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Price-determination and -setting in global production networks of critical minerals – The London Metal Exchange, price reporting agencies and digital trading platforms

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List of Abbreviations

ASM	Artisanal and Small-Scale Mining
BMI	Benchmark Mineral Intelligence
CME	Chicago Mercantile Exchange
DRC	Democratic Republic of the Congo
DTP	Digital Trading Platforms
EU	European Union
EV	Electric Vehicle
GPN	Global Production Network
GVC	Global Value Chain
HKEX	Hong Kong Exchange and Clearing
ICGS	International Copper Study Group
LFP	Lithium Ferro-Phosphate
LME	London Metal Exchange
NGO	Non-Governmental Organization
NMC	Nickel-Manganese-Cobalt
PRA	Price Reporting Agency
SGX	Singapore Exchange
SHFE	Shanghai Futures Exchange
UK	United Kingdom
US / USA	United States of America
USD	US Dollar

Abstract

Despite frequent debates on commodity prices, limited attention has been paid to the processes, strategies and practices through which commodity prices are ‘made’ and related institutions and infrastructures. ‘World commodity prices’ are not passively ‘discovered’ but are outcomes of contested price-making processes. This paper assesses how prices are determined and how they are set along global production networks (GPNs) for the critical metals copper, cobalt and lithium that are undergoing shifts in the context of green transitions. Conceptually, we link concepts of extractive industries in GPNs with sociological approaches to price-making and an infrastructural perspective. While the London Metal Exchange (LME) has been the established price-determination institution for copper and a leading price reporting agency (PRA) benchmark exists for cobalt, there is contestation between PRAs to become the dominant benchmark for lithium with the potential emergence of digital trading platforms. These differences are explained by particular materialities of metals and territorialities of their networks interrelated with historically developed production and organizational structures and powerful physical as well as financial actors’ interests. There are however ongoing struggles within and between price-determination institutions. Generally, there is a trend to more short-term benchmarks linked to derivative markets, driven by financial actors’ interest in getting exposure to metal price developments and financialization processes at the LME. The related increased price volatility has uneven distributional consequences along GPNs and is problematic for actors with limited access to price risk management. Methodologically, the paper is based on trade and financial data and semi-structured interviews with price-determination institutions and GPN actors.

Keywords: price-making, global production networks, critical minerals, financialization, commodity derivative markets

1. Introduction

Debates around commodity prices follow cyclical patterns as commodity prices themselves. Related to the COVID-19 pandemic and the war in Ukraine, commodity prices experienced pronounced spikes which again fueled debates on the volatility of these prices and the factors driving it (Baffes/Nagle 2022; Clapp 2023; Tröster/Küblböck 2020). The importance of these prices is clear, as they directly impact the trajectories of commodity production, trade and use as well as many industries that use commodities as inputs and the global economy as a whole. In this way, commodity prices have important distributional consequences on the distribution of value, income and wealth – but also economic, social and environmental costs and risks related to commodity production, trade and use – between actors and locations.

Limited attention has however been paid to the processes, strategies and practices through which commodity prices are 'made' and related institutions and infrastructures. 'World commodity prices' – be it for wheat, coffee, oil or copper – are generally perceived as 'neutral' benchmarks. However, these prices are not passively 'discovered' through objective processes taking place on abstract markets. Instead, they are the result of contested price-making processes that involve buyers and sellers of physical commodities, but also financial actors that see commodities as asset classes, as well as various institutions through which prices are determined and states. These contestations are reflective of governance and power struggles over specific rules, devices and infrastructures of price-making (Beckert 2011; Callon/Muniesa 2005). In this vein, Russel (2022) calls these processes "price wars", questioning the seemingly neutral basis, where prices are framed as magical systems such as, most prominently, the invisible hand of the market.

This paper assesses the price-making of commodities, which involves how commodity 'world prices' are determined and how they are set along global production networks (GPNs) that span multiple national borders, as well as the distributional implications of these processes. Empirically, we focus on the critical metals copper, cobalt and lithium that are currently undergoing important shifts in the context of green transitions. These shifts have led to increased demand and the expansion of extractive activities in existing and new producer countries (Dorn et al. 2022; Hund et al. 2020) as well as to changes in price-making, linked to shifting power relations within GPNs.

Conceptually, we use the GPN approach, but criticize its limited focus on prices as the subject of research per se, despite the emphasis on governance and value distribution. Specifically, we draw on the small literature that explicitly assesses the 'making of prices' in GPNs (Bargawi/Newman 2017; Çalışkan 2007; Newman 2009; Purcell 2018; Staritz et al. 2023, 2018; van Huellen 2015), linking it to sociological approaches to price formation and an infrastructure perspective to integrate price-making as an additional governance dimension and a contested process into GPN research. Through this, we put a focus on the concepts of materiality and territoriality of commodities and expand the array of actors and institutions considered (commodity derivative markets such as the London Metal Exchange (LME), price reporting agencies (PRAs), digital trading platforms (DTPs), brokers, financial investors) and the channels through which actors can exert power in GPNs.

In our empirical analysis, we focus on the different, but interrelated role of derivative markets, particularly the LME, PRAs and DTPs in price-determination of copper, cobalt and lithium, and how this is related to the materiality of metals, the territoriality of their networks and production and organizational structures in GPNs and related physical actors' and financial actor' interests. While the LME has been the established price-determination institution for the base metal copper for a long time and, for cobalt, a leading PRA benchmark exists, no dominant price-determination institution for lithium has been established yet with contestation between PRAs and the potential emergence of DTPs. Contracts for both minor metals were established at the LME, but PRAs remain important given the materiality of the two metals that makes

standardization difficult and powerful physical actors' interests. Regarding price-setting in contracts along metal GPNs, there has generally been a shift towards the use of benchmarks (futures or PRA prices), shorter term-structures and more frequent (monthly, weekly, daily) price assessments, with related short-term volatility more strongly transmitted to actors along GPNs. Overall, financial actors have become more influential in determining prices through LME trading and PRA methodologies, but financial interests are also present in physical actors' strategies.

Methodologically, the paper is based on trade and financial data and document analysis focusing on LME regulations and guides; PRA methodologies and market analysis; trading platform strategies; and regulations and policies in trading hubs (London, Switzerland). Most importantly, 96 semi-structured interviews were conducted at price-determination institutions (LME, PRAs, DTPs, financial investors and experts); metal GPN actors (mining companies, commodity traders, industry associations and experts); and producer country actors (ministries and other state institutions, sector associations, artisanal mining cooperatives, industry experts, NGOs). Interviews focused on actors in the central metal trading hubs London and Switzerland as well as in dominant producer countries for copper (Chile, Zambia), cobalt (Democratic Republic of the Congo – DRC) and lithium (Chile, Zimbabwe).

2. Theoretical approaches to price-making in GPNs

2.1. GPN approach and extractive industries

The GPN literature is primarily concerned with organizational and governance patterns within and across industries in the global economy and the resulting unevenness of regional development outcomes. As such, GPN problematizes accounts of production, exchange and value distribution, viewing these processes as driven by power struggles between different firm and non-firm actors (Yeung/Coe 2015). Related to extractive industries, the concepts of materiality and territoriality have been put center stage (Bridge 2008; Bridge/Bradshaw 2017). Materiality is understood as the physical and chemical characteristics of resources and the processes required for their transformation. Bridge and Bradshaw (2017) define territoriality as "the practices undertaken by network actors to establish, maintain, and adapt a production network's territorial form" (ibid.: 219). Territoriality is also importantly determined by the presence of and access to economically profitable reserves, which are embedded within locations and state structures (Bridge 2008). Both conceptual elements affect the organizational form of networks and related development outcomes. Bridge and Bradshaw (2017) also introduced the concept of "network practices", which captures how buyers and sellers interact and continuously reshape networks through the ongoing realignment of interests, re-negotiation of terms and associated power struggles over governance in GPNs. They specifically pay attention to "devices through which practices are negotiated and prescribed, such as contract terms" (ibid.: 222).

Despite the acknowledgment of contract terms as a key governance factor, there is a limited explicit focus on price-making processes and related struggles. As the few existing studies on price-setting in agricultural commodity sectors (Newman 2009; Bargawi/Newman 2017 for coffee; Purcell 2018; Staritz et al. 2018 for cotton; Purcell 2018; Staritz et al. 2023; van Huellen 2015 for cocoa) show, price-setting processes are a crucial element of network governance where powerful actors impose benchmarks and methods of valuation on other actors, influencing production and trade patterns and the distribution of value and risks among actors and locations. This is particularly important in commodity sectors, where prices are commonly determined at derivative markets and transmitted

along GPNs to different types of producers, strengthening the interconnections between financial and physical markets (Newman 2009; Purcell 2018; Staritz et al. 2018).

The limited focus on price-making in GPNs is related more generally to the limited analysis of finance, financial markets and financialization within GPN research. Conceptually, this lacuna has been stated (most prominently by Coe et al. 2014 and Coe/Yeung 2019), but there remains limited empirical research including on extractive sectors. Exceptions are a handful of analyses on the role of shareholder value in driving particularly mining companies' strategies and financialization processes and how this accelerated 'boom and bust' cycles (Bowman 2018; de los Reyes 2017; Parker et al. 2018). This paper focuses on the financialization of commodity markets, which we understand as the increasing dominance of financial investors and financial trading strategies, also by physical actors, on commodity derivative markets and also at other price-determination institutions such as PRAs through including financial actors and their opinions in their methodologies. By doing so, we focus on price-making processes, drawing on sociological and infrastructure approaches to price-making.

2.2. Sociological and infrastructure approaches to price-making

The neoclassical theory of price formation describes an automatic process of individual demand and supply, meeting in competitive markets, which is assumed to ensure an efficient allocation of goods (Bargawi/Newman 2017). Sociological approaches criticize this 'objective', 'abstract' and 'naturally given' view of markets and prices 'discovered' therein as disembedded from institutional, social, cultural and political contexts. They, in turn, highlight the importance of institutions, relationships of power, trust and status, cultural meanings and the creation and use of market devices in price-making.

In analyzing approaches to price formation, Beckert (2011) emphasizes that studies of price formation should embrace the particularity of socially constructed institutions and power structures within which prices are 'made'. First, institutional price theories stress that prices and their volatility in market economies are an outcome of particular institutional settings, which have not emerged spontaneously but have been constructed by political and social forces (see Polanyi 1992). As a result, price struggles take place at two levels – both over prices that are settled in acts of exchange, but also over the ability to influence and control the rules and institutions in which price determination takes place, which involves fiscal and monetary policies, labor and environmental standards, financial trading regulations, etc.

Second, relational, or network, price theories see economic action as "embedded in ongoing networks of personal relationships rather than being carried out by atomized actors" (Granovetter/Swedberg 1992: 9). They hence focus on the role of relationships, where power, trust, status and positions in markets and networks are leveraged as tools to influence price formation. Existing hierarchies within relational structures affect what prices different actors receive, space for price negotiations and to what extent actors are shielded from price-based competition (Ouma 2012). Third, cultural price theories center on ways in which 'conceptions of control' (Beckert 2011: 13) are structured by market actors and reflected in aspects such as social construction of preferences or expectations and legitimacy. Some authors in this tradition (e.g., Scott 2008) conceptualize institutions as "cultural scripts providing orientation for actors under conditions of uncertainty" (Beckert 2011: 10) through specific pricing technologies.

Similarly, Bååth's (2023) coordinative price theories classify prices as an "outcome of a process whereby institutionalized social structures […] coordinate market exchange through price formation" (ibid.: 6) where actors follow particular 'pricing scripts' (ibid.: 10). Performative price theories however, while acknowledging the influence of institutions,

relations and culture, see prices as active market-making devices, rather than passive reflections of embedding structures, and that struggles over prices are also struggles over the tools of quantification and calculation that produce them (Adkins/Lehtonen 2018). This approach is related to broader marketization theories, which study the materialities of market-making and how materials are reconfigured into market commodities and producers into market actors (Çalışkan/Callon 2010; Callon/Muniesa 2005; Ouma 2012), tracing back to Weber (1978). Callon and Muniesa (2005) refer to markets as "calculative collective devices" within which struggles over definitions of the object of exchange (material characteristics) and the associated valuation are undertaken by market actors.

A literature related to performative price theories and marketization approaches highlights the crucial role of infrastructures in how markets are organised and function. Infrastructures are understood as assemblages of socio-technical devices, which underlie and enable the functioning of large-scale systems (Edwards et al. 2009; Star/Ruhleder 1996). Analyzing financial markets through an infrastructural lens highlights first, the inseparability of finance from the "real" economy and specifically, the devices through which "patterns of production and accumulation are translated into values and instruments amenable to speculation" (Bernards/Campbell-Verduyn 2019: 781; see also Muellerleile 2018). Second, by looking at the processes through which markets are created and sustained, by whom and whose interests are reflected in the material construction of markets, an infrastructure lens counters the tendency to treat (financial) markets as 'abstract' and 'objective' places and more generally global finance as apolitical (Braun 2020; Cerny 1994). For instance, Pinzur (2016) in his comparative historical study of the creation of futures markets on the Chicago Board of Trade and the New Orleans Cotton Exchange analyzed how the infrastructure of classification systems influences the functioning and outcomes in terms of contrasting levels of volatility on these markets (see also Genito 2019; MacKenzie/Millo 2003).

Finally, Bargawi and Newman (2017) link approaches to price formation with global value chain (GVC) and GPN literature. They emphasize that prices are influenced by institutional, relational and market factors, which interact producing differential results across commodities, space and time. By introducing the concept of 'price chains' they add a vertical dimension to the study of prices, by analyzing how prices are formed at different points of trade. In their case study on coffee GVCs, this chain spans from international derivative markets in London and New York to raw commodity prices for smallholder farmers in Tanzania. Their approach does not prioritize institutional, relational or market factors, but accounts for the importance of and heterogeneity in institutions, strategies and power relations along price chains.

2.3. Our theoretical approach

Building upon these literatures, we argue that price-making in extractive (and other commodity) sectors is impacted by (Figure 1): (i) materiality of metals, (ii) territoriality of their networks, (iii) production and organisational structures and interests of physical actors, and (iv) interests of financial actors and institutions. These factors affect 'price struggles' over (money) prices but also over the specific institutions and infrastructures that determine prices. Attention to these 'price struggles' exposes additional channels through which power can be exerted and uneven outcomes created within GPNs, with implications in terms of value distribution and price risk exposure for different actors and locations.

Following Bridge and Bradshaw (2017), we conceptualize price-making as a network practice and distinguish between price-determination and -setting. Price-determination addresses how global benchmark prices are determined. The emerging benchmark prices can be understood as market devices. They are the results of struggles over

infrastructures and have a ‘market-making’ function, as they are taken up in transactions and contracts between sellers and buyers along GPNs. We refer to this process of applying benchmarks in pricing formulas in contracts (including discounts/premiums and other price-related stipulations) as price-setting.

Price-determination takes place at, and is directly mediated through, price-determination institutions (such as derivative markets, PRAs, DTPs), who have their own interests in how prices are determined. Struggles within and between price-determination institutions create infrastructures that determine e.g., which actors are allowed to participate in price-determination, what types of calculative tools, methodologies etc. are used and in which ways they systematically link financial and physical spheres of markets. Price-determination institutions are frequently pictured as impartial facilitators of price ‘discovery’ – a term that implies that prices are simply revealed. On the contrary, the term price-determination highlights the active process and the decisions, interests and power struggles that come into play over how, where and by whom prices are determined.

The interests of physical actors in price-determination are generally reliability and practicality, which they judge on whether benchmark prices reflect physical trading processes and market conditions as they view them Their interests also depend on the production structures of specific metals and their positions in GPNs and hence which type of products they are engaged with, which transactions they pursue, and whether they are interested in price risk management. For the latter, only benchmark prices linked to derivative markets allow for financial hedging, which means that physical actors that aim to engage in price risk management tend to favor derivative markets. Financial actors’ interests are less diverse, linked to their overall investment strategies, which generally rely on getting exposure to commodity price developments without holding the physical commodity or shares of firms engaged in physical extraction; rather through liquid, standardized and easy-to-handle derivative contracts, which allow them to handle commodities like their other investment products (stocks, bonds, derivatives, etc.). The distinction between physical and financial interests is however not straightforward as physical actors also pursue speculative strategies in addition to their physical commodity business.

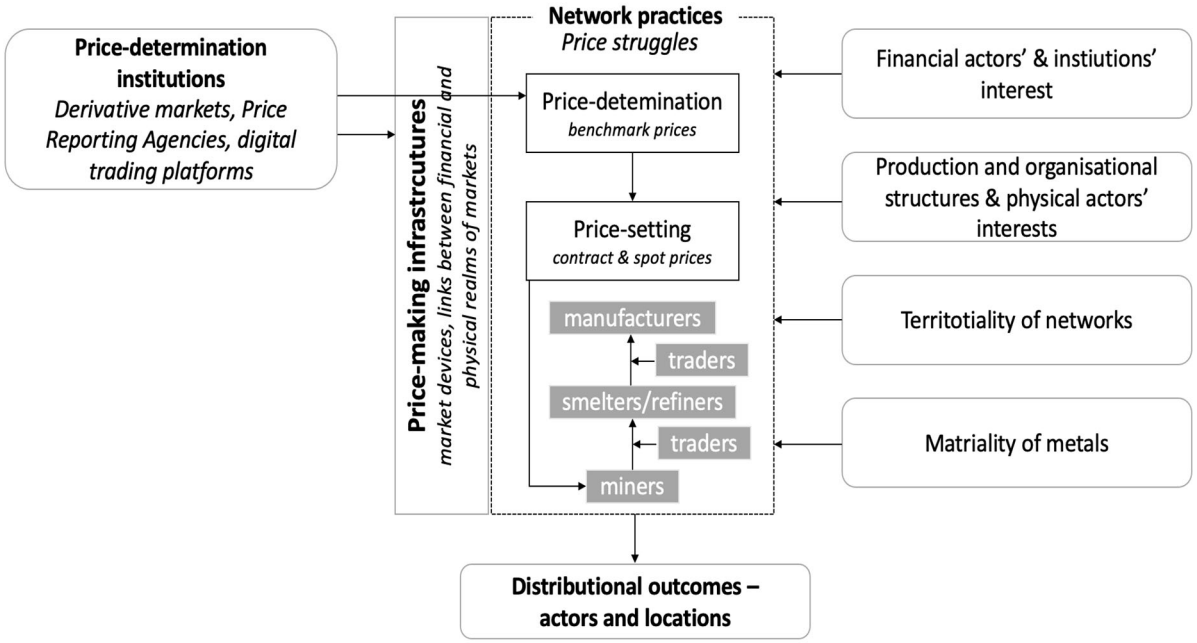
Materiality and territoriality of resources matter in price-determination and -setting. While the material properties of a material do not change, the technological capabilities to use them and societal needs and power relations constantly evolve (Bridge 2009). Commodities differ in storability, ease of transportation, expertise required in their extraction and processing and other characteristics, which delineate the degree of their possible standardization and commodification. This importantly relates to the possibilities, and limits, of specific price-determination processes and more broadly of the degree of inclusion in financial markets. Generally, as (Bracking 2020: 216) states: “[c]ommodification processes are a precursor of financialization, in that they create a pacified commodity which is free to be sold, traded and circulated in a market.” Yet, there are tensions in commodification processes linked to particular materialities that do not lend themselves easily to standardization (Bernards 2021; Bridge 2009).

Territoriality at the point of extraction is bound by the ‘landed nature’ of economically profitable reserves, but practices by network actors can establish, maintain, and adapt the territorial form of GPNs (Bridge/Bradshaw 2017). The understanding of territoriality can be expanded to also include central locations where regulations or decisions with global reach are made and related struggles take place, which is the case for price-determination institutions. Price-determination institutions are located in particular jurisdictions, governed by specific policies and regulations (e.g., through price reporting standards, financial market regulations, central bank policies) and out of reach of others, but the resulting prices are taken up as ‘world prices’ throughout GPNs. Particularly the US, but

also the UK, act as dominant players in world price-determination. More generally, as Bernards and Campbell-Verduyn (2019) state, “global finance facilitates connections between some kinds of places and some kinds of activities more easily than others” (ibid.: 779) and, we add, is governed and regulated by some actors and excludes others.

Decisions about price benchmarks and related terms, as market devices, have important distributional implications. The use of benchmarks makes the contracting process for physical actors simpler, but it is also closely related to the interests of powerful physical, and financial, actors that generally impose their benchmark of choice in GPNs. Established benchmarks are often difficult to change once taken up (or imposed) broadly, hence reinforcing the power of institutions and actors producing them. Different price-determination institutions and their benchmarks come with different methodologies and lead to different price levels, frequencies (monthly, weekly, daily), volatilities and the possibility of price risk management (through derivative markets) or not. Benchmarks are not only influenced by production and organizational structures in GPNs and the position of powerful actors, but in turn, also influence these structures, the type of firms involved and their relations. For instance, increased frequency of benchmark reporting and/or developing hedging tools on derivative markets enables entry of certain firm actors such as international traders which require these infrastructures for their business model, but is detrimental to other actors that do not have the same sophistication of financial trading.

Figure 1: Price-determination and -setting in GPNs



Source: Own elaboration.

3. Price-determination institutions in metal markets

Establishing contract prices on a case-by-case basis would be a lengthy and expensive process for actors that deal with physical commodities. Thus, price benchmarks play a crucial role and are applied in price-setting in physical transactions along commodity GPNs, but they are also used by states as the basis to calculate taxes or assess whether a transaction is conducted at arm's length basis in cases of alleged transfer pricing (Musselli 2019). For base metals, derivative markets are the dominant price-determination institution, while PRAs are the key price benchmark institutions for minor metals. However, the benchmark may change and, more recently, DTPs aim to become alternative price-determination institutions.

There are three major derivate exchanges for metals – LME, Continental Mercantile Exchange (CME) in New York and Shanghai Futures Exchange (SHFE).[1] The LME has the longest tradition and was formed in the context of surging metal imports to the UK in the 1870s (Seddon 2020). Trading of copper and tin forward contracts at the LME started in 1877, with copper futures still being one of the most traded today (Table 1). The LME is the dominant institution for price benchmarks of base metals, which is also related to the LME infrastructure more strongly representing industry actors' interests. Derivative markets are the only institutions that determine forward-looking prices of metals, with the main derivative products traded being futures contracts, which represent the ability to buy or sell a commodity at a predetermined price at a specified time in the future. Trade in these contracts does not require to deal with physical commodities but still provides actors exposure to price developments to pursue price-risk management (hedging by physical actors to secure purchase or sales price of metals) and speculation (by both financial and physical actors).

Derivative markets are linked to physical metal trading due to warehouse systems, which ensure that the prices of expiring futures contracts converge on prevailing spot prices (Adams 2019).[2] For this purpose, physically settled contracts require a standardized materiality that needs to be storable (e.g., do not corrode or deteriorate), transportable (deliverability) and substitutable to most users (Radetzki/Wårell 2020). However, rates of physical settlement are very low (at the LME, less than 5 %), since the majority of members use derivative markets not for physical trade, but for price risk management or speculation (Adams 2019). More recently, metal exchanges also introduced cash-settled contracts on minor metals. These contracts are paid off in cash upon expiry based on spot reference prices obtained from PRAs.

[1] Other exchanges with metal futures contracts are the Multi Commodity Exchange (MCX) in Mumbai, the Singapore Exchange (SGX) and the Tokyo Commodity Exchange (TOCOM).

[2] At the LME, futures contracts are settled through delivery into a worldwide network of warehouses and warrants (Adams 2019).

Table 1: Metals traded on LME

Mineral/Metal	Trading established	Contract	Annual Trading volume 2022 (*in thousand lots*)
Physically settled			
Copper	**1877**	**Copper A-Grade (CA)**	**29,377**
		Monthly Average Future (OC)	**29**
Tin	1877	Tin (SN)	1,009
Lead	1903	Lead (PB)	10,277
Zinc	1915	Special High Grade Zinc (ZS)	21,332
Aluminium	1978	Aluminium High Grade (AH)	52,048
Nickel	1979	Primary Nickel (NI)	12,106
Cobalt	**2010**	**Cobalt (CO)**	**0,290**
Cash settled			
Steel	2015	Steel Scrap (SC)	431
		Steel Rebar (SR)	99
Cobalt	**2019**	**Cobalt Fastmarkets MB (CB)**	**0**
Molybdenum	2010 / 2019*	Molybdenum Platts (MD)	0
Lithium	**2021**	**Lithium Hydroxide Fastmarkets MB (LH)**	**0**

* Introduced as physically-settled contract in 2010, but switched to cash-settled in 2019
Note: Contracts considered in this article are highlighted in bold.
Source: LME (2022b).

In metals without liquid trading, particularly minor metals, reference prices are 'identified' by PRAs. These are specialized companies "that assess the 'fair' price of commodities and report these values" to customers against subscription fees (Johnson 2018: 4). The origin of PRAs are journalistic enterprises, that were formed in the late 19th century and provided information services about market developments and company activities in specific commodity markets, but also information on prices. These price data were initially picked up as reference points in price negotiations on long-term, fixed-price contracts. PRA benchmark pricing system emerged with the liberalization and fragmentation of many commodity sectors, starting in the 1980s (Johnson 2018). Today, PRAs poll price information from different types of physical actors based on their transactions, but also include information from financial actors. Every PRA has a unique process of editing or 'normalizing' these primary data, as the type and quality of the information in the polls can

fluctuate strongly, particularly in small markets with few actors and less frequent transactions. General descriptions of methodologies are publicly accessible, but information about participants is not made public. As Johnson (ibid.: 104) writes "Methodologies matter. Almost every time a commodity market has changed from using one PRA's assessment as a benchmark to another rival provider, the root cause has been users' preference for a different type of methodology."

There are more than 100 commodity PRAs, with major actors covering several commodity sectors, while others are specialized in specific commodities; seven PRAs are key for metal price benchmarks (Table 2). Fastmarkets and Benchmark Mineral Intelligence (BMI) report multiple benchmarks on cobalt and lithium with different frequencies, underlying grades, spot trading locations and currencies. The dominant position of certain PRAs is rooted in their first-mover advantage in the context of market liberalization in the 1980s and 1990s and particular industry structures. The headquarters of PRAs are primarily located in London, the US and China, and most major PRAs are privately owned companies (Johnson 2018). A market analyst states: "Most of them that are considered to be reliable are based in London. Which, again, from the political point of view, means that after Brexit, there is no single EU-based price reporting agency."

Table 2: Major PRAs in metal markets

	Metals	Energy	Agriculture
S&P Global Platts, USA	x	x	x
Argus Media, UK	x	x	x
Benchmark Mineral Intelligence, UK	x		
Fastmarkets (former Metal Bulletin), UK	x	x	x
Asian Metal Benchmark, China	x		
CRU International Limited, UK	x		
Shanghai Metals Market (SMM), China	x	x	

Source: Based on Baffes 2018 and Johnson 2018; adapted with interviews.

DTPs emerged in the late 2010s as alternative price-determination institutions, which aim to provide price assessments based on online transaction systems. Initially introduced for ferroalloys markets, they also exist for copper, cobalt, aluminum, lead, manganese, molybdenum, nickel and zinc. As spot markets, their objective is to facilitate transactions between buyers and sellers. These platforms, such as Metalshub and Open Mineral, act as online marketplaces to conclude physical transactions and use the prices of these transactions as the basis of their price assessments. As a representative of a DTP explains: "(…) the entire process of metals trading is quite old fashioned and as undigital as possible (…) the idea of DTPs was to create a marketplace which will help the market participants to negotiate on contract terms and conclude and execute these deals by having a digital tool for payment, paperwork, compliance, and so on". Another representative explains "the entire idea […] is to convince the market to switch long term contracts from non-transparent journalistic indices of PRAs and replace them with our indices […] all data are collected automatically by software, and can be again automatically evaluated, normalized, adjusted and calculated into the index with no any single person physically involved. […]".

The three-price determination institutions in metals not only compete with each other to gain revenue from their price benchmarks being used in trade, whether on a subscription basis (PRAs, DTPs) or through linking the benchmark to financial products (derivative

markets), but also cooperate. This includes the use of PRA benchmarks by derivative exchanges as a basis for cash-settled futures, which has been a major growth market for PRAs as one expert explains: “I think they have done extremely well out of this. […] And also, I think they are very clever in joining up with exchanges to create these products where there is a lot more liquidity in them and […] the prices are much more real.” Through such cooperations derivative markets can create products on metals that are not suitable for the warehouse settlement system and generate more trading volumes. DTPs also cooperate with derivative markets. In 2021, LME announced a collaboration with Metalshub with the goal to “complement the LME’s existing offering, and […] expand the physical product suite available on Metalshub” (LME 2021c). Hence, struggles, but also cooperation, over price-determination take place between these institutions as well as within them, which is discussed for copper, cobalt and lithium next.

4. Price-determination and -setting in copper, cobalt and lithium

4.1. Copper

Materiality, territoriality and production/organizational structures

Copper is a standardizable, non-ferrous base metal. Major copper grades traded include copper concentrates (30 % copper content), copper blister and anode (99 %) and copper cathodes (99.99 %). Copper cathodes are processed further into wires, rods, tubes or foils, which are used in electronic equipment (including for Electric Vehicles (EVs)), machinery and construction (ICGS 2023). Copper is extracted from sulfide (80 % of mine production) and oxide ores (20 %) and the main mining countries in 2021 were Chile (27 %), Peru (11 %), DRC (9 %), China (9 %) and the US (6 %) (Reichl/Schatz 2023). In 2021, China produced 42 % of refined copper through smelting and refining, followed by Chile (9 %), Japan (6 %) and DRC (5 %) (ICGS 2023).

There is a large number of copper mining companies, of which the Top 5 (Codelco, BHP, Freeport-McMoRan, Glencore, Southern Copper) had a market share of 35 % in 2020 (NS Energy 2021). Smelting and refining is primarily operated by large Chinese companies (ICGS 2023). International traders are present at every stage of the GPN due to the many actors involved and different copper products traded globally; being headquartered in centralized logistic and finance hubs such as Switzerland and London (Dobler/Kesselring 2019). Some traders, such as Glencore, Trafigura or IXM, are also engaged in extractive and refining activities.

Key price-determination institutions

LME copper derivatives were introduced in 1877 and the official settlement price of futures contracts on copper cathodes has become the central price benchmark despite several attempts of producer cartelization after World War I and II as well as after independence in Global South copper producer countries with the aim to stabilize or raise copper prices (Declercq 2020). The CME emerged as a derivative exchange after the end of annual price negotiations between miners, refiners and industry users in in North America only in 1988 and the SHFE commenced derivative trading in 1999 focusing on intra-China trade. In 2021, the LME obtained 70 % of global trading volume in copper derivatives (LME, CME, SHFE data).

The increasingly fragmented organizational structure in the copper sector since the 1980s has created hedging needs. Particularly copper traders, but also independent smelters and refiners hedge their price risks on the purchase and sale side. Firms that hedge require the use of derivative market benchmarks in physical transactions. Therefore, even

actors that do not pursue hedging use LME benchmarks as this is considered a ‘standard’ required to do business with larger players. The only key physical actors that hedge selectively are mining companies, which is motivated by their shareholders’ wish to have exposure to changing prices, but also the expenditures related to operating hedging (Adams 2019).

Physical actors, however, not only engage in derivative markets for hedging but also for speculation, with a prime example being international traders. One trader said: "So, we trade a lot on a financial basis, because essentially if you just try to trade physical copper cathode on the stand-alone basis it's very, very difficult to make money". Another trader explains that copper is a “mature”, relatively transparent market with many actors and hence fewer possibilities for high margins. Traders also increasingly offer hedging and other financial solutions to other physical actors, increasingly resembling financial companies, a trend that developed largely in the aftermath of the 2008 financial crisis based on a significant retreat of commercial banks from commodity sectors (Perks 2016).

The dominant position of the LME is explained in its historically strong physical trade orientation. However, members and financial investors contested this orientation since the 1980s, advocating for infrastructures with liquid and easy-to-handle derivative contracts as well as electronic trading (Seddon 2020). Consequently, LME trading volumes increased strongly in the 1990s and 2000s, also driven by more financialized strategies of physical actors (ibid.; Spinks 1996). In 2001, the demutualization of the LME, that is the separation of ownership and trading rights, contributed to LME’s “market-structural financialization” (Seddon 2020: 537), which has accelerated since 2011 when the new LME holdings were sold to the Hong Kong Exchange and Clearing (HKEX). One commentator noted “[since] 2012, when the Hong Kong Exchange and Clearing bought the LME, they may not be satisfied with the income they have earned from the LME and they are now looking at other ways to bump up the volume, to increase earnings.”

Despite the growing role of financial investors, which held 65 % of all open interest (not yet closed) positions in copper contracts from 2020 to 2022 (LME data), the LME has remained a unique infrastructure, which causes struggles between the interests of owners, members, physical actors and financial investors, exemplifies around three key issues. First, the LME offers daily expiry dates, which enables a daily official settlement price applied in tailored hedging strategies of physical actors.[3] This date structure is contested by financial investors, as it results in lower liquidity per contract and complicates investment strategies, requiring more active (and costly) management of investment portfolios. Second, the LME has three different trading platforms – electronic trading (“LMEselect”), but also one of the last open-outcry trading floors – the “Ring” – and an inter-office telephone market, where at the latter brokers can offer tailored hedging solutions. Around 60 % of trading volumes still go primarily through the telephone market and, despite contestation, official benchmarks are determined in the Ring, which is operated by nine brokers. Third, the LME introduced a clearing system only in 1987 but does not ‘cash-clear’ contracts before the final settlement, which favors physical actors. Financial actors, in light of their shorter-term strategies, would prefer a system where profits and losses from margins are cleared daily (LME 2022a; Seddon 2020).

In particular, the small-scale structure of multiple forward-like contracts and the importance of the less transparent and accessible Ring and inter-office telephone market is not in line with the trading strategies of financial investors (LME 2021a). Based on their interest in increasing trading volumes, the LME has made several attempts to integrate and adjust the industry-rooted features to a more financialized market structure; e.g., enhanced access to electronic trading platform and attempts to increase fees in the inter-

[3] In contrast, CME’s and SHFE’s main products are copper futures contracts with monthly expiries, that are typically rolled over before expiry.

office telephone market (LME 2017, 2021e, 2021d). Overall, there is an agreement among physical actors that the LME is moving away from its physical user orientation, in order to attract financial interests. One commentator noted "the speculative part of pricing and volume in copper has increased dramatically over last 10-15 years; that's why you can see moves in copper such as a sudden increase or fall 300 USD per tonne in a day with absolutely no change in physical supply and demand – it's probably a black box algorithm, e.g., oil prices and the Dow Jones Index changed in a certain way, and it impacted on the algorithms and therefore put orders into the copper market."

Price-setting along GPN

Long-term annual contracts account for 80 % of copper trade and sometimes secure sales for up to 30 years (Greenberg/Różycka 2019). Spot trading accounts for the remaining transactions where traders play a major role as intermediaries. Prices in long-term contracts are however flexible[4] as the final price is set as the monthly average of the daily settlement of LME futures in the so-called quotational period when copper will be delivered (frequently three months). To hedge its price risks, a buyer sells the corresponding LME futures contracts that expire during the quotational period (LME 2018).

As the LME futures refer to copper cathodes, only this product can be directly priced using the LME official price. For copper at other production stages – e.g., concentrate, blister or wires – the benchmark is adjusted. For instance, the price of copper concentrates requires multiplying the traded copper content by the LME cathode price and accounting for treatment charges (TCs) and refining charges (RCs) by refiners. In addition, deductions and payables are included for arsenic and silver content as well as volume or location premia or discounts. Hence, a price formula in a physical transaction of copper concentrate can look as follows:

$$Price\ of\ copper\ concentrate = (Copper\ content\%x\ LME\ Price) - TC - RC - deductions\ (e.g., arsenic) + payables\ (e.g., silver) - volume\ discount + location\ premium$$

While PRAs do not play a role in determining the copper benchmark price per se, they report prices of additional price components used in the pricing formulas and assess TC/RCs linked to specific trading locations based on spot transactions of refiners. DTPs also play an indirect role in price-setting, as they index and report prices to their users for a broader set of metal specifications (e.g., low-carbon copper, semi-fabricated copper), which they can refer to when negotiating. In contracts, premia and discounts can therefore be set in different ways – directly referencing a floating PRA benchmark or a price based on an index reported by a DTP, quoting a fixed annual producer-set price, or another formula or number agreed between parties through negotiation. Hedging at the LME is still viable as the LME-related component makes up for the largest part of the copper concentrate price.

[4] An exception is streaming agreements, which are usually long-term contracts (generally at least 10 years, but can also cover the whole life of mines). They involve an upfront deposit paid to a mine for a right to all or part of the mine's production at a predetermined, fixed price, usually set at the cost of production. They are a kind of debt instrument used for new mines and emerged around 2004, primarily as a result of the difficulties in obtaining favorable debt or equity financing (Perks 2016).

4.2. Cobalt

Materiality, territoriality and production/organizational structures

Cobalt is a minor metal and is considered a micro-market despite the recent demand boom related to EV-linked lithium-ion batteries. Cobalt is largely a by-product of copper and nickel mining. The concentrate can be processed in two main ways – the metallurgical route (20 % of refined cobalt) with metal being used in superalloys and other metallurgical applications and the chemical route (80 % of refined cobalt) with cobalt hydroxide, oxide and sulfate being used for batteries, catalysts or paint (Darton Commodities 2021). DRC is the leading producer country (69 % of supply in 2021; Reichl/Schatz 2023). Short-term demand gaps have been filled by artisanal and small-scale mining (ASM) in DRC, which accounts for approximately 18-30 % of world's cobalt production (World Bank 2020). In 2020, China accounted for 70 % of global refined cobalt output (chemicals and metals) and approximately 86 % of cobalt battery chemicals production (Darton Commodities 2021).

In 2020, the largest miners were Glencore (20 % of global supply), Eurasian Resources Group (ERG, 11,5 %) and China Molybdenum (CMOC, 10,8 %) (ibid.), but the relevance of Chinese companies in mining is expanding. Only a few traders are active in hydroxide (e.g., Stratton Metals) and metal (e.g., Darton Commodities) and more recently the Swiss trader Trafigura is solidifying its role (Trafigura 2022). A key actor in governing extraction is the DRC state-owned company Gécamines which is primarily responsible for allocating concessions to multinational companies through joint ventures (Bolay/Calvão 2022). In light of tight supply and a push to reduce reliance on DRC, new actors moved into upstream segments, especially battery producers (e.g., LG Energy Solutions) and automakers (e.g., BMW). This is also reflected in technology developments, with a drive to reduce cobalt content in nickel-manganese-cobalt (NMC) batteries and greater adoption of cobalt-free lithium-iron-phosphate (LFP) batteries (most notably by Tesla; Bridge/Faigen 2022).

Key price-determination institutions

In the 1970s, the cobalt price in DRC, which was already back then leading cobalt extraction, was set by Gécamines as a producer price (Campbell 2020). Liberalization at the end of the Mobutu regime in 1996 and the privatization of Gécamines in 2002 (Küblböck/Grohs 2017) led to price determination evolving away from producer-set prices. This created an opportunity for PRAs and the cobalt metal price index of PRA Metal Bulletin (now Fastmarkets, after the 2016 acquisition) became a dominant benchmark in the early 2000s, which is based on European industry transactions. Given the materiality of cobalt, low liquidity and the consolidated structure of physical actors that initially had limited hedging interests, PRAs were better positioned to determine cobalt prices than derivative markets.

Yet, there are struggles among PRAs over the superior methodology and generally over journalist price-determination. Regarding the latter, journalistic price-determination methodologies involve subjective interpretation of primary data, specifically as transactions in minor metals appear less frequent and with changing volumes and actors. Thus, the reported prices depend on the judgment and expertise of individual reporters. One PRA stated that "quantity of data and a diversity of assessments is important so each player on the chain, as long as they're involved in the physical space, has a say. But it is the quality of them, how active [they are], what's their kind of visibility." This preference for large flows can reinforce the power of dominant physical actors. A sector expert explains further "I can say this very openly, journalists, unfortunately, are very limited in their capability (…) to verify the figures they receive during their phone calls (…) it's very hard

to establish a trustable and open relationship with some market players (…).” It is also difficult to judge the degree of engagement of actors predominantly interested in speculation. One PRA representatives explains: “a risk that you have with some PRAs is they might be collecting the price only from financial institutions or trading companies, that are not using those commodities for a product. For example, they don't care particularly about what grade the cobalt (or lithium) they trade, they want to make money on buying it low and selling it high.”

There is also critique on the specific price-determination methodology of Fastmarkets’ major cobalt price, which is based on cobalt metal in Rotterdam and discounted by a payable indicator for hydroxide delivered to China. This payable has no grounding in the actual material transformation of cobalt, as one trader emphasizes “pricing hydroxide on the basis of the metal price you are forcing a link even though they are totally separate products and could have totally different fundamentals.” This indicates, on the one hand, that established PRA benchmarks enjoy high reliability by industry actors, but shows, on the other hand, the power of PRAs and established physical actors to maintain the territoriality of price-determination, even though physical cobalt flows have changed from metal to hydroxide and from Europe to China. Hence, PRAs are not passive actors, but one of the architects of price-determination infrastructures.

There have been attempts to change price-determination in cobalt from PRAs to exchange-based benchmarks. Physically-settled futures for cobalt metal were introduced at the LME in 2010, but these were hardly traded. This can be accredited to the limited hedging interest of large physical actors. Further, the physical settlement of cobalt metal by the LME became a risk given that delivery of cobalt from DRC free of child labor could not be guaranteed (Bernards 2021). In 2019, the LME introduced cash-settled futures based on the dominant Fastmarkets benchmark to attract physical and financial actors, yet it has not been traded since its introduction. Instead, CME brokers introduced some mining and particularly EV-related actors (automakers, battery producers) as well as financial investors in 2022 to trade the more financial actor friendly CME’s cash-settled cobalt futures (Spilker 2022). The entry barriers of EV-sector actors to financial hedging are low, as they frequently hedge across various metals used in manufacturing.

Price-setting along GPN

Cobalt products are traded mainly in long-term contacts (70 %) but with flexible prices based on the average monthly Fastmarkets prices for cobalt metal. EV-related actors who buy cobalt hydroxide use the Fastmarkets cobalt metal price and the hydroxide payable, which works as a discount to the metal price. Other quality discounts and premia also play a role; however, they are less standardized as compared to copper and are established largely in negotiations between buyers and sellers. More recently, battery and auto producers have signed long-term contracts with miners due to the fear of tight supply, dependence on DRC and the growing dominance of Chinese companies (Bernards 2021).

There is also informal cobalt trade from ASM, which is sold through local trader depots located close to extraction points. In interviews conducted at two depots in Kolwezi, DRC, traders confirmed that the underlying price paid for the cobalt content in the ores is based on prices reported on the LME website (i.e., the cash-settled futures price based on the PRA Fastmarkets price). In these arrangements artisanal miners have very little room for negotiation and depend on the content measurement which is done by traders at the depot, using their own equipment (so-called Metorex tools) with common allegations about wrongly calibrated scales (Calvão et al. 2021). While there is a relation between ASM cobalt prices and the global benchmark, prices are still very much at the local traders’ discretion.

4.3. Lithium

Materiality, territoriality and production/organizational structures

Lithium is considered a minor metal; it is difficult to standardize and often described as a specialty chemical as many different specifications are traded. Only eight countries at present are producing lithium, from which Chile (dominating brine production), Australia (dominating mining) and China (brine and hard rock) are responsible for nearly 90 % of the global supply (Reichl/Schatz 2023). But new lithium operations are being established in e.g., Brazil, Canada, DRC and Zimbabwe. Around 70 % of supply is used in lithium-ion batteries for EV and electronic devices. Lithium occurs mainly in two forms: carbonate (largely from brines, used in LFP battery cathodes and hydroxide (primarily from hard rock, used in NMC cathodes). With China's large manufacturing capacities of lithium-ion batteries, the majority of downstream activities take place there (LaRocca 2020).

The lithium market is dominated by a small number of large producers, which integrate mining and refining. The Latin American big four producers – Albemarle, Livent, Tianqi Lithium and SQM – still play a key role, but new players such as the Australian Pilbara Minerals and many Chinese actors have emerged. In addition, battery producers (e.g., CATL, LG Chem) and automakers (e.g., Tesla, BMW, BYD) have moved into upstream parts to secure volumes in light of tight supply, through off-take agreements and direct investment into mining and refining capacities. Growing demand and increased spot trade are also attracting international traders, and traders play already a significant role in the Chinese domestic market.

Key price-determination institutions

Before 2021, the majority of transactions in lithium were conducted in long-term contracts on the basis of fixed prices set by leading producers for one or more years, without the direct engagement of any price-determination institution. Frequently, 'world prices' were assessed on the basis of trade statistics, which reflected the multi-year contract prices of major producers (e.g., SQM, Albemarle). Initially, large physical actors dominating the industry argued against benchmark-based pricing given the materiality of lithium (specialty chemical, difficult standardization) but also as the producer-price system reinforced the market power of established producers. However, as higher demand for lithium caused rising prices around 2017 and 2018, lithium producers and an emerging pool of traders used spot transactions to benefit from high margins outside of long-term contracts.

This resulted in more frequent transactions and has enabled the entry of PRAs, which now play a leading role in price-determination. Generally, across PRAs, the territoriality of price-determination is linked to the physical trade of lithium in Asia. Spot prices from the Chinese market are considered a robust indicator, as one analyst stated "in China negotiations are very short-term for a specific quantity. […] So, it's very easy to assume that those prices more or less reflect what Chinese cathode producers are paying." Prices in the seaborn market in Japan and South Korea are another important indicator, as they represent both spot and contract prices. The emergence of PRA benchmarks on bi-weekly, weekly and daily basis created a dynamic of short-termism and enabled shareholders to put pressure on producers to move to benchmark-based and more short-term price-setting. Fastmarkets and BMI are currently the most relevant PRAs, which produce multiple reference prices. However, there is still no single dominant benchmark.

The major derivative markets LME, CME and SGX listed lithium futures in 2021 and 2022. The LME launched a cash-settled lithium contract in 2021 after a lengthy and contested process. First, the choice of Fastmarkets as the provider of lithium pricing came as a surprise when announced in 2019 as at that time BMI was considered the market leader

in lithium pricing. It seems that the decision was made on the basis of Fastmarkets' methodology and experience, the existing working relationships on other cash-settled futures, but crucially due to Fastmarkets' willingness to issue a weekly lithium price index. This was controversial, as at the time the lithium market was still characterized by low numbers of transactions outside long-term contracts. Second, the LME future was contested for choosing lithium hydroxide as underlying as the exchange expected increasing demand for hydroxide in Europe and the USA. However, the carbonate-based battery technology (LFP) has remained dominant, especially in China. Hence, there is contestation around the underlying, which also has a geopolitical element linked to different technologies in the EU/US and China. LME's selection was also criticized for settling simply on the highest value-added product. As an analysis explained: "It's the highest priced product in the market. So, I guess if you are looking at it from an exchange perspective, they'll charge a fee per contracts. If the value of the contracts is higher the fee is a much smaller percentage of the total what you are actually buying." So far, the LME lithium futures have not been traded, similar to the SGX futures based on Fastmarkets lithium carbonate index. Only, lithium futures at the CME that also refers to Fastmarkets lithium hydroxide index are actually traded, but at low volumes.[5]

Critics expressed however doubts, whether the LME or other exchanges can establish futures contracts on lithium useful for physical actors. First, the contractual agreements in physical trade would have to quote the Fastmarkets monthly average price index, which cannot (yet) be considered a leading benchmark price. Second, the technologies of lithium extraction and battery chemistries are dynamically changing, making it difficult to assess which particular grade of lithium is actually going to become dominant. Third, however, hedging interests among physical actors are changing. Traditional producers were skeptical of adopting derivative markets due to their considerable pricing power and lack of derivative trading expertise, but this is changing due to increased volatility and pressures towards more short-term price-setting. Similarly, to cobalt, new market actors (automakers, battery producers, international traders) are more enthusiastic of using futures to manage price risks and often have experience in hedging. 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 hedging and speculation playing a role (Home 2023; Ouerghi/Yang 2023).

Currently, DTPs do not play a role in lithium, but they could become important in lithium as they are ideally positioned for price-determination of minor metals and less standardized grades. Compared to journalistic price determination methodologies, DTPs are cheap to maintain and subject to less individual judgment, but they are still very small and subscription-based. Similarly, to PRAs, DTPs' benchmarks could be used for price-determination underlying cash-settled derivative trading. This is evidenced by LME's collaboration with Metalshub; one market expert explained "Partnerships like with Metalshub, could help LME develop new systems that would have the possibility in the next decades to address those markets"

Price-setting along GPN

Producers initially preferred fixed producer-set prices in long-term contracts to stabilize revenues, but as demand for lithium expanded and spot markets emerged, physical actors, particularly shareholders of mining companies, together with financial investors wanted to get exposure to increasing prices (LME 2021b). The move towards PRA benchmark pricing in short-term contracts is not yet settled or complete – not a single PRA

[5] Within China, the Wuxi Stainless Steel Exchange (EXBXG) offers lithium carbonate futures. According to Home (2023) "China's spot market and the Wuxi futures exchange play [a key role] in the fast-growing industry's price discovery process [in China]".

is a dominant benchmark and large producers pursue mixed strategies in their contracts – e.g., Livent still uses fixed-price annual contracts in 70 % of its 2023 sales (Home 2023). Yet, there is a clear trend towards benchmarking and more short-term pricing, which contributed to higher volatility and more pronounced boom-bust cycles. The use of PRA benchmarks in contracts also allows physical actors to satisfy financing needs, presenting more transparent prices to banks and other financial institutions.

Benchmarks are applied with premiums and discounts. Even though PRAs provide more price specifications than derivative markets, one PRA representative describes: “PRAs price to a certain standard specification and if you had a lithium hydroxide or carbonate of better quality, (…), then you might negotiate a premium (…). There’s always the understanding that commodities like this aren’t really true commodities. They’re variable, they’re non-fungible so what PRAs do is provide a standard reference price, but in full understanding that actual market players are going to negotiate premiums and discounts from that.” Premiums and discounts are frequently determined in bilateral negotiations.

4.4. Comparative analysis

There are ongoing struggles among and within price-determination institutions and despite the increasing role of derivative markets also in minor metals, there remain differences in global benchmarks: physically-settled LME futures for copper, established PRA benchmark along with physically- and cash-settled futures for cobalt, and competing benchmarks of PRAs with links to cash-settled futures for lithium (Table 3). This includes new forms of cooperation between price-determination institutions, particularly as a way to develop new derivative products for minor metals.

The dominant price-determination institution in each metal depends on the materiality of metals, interests of physical and financial actors and related production and organizational structures. In copper, price determination through physically-settled futures is possible given its specific materiality that allows for standardisation. Further, the large number of miners, smelters, refiners and traders at every stage lead to price risk management needs by most powerful physical actors. This has supported the development of derivative markets and futures prices becoming the global benchmark, making London a ‘centre of gravity’ in the copper GPN, where annual contracts are renegotiated during the ‘LME week’, and a meeting point of physical and financial interests. In contrast to other derivative markets, elements of a infrastructure oriented towards physical actors are still in place at the LME. However, there are struggles between physically-oriented and financial interests that have led to the LME becoming more financialized and increasingly dominated by financial actors, which was accelerated through the purchase by HKEX.

In cobalt and lithium, PRAs have become dominant price-determination institutions, yet not without struggles between them and competition by derivative markets. The basis for the dominant PRA price in cobalt is the historically more important cobalt metal trade in Europe, which is contested by the now dominant EV-actors who use cobalt hydroxide and are based in Asia. For lithium, emerging battery technologies demand different products (carbonate for LFP in China versus hydroxide for NCM in Europe/US). Changes in uses and technologies (and hence materiality) therefore change the relevance of specific basis for benchmarks. This can include geopolitical elements as in both cobalt and lithium the historically dominant (but now smaller) role of European and US actors is still enshrined in PRA benchmarks. This highlights our broader understanding of territoriality that also considers financial and trading hubs, where price-determination institutions are largely located. In all three metals, China has emerged as the dominant location of processing and trade in the physical dimension of the GPNs, but exchanges and PRAs based (and regulated) in the Global North, in particular the UK, still control global price-determination.

Yet, also for minor metals derivative markets – through cash-settled futures – have become more important. Traditionally, the small number of large, vertically-integrated and territorially concentrated firms in both cobalt and lithium GPNs led to limited hedging interest among these dominant actors, as they had considerable power to influence PRA prices (cobalt) or set producer prices (lithium). This is however changing with new extractive frontiers opening and new actors entering the GPNs (battery and car makers, international traders) that have hedging interests to deal with price risks in these still opaque markets, evidenced by the recent take-up of trade of cobalt and lithium futures at the CME. PRAs favor these developments as they co-create cash-settled futures infrastructures and so can profit from derivative market growth.

Financial actors and their speculative interests, together with physical actors' price risk management and speculative interests, have also a key role in the strategies of price-determination institutions. This is evident in the struggles around infrastructures at the LME that have defined trajectories of financialization and its limits. The LME was responsive especially to the interests of financial investors through the provision of standardised futures contracts for cobalt and lithium. It is however unclear to what extent these products responded to the needs of physical actors, in terms of the underlying materialities of the two metals and prevailing pricing power. Even though financial actors' needs are easier to satisfy, they seem to be reluctant to adopt futures contracts that are not actively traded by large physical actors, resulting in low trade as in the cases of cobalt and lithium at the LME. Financialization in metal markets therefore also depends on the usability of contracts for physical actors and their willingness to use derivative markets for price risk management and/or speculation. This limits the de-linking of derivative markets and price-determination from physical actors' needs and sets limits to financialization.

In price-setting of all three metals, we see a continuous importance of long-term contracts, but with variable price components through benchmarks. The creation of more short-term benchmarks' (hence specific market devices) has also enabled more spot and short-term contracting. While copper contracts have for a long time used average LME futures price benchmarks, PRAs report diverse premiums and discounts, particularly applied in spot transactions. PRAs benchmark-based price-setting in cobalt and lithium has replaced producer-pricing. In cobalt, this shift took place two decades ago, but for lithium, these changes are rather recent. PRAs support this by providing bi-weekly, weekly and now daily benchmark prices. Their cooperation with derivative exchanges increases the possibilities for more short-term trades. The increased use of benchmarks in contracts means that dynamics within price-determination processes are transmitted directly to actors and locations in GPNs via price-setting.

These developments in price-making processes have distributional implications. First, different price-determination institutions and benchmarks impact actors and locations along GPNs differently. The cases of cobalt and lithium show how specific underlying grades of futures or PRA assessments favor some actors (cobalt metal users, lithium hydroxide users) vis a vis others (cobalt hydroxide users, lithium carbonate users), and how this is linked to established locations and interconnections of physical actors and price-determination institutions. Different PRAs have different methodologies, but they generally give power to dominant physical actors' transactions and, in some cases, opinions of financial actors. Whereas derivative markets are portrayed as an open marketplace, their infrastructures have high entry barriers (know-how, technology, access to finance, costs) which have increased with sophisticated trading strategies and large physical and increasingly also financial actors can easily dominate markets and prices. This favors financial interests and specific physical actors such as international traders that can optimize hedging and speculation strategies. Production and organisational structures therefore not only impact price-determination and -setting, but also vice versa

– the use of specific market devices such as benchmarks generally, specific PRA basis or futures have organizational as well as distributional implications on GPNs.

Second, price volatility and related risks have increased due to higher transmission along GPNs but also more volatile benchmark prices. The shift to benchmark-based price-setting is linked to price changes being transmitted more strongly to actors in GPNs and hence increases short-termism, particularly as price benchmarks have become more short-term from bi-weekly to weekly and daily. In addition, price volatilities have also shown new dynamics given the dominance of financial actors and trading strategies (Chen et al. 2019). Some physical actors contest price-determination being heavily influenced by "modern speculators", such as high-frequency traders, and that metal price dynamics become increasingly interlinked with other assets via financial actors' portfolios. This is most importantly the case on derivative markets linked to institutional changes that made these markets more financialized and dominated by financial trading strategies. PRAs and DTPs also play a role in expanding the relevance of financial actors as they support the creation of cash-settled futures, enabling the integration of more metals and price components into derivative markets. But PRAs also draw in their methodologies on financial actors. While exposure to short-term price volatility is favored by some actors (shareholders of mining companies, international traders, financial actors), for other actors it means being exposed to (more short-term) price changes without being able to deal with these risks. In particular, actors in producer countries often have limited access to any form of price risk management. In the mining sector, this includes local mining companies and the ASM sector, but also state revenues via taxes and royalties or through the more variable income of state-owned mining companies.

Third, the use of global benchmarks does not reflect local cost structures (mining, electricity, labor, etc.) at locations of extraction and therefore actual costs of production. It rather assumes an 'average' or 'standardized' costs. As such it is difficult to talk about benchmark prices as standardised; rather, they define the end product, but not the specific standards of production, ignoring in fact the complexity and reality of local production systems. This is problematic as it affects the margins of different actors in GPNs and the adoption of improved production standards. If all materials are traded at comparable prices irrelevant of actual costs, 'cheaper' producers retain a higher revenue. This encourages cost-cutting, with likely labor, social and environmental consequences and problematic implications for adopting socially and environmentally sustainable standards. Price-determination institutions are also difficult to regulate on a global level, given their embeddedness in financial and trading hubs and remoteness from extractive locations. Hence, producer countries have generally lost power to determine prices through the dominance of global benchmarks and the regulations of price-determination institutions in few, often very liberal, jurisdictions. But producer country sates have also reinforced the role of global benchmarks by demanding the use of benchmarks as the basis for taxes which links their revenues directly to benchmark volatilities.

Table 3: Price-determination and -setting in copper, cobalt and lithium

	Copper	Cobalt	Lithium
Materiality of metal	Base metal Standardized and storable end product (copper cathode)	Minor metal By-product of copper and nickel Different processing routes (cobalt hydroxide – chemical processing, cobalt metal – metallurgy) with different intermediate and end products	Minor metal Two extraction methods – brine and mining Large variety of specifications dependent on particular buyers' needs Some refined lithium products are not easily storable Changing technology – not clear if carbonate (usually from brine) or hydroxide (usually mined) dominant in battery production
Territoriality of network	Extraction and processing distributed globally (Chile, Peru, China, DRC, Zambia) Large share of processing capacity based in China Switzerland is key trading hub LME based in London	High concentration – 70 % of cobalt extracted in DRC Majority of processing based in China Key PRAs based in London – price assessment based on historical (Rotterdam) or current (China, Korea, Japan) import locations	Traditionally concentrated in Latin America (brine) New mining operations (spodumene) in Australia, China, DRC, Ghana, Zimbabwe Majority of processing based in China Key PRAs based in London and China
Production and organisational structures	Large annual volumes traded Large number of miners, smelters, refiners Large number of international traders at every stage (partially vertically integrated) Industrial mining	Micro-market Small number of integrated firms (international traders, mining companies) Few but powerful international traders Battery and car makers engaged upstream Industrial and artisanal mining	Small, but growing market Historically a small number of mining/extractive (some with integrated refining) firms, but new mining/refining actors linked to EV-boom Battery and car makers engaged upstream Very few international traders Large spot market in China and many domestic traders Industrial mining

Physical actors' interests	Price risk management by all actors except miners – shareholders' exposure Financial speculation also by physical actors Influence of LME processes to remain physically-oriented (Ring, date structure, clearing)	Few actors with hedging needs Large actors' views strongly represented in PRA benchmark EV-linked actors want to hedge, but without large actors not sufficient liquidity	Development of new operations to secure supply including by battery and EV manufacturers Little interest in hedging among traditional actors Different interests for benchmark (carbonate vs hydroxide) linked to battery technology (LFP in China vs NCM in Europe/US) EV-linked actors want to hedge, but without large actors not sufficient liquidity
Financial investors' interests	Exposure to price movements through simplified, liquid derivative markets Exposed to risk when trading physically-settled futures in non-liquid/small markets – favor cash-settled futures in these markets Interest in electronic and high-frequency trading Simplified derivative characteristics (no date structure, futures vs forwards, daily clearing) Shareholders favor use of benchmarks in contracts		
Price-determination	LME physically-settled future as a benchmark LME undergoing changes (purchase by HKEX, electronic trading, financialization) Struggles between financial & physical interests over infrastructures PRAs and DTPs can determine prices of less standardized grades	Established benchmark PRA Fastmarkets Pricing based on cobalt metal – contested by users as reinforces historical market powers (EU-based trade) and not relevant for EV-sector Physical- and cash-settled futures at LME but not traded, growing trade on CME DTPs as potential future price-determination venue	Growing spot market in China created opportunities for PRAs No single established benchmark (large number of PRA benchmarks but dominance of Fastmarkets and BMI) Cash-settled hydroxide futures at LME but not traded, some trade on CME DTPs as potential future price-determination venue
Price-setting	80 % long-term contracts (annual re-negotiations at LME week) and 20 % spot Variable prices in contracts based on benchmark average monthly LME price Use of benchmarks also for other price components, based also on PRAs	70 % long-term contracts (also to secure supply for battery and EV producers) with variable prices Benchmark is average monthly PRA price (payable structure) for cobalt hydroxide Some fixed price sales by traders Move to more short-term benchmarks Other price components largely negotiated bilaterally	Traditionally traded under multi-year contracts with fixed prices set by producers Recently mixed strategies – producers sell parts of supply on fixed prices and rest on spot/benchmark prices Recently drive towards shorter-term contracts and benchmark prices (PRAs – Fastmarkets and BMI) especially among new EV-linked market actors Other price components largely negotiated bilaterally

Source: Own elaboration.

5. Conclusions

In this paper, we conceptually and empirically analyzed the making of ‘world prices’ and their use along GPNs for the critical metals copper, cobalt and lithium. We demonstrate that price-making processes are not abstract or objective, but subject to struggles. The use of specific price-determination institutions for global benchmarks and the general use of more short-term benchmarks – be it based on futures, PRAs or DTPs – reinforces the power of certain institutions and actors, with distributional implications. Hence, price-making, and questions around who is involved in price-determination and can demand specific price-setting along GPNs (e.g., use of benchmark, short-term changes), add important power dimensions to governance and through this new actors and channels to exert power in GPNs. By explicitly assessing price-making and struggles around it, we politicise and problematize the processes leading to ‘world’ prices in metal markets and their transmission through GPNs.

We end with two conclusions. First, price-making in metals is a contested process that is influenced by power struggles between physical and financial actors’ interests and the materiality of metals. For the three analysed metals, power struggles emerge on different levels and with different intensities, depending on the type of dominant price-determination institutions and GPN territoriality and organizational dynamics, but they are an important governance dimension for all. Generally, benchmark-based price-setting has increased and has contributed to increased short-termism in contracts and trade. We see financialization processes in all three metals as newly developed benchmarks and futures are promoted by financial interests and specific physical actors as it allows for easier and short-term exposure to metal price developments. The specific materialities of metals can however limit the creation of futures markets and production and organizational structures can constrain the use of derivatives and benchmarks. In addition, the territoriality of established price-determination institutions located in the Global North is relatively persistent due to strong links with powerful physical actors. However, the entry of new actors in metal GPNs, such as auto- and battery makers in the cobalt and lithium sector or large international traders, could alter price-making in the near future.

Second, the key institutions and actors that determine prices (LME, PRA, DTPs) do not act transparently and are even less democratically legitimated, portraying themselves as mere ‘price discoverers’. Price-determination institutions do generally not view themselves as having price-making power; rather, they present themselves as passive markets, trade enablers, media companies, impartial and passive actors, which obscures the role of their infrastructures on prices and related struggles. The LME is presented as a common market place, which provides access to information for all actors and locations, but it is dominated by a small number of actors that were until recently physically-based and moved increasingly to being driven by financial motives. PRAs and DTPs by themselves have power by deciding on their methodologies and the involved physical and financial actors. PRAs state their aim as providing transparency in markets and acting as a "mirror to the trade" (Horsnell/Mabro 1994), but they do not just ‘mirror’ trade, but actively influence its image (Adams 2019).

More generally, questions related to how prices are made in metal markets are frequently discussed in terms of ‘market maturity’. Mature markets (such as copper) are considered to be those with dominant global benchmarks, standardized contract structures and liquid futures, while immaturity is linked to greater discretion of physical actors, benchmarks not being (fully) adopted in contract terms, or lack of well-functioning derivative markets (cobalt and lithium, to different extents). This framing is problematic, as it assumes not only a certain ‘natural’ trajectory of price-making processes, with price-making based on liquid financial products as the most desirable (“mature”) outcome. Such a narrative bypasses the role of institutions, actors and interests who actively shape these very processes. This highlights the academic and political need to talk about price-determination institutions, price-setting and their regulation, and who has access to determine and set prices and who does not.

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