored and developed the project from 2016 to 2022, financed by several equity raisings (in total AUD 84 million). Upon the sale of 87% of its assets in Arcadia to Zhejiang Huayou Cobalt in April 2022, Prospect Resources was able to distribute AUD 444 million as cash dividends to its shareholders. Currently, Prospect Resources is developing two further lithium projects in Africa (Step Aside in Zimbabwe and Omaruru in Namibia).[38]

The business logics of junior producers make their strategies highly speculative and short-term oriented. Hence, a specific class of high-risk/high-gain investors is engaged in these companies (Nunez-Picado, Martinus, and Sigler 2022), including asset managers but also venture capital companies and hedge funds. But more generally, the lithium price surge in 2021 attracted substantial investments by financial actors such as mutual funds, which actively allocate funds of private and institutional investors to stocks, and exchange traded funds (ETFs), which passively invest according to stock indices. For instance, the largest ETF in this segment, the Global X Lithium & Battery replicates an index of lithium stocks (Solactive Global Lithium Index), and experienced an inflow of USD 3 billion from 2020 to 2022 and had USD 4.6 billion of assets under management by the end of 2022. Such investment funds are typically advertised under a green finance label linked to advancing clean technologies, the zero direct emissions of EVs and the potential reduced greenhouse gas emissions.[39] The increasing investment sums are supported by green investment stories of asset managers who grow their ESG-based funds by holding equity in firms such as Albemarle, Livent and SQM which are rated with a medium ESG risk[40] (see section 5.3), and are constituents of ESG-based indices such as the MSCI Future Mobility ESG Filtered Index.

The mobilization of ESG-driven green investment stories enabled major lithium producers access to sustainability-motivated equity capital and contributed to asset management firms such as BlackRock, Vanguard or Capital Research & Management Company and ETFs such as Global X Management or VanEck becoming the major shareholders of Albemarle, Livent and Pilbara, holding 85 to 98% of their outstanding shares.[41] This has impacts on strategies, particularly related to price-setting. In 2021, as equity flows were growing, a PRA representative stated: "[F]rom a kind of evolutionary point (price-setting) has to change, even the pressure is starting to be felt by the market players themselves, as well. Often, they are public companies, they have shareholders and they are expecting to see some sort of exposure to a market price. And if they're not, if they [shareholders] are just being told that the company's material is contracted at a certain level for a number of years then they're going to put the pressure."[42] Indeed, the major lithium producers that switched to spot market transactions and benchmarking such as Albemarle and SQM could increase their operating income from 2020 to 2022 substantially. Generally, Baines and Hager (2021, 5) note that shareholding asset management firms in commodity sectors "almost always vote in favor of management resolutions seeking approval for dividend payouts and stock buybacks, and they almost invariably vote against shareholder resolutions aimed at improving environmental and social governance". This is even true for ESG-based investment funds (Li et al., 2021). Yet, given their high shareholdings, asset management companies can also influence strategies of lithium producers less overtly (outside of the open voting process) through the threat of disinvestment (Buller 2022).

The criticality of lithium and the aim to be exposed to growing lithium spot prices by financial investors from late 2020 onwards brough an influx of investment into equity markets, which led to changes in the governance of the lithium GPN. New strategies of major producers began to emerge, motivated by shareholders' expectations of increased earnings from higher lithium prices, which favored short-term profit and shareholder value maximization, including through variable, short-term price-setting, over long-term stability. In addition, this equity influx facilitated the entry of new actors, specifically junior miners, who pursue more speculative and high-risk/high-gain strategies, importantly contributing to the expansion of resource frontiers and the acceleration of boom-bust patterns in the sector.

5.3. Debt financing

Besides equity, debt is a second important source of finance for major mining companies. For example, major lithium producers such as Albemarle and SQM issued several bonds to finance the expansion of their operations in Chile and other locations. Both have long-term bonds with a notional value of USD 2.7 billion (SQM) and USD 3.1 billion (Albemarle) outstanding. Major producers such as Albemarle and Livent have a relatively low debt-to-equity ratio of less than 0.37 and 0.14, respectively in 2023[43] and Albemarle used its equity issues in 2021to pay back outstanding debt[44], showing the importance of equity capital, which could be easily issued in recent years. In contrast, SQM has a higher debt-to-equity ratio of 0.68.[45]

The criticality of lithium and the specific classifications of major lithium producers in ESG rankings as chemical companies are, however, also opening up better debt financing conditions. Generally, higher ESG-rankings reduce the cost of debt finance (Raimo et al. 2021). ESG rankings are typically conducted for sub-industries with specific weightings for different ESG criteria. As lithium producers are classified in the sub-industry 'specialty chemicals' instead of 'diversified metals & mining' as they typically process lithium carbonate and hydroxide, their risk related to land use and biodiversity is not taken into account and

[35] In 2022, it was estimated that 131 lithium producers, developers and explorers were listed on the ASX, of which most became listed in 2020 (https://bit.ly.ws/32Jic). Additionally, there were 129 such companies listed on the TSX and NASDAQ in 2022 (Henderson 2022).

[36] The underlying data is available at https://www.asx.com.au/markets/trade-our-cash-market/directory

[37] https://energycapitalpower.com/top-10-lithium-mines-in-africa/

[38] https://prospectresources.com.au/arcadia-case-study/

[39] https://www.globalxetfs.com/funds/lit/

[40] Several providers offer ESG rankings. The rankings of specific companies can be found on the websites of the providers, for instance on https://www.sustainalytics.com/

[41] The breakdown of major shareholder are available on various finance web sites. Here for the example of Albemarle - https://bitly.ws/32IzH.

[42] Senior data officer at PRA (2), November 2021, London

[43] https://finance.yahoo.com/quote/ALB/key-statistics/; https://finance.yahoo.com/quote/LTHM/key-statistics?p=LTHM

[44] Albemarle 2022 Annual Report (https://bitly.ws/32Jdi)

[45] https://finance.yahoo.com/quote/LTHM/key-statistics?p=LTHM

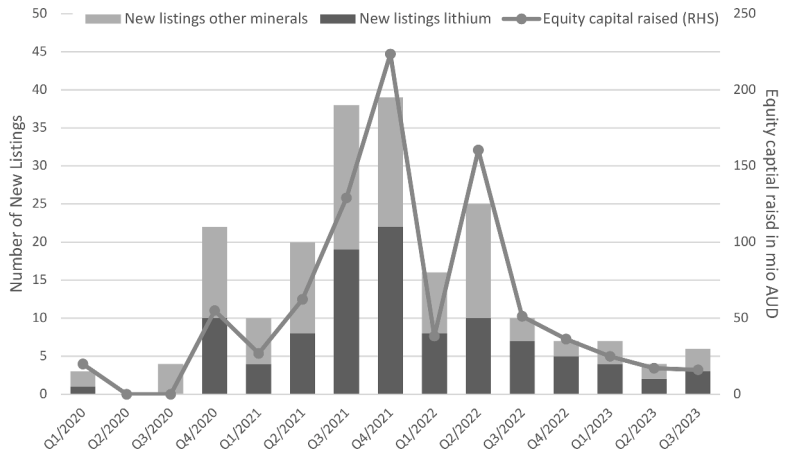

Fig. 6. New equity listings of junior producers at the ASX, 2020 to 2023.
Source: Own elaboration based on ASX data and company information.

they benefit from their 'opportunities in clean tech'.[46] Thus, major lithium producers avoid lower ESG ranking, which they would receive when classified as mining companies.

Lithium producers can benefit from access to green finance through green bonds - debt securities issued to raise capital to support climate related or environmental projects (Jones et al. 2020). The first green bond was issued by the World Bank in 2008 and since then the green bond market has accelerated rapidly, with cumulative investments of USD 1 trillion in 2022 compared to USD 100 billion in 2017 (Grzegorczyk and Wolff 2022). The high demand for green bonds indicates the increasing importance of green investments, for which investors accept an interest rate discount (i.e., pay a green premium, called 'greenium' as compared to ordinary 'brown' or 'vanilla' bonds), thereby offering more favorable lending conditions to green projects.[47]

The mining and metals sector has played a subordinate role in the green bonds market so far capturing little more than 1% of green bonds volumes.[48] Selected mining companies raised funds through green bonds for energy efficiency, clean transport or renewable energy projects, but usually not for mining activities.[49] However, the lithium producers SQM and Livent have issued green bonds to explicitly finance development, operation and expansion of lithium extraction. SQM raised USD 700 million out of their USD 2.7 billion total debt and Livent USD 238 million, which is its only outstanding bond.[50]

Generally, there are no legally binding characteristics a green bond must fulfil. Hence issuers have a lot of discretion in attaching a green label, usually opting for using one of the two voluntary standards – most often the Climate Bond Standard (a certification for identifying and labelling green investments that meet the set of standardised criteria) or the Green Bond Principles (a set of "best practices" established by a consortium of banks).[51] SQM uses the latter, intending to "[…] allocate an amount equal to the net proceeds from the sale of any Green Bond issuances to finance or refinance, in whole or in part, one or more new or existing Eligible Green Projects."[52] The Eligible Green Projects are defined on the basis of an Eligible Categories Taxonomy where, in this case, two categories are applied: Clean Transportation ("Expenditures primarily dedicated to Lithium extraction and processing for application in the manufacture of batteries for Electric Vehicles.") and Energy Efficiency ("Expenditures primarily dedicated to Lithium extraction and processing for application in the manufacture of batteries for Energy Storage."). Such taxonomy conflates criticality and the greenness of lithium-based technologies. Stating that lithium extraction is a necessity for clean transportation and energy renders lithium production as green by default, which obscures the actual activities of lithium producers, extractivist dynamics and associated outcomes in producer countries.

In this context, green bonds have been criticised as ineffective tools in heralding "the promise of treating our ecological deficit with debt" (Jones et al. 2020, 50). As such, it can be argued that it is the sheer process and methodology of evaluation of the greenness that creates the surplus value or 'greenium' of green bonds (Bigger 2017; Christophers 2019) without assuring or monitoring the actual environmental impacts, creating the risk of environmental non-performance, also called 'green default' (Talbot 2017). This also means that the positive environmental value of green-bond financed projects (frequently located in producer countries in the Global South) may be small or even non-existent, despite the value of green bond markets (in the Global North) expanding (Bracking 2015; Jones et al. 2020). As such, the value from creating green bonds is retained by financial actors in financial hubs in the Global North and major lithium producers that benefit from preferential financing conditions, but these financial instruments actively shape GPNs by financing expansions of extractive projects, yet delinked from the sites of extraction, which may bear the environmental and other costs of "green" investment.

6. Conclusions

Criticality legitimizes extractivism for sustainability transformations and is made by articulations of the risk of disruption based on demand, supply and price perceptions, policies linked to green extractivism, and underlying narratives around the role of commodities for sustainable development. The lithium boom has led to major changes in GPN dynamics, including the entrance of new actors and changes in strategies of actors and power relations. Firms have an interest to either control supply (mining and refining companies, battery producers, automakers), develop and resell exploration projects (junior producers), and take on and profit from price risks (international traders). Major lithium

[46] https://www.msci.com/our-solutions/esg-investing/esg-industry-materiality-map
[47] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/green-bond-premium-justified-by-strong-secondary-market-performance-flexibility-66696509.
[48] https://assets.ey.com/content/dam/ey-sites/ey-com/en_za/people/ey-green-bonds-brochure.pdf
[49] https://www.reuters.com/markets/commodities/lithium-slump-puts-chinas-spot-price-under-spotlight-andy-home-2023-05-19/
[50] Livent Annual Report 2021, FORM 10-K (https://bitly.ws/32Jhg); SQM 2021 Green Bond Financing Framework (https://bitly.ws/32Jhc)
[51] See also the discussion on voluntary EuGBs standard in Section 4.
[52] SQM 2021 Green Bond Financing Framework (https://bitly.ws/32Jhc)

producers focused on consolidating their power, through the expansion of their lithium projects and integration of processing, but power is also shifting to buyers (automakers, battery producers) that entered upstream nodes to secure supply. Junior producers became dominant in exploration projects, following speculative high-risk/high-gain strategies, and the more volatile and risky market provided more room for international traders. Financial actors have contributed to the lithium boom through financing the massive increase in extraction projects via debt, including green bonds, and specifically equity involvements, shaping producer firm strategies, and through the change to variable short-term price-setting.

In this paper we demonstrate how through the finance-sustainability nexus financial actors' strategies and interests impact on dynamics in the lithium GPN and on producer country outcomes. The nexus is based on, and underscores, the perception of finance as an enabler of sustainability transformations by mobilising and channelling capital flows to sustainable investments encouraged by incentives and de-risking of public policies and private sector initiatives. This is exemplified in green investment stories mobilized by financial actors, which endorse investment (and speculation) that has any link to products and projects defined as green. In particular, the strong speculative inflows to equity markets generated large budgets to fund high-risk expansions of existing projects and explorations and development of new projects, substantially expanding resource frontiers and accelerating boom (and bust) patterns. This is particularly driven by junior producers with their high-risk/high-gain speculative strategies and specific group of shareholders that have limited interest in long-term business sustainability, accelerating shareholder value orientation and related short-termism and uncertainty in producer countries. The shift to more short-term price-setting linked to PRA benchmarks and derivative markets is linked to the equity boom but also accelerates short-termism and volatility by providing short-term price benchmarks to be used in physical trade as well as by potentially expanding the role of financial trading strategies on these markets by financial and physical actors. This also generally increases the role of financial actors, while reducing the power of states in producer countries to set and regulate prices. In parallel, the growing green bonds market enabled the expansion of green projects, yet due to lack of mandatory standards, their outcomes may be a far-cry from sustainable, with negative outcomes incurred in producer countries.

Summing up, the following impacts are central: (i) overall there is a stronger involvement of financial actors in activities in the lithium GPN through the three channels price-setting, equity and debt financing affecting power relations and governance; (ii) financial actors' equity involvement and a related stock market boom have enabled major and particularly junior producers to engage in high-risk strategies; (iii) through poorly regulated green bonds major producers have had easier access to financing, yet not necessarily based on actual environmental performance; (iv) the overall easier access to finance for new extractive activities have contributed to the expansion of resource frontiers; (v) short-term price reporting is not only caused by, but also, based on shareholder pressure to get exposure to price movements through variable price-setting, contributes to increased price volatility and short-termism; and (vi) the responsiveness of capital investors to price changes has led to investment-disinvestment patterns, accelerating boom-bust patterns in the lithium GPN with negative consequences for producer countries.

CRediT authorship contribution statement

Aleksandra Natalia Wojewska: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Cornelia Staritz:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Bernhard Tröster:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Luisa Leisenheimer:** Data curation, Investigation, Writing – original draft.

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Appendix

Table A1
Active and new lithium production projects in 2022.

Number of active and new projects in 2022	Country
over 25 projects	Canada
15-25 projects	**Argentina**
	Australia
	United States
10-15 projects	**China**
5 - 10 projects	**Chile**
2-5 projects	**Brazil**
	Germany
	Mali
	Mexico
	Portugal
	Serbia
	Spain
	Zimbabwe
1 project	Austria
	Bolivia
	Czech Republic
	DRC
	Finland
	Ghana
	Ireland
	Namibia

(*continued on next page*)

Table A1 (*continued*)

Number of active and new projects in 2022	Country
	Peru
	United Kingdom

Source: Own complication on the basis of Fitch Solutions (2022).
Note: Countries with active production in bold font. New projects include projects at varying stages of development, including in exploration.

Table A2
Glossary of acronyms.

A2Z	Accelerating to Zero Coalition
AIM	Alternative Investment Market
ASX	Australian Stock Exchange
BMI	Benchmark Mineral Intelligence
CIF	Cost, Insurance, Freight
CME	Chicago Mercantile Exchange
DLE	Direct lithium extraction
DRC	Democratic Republic of Congo
ESG	Environmental, Social and Governance
ETF	Exchange traded fund
EU	European Union
EuGB	European Green Bond
EVs	Electric vehicles
GFEX	Guangzhou Exchange
GPN	Global Production Network
IPCEI	Important Projects of Common European Interests
IPO	Initial public offering
IPSF	International Platform on Sustainable Finance
LME	London Metal Exchange
LSE	London Stock Exchange
PRA	Price Reporting Agency
SGX	Singapore Stock Exchange
TSX	Toronto Stock Exchange

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