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Traceability and foreign corporate accountability in mineral supply chains

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Abstract

Industrialized economies in the EU depend heavily on imports of minerals. The extraction and parts of the transport and processing of these minerals take place in the Global South and often bear high human rights and environmental risks. A lack of traceability in mineral supply chains makes it particularly difficult to hold companies accountable for negative environmental and social impacts of their operations and those of their suppliers. This paper analyses three mineral supply chains (copper, platinum, and gold) in order to develop propositions about how supply chain-specific characteristics affect traceability and foreign corporate accountability (FCA) in mineral supply chains. The analytical framework focuses on three dimensions: geopolitical dynamics, industry characteristics, and private governance mechanisms. The authors argue that chain-specific characteristics may foster or thwart traceability and FCA in mineral supply chains and thus provides a novel contribution to the debate on traceability and accountability in mineral supply chains.

Keywords: copper, gold, mineral supply chains, platinum, traceability.

1. Introduction

New legislation, such as the German Supply Chain Due Diligence Act or the planned EU Directive on corporate sustainability due diligence, enhance the legal requirements for companies in the EU that are involved in mineral supply chains. Severe human rights and environmental risks related to the extraction and processing of some minerals as well as the high level of complexity of mineral supply chains make it important and challenging to hold foreign companies accountable for possible malpractices in these chains (e.g., Deberdt & Le Billon, 2021; Kim & Davis, 2016; Nepstad et al., 2014). Foreign corporate accountability (FCA) is understood as the assumption of responsibility by companies in the Global North for negative social and environmental impacts of their operations or those of their suppliers and sub-suppliers in the supply chain (Gustafsson et al., 2023). Environmental and human rights due diligence has gained importance in mineral supply chains; however, a lack of information about the provenance of minerals as well as production and processing locations and conditions presents a challenge for companies and actors that seek to hold companies accountable (Burritt & Schaltegger, 2014).

An important prerequisite for assuming FCA is the "ability to identify and trace the history, distribution, location and application of products, parts and materials" (United Nations Global Compact and BSR, 2014, p. 6). This includes knowing which actors are involved at the different tiers of a supply chain (including production, processing, transport, trade, distribution and application) as well as the respective production and processing localities (Barash-Harman, 2020; Gardner et al., 2019). Traceability allows companies, regulatory authorities, and right holders to ensure and verify the accuracy of information related to a product's origin, composition, processing history, quality, safety, and labeling but also related to the compliance with environmental and social standards (Konstantinov, 2021). Enhancing product traceability involves establishing tracking systems, tools for data collection as well as engaging and sharing information with suppliers. This increases transparency and information about a product's journey and its production and processing conditions (product traceability) as well as the firms that form part of a given supply chain (supplier traceability). Having access to this type of information is a precondition for companies to be able to assess (and mitigate) the human rights and environmental risks

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along their supply chains and for regulatory bodies and civil society groups to hold companies accountable. In short, traceability is a means to enhance transparency, and accountability in global supply chains is premised on transparency regarding corporate practice.

Ensuring FCA in mineral supply chains is particularly challenging due to the low level of traceability of these chains. Mineral supply chains are characterized by complex governance structures. While the extraction of minerals mainly takes place in the Global South, the processing, trading, and transport of minerals involve numerous actors in various countries with varying regulations. Hence, the governance of mineral supply chains is driven by a range of local, regional, and transnational public, private, and civil society actors with diverging degrees of resources and power (Partzsch, 2020). Furthermore, most minerals are undifferentiated goods (Barash-Harman, 2020), that is, products with the same material specifics regardless of where they have been extracted, making it more difficult to trace them back to individual mines. Mineral aggregation points, for instance, smelters or refineries, where material from different mines is mixed, present the biggest obstacle to traceability (Muirhead & Porter, 2019).

The issue of traceability in mineral supply chains has mainly been addressed by three strands of literatures. First, the literature on supply chain management (e.g., Calvão & Archer, 2021; Hofstetter, 2019; Kros et al., 2019; Liao et al., 2020) centers on the systems and tools of individual firms for tracking the provenance and journey of products along supply chains, with a focus on food and textile supply chains. Second, global value chain scholars discuss how the governance of global value chains and the strategies of lead firms affect the enforcement of sustainability standards along these chains (Gereffi et al., 2005; Humphrey & Memedovic, 2006; Pietrobelli & Rabellotti, 2011; Ponte & Gibbon, 2005; Staritz & Whitfield, 2017). Third, the literature on traceability and due diligence schemes (e.g., Cartier et al., 2018; Deberdt & Le Billon, 2021; Potts et al., 2018; United Nations Global Compact and BSR, 2014; Young, 2018) explores the traceability or chain of custody models of specific traceability schemes and their effects with a particular focus on "conflict minerals." Despite the many contributions of these literatures, they shed little light on the supply chain and commodity-specific characteristics that shape traceability and FCA in mineral supply chains. This paper, therefore, asks the question: How do supply chain characteristics affect traceability as a necessary precondition for FCA?

To answer this question, we develop a framework for analyzing how supply chain-specific characteristics affect traceability in mineral supply chains. The framework consists of three interrelated categories: geopolitical dynamics, industry characteristics, and private governance mechanisms. All three categories have important implications on the traceability of metals along supply chains. Building on the insights of three case studies (copper, platinum, and gold), the paper teases out factors within each category that may foster or hinder traceability in mineral supply chains. While the paper does not study FCA empirically, it develops propositions about how these factors may affect FCA. The framework brings together the existing literature on global value chain, supply chain management, and traceability schemes in mineral supply chains and comprehensive empirical data with the aim to contribute to theory construction. The case studies are based on an analysis of comprehensive empirical data collected during several weeks of field research in Switzerland, Chile, Peru, and South Africa in 2021 and 2022 as well as online interviews with actors in Zimbabwe, the United Kingdom, and Germany.

The paper is structured into five sections. Section 2 reviews the core findings and gaps of the literature on traceability in global (mineral) supply chains. Section 3 develops an analytical framework for studying the specific contextual circumstances of mineral supply chains and their effects on traceability. Section 4 presents the methodology used in this paper. Section 5 explores how supply chain-specific characteristics affect traceability in the copper, platinum, and gold supply chains. Building on the three case studies, Section 5 develops propositions about how traceability affects FCA. The final section discusses practical implications of our findings for FCA in mineral supply chains.

2. Traceability in global supply chains

This section reviews how traceability has been studied by the literatures on supply chain management, global value chains, and on traceability schemes with a focus on mineral supply chains. The literature on supply chain management views traceability as a strategic tool for sustainable supply chain management that supports companies in achieving key sustainability objectives and in reducing reputational risks. The primary units of analysis of

this strand of literature are individual firms and the systems and tools they use for tracking the provenance and journey of products and their inputs along supply chains (Germani et al., 2015). Studies have particularly focused on (a) different traceability or chain of custody models, such as mass balance, book and claim, identity preservation, and product segregation (see United Nations Global Compact and BSR, 2014; van den Brink et al., 2019); (b) the role of new technologies and information systems, such as blockchain technology (Calvão & Archer, 2021; RCS Global & ICMM, 2017); and (c) traceability effectiveness (Kros et al., 2019; Liao et al., 2020).

The literature on global value chains adds to the literature on traceability by looking at how the governance structure(s) within a supply chain, that is, the relations between firms in different countries with varying capabilities, functions, and power, and the strategies of lead firms affect the enforcement of sustainability standards along the chain (Gereffi et al., 2005; Ponte & Gibbon, 2005; Staritz & Whitfield, 2017). Lead firms may not be involved in the production process themselves but have the power to enforce specifications related to the product and the production process, including traceability requirements. Lead firms only tend to establish and enforce traceability systems if they are forced to do so by law or because this is part of the firm's corporate social responsibility strategy (Humphrey & Memedovic, 2006; Pietrobelli & Rabellotti, 2011).

Many companies that manufacture complex products rely on voluntary schemes or standards, such as the Jewelry Council Chain-of-Custody standard, that establish models for entire mineral supply chains or specific tiers, for example, from mine to smelter (van den Brink et al., 2019). The literature on traceability schemes mainly assesses the purposes and effects of specific sustainability and responsible sourcing schemes (Cartier et al., 2018; Potts et al., 2018; Young, 2018). Many studies focus on potential negative impacts of traceability schemes in supply chains of so-called conflict minerals (Deberdt & Le Billon, 2021; Hilson, 2014; Muirhead & Porter, 2019). Thereby, the primary unit of analysis is specific traceability schemes, either studied as single cases or using comparative designs. From this perspective, traceability of materials is viewed as a requirement that assures that certified minerals are not mixed with non-certified or illegal minerals.

In a comparative study, Muirhead and Porter (2019) identify three properties that shape traceability systems across different sectors: the physical characteristics of the traced object; the distance between the traced object, the monitoring technology used, and the effect that the traceability system seeks to control; and institutionalized power relations understood as a mix of public, private and technical components that enable or thwart traceability systems. The authors tease out relevant material and supply chain-specific properties that affect traceability systems at sectoral level that inform the analytical framework of this paper. However, the authors do not investigate how these properties vary within sectors. Since supply chain-specific characteristics vary for each metal, they impact traceability within the supply chain in different ways. This paper contributes to the debate by developing a framework for studying how chain-specific characteristics affect traceability and its effects on FCA in metal supply chains.

The strands of literature discussed in this review identify a range of obstacles related to implementing supply chain traceability at firm level. First, suppliers are not always willing (or able) to share critical, accurate, and up-to-date product and process-related information about themselves and their sub-suppliers with their buyers due to confidentiality concerns (Kros et al., 2019; United Nations Global Compact & BSR, 2014). Second, establishing supply chain traceability is costly and time-consuming. It requires long-term investments in technologies and information systems, high levels of engagement and commitment within firms, and extended networks and coordination between different supply chain actors, for example, through industry-wide traceability schemes. Without top management support, firms are therefore unlikely to establish solid traceability practices and processes. Third, enhancing supply chain traceability is not always considered a priority by the top management and is therefore often only pursued as a reaction to certain supply chain challenges or regulatory obligations (Liao et al., 2020). Fourth, the pressure to install traceability systems and to make information publicly available differs between firms and industries due to varying risks, complexities, and regulations (Kros et al., 2019). Finally, pursuing traceability is particularly challenging in long and complex supply chains with tiers that are opaque, for example, distributors or traders that are reluctant to share information (Muirhead & Porter, 2019; United Nations Global Compact & BSR, 2014; Young, 2018). In the case of mineral supply chains, material aggregation points, such as smelters or refineries, present chokepoints that make traceability particularly challenging because minerals from different sources are mixed and undergo significant chemical and physical transformations (RCS Global and ICMM, 2017). Buyers in the Global North, therefore, face the challenge that the longer and more complex the

supply chain, the more limited their ability to track products and processes along the chain and to enforce traceability (Hofstetter, 2019).

The discussed strands of literature have generated important findings on how traceability can be implemented effectively by firms in global supply chains, the role of sustainability schemes in enhancing traceability, and by teasing out obstacles to supply chain traceability at firm level. But they shed little light on how the specific characteristics of mineral supply chains shape traceability in these chains and with which effects on FCA. This article aims to close this gap by developing an analytical framework for studying how supply chain characteristics affect traceability in mineral supply chains and by laying out the relationship between traceability and FCA.

3. Analytical framework

3.1. The relationship between traceability and FCA

FCA has two dimensions. The first dimension relates to the ability of companies to take corporate social responsibility, for example, for adverse impacts of their business activities or those of their suppliers. The second dimension of FCA centers on the ability of state and civil society actors to hold companies accountable. Enhancing product and supplier traceability in global supply chains is of particular importance for both dimensions of FCA because it is directly linked to achieving higher levels of supply chain transparency. Traceability schemes are therefore an important element of many sustainability standards and measures at firm level (United Nations Global Compact & BSR, 2014). Enhancing traceability involves establishing tracking systems, tools for data collection as well as engaging and sharing information with suppliers. This increases transparency about a product's journey, its production and processing conditions (product traceability), and the companies involved in production, processing, trading, and transport (supplier traceability). Accountability in global supply chains is premised on transparency regarding corporate practice, for example, information about which companies form part of a given chain, factory locations, transport, working conditions, and social and environmental impacts (Doorey, 2011; Islam & Van Staden, 2022). Supply chain traceability, transparency, and FCA are therefore not only interlinked but may affect each other.

Enhancing traceability in global supply chains may have positive effects on quality control (Chen et al., 2014) and supplier management (Handfield et al., 2015) but also makes it easier for companies to assess (and mitigate) potential social and environmental risks along the supply chain because they have more information on their suppliers and production conditions (Grötsch et al., 2013; Kleindorfer & Saad, 2005; Steven, 2015). Social risks in mineral supply chains may include conflicts over land, resettlements, and the provision of infrastructure with local communities in mining areas, ineffective complaints mechanisms, unsafe working conditions, and the violation of workers' rights as well as issues related to gender and the equitable distribution of benefits (Kemp et al., 2016). Environmental risks refer to the contamination of water and water shortages in mining regions, air pollution due to emissions and dust, acid mine drainage, and inadequate mine site rehabilitation (Rüttinger & Corder, 2020). Engaging more closely with suppliers and stakeholders along mineral supply chains, building multi-stakeholder initiatives to trace commodities collaboratively, and establishing tracking systems can help companies to identify (sub-)suppliers and potential risks associated with their businesses and to prove claims about sustainability by their suppliers (United Nations Global Compact and BSR, 2014). Supply chain traceability may therefore help companies to assume responsibility for negative social and environmental impacts in their mineral supply chains.

From a different perspective, traceability data can be used by state actors, civil society organizations, and negatively affected stakeholders to hold companies accountable (Grant & Keohane, 2005; Gustafsson et al., 2023; Kramarz et al., 2022). If a chain's lead firms as well as environmental and human rights risks are widely known, regulatory authorities, civil society actors, and right holders have more leverage to push for the mitigation of these risks and the enforcement of certain standards by companies. In contrast, if there is little information available about the companies and risks involved in mineral supply chains, these actors are neither able to monitor whether companies comply with binding legislation and voluntary standards nor to connect transnationally in order to exchange information and build alliances (see e.g., Grimard et al., 2017; Rotter et al., 2014).

3.2. Supply chain characteristics and traceability

Supply chain-specific characteristics, such as material specifics, the organizational structure of a supply chain, or the regulatory frameworks in the countries where mineral extraction and processing take place, have a significant impact on traceability in mineral supply chains (Muirhead & Porter, 2019). The effects of these supply chain characteristics on traceability may differ between chains but also between the individual tiers of mineral supply chains. Our analytical framework (see Fig. 1) groups these characteristics into three interrelated categories that affect traceability and FCA in mineral supply chains: geopolitical dynamics, industry characteristics, and private governance mechanisms. The framework builds on the analysis of our empirical data as well as on the literatures on global value chains.

3.2.1. Geopolitical dynamics

The category geopolitical dynamics is concerned with how geography affects the scope of influence of key states and regional organizations, for example, the EU, in mineral supply chains and the relationships between them. These states and organizations may form part of mineral supply chains as producers, processors, traders, manufacturers, consumers, or recycling countries. The political relations and power dynamics between these states and/or organizations have an impact on the implementation of sustainability and traceability standards along the chain (e.g., Liao et al., 2020; Maihold 2022). It is therefore important to identify which states and regional organizations dominate mineral supply chains or individual tiers of these chains and to analyze the power dynamics between them in order to gain a better understanding of the process of standard setting, enforcement, and compliance. For instance, countries or regions that play a dominant role on the demand side as important buyers of minerals, for example, the EU, have the power to implement their normative agenda with effects on the entire supply chain. Due to their powerful position in some mineral supply chains, they are able to set and enforce standards related to sustainability and traceability that not only affect companies within their jurisdiction but also companies in mineral producing, processing, or trading countries that seek to export to the EU and force them to adapt to EU legislation. Various EU member states have recently adopted mandatory due diligence laws and a proposal for an EU supply chain law is currently under discussion. The EU and the United States have also adopted binding legislation that particularly targets minerals that are labeled as "conflict minerals": tin, tungsten, tantalum, and gold (3TG). These types of mandatory regulations oblige companies to enhance traceability and transparency along their downstream supply chains, to conduct risk assessments, and to disclose sustainability-related information. They also increase the ability of state actors, civil society organizations, and right holders to hold companies at the buying end of supply chains accountable for their actions and those of their suppliers (e.g., Deberdt & Le Billon, 2021; Kim & Davis, 2016). In contrast, regions or states that have not adopted or even oppose binding supply chain regulations and do not engage in international standard-setting organizations, such as the OECD, present a challenge for traceability and FCA along mineral supply chains. This becomes particularly problematic when these states dominate mineral supply chains or specific tiers, for instance, China in the copper supply chain (see Lin, 2010). The position of states and regional organizations in mineral supply chains as producing, processing, manufacturing, trading, or consumer countries, as well as the power dynamics between them is therefore one important factor that affects traceability and FCA.

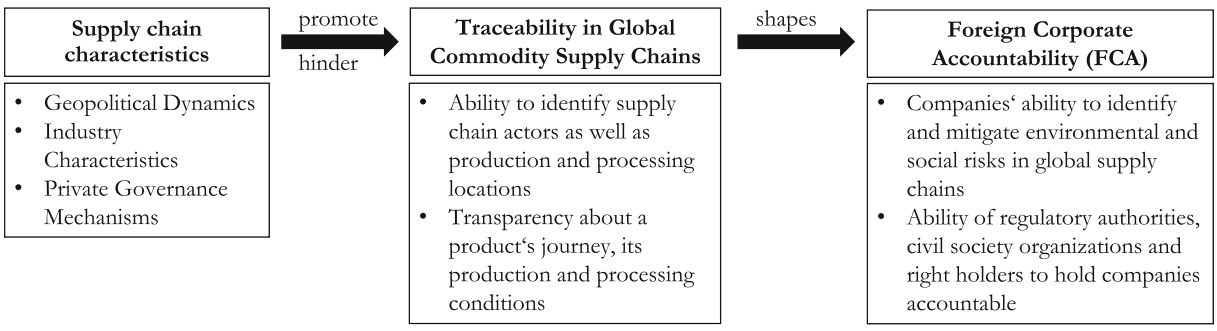

Figure 1 Supply chain characteristics, traceability, and FCA in mineral supply chains. *Source*: The authors.

3.2.2. Industry characteristics

Industry characteristics relate to where and how a commodity can be extracted, transported, and processed, its value and its use. On the one hand, the level of concentration of deposits affects traceability: it is much easier to trace the provenance of minerals if deposits are concentrated in a few countries. On the other hand, geological particularities and the chemical composition of minerals can impact the ability to trace minerals (Muirhead & Porter, 2019). For instance, some minerals can only be extracted via large scale, industrial mining. This makes it easier to track the actors involved in extraction compared to (in some cases illicit) artisanal mining (Finlay, 2020; Hirons, 2020). The main use and value of commodities also play a role in supply chain traceability. Pressure from end consumers to enhance traceability and sustainability as well as public scrutiny tends to be higher for minerals from conflict-affected and high-risk areas and for minerals that are used for jewelry, such as gold, than for industrial metals that are used in complex end products like electronic devices, such as copper. In the same vein, the introduction of "tagging initiatives" such as mineralogical fingerprinting in mineral supply chains is only economically viable for-high value and high-risk minerals such as gold (Melcher et al., 2008; van den Brink et al., 2019). Finally, industry characteristics determine how minerals are transported with effects on traceability. Tracking the journey of commodities that are transported in bulk, such as copper, is easier than precious metals that can be smuggled and traded in small quantities.

3.2.3. Private governance mechanisms

This category centers on how lead firms, existing private governance mechanisms, such as voluntary standards and certification schemes, and the overall firm structure of specific mineral supply chains shape traceability in mineral supply chains. Lead firms not only have the power to enforce requirements related to a product's quality and its production process but also related to sustainability and traceability at specific tiers of mineral supply chains or along the entire chain (Kaplinsky & Morris, 2001; Ponte & Gibbon, 2005; Staritz & Whitfield, 2017). In mineral supply chains, such lead firms include large mining companies and refiners as well as major trading houses and manufacturers with a large market share. In contrast to agricultural value chains, which are often dominated by large manufacturers or retailers, the power relations between dominant firms at different tiers of mineral supply chains are more balanced (Müller et al., 2022). Enforcing traceability in these chains therefore requires cooperation between dominant firms at all tiers of mineral supply chains. Lead firms use different avenues to set and enforce standards related to traceability and sustainability in mineral supply chains. On the one hand, they specify their traceability requirements in their contracts with suppliers. On the other hand, they also engage in industry associations that bring together lead firms at different tiers of supply chains and set industry standards, such as the International Council on Mining and Metals (ICMM), or in voluntary standards and certification schemes, for example, the Copper Mark. The level of traceability in a given mineral supply chain also depends on its firm structure, that is, the number of tiers it encompasses and the number of companies that are involved at each tier of the supply chain. For instance, tracking the provenance and journey of metals is easier in chains where manufacturers buy directly from metal producers or refineries, in contrast to chains with several layers of traders which are often reluctant to provide information about their suppliers. In the same vein, it is easier to trace minerals in chains in which a small number of companies operate at each tier or at some tiers of the chain than in chains with a high level of fragmentation at firm level.

Figure 1 presents a summary of our analytical framework. Supply chain characteristics affect traceability in mineral supply chain, that is, the ability to identify supply chain actors, production and processing locations as well as transparency about a product's journey and its production and processing conditions. Enhanced traceability and transparency in turn may affect the ability of companies to identify and mitigate environmental and social risks in their supply chains as well as the ability of regulatory authorities, civil society organizations, and right holders to hold companies accountable.

4. Methodology

This paper seeks to contribute to constructing theory by developing (tentative) propositions about how supply chain characteristics affect traceability and FCA in global mineral supply chains (Levy, 2008). These propositions are derived from three case studies: the copper, the platinum, and the gold supply chain. These commodities are

mainly sourced outside the EU and their supply chains involve states, companies, and right holders from the Global South as well as the Global North. The three supply chains highlight different aspects of our analytical framework which helps us to develop propositions about how these aspects affect traceability and FCA in mineral supply chains. For instance, platinum, copper, and gold vary regarding their use, existing regulation, and the concentration of production with effects on FCA. While gold is mainly used for jewelry and as an investment, copper is a purely industrial metal, and platinum is used in all three fields of investment, jewelry, and industrial use. The gold supply chain is already more strictly regulated than the supply chains for copper and platinum. The platinum supply chain is highly concentrated at country and firm level with more than 90% of platinum reserves located in Southern Africa while the copper and gold supply chains are highly fragmented.

The paper follows a three-step approach. First, we analyze how geopolitical dynamics, industrial characteristics, and private governance mechanisms affect traceability in the copper, platinum, and gold supply chains. Building on the three case studies, we then identify factors within each category that affect traceability in mineral supply chains in positive or negative ways. Finally, we discuss how these factors may affect FCA.

The analysis of the three supply chains is based on a triangulation of research data from three sources of evidence. It draws on comprehensive desk research, statistical data (UN Comtrade (n.d.) and data provided by national statistics offices), as well as on expert interviews with supply chain actors, public entities, international organizations, and civil society representatives. Desk research included scientific literature, reports by civil society organizations about mineral extraction and processing in Latin America, Sub-Saharan Africa, China, and the EU with a particular focus on the implementation of sustainability and traceability schemes; reports of mining companies, refineries, manufacturers, traders, lead firms; reports of the London Metal Exchange and the London Platinum and Palladium Market; reports by industry associations on sustainability and traceability, for example, the ICMM and the Swiss Trading and Shipping Association; as well as press clippings on conflicts surrounding copper, platinum, and gold mining in Chile, Peru, South Africa, and Zimbabwe. In total, 130 semi-structured interviews were conducted between August 2021 and April 2022 during several weeks of field research. The unit of analysis of the three case studies is the entire supply chain from extraction to recycling. Expert interviews were therefore conducted at all tiers of the copper, platinum, and gold supply chains, including extraction (South Africa, Zimbabwe, Chile, and Peru), processing (South Africa, Chile, Switzerland, and Germany), trading (Switzerland and United Kingdom), manufacturing (Germany), and recycling (Germany). Switzerland and the United Kingdom are also home to relevant industry associations, sustainability schemes and NGOs, such as the ICMM, the Copper Mark, or the Responsible Mining Foundation.

Interviews served to collect information on how sustainability is governed along the chains (by which [networks of] actors and using which standards), which factors shape traceability along the three chains, and which challenges related to the enforcement of sustainability standards and traceability exist at different tiers of the supply chains.

5. Analyzing traceability in three mineral supply chains

The processing of minerals like copper, platinum, and gold broadly includes five steps. The first step is the extraction of ore by mining companies or artisanal miners and the production of ore concentrate close to the mine site. Following extraction, ore concentrates are transported to a smelter and refinery that may be located close to the mine or in great distance. As a third step, refined minerals are further processed into semi-finished products, such as sheets, wires, or tubes. These semi-finished products are then incorporated into end products, such as cars, electrical appliances, or jewelry. The final processing step is the recycling of used minerals. The following analysis teases out how geopolitical dynamics, industry characteristics, and private governance mechanisms affect traceability in mineral supply chains, building on the cases of copper, platinum, and gold.

5.1. Geopolitical dynamics

Geopolitical dynamics have a significant influence on traceability in all three mineral supply chains. The study of the copper, platinum, and gold chain highlights that the regulatory frameworks and enforcement capacity of powerful countries in each chain as well as their membership in international standards-setting bodies has important

effects on traceability. In the case of copper and platinum, major producers and major fabricators of semi-finished products as well as original equipment manufacturers (OEMs) in the automotive industry are located in OECD member states. These states have adopted guidelines for multinational enterprises for responsible business conduct along global supply chains. In the copper sector, Chile plays a major role in production and processing of copper, and South Africa is the biggest producer and processor of platinum (EU Commission, 2021). While not an OECD member itself, South Africa participates in committees of OECD bodies, adheres to several of the organization's instruments, and promotes OECD standards within the region.

OECD member states play a less important role as sourcing countries for gold. However, gold has been labeled a "conflict mineral" because of its central role in financing actors in armed conflicts in the Great Lakes region, especially in the Democratic Republic Congo (DRC). In 2011, the OECD developed the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. This aimed to provide guidance for companies to ensure that their imports of the 3TG commodities do not contribute to the direct or indirect financing of conflict (OECD, 2016). The aim of the OECD process was for member states to transpose the guidelines into national law, which was achieved in the EU a few years later with the implementation of the EU Conflict Minerals Regulation that entered into force in January 2021. With the introduction of this regulation, EU companies must undergo a due diligence procedure when importing 3TG minerals. Companies therefore have to develop a management system in order to identify and mitigate risks in their supply chain, which increases the traceability of these minerals (EU Commission, 2017). Many large companies that either extract, sell or buy gold therefore have high transparency and sustainability standards in place (interview with Gold Refinery/CEO, 2022, August 31). In addition, the EU, the United States, and Japan have either passed or are in the process of adopting binding legislation on corporate sustainability due diligence, which may also contribute to enhancing traceability in global supply chains in general.

In some production countries, such as Peru for copper or South Africa for platinum, rather strict laws on environmental safety in the mining sector, which aim to protect people and the environment and prevent social conflicts, do not produce the desired effect. South Africa's mining regulatory framework establishes high social and environmental standards; however, a lack of state capacity and resources to enforce these standards poses a risk for actors in the platinum supply chain (Alence & Mattes, 2016). Peru has witnessed numerous mining conflicts in the past decades in which the respective companies could not be held accountable for misconduct (Ríos et al., 2015). Mining operations in Peru often take place in remote rural areas where the presence of national institutions is weak and small-scale farming communities often bear the brunt of the direct negative effects of extraction. A lack of state capacities to monitor the mining industry and high levels of corruption have negative effects on transparency (Helwege, 2015). A lack of state capacity to implement regulations regarding human and environmental rights, even though the latter exist on paper, thus represents a challenge for FCA and for traceability (interview with CEO of a Peruvian copper mine, 2021, November 30). In producing countries with less comprehensive mining legislation, such as the DRC for gold and Zimbabwe for platinum, the possibility to trace metals and the options for right holders to claim their rights are limited. Traceability is major challenge in artisanal mining sectors (ASM) when artisanal mining is not legalized and is therefore carried out as an illegal activity, for example, in South Africa (Müller, 2022).

The biggest challenge for traceability and FCA in the three supply chains is the involvement of countries in which the implementation of regulatory frameworks and sustainability standards is non-transparent. For instance, China plays a major role as a manufacturer of semi-finished products in the copper supply chain (ICSG, 2022). The adoption of sustainability principles such as labor rights and environmental standards has received increasing political attention in China, yet compliance with these standards is often difficult to verify for buyers and international civil society actors because access to information is severely limited. This poses an obstacle to companies that seek to implement due diligence processes and to right holders that seek to hold companies accountable (Chahoud, 2008). The dominance of China as a smelter and manufacturer in the copper supply chain therefore has negative effects on traceability and FCA.

In the gold supply chain, some countries act as enablers of international trade of illegally mined gold or illicit gold. Recent studies particularly highlight the important role of the United Arab Emirates (UAE) for illicit gold from African countries (Lezhnev, 2021). The legal frameworks of some major trading hubs or the lack of implementation of regulation allow for the origin of the metal to be concealed. There is evidence to suggest that as

illicit trading hubs, these countries benefit economically from their opaque trading frameworks. This has negative effects on traceability and FCA and creates loopholes for illegally mined or illicit gold to enter the EU (Grynberg & Singogo, 2021).

5.2. Industry characteristics

Industry characteristics affect traceability in the gold, copper, and platinum supply chains in different ways. Copper and platinum are almost exclusively mined via industrial mining, which requires official permits. Gold is often extracted by artisanal and small-scale miners using simple tools and without the use of technology. This often takes place in smaller mines with less capacity to monitor production conditions (Hilson et al., 2017). In countries such as South Africa, artisanal miners often search for gold on former industrial mining sites—in mine tailings or in shafts of mines, where regulations for safety are difficult to apply. Tracking the provenance of gold that has been extracted by artisanal miners is extremely difficult once it has been sold to intermediaries (Müller, 2022). In many countries—especially in those that have not yet regulated ASM—illicit or illegal networks around gold mining exist. The informality under which ASM is carried out makes it easier for actors in the illicit trade of gold to obscure the gold's origin and smuggle it to neighboring countries.

Tracking the provenance of metals in geographically concentrated large-scale mining sectors is generally easier than in mining sectors where ASM is widespread because less actors are involved. For instance, mining PGMs is a knowledge-, heavy equipment- and capital-intensive industry that is dominated by large international mining companies. The latter are more firmly monitored and usually have sustainability departments in place and are listed on stock exchanges that require or recommend the disclosure of ESG-related data (Hirons, 2020). Traceability in the platinum supply chain is also less complex because the production and processing of platinum are highly concentrated in Southern Africa. South Africa is the world's largest platinum producer with approximately 67.5% of world mine production in 2021, followed by Russia (13.9%) and Zimbabwe (9%) (U.S. Geological Survey, 2022). Gold and copper are produced in many countries and regions and primary processing usually takes place in different regions than extraction. In contrast, platinum concentrate produced in Southern Africa is refined in South Africa and not exported to other regions for further processing. The platinum supply chain is therefore shorter and less complex than the chains for copper and gold (Müller et al., 2022).

The analysis of the three supply chains also highlights how the value of minerals and mode of transport affect product traceability. Mineralogical fingerprints or other types of "tagging initiatives," which can be used to trace metals back to specific mines, are only economically viable for high-value and high-risk minerals like gold (see Melcher et al., 2008; van den Brink et al., 2019). Due to the rather low value of copper per ton, it would not be economically viable to install tagging initiatives. At the same time, gold and to a lesser extent platinum are also particularly prone to illicit trade because of their high value and because they are transported in smaller quantities compared to copper which is transported in bulk.

In the case of gold, illicit flows play a significant role internationally. Like in all metal supply chains, refineries can be considered choke points for traceability because metal concentrates from different mines are mixed and there are usually no systems in place to track batches from specific mines. This makes it particularly attractive for criminal actors to engage in the illegal trade of gold (interview with Gold Refinery/CEO, 2022, August 31). In the platinum supply chain, the high value of platinum makes the trade of used catalytic converters a target for criminal activities (interview with Precious metals refinery and recycling group, 2022, February 10). Copper is less suitable for illicit trade because it would require actors to illegitimately obtain and sell large quantities of the heavy product in order to make a profit. Illicit trade of copper is therefore less common (or less known); however, with rising copper prices this might change in the future (see Pistilli, 2021). Next to illicit flows, misinvoicing and fraud, for example, of certificates, are a challenge for all three supply chains (Hanni & Podestá, 2019; Ray, 2023).

Finally, the use of platinum, copper, and gold has impacts on traceability in the three chains. In the case of gold, public attention from buyers and civil society actors as well as the level of regulation are higher (Partzsch, 2018). This increases traceability and transparency in the gold supply chain. In the cases of platinum and copper, pressure from individual end consumers to enhance sustainability in the supply chain and public scrutiny in the Global North exists but is lower than for gold because platinum and copper are mainly for industrial use and are not considered "conflict minerals." Platinum is mainly used in autocatalysts (circa 32% of world

demand) and in various industrial processes. However, it is also used to produce jewelry (circa 23% of world demand) and as an investment (circa 13% of world demand) (Schmidt, 2021). Copper is usually used in complex electronic devices or buildings consisting of a vast variety of different materials. While sustainability concerns are increasing in the platinum jewelry segment (Heraeus, 2021), the demand for sustainably-produced platinum jewelry remains low compared to other precious metals (interview with Platinum Jewelry Marketing Organization/COO, 2022, February 14). In the case of copper, the metal's significance for many crucial industrial sectors such as the automobile industry or mechanical engineering in the Global North has put copper in the focus of attention of industry associations as well as NGOs and civil society organizations working on sustainability.

5.3. Private governance mechanisms

The analysis of the three case studies revealed that the firm structure and private governance mechanisms in the copper, platinum, and gold supply chains have important effects on traceability. In the supply chains for copper and gold, traders and metal exchanges, such as the London Metal Exchange (LME) and the London Bullion Market, are important actors. Traders and exchanges present bottlenecks for traceability in mineral supply chains because metal trading companies currently disclose little information about their business partners and the origin of the metals they sell (Dobler & Kesselring, 2019; Müller et al., 2022; Responsible Mining Foundation, 2021). While Platinum is also traded via metal exchanges, for example, the London Platinum and Palladium Market (LPPM), direct buyer–supplier relations are much more frequent in the platinum supply chain. South African platinum mining companies mainly sell directly to fabricators in Europe, Japan, and the United States, or in some instances to car manufacturers. Many European automotive OEMs can trace the platinum used in their vehicles back to specific mining companies or even to specific mines. Next to direct buyer–supplier relations, the level of concentration at firm level in the platinum supply chain is also much higher, both at the lower end (mining companies and refiners), the middle (fabricators in the PGMs industry), and at the upper end of the supply chain (OEMs in the automotive industry). For instance, the five largest South African platinum mining companies together produced approximately 95% of total domestic platinum production in 2018 (Cameron et al., 2019). The number of companies—and in the case of gold small-scale miners—involved in copper and gold production is much higher. This makes it more challenging to trace the provenance and journey of the two metals.

Tracking the provenance and journey of gold is particularly challenging because there exist two types of gold supply chains that include different actors. The legal supply chain involves large industrial mining companies, and in some cases artisanal miners, smelters, international traders, and manufacturers. The illegal supply chain often involves illegitimate and even criminal actors. The most fundamental difference between the two chains is the metal's origin. In the illegal supply chain gold is usually extracted via artisanal mining that either has not been legalized in the country or takes place in conflict and high-risk areas. At a certain point, this gold must find its way into the legal supply chain. Here, legal and illegal networks often overlap: criminal networks, but also actors involved in the legal supply chain can play a role in facilitating illegal trade (Müller, 2022, for Peru see also Damonte & Schorr, 2022). Conflict actors often control access to mining sites, trade routes, and force workers to work in illegal mines, pay illegal taxes, or raid them and steal gold that has been mined. These actors sell the gold to traders who buy the gold from them and/or then move the money further into the market legally. In most cases, this requires a widespread network that also involves economic and political actors who profit from the illegal trade in gold (Lezhnev, 2021). For obvious reasons, these actors have no interest in promoting traceability along the chain but rather seek to make it impossible to track the provenance of gold.

Voluntary sustainability standards and certification schemes have gained importance in all three supply chains; however, they are most prominent in the gold supply chain because it is considered a conflict mineral and the EU Conflict Minerals Regulation promotes the application of certain standards. Next to binding legislation, there are a number of voluntary standards and certification schemes, for example, the Fairmined standard for gold or the conflict-free gold standard by the World Gold Council, that particularly focus on gold (Deberdt & Le Billon, 2021). These apply not only to artisanal mining, but also to industrial mining. Many international companies have certified their gold, also to counteract reputational losses. A standard that is specifically tailored to the copper supply chain was developed in 2019 by industry actors: The Copper Mark. Next to these metal-specific standards, some companies in the three supply chains also comply with sector-specific standards, such as the

multi-stakeholder initiative IRMA, which is currently gaining importance in the platinum supply chain. More recently, the LME and the London Bullion Market Association have also developed responsible sourcing guidelines based on the OECD responsible business conduct and human rights guidelines. While these initiatives seek to enhance transparency, sustainability, and human rights compliance, they only cover certain risks and challenges at specific tiers of the three chains—extraction and in some cases refining—and may create a false "sense of security" among buyers (Franken et al., 2020). In addition, these standards and guidelines usually do not establish chain-of-custody models along the chain and are mainly voluntary. However, voluntary standards have created platforms for dialogue and sharing information for corporate and non-corporate actors along mineral supply chains. While this tends to enhance transparency about risks in mineral supply chains, it is difficult to assess whether standards actually contribute to enhancing supply chain traceability.

6. Discussion of findings and implications for FCA

The analysis of the three metal supply chains highlights that chain-specific characteristics affect traceability. It further revealed that geopolitical dynamics, industry characteristics, and private governance mechanisms may affect traceability in positive and negative ways in each of the three chains under study. The summary of findings

Table 1 Effects of supply chain characteristics on traceability and foreign corporate accountability (FCA)

	Negative effects on traceability	Positive effects on traceability	Implications for FCA
Geopolitical dynamics	• Dominant role of states with weak mining legislation or weak state capacity and/or willingness to enforce legislation • Lack of international cooperation between mineral producing, processing, trading, and consuming states	• Binding due diligence laws in mineral importing countries/ regions • Membership in/affiliation with international standard-setting organizations (e.g., OECD)	• Weak local legal frameworks do not provide for possibility to hold companies accountable or the establishment of public complaints mechanisms • Weak legislation and law enforcement capacity may increase risks for companies and diminish ability to mitigate risks • States with a strong sustainability agenda are more likely to promote disclosure of sustainability-related information by companies in line with international standards
Industry characteristics	• Unformalized small-scale and artisanal mining • Geographical fragmentation of metal reserves, extraction, and processing • Existence of illicit material flows	• Tagging initiatives or methods like analytical fingerprints economically viable • High pressure from industrial and individual end consumers and high public scrutiny	• Industrial characteristics affect length and complexity of mineral supply chains and ability to identify suppliers and production sites as well as potential risks • High public scrutiny can promote adoption of binding due diligence regulation and voluntary standards and push for disclosure of information about suppliers and risks
Private governance mechanisms	• High level of fragmentation at firm level • Traders and stock exchanges as choke points • No links between right holders and civil society actors along mineral supply chains	• Lead firms have high sustainability standards • Companies comply with voluntary standards (with chain-of-custody systems) and participate in multi-stakeholder processes	• Level of fragmentation/ concentration at firm level affects ability to identify suppliers and production locations as well as potential risks • Dominance of lead firms with low traceability and sustainability requirements thwarts implementation of environmental and human rights due diligence along the chain • Compliance with sustainability standards and well-established relationships between actor groups along the chain enhance transparency

in Table 1 seeks to go beyond the three cases by developing more general propositions about how supply chain characteristics affect traceability in mineral supply chains and which implications this has on FCA.

Geopolitical dynamics negatively affect traceability and FCA in metal supply chains when countries with weak regulatory frameworks, law enforcement capacities, and overall low levels of transparency in the mining, mineral processing, and/or trading sectors play a dominant role in one or more tiers of the supply chain. This is for example the case in the copper supply chain due to the dominance of China as a major manufacturer and supplier of copper products and in the gold supply chain where trading hubs that benefit economically from trade of (illegally mined) gold, for example, the UAE, refrain from taking steps to enhance transparency in the chain. Weak legislation and enforcement capacities and a lack of willingness to enhance transparency at state level enhance the risks for companies along the chain, for example, because states do not monitor compliance with working or environmental standards, and diminishes their ability to mitigate these risks. At the same time, the legal frameworks in these countries may simply not provide for the possibility to hold companies responsible for harm caused to people and the environment or to establish public complaints mechanisms. The case of gold, however, has shown that binding due diligence legislation such as the EU Conflict Minerals Regulation can contribute to fostering traceability in mineral supply chains and enhance the ability of civil society organizations, and right holders to hold companies accountable, but possible unintended consequences need to be mitigated. In the same vein, established diplomatic and trade relations among countries along mineral value chains as well as the membership in international standard-setting organizations such as the OECD tend to have a positive effect on traceability and FCA, for example, by promoting the disclosure of sustainability-related information by companies in line with international standards. Having access to this type of information is pivotal for right holders and civil society organizations that seek to hold companies accountable.

The industrial characteristics of metals may also affect supply chain traceability and FCA in positive and negative ways. Metals with reserves and production facilities in many different parts of the world, for example, copper or gold, are more difficult to trace because supply chains tend to be longer or more complex. Identifying (sub-)suppliers, production, and processing locations and conditions is a challenge in these types of chains. If the extraction and processing of a metal is concentrated in one region, for example, in the case of platinum, it is easier to track its provenance and journey and to identify (and mitigate) potential social and environmental risks along the chain. Metals are also differently prone to illicit material flows, depending on their value and usual transport volumes. For instance, metals that are transported in large quantities, for example, copper, are usually easier to track due to pure volume. However, tagging initiatives or analytical fingerprints (AFPs), which can improve traceability significantly, are only economically viable for high-value and high-risk metals, such as gold. Tracking the provenance and journey of metals that are extracted via small-scale and artisanal mining in countries that have not formalized ASM presents a challenge for buyers. Industrial large-scale mining on the contrary is usually dominated by large transnational companies that are embedded in global capital and finance markets and have established internal processes related to sustainability and CSR. While this tends to enhance traceability and transparency, it still depends on the willingness of companies, particularly lead firms, to implement measures and processes that enhance traceability and to disclose information about the origin of metals.

The industrial characteristics of metals may also affect the level of consumer pressure for more supply chain traceability and sustainability. Metals that are associated with high environmental and social risks and that are "visible" for individual end consumers, for example, jewelry, are more likely to receive public attention than industrial metals that are majorly used in complex electronic devices. High levels of public scrutiny can promote the adoption of binding regulation and voluntary sustainability standards in mineral supply chains and push companies to conduct risk analyses and disclose information about production sites and conditions. This makes it easier for state authorities, civil society organizations, and right holders to hold companies accountable.

Finally, a supply chain's firm structure and private governance mechanisms also affects traceability in mineral supply chains and FCA. The analysis of the three supply chains revealed that it is easier for buyers in the Global North to trace back where the metals they use have been extracted and processed and by whom in chains with a high level of concentration at firm level or in chains with direct relationships between refiners and industrial processors. This also makes it easier for firms to identify and mitigate risks in these types of supply chains because the actors and production locations are known. Carrying out human rights and environmental due diligence becomes significantly more challenging for buyers in mineral supply chains that include powerful firms with low

requirements related to traceability and sustainability/or actors that seek to thwart traceability, for example, because metals were mined illegally. Traders and metal exchanges also tend to be choke points for traceability. In mineral supply chains that include several layers of traders, buyers have little or no information about where metals have been extracted and processed and under which conditions, hence identifying risks beyond their tier-one suppliers becomes difficult. In the same vein, the ability of state authorities, civil society actors, or right holders to hold companies accountable is also severely limited. For instance, if right holders in countries where metals are extracted and processed do not know which companies ultimately buy these metals, they cannot make use of complaints mechanisms by international buyers or connect with civil society organizations or trade unions along the chain that provide support to workers and communities that are negatively affected by mining. Voluntary standards and certification schemes, particularly if they establish chain-of-custody systems, can promote traceability and FCA because they can enhance dialogue and the flow of information between corporate and non-corporate actors along mineral supply chains and provide a platform for discussion about social and environmental risks and challenges for traceability.

So far, the literature on supply chains and traceability identified several obstacles for implementing traceability because of the complex nature, especially of mineral supply chains, as well as findings on how traceability schemes can be implemented (e.g., Hofstetter, 2019; Muirhead & Porter, 2019; United Nations Global Compact & BSR, 2014; Young, 2018). The findings of this paper add to this literate by identifying particular characteristics of supply chains, which foster or hinder traceability and go beyond the scope of the discussion of transparency and traceability in supply chains by showing how traceability is closely interlinked with accountability.

7. Conclusion

The analysis of how supply chain-specific characteristics affect traceability in three mineral supply chains provides important insights of practical relevance related to FCA. First, traceability in mineral supply chains is shaped by a range of chain-specific characteristics that relate to geopolitical dynamics between the states that are involved in a chain, the industrial characteristics of minerals, and private governance mechanisms in supply chains. Second, these characteristics may have positive or negative effects on supply chain traceability and FCA. Third, a thorough understanding of the supply chain-specific characteristics that shape traceability in mineral supply chains can help actors to identify factors and choke points in supply chains that thwart traceability such as traders or metal exchanges. This is a prerequisite for identifying levers and strategies that enhance traceability, such as participating in multi-stakeholder dialogues or industry initiatives, establishing direct business relationships with suppliers that are able and willing to provide product- and process-related information, or pushing for (the enforcement of) legislation in producer and buyer countries that enhances traceability. Finally, enhancing traceability involves collecting information about a product's provenance, journey, and production conditions as well as identifying companies that form part of a supply chain. It therefore increases transparency in supply chains. This is a precondition for companies to be able to take corporate social responsibility, for example, for adverse impacts of their business activities or those of their suppliers, and for state and civil society actors to be able to hold companies accountable. In particular, it helps civil society actors at the different tiers of mineral supply chains to connect transnationally.

This paper aims to contribute to closing some of the gaps in the academic literature on traceability in supply chains, which mainly focuses on food and textile supply chains and on measures to enhance traceability at firm level. On the one hand, it makes a contribution by studying three mineral supply chains. On the other hand, the paper centers on how external and supply chain-specific characteristics shape traceability in these chains (see Muirhead & Porter, 2019; Nepstad et al., 2014). Mineral supply chains differ in various ways from chains in other industrial sectors because they are particularly complex and associated with high environmental and human rights risks. The findings of this paper may therefore only partly apply to supply chains in other industrial sectors. To our knowledge, the link between supply chain characteristics, traceability, and FCA has not been studied in a systematic manner. The analytical framework proposed in this paper aims to contribute to a more structured analysis of how supply chain characteristics affect traceability and FCA in global supply chains. Applying this framework to other industrial sectors and comparing our findings with insights from other case studies would help to develop it further for future research.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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