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“Doing ASGM without mercury is like trying to make omelets without eggs”. Understanding the persistence of mercury use among artisanal gold miners in Burkina Faso

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ABSTRACT

Researchers and policymakers are concerned with the uncontrolled use of mercury in artisanal and small-scale gold mining (ASGM). Despite the availability of alternative technologies, mercury is still the first choice to separate gold from ore on most ASGM sites. Taking the case of Burkina Faso, this mixed methods study contributes to understanding the continued use of mercury by analyzing the non-technical functions that mercury accomplishes. Applying a political ecology lens, we analyze the mechanisms that actors deploy to access benefits from ASGM and manage business-related risks, revealing dependencies on webs of power that govern the informal setting of the ASGM value chain from production to export. Our results challenge conventional wisdom about poverty-driven ASGM. We demonstrate that the sector is not simply propelled by jobless rural youth and poor farmers eager to make a lucky strike. Instead, the need of ASGM for prefinancing extraction made it as much the product of capital looking for lucrative investment. The business model of investors is based on prefinancing extraction, controlling access to market, and taking advantage of excess labor by shifting operational and financial risks upstream. In an entirely informal scheme of cascading prefinancing arrangements, mercury serves as a ‘commitment and controlling device.’ The provision of mercury guarantees that the financier can access the gold at the exact moment of recovery, regain the loan, and secure the return on investment. Phasing out mercury will remain a challenge as long as it is used as a social control device.

1. Introduction

Industrial mining accounts for roughly 80% of global gold production and directly employs about one million people (WGC, 2015). Low-tech artisanal and small-scale gold mining (ASGM) produces the remaining 20% but employs up to 16 million people in about 80 countries (Seccatore et al., 2014).

However, ASGM income opportunities come at high costs. Among others, regular exposure to mercury vapor when burning an amalgam can severely impact human health. The non-biodegradable mercury also travels great distances by bio-accumulating in the environment and food chain (Gibb and O’Leary, 2014; WHO, 2016). Today, ASGM is the

largest source of anthropogenic mercury emissions, releasing between 700 and 1600 tons per year into the environment (UNEP, 2019).

Policymakers have long been concerned with the uncontrolled use of mercury in ASGM. The most comprehensive attempt to eliminate or at least reduce the application of mercury is the UN Minamata Convention. It entered into force in 2017 and has been fully ratified by 97 countries as of early 2022 (UN, 2022). However, despite all efforts, mercury is still the first choice to extract the gold from the ore on ASGM sites. Most explanations point to unsuitable or unaffordable technological alternatives and dysfunctional regulatory approaches. More recently, trade dynamics have been suspected of undermining efforts to phase-out mercury, but knowledge about mercury trading channels is still

Abbreviation: ASGM, artisanal and small-scale gold mining; UN, United Nations.

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limited (Hendus, 2020; Hunter, 2018).

We add to the literature a political ecology perspective that investigates the social function mercury fulfills in the gold value chain, making it a production factor that is hard to replace. Our findings reveal that mercury serves as a ‘commitment and controlling device’ in the local trade dynamics where gold exporters play a key role in pre-financing extraction. Although traded separately from gold, providing mercury is an important mechanism to secure access to gold supply and, hence, return on investment.

We proceed as follows: after a review of the literature, we introduce the political ecology framework focusing on access mechanisms, followed by the methodology and the case context. Then, we present and discuss the findings before we conclude.

2. Literature review

Three strands of literature address the persisting use of mercury in ASGM. The first investigates technological upgrading, the second regulatory approaches, and the third, more recent body of literature, analyzes the mercury market.

Research on **improved technology** goes back to the early 1990s and studies technical solutions to make mercury safer for human health and the environment. The most common approaches include minimizing the exposure to mercury by using retorts when burning an amalgam; establishing professionally managed processing centers; and replacing mercury with less dangerous chemicals such as borax or with gravitational methods (e.g., Appel and Na-Oy, 2014; Styles et al., 2010; Teschner et al., 2017; Veiga et al., 2014a; Veiga and Gunson, 2020; Vieira, 2006).

The technology-developmental literature takes a positivist stance on human-nature interaction. Superior technology is expected to deliver the solution that humans as rational agents will embrace (Robbins, 2011). As a rich collection of case studies illustrates, all solutions suffer from a lack of adoption by artisanal and small-scale miners. Obstacles include a lack of knowledge by the miners, lack of capital for new technology, and a lack of trust that the new solution delivers the promised results (Malehase et al., 2017; Smith, 2019; Spiegel et al., 2018; Tschakert and Singha, 2007; Veiga et al., 2014b).

The **regulatory approach** to eliminate mercury is informed by the new-institutionalist theory that the incentives built into regimes steer human behavior (Ostrom, 1990). Formalization of the sector would allow miners to invest and increase efficiency and simultaneously allow governments to train miners, enforce environmental laws, health and labor safety regulations, or reorganize the sector, for example, by introducing processing centers. Formalization has become the bearer of hope to put the Minamata Convention into practice (Singo and Seguin, 2018).

The scholarly literature provides evidence on the challenges of formalizing ASGM. For example, mining communities are not sufficiently informed or lack the motivation to engage; they want to avoid the additional work to adhere to regulations or mistrust the government altogether. Formalization efforts also tend to fail due to neglect of informal rules and local dynamics on mine-sites and administrative and financial hurdles for the miners who try to obtain licenses (Hilson et al., 2017; Marshall and Veiga, 2017; Salo et al., 2016; Verbrugge and Besmanos, 2016).

Finally, the most recent body of literature analyzes the **mercury trade**. It is motivated by global policy measures, which have restricted the formal trade in mercury and moved trade to clandestine networks. The macro-level analysis maps international mercury flows and trade routes. Little is known about the related financial flows and trade networks (Fritz et al., 2016; Gi, 2018; Hendus, 2020; Hunter, 2018; Lassen et al., 2016).

Few studies investigate the micro-level mercury trade dynamics on ASGM sites and potential linkages between the mercury and the gold markets based on the observation that gold buyers are often the same

who provide miners with mercury (Hilson and Pardie, 2006). Investigating mercury practice on the ASGM site of Relave, Peru, Smith (2019) finds that the local gold buyers enforce the use of mercury by only buying gold from miners who provide it in an amalgamated form. The author concludes that the gold buyers are the actual emitters of mercury, perpetuate its use, and that introducing mercury-free technologies can be “only as effective as the supply chain allows them to be” (Smith, 2019, p. 653).

Our original study on mercury trade dynamics in Burkina Faso expands on the link between mercury use and supply chains identified by Smith (2019) and fills the gap between the site-level micro-analysis and the macro-analysis of regional and global trading. We investigate the meso-level by adopting a national value chain perspective, covering the trading posts from the import of mercury to mine sites and the trading chain from ore extraction to the export of gold. Understanding value creation as socio-technical and relational processes, we ask how the actors along the value chain secure access to whatever is needed to generate profit while mitigating associated risks.

3. Theory

To answer our research question, we build on political ecology. In contrast to techno-developmental or neo-institutionalist approaches, political ecology posits that the human-nature relationship is inseparable from the social relations in which access to natural resources is embedded (Perreault et al., 2015). Understanding social-ecological sustainability as a function of implementing the correct technologies or institutions is considered oversimplistic since it tends to overshadow the importance of power and distributional effects enshrined in institutions. Instead, political ecology is interested in uncovering how structural power shapes access to and control over resources and how the dominance of certain forms of knowledge and discourses determine outcomes (Agrawal, 2003; Robbins, 2011).

Political ecology conceives of mercury use as the result of social, economic, and political dynamics that shape control, cooperation, and dependence along the value chain. Actors seek to participate in the value chain to derive (economic) profit from this activity. However, there are barriers to entry and benefits. At each stage along the value chain, laborers and entrepreneurs need access to at least some rudimentary technology, labor, capital, and markets. Access is always controlled by certain actors and formal or informal rules that incorporate distributional effects. These controlling forces represent the “web of power” that determines who can access the value chain and under what conditions, who will benefit from gold extraction, and who is constrained or even excluded.

Ribot and Peluso (2003, p. 155) have theorized how power manifests in natural resource extraction and governance. They combine a new-Weberian, actor-oriented understanding of power as “the capacity of some actors to affect the practices and ideas of others” with historic-materialist and Foucauldian perspectives that emphasize historically established social structures and discourses that produce and constrain human agency.

The starting point for the analysis of power relations and dependencies in natural resource extraction is the deconstruction of how actors access the value chain. First, a differentiation is made between ‘de jure’ entitlement in the form of formally held rights and ‘de-facto’ access based on the agent’s ability to access resources irrespective of legal titles. A political ecology analysis considers both dimensions and their interplay to detect the power dynamics that shape real-life access to natural resources (Fig. 1).

Second, different access to mechanisms need to be disentangled. A ‘mechanism’ is shorthand for “means, processes, and relations by which actors are enabled to gain, control, and maintain access to resources” (Ribot and Peluso, 2003, p. 160). They include access to technology, capital, labor, markets, knowledge, authority, social identity, and social relations. Commanding the ‘right’ mechanism or set of mechanisms in a

		De jure access	
		Allowed	Prohibited
De facto access	Have	The actor is legally entitled to access a resource and can also access it without restriction.	The actor has no legal title to resources but manages to access it through other means such as relationships, force, tradition, etc.
	Have not	Despite having a legal title, the actor is prevented from exercising his/her right to access by being either passively or actively restrained from benefitting (e.g., opportunity cost are too high; activity is not profitable, complementary resources such as labor, capital required are lacking/denied, extortion by 3rd parties).	

		Authorized benefit	Illicit benefit
		Denied benefit	Excluded from benefit

Fig. 1. Typology of access (authors, based on Ribot and Peluso, 2003).

given situation is critical to accessing the resource and deriving benefits. Whereas some individuals and institutions directly control resource access, others must gain access through those who have control.

The access framework has been applied to fields such as the charcoal commodity chain in Senegal (Ribot, 2002), vanilla production in Madagascar (Neimark et al., 2019), ecosystem services from coral reefs (Hicks and Cinner, 2014), or tuna fisheries in the West Indian Ocean (Andriamahefazafy and Kull, 2019). To our knowledge, the access framework has never been applied to non-renewable resources or more complex and longer value chains such as gold. Two differences are important: first, ASGM depends on functioning input value chains, particularly for mercury but also for explosives and cyanide. Second, valorizing the raw gold requires local traders, exporters, refineries, and international markets.

More complex value chains tend to present significant risks that are not explicitly considered in the access framework. Gaining access to resources but not being able to manage related risks limits the ability to benefit from resources. Risks can thus be seen as the flipside of access. The longer and the more complex value chains grow, the more important becomes the capacity to mitigate risks or absorb losses. In the gold sector, risks are related to significant capital flows or the use of banned chemicals and explosives, among others. Therefore, the ability to manage risk also needs to be conceived as an essential feature of power (Khan, 2010).

To account for the importance of risks, we expand the theory of access by introducing the capacity of actors to mitigate risks and absorb losses as an additional theoretical and analytical dimension. Standard risk theory provides a heuristic to identify risks that can affect the viability of business models, value chains, and supply networks. A common classification distinguishes eleven risk types: strategic, operations, supply, financial, legal, fiscal, reputational, regulatory, customer, asset impairment, and competitive. The heuristic also suggests six types of potential losses that can materialize in a risk event: financial, performance, physical, psychological, social, and time (Harland et al., 2003).

The capacity to manage risks adds power to a (potentially already strong) agent, whereas the lack thereof weakens its position. The expanded theory of access enables more extensive and comprehensive analysis of power mechanisms shaping access to resource benefits.

4. Methodology

We operationalize the access framework in three steps (Ribot and Peluso, 2003): first, we map the flow of benefits and risks along the gold and mercury value chains. Second, we identify the mechanisms that the different actors deploy to access and benefit from resources and their

capacity to manage risks. Finally, we analyze the power relations at work, i.e., how the means, processes, and relations deployed by various actors to gain, control, and maintain access to resources shape distributive outcomes.

Our study deploys a mixed-methods approach with an embedded design and qualitative research being the main method of inquiry (Creswel and Plano Clark, 2017). The qualitative research uses semi-structured interviews with actors along the value chain from mine sites to the point of export. On the mine sites, we conducted 30 interviews with laborers, pit owners, gold and mercury traders, site managers, local police officers, and representatives of the local environmental department. We applied a snowball sampling strategy starting with those easily identifiable such as laborers working in the mine shafts. They introduced us to pit owners, traders, and mercury sellers. Interviews were not recorded to reduce potential unease when talking about sensitive issues.

In addition, a survey was administered to 276 individuals to study the socio-demographic composition of the mining communities, the distribution of tasks, and gold and mercury trading practices. Additional questions covered risk perception, knowledge on the health effects of mercury contamination, and protective behavior.¹ Since movement on the sites was restricted for security reasons, a combination of geographical systematic and snowball sampling techniques was applied. Enumerators fanned out from a central point identified with local partners from where they approached participants. After completing a survey, enumerators asked the participant to recommend other people from their working group to be surveyed. If a person cannot recommend further people, enumerators would continue in their dedicated direction to identify more participants.

In Ouagadougou, we conducted 34 semi-structured interviews with the patrons of registered gold trading companies (comptoirs), shop-owners selling mercury, and government officials from the Ministry of Mines, the Ministry of Environment, and the customs authority. Some interviews were recorded; otherwise, notes were taken carefully. Sampling was purposeful; transcripts and notes were coded and analyzed in Nvivo.

The survey results were used to analyze the qualitative findings to get a more representative understanding of which actors are involved in handling mercury; to test factors influencing gold and mercury prices,

¹ In a parallel study conducted on the same survey participants we studied miners' protective strategies when using mercury. Survey respondents were also invited to participate in the measurement of mercury levels in their bodies (through the analysis of hair samples) and were provided with protection gear (gloves and masks) to study protection behavior (Van der Merwe, 2022).

and; support interpreting the results from the semi-structured interviews.

5. ASGM dynamics in Burkina Faso

Burkina Faso is an ideal place to study the interlinkage of the mercury and gold value chains. The country has a vibrant ASGM sector producing 9.5 – 25 tons of gold in up to 2200 mine-sites, and amalgamation is the dominant extraction method (ANEEMAS, 2018; Hunter, 2019). Burkina Faso has banned mercury in 2015 but still consumes 25 – 90 tons of mercury per year (UNEP, 2019). Ouagadougou is further deemed to be the mercury trading hub for West Africa. Mercury is presumably imported from China, Indonesia, Hongkong, Singapore, and Vietnam through the port of Lomé in Togo, from where it is transported informally to Ouagadougou and then traded to Niger, Mali, and Ivory Coast. (GI, 2018; Hendus, 2020; Lassen et al., 2016).

There are three actor groups along the gold value chain: upstream, those extracting the gold on mine sites are a myriad of micro-businesses typically organized around a pit owner (“*propriétaire du trou*”) who hires labor for digging, extracting, crushing, and amalgamating the ore (“*creuseurs*”). A manager organizes the site, collects fees from miners and other businesses, pays the landowner(s) and other parties with socially recognized entitlements, and provides security. If the site has a permit, the manager is a representative of the permit holder; otherwise, another person or entity is entrusted with the management (Ouedraogo and Mundler, 2019). The midstream consists of the gold collectors present on the mine-sites buying small quantities of gold. While some are stationary, others travel between sites; some even collect gold in Ghana, Ivory Coast, and Niger. Most gold collectors operate without a license as “*acheteur d’or*” and without the legally required formal association to an exporter. Further downstream are the exporters, called “*comptoirs*”. They need an export license approved by the Ministry of Mines, the Ministry of Finance, and the Ministry of Commerce; it is valid for three years. The roles described can overlap in reality. For example, a gold collector can also be the owner of one or several pits, or a *comptoir* may own site permits (Ouedraogo and Mundler, 2019).

We conducted our upstream research in four mine sites in the Center-North region (Fig. 2). For *Galong-Tenga*, the permit was initially held by the *comptoir* SOMIKA. The trading company enforced gold prices around half of that on other ASGM sites against the claim to provide infrastructure to nearby villages. Miners were unwilling to accept these conditions and set SOMIKA’s trading facilities on fire in 2014 (Werthmann, 2017). Today, the national syndicate of small-scale miners manages the site based on an agreement with the landowner and the mayor of Tikaré. SOMIKA holds the permit for *Zomnkalgá* and manages the mine site. Production has been decreasing since 2015, when the galleries reached groundwater, and many miners left the site. Mining focuses on pits prefunded by SOMIKA. *Rongouin* is situated on the large-scale mining concession of Bissa Gold SA and in the proximity of their open pit and processing plant. Relationships are tense, and conflicts between the ASGM community, nearby villages, and Bissa Gold are frequent. The site is managed by the national syndicate of small-scale miners. Finally, for *Sandouré*, we are not aware of an existing permit. An independent manager organizes the site in agreement with the landowner and the surrounding communities.

6. Results

6.1. The flow of benefit from gold mining

The distribution of benefits follows a distinct order, as illustrated in Fig. 4. Once the ore has been extracted, it is packed into large bags. The “bag of ore” is the standard unit in which the *propriétaire du trou* pays fees and distributes the benefits. First in the queue are the landowners, the local political and customary authorities, and the site manager who can get up to one out of ten bags each in a site with constant production.

One bag per shaft is due independent of how many bags are recovered for security providers. On sites with low or declining production, shares can be lower.

Next, the *propriétaire du trou* keeps several bags to cover the expenses incurred for the extraction, including tools, machinery, material, food, and medical support for his team of usually six to 15 *creuseurs*. The remaining bags of ore are divided in two: one half is the benefit of the *propriétaire du trou*, and the other half is the remuneration of the *creuseurs*, which they share among themselves. In some cases, the bags are distributed between *creuseurs* and *propriétaire de trou* after the amalgamation.

After distributing the ore, the owners of the different bags crush and wash the ore and prepare it for mercury amalgamation, which liberates the gold from the ore. The amalgamation and subsequent separation of the amalgam from the excess liquid mercury is done by *creuseurs*. Landowners and the local authorities either do the processing themselves to make sure the gold is not stolen, or they let young miners do it for free under their close supervision in exchange for establishing valuable relations and, eventually, some gifts. The next step, the burning of the amalgam to vaporize the mercury and recover the ‘sponge gold’,² is done or at least overseen by the gold collectors. For weighing the sponge gold, the gold collector either uses an electrical scale or a traditional hand-held brass scale with matches or 10 or 25 FCFA³ coins as counterweights.

Survey respondents who have sold gold during the last month report a considerable price range with some reporting prices more than 30% below the world gold price while others stated to be paid 20% above the world gold price (see Fig. 3). However, this information must be taken with caution: first, the unit used on mine sites to weigh sponge gold are often not grams but matches or coins, the conversion can easily distort answers when miners are asked to indicate prices per gram; even where the unit used are grams, the correctness of the measure is often questioned. Second, people on mine sites do not have the equipment to assess their gold’s purity properly. Instead, a certain purity level is assumed for an entire site which implies a certain discount. Finally, all *creuseurs* and *propriétaires du trou* interviewed stated that they call friends on other ASGM sites to decide what price they are supposed to sell their gold. No miner mentioned that he uses international prices as a reference. This was confirmed by follow-up phone surveys with the same sample: more than 90% of respondents did not know the world gold price (Van der Merwe, 2022).

The gold collectors are the intermediaries between the *creuseurs* and *propriétaires du trou* and the *comptoirs*. The collectors smelt the sponge gold to increase the purity and cast it into a doré, called *lingot*, which they sell to the *comptoir*. There are two to three gold collectors on each of the surveyed sites, others are in the nearby economic centers. Survey respondents stated that they know between one and seven traders (2.6 traders on average) to whom they can sell their gold. Of all participants who sold gold in the last month, 41% sold gold on the mine site, 19% at their home, 9% at the nearest processing center, and 31% in the next town or larger city.

The business model of gold collectors is based on the price difference paid on the mine site and what they will receive from the *comptoirs*. Many traders on the same site would drive up prices and lower the gold available to each trader. How much gold a collector can buy further

² Given its sponge-like appearance, sponge gold is the term used for the gold recovered after burning a gold amalgam and evaporating the mercury. It is a semi-refined lump of bronze-gold material with a porous surface (O’Neill and Telmer, 2017)

³ FCFA stands for the *franc CFA* (*Communauté Financière Africaine*). It is the name of two currencies, the *West African franc CFA* (ISO code XOF), used in eight West African countries, including Burkina Faso, and the *Central African franc CFA* (ISO code XAF), used in six Central African countries. Although separate, the two *franc CFA* currencies have a fixed exchange rate to the euro.

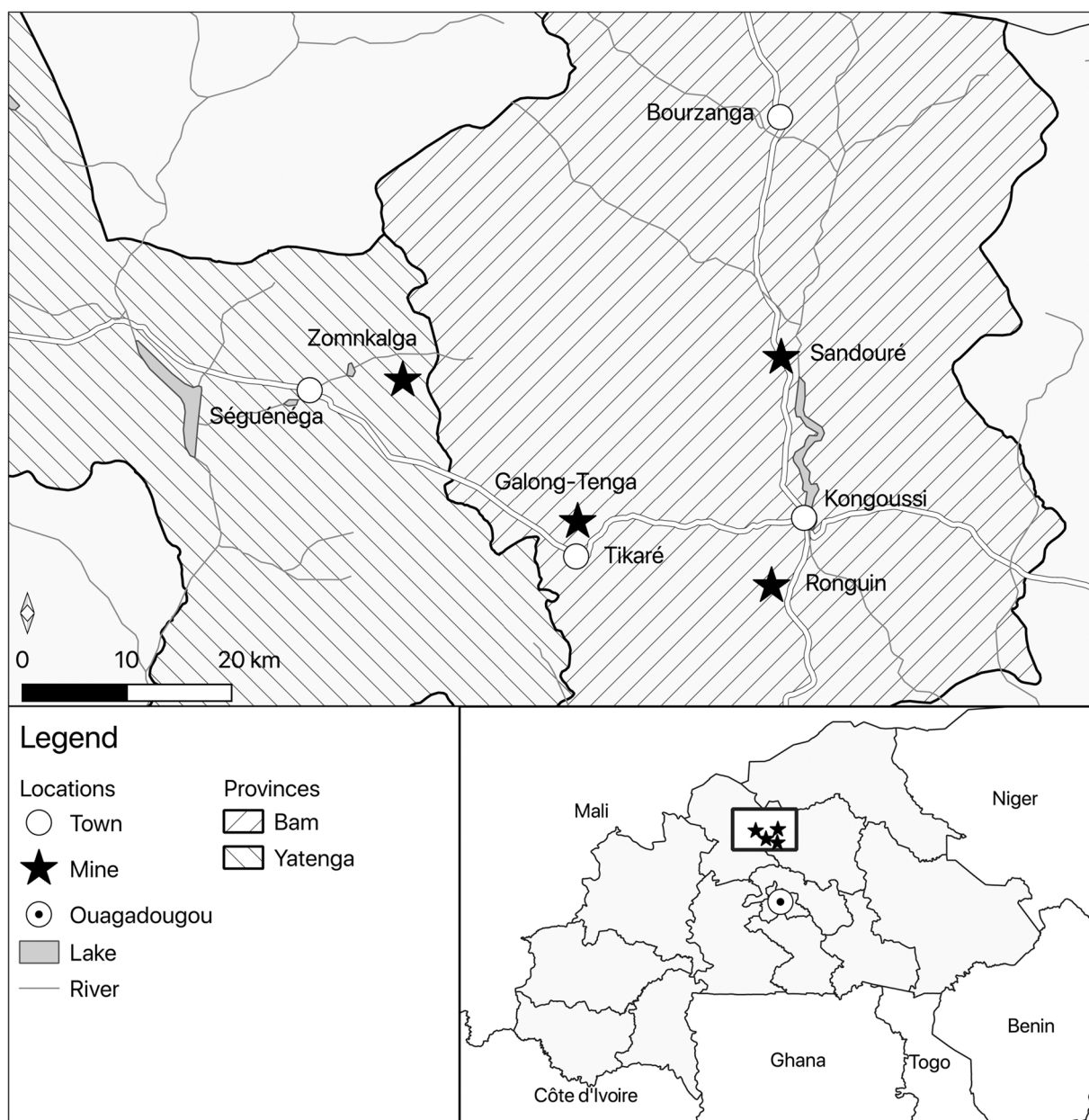


Fig. 2. The Provinces Bam and Yatenga are in one of the main mining areas of Burkina-Faso's Center-North. (Source: authors).

depends on his liquidity since nearly all transactions are cash-based; only 8% report that they also receive some credit for their gold.

In Ouagadougou, trade is centered around about 60 *comptoirs* holding a license to export gold. The *comptoirs* usually have a network of gold collectors from whom they buy gold. Most *comptoirs* we interviewed sell their gold to buyers in Dubai, either by taking gold there physically or by hosting buyers in Ouagadougou. Some *comptoirs* also sell regionally (e. g., Togo, Mali or Ghana) and within the country to licensed and also to non-licensed exporters. Here, the business model is based on high volumes and low margins, as the *patron* of a *comptoir* puts it: “In Ouaga: large quantity, small margin. On the sites: small quantity, large margin.” (ID02).

6.1.1. The flow of the benefit from mercury trade

According to our survey, 63% of the *creuseurs* and *propriétaires du trou* have access to one or two mercury retailers and 10% to four or more. Mercury is sold in 10-gram bags for \$3–5 US dollars. Many mercury retailers also sell other banned products such as cyanide or dynamite. To

avoid the risk of being detected, most prefer to stay in nearby villages and visit the mine at irregular intervals.

Mercury retailers get their supply in Ouagadougou. Numerous shops that sell crushing machines, mills, and other equipment also sell mercury, cyanide, and dynamite underhand. These wholesalers source mercury either from their trusted *patrons* who import mercury illegally (supposedly not identical with the *patrons* of the *comptoirs*), or they import mercury themselves.

Gold collectors who provide mercury to miners get it from the same wholesalers in Ouagadougou as the mercury retailers. Some tried to import directly but it is not lucrative: “It is me who brings [mercury] to the sites. We buy it from the traders in Ouaga. I used to look for it on the other side of the border, but I stopped. There was not much profit [...] so I abandoned.” (ID01).

Wholesalers in Ouagadougou offer standard 34 kg mercury bottles for around \$2400 US dollars. The price can rise from \$70 up to \$140 US dollars per kg when border controls and confiscations cut off supplies.

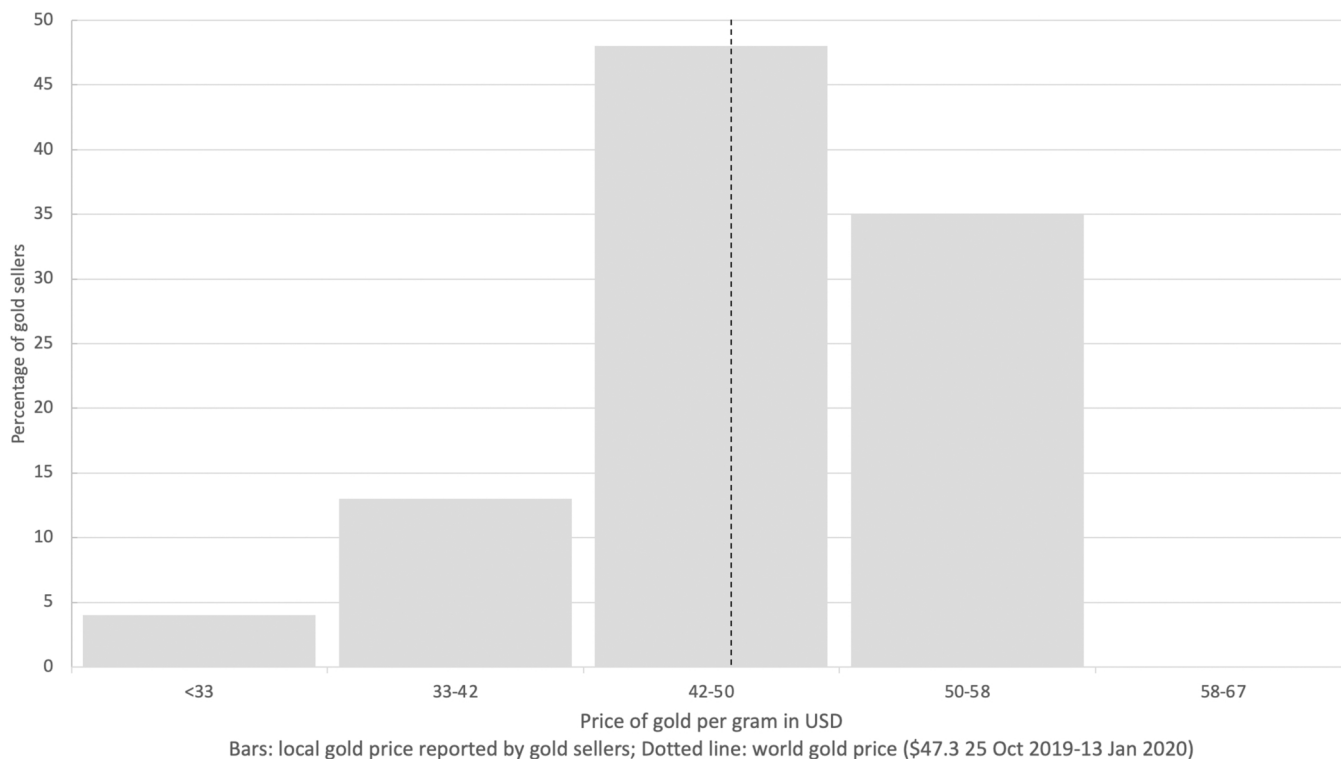


Fig. 3. Mine-site gold prices (n = 168). The nominal values reported must be taken with caution. On mines, the unit used are not always grams but more often expressed in “strands” of gold, which is the weight of one match. Ten or 25 FCFA coins are also used. The conversion can easily distort answers when people are asked for prices per gram.

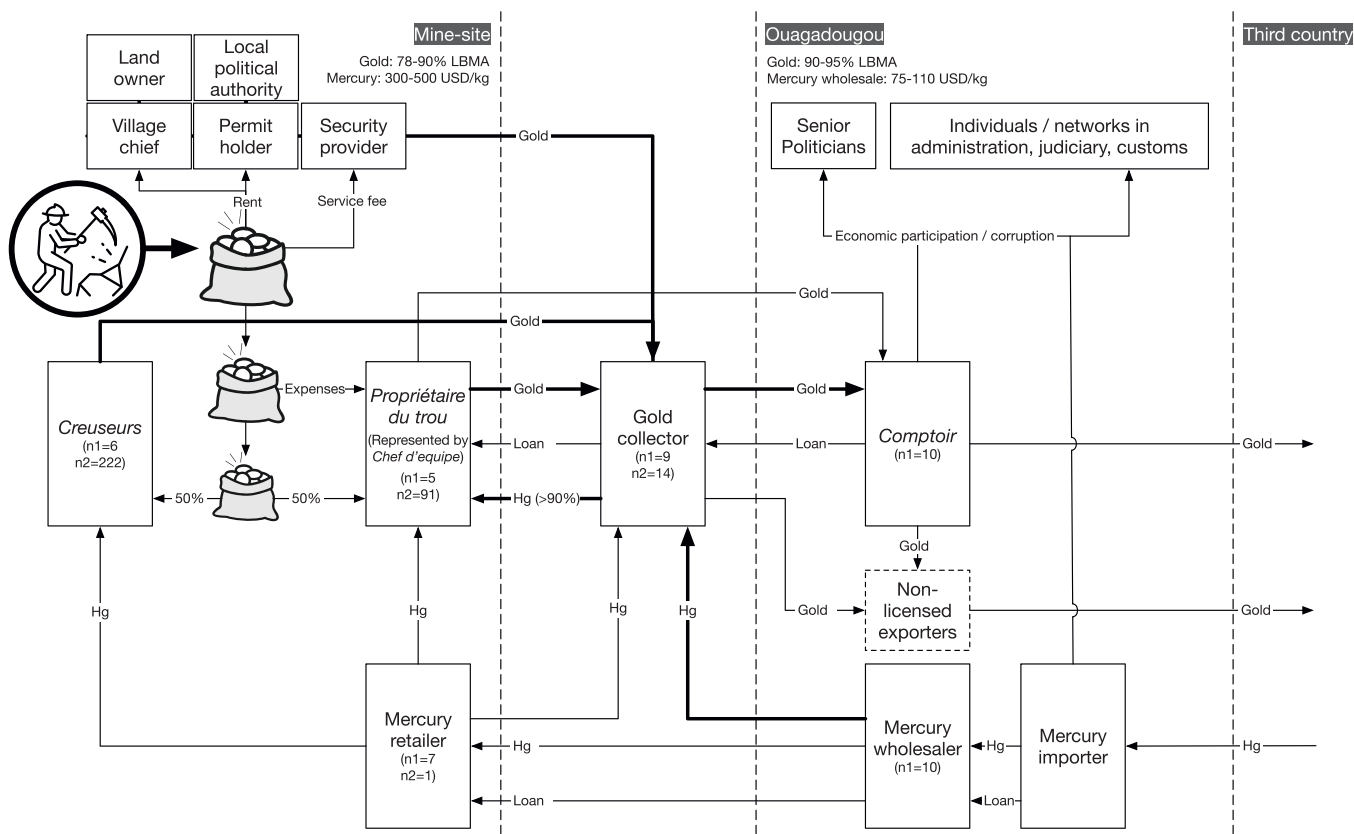


Fig. 4. Flow of benefit from gold and mercury. Bold arrows: main channel for this transaction. N1 = number of people interviewed; n2 = number of survey participants; each actor can fulfill multiple functions; Hg = mercury. (Source: authors).

Since most retailers are short on cash, wholesalers sell one-kilogram units, often on credit. For the mercury retailer, this translates into a gross margin of around 350% between Ouagadougou and the sites, from which the cost of credit and transport must be paid.

6.2. Access analysis

Next, we consider the access mechanisms, i.e., the means, processes, and relations by which the actors gain, control, and maintain access to benefits from gold, and their capacity to manage risks that might cut-off this access (Fig. 5).

6.2.1. Access to the gold value chain

The *creuseurs* command one single access mechanism to the gold value chain, which is offering their labor. For their offer to be taken, they have to accept significant operational risks, including accidents, shaft collapse, and psychological stress from working in extremely dangerous conditions like, e.g., descending into narrow unventilated shafts. As our survey finds, these risks are the most significant for *creuseurs*, more pressing than a low-onset health risk, such as exposure to mercury vapor.⁴ In addition, *creuseurs* must accept financial risk: in the worst case, when no gold is found, they just worked for daily food. The vast amount of excess labor in rural areas constrains *creuseurs*' position to negotiate better working and payment conditions.

The *propriétaire du trou* is the local entrepreneur who facilitates access to resource benefits through facilitating the necessary approvals from landowners and authorities and from organizing funding, labor, and equipment. Some *propriétaires du trou* are miners who work with their *creuseurs* on the site. Other *propriétaires du trou* do not work on-site and do not want to be officially associated with the gold business. In this case, he is represented by a *chef d'équipe* who manages the day-to-day mining operations. Such 'remote' *propriétaires du trou* can be well-connected merchants from the area or civil servants like e.g., teachers, administrators, or policemen. Some also come from Ouagadougou or other commercial centers.

Few *propriétaires du trou* have the means to prefinance the opening of a new shaft, i.e., paying for tools, equipment, and food for the *creuseurs* until the first gold is sold. Most rely on an investor to prefinance extraction in exchange for economic participation. The *propriétaire du trou* remains with the financial risk of lost investment, e.g., when small or no quantities of gold are extracted or when he loses approval from local authorities (e.g., the arrival of a new village chief).

Gold collectors deploy four complimentary access mechanisms through which they secure benefits. The most important is access to capital: gold collectors prefinance *propriétaires du trou* to open a new shaft. In return, they are entitled to buy all gold. When significant quantities are recovered, the sales obligation expires after a certain time. The prefinancing strategy also increases the gold collector's margin: "If you prefinance, you can pay less because you give the money. The pit they work in is for you. [...] If the price on the site is 10,000 [FCFA] per gram, we'll give them 7500 or 8000 max. [...] We lower the price, that's how we do it." (ID01). While prefinancing creates a monopoly for the gold collector, cash for buying gold and for prefinancing operation is not the gold collector's own money. He relies on advances from a *comptoir*.

Second, gold collectors control access to technology. They provide mercury for free or at a reduced price. They do so when they prefinance

but also provide mercury to other gold producers. Gold collectors see this as a strategy to enhance the loyalty of gold sellers: 90.56% of the mercury users (n = 180) get it from the gold collector; 53% of them for free. We used an ordered logit regression to estimate if gold collectors charge for this service by lowering the gold price (see e.g., Hilson and Pardie, 2006). However, although not significant, when controlling for each mine, we find a positive correlation between the reported gold price level and receiving mercury from the gold collector (odd ratio >1 in column 1, Table 1). Only miners who said they received mercury from the same person that buys their gold reported receiving mercury for free. We do find a significant negative correlation between the mercury price level and if the miners reported that they get the mercury from their gold collector (odd ratio <1 in column 2, Table 1).

In the case of prefinancing, gold collectors require that the amalgamation is performed directly after the extraction by themselves or in their presence to avoid that part of the ore is clandestinely removed: "For the prefinanced pits, we apply [the mercury] on the site. [...] You always have to be there when they hit the vein. If it's pure gold that comes out you make a pool, put water in, if someone comes out of the pit he goes in and washes himself. He'll take off all his clothes and then everything will stay there." (ID01).

Third, gold collectors invest in social relations and long-term business relationships by giving the gold sellers room to negotiate a better price, usually \$2–3 US dollars per gram, i.e., 3–5%. Finally, while gold collectors create the illusion that they are giving generous prices, they are rigging counterweights and purity measurements. The manipulation of the scales and artificially decreasing the heaviness of the counterweights (usually coins or matches) are common practices to make gold sellers believe that the gold was worth less than it actually is: "The gold miners don't know the weighing tools very well. So, if you manage to use the modified 10 FCFA coin you can decrease because if the [amount of gold equivalent to the weight of a] normal 10 FCFA coin costs 75,000 FCFA, [using] the modified 10 FCFA coin for weighing is [equivalent to the amount of gold] worth 85,000 FCFA or even more. We accept to decrease but in reality, we do not decrease." (ID03).

The simultaneous use of access mechanisms works out: Although 63% of gold sellers stated that they know more than one gold collector and choose the one who offers the best price, 90% of this group also stated that they always sell their gold to the same gold collector.

Gold collectors face risks, too: One is security, particularly when commuting to Ouagadougou to sell gold. "Many of our patrons are afraid to give us a lot of money because of the attacks by armed groups." (ID04). The other is the increasing amounts of prefinancing needed: deeper shafts and the use of motorized equipment make operations more expensive: "The business used to require less money. Today, the methods are more efficient, but they also require more means, for example, to stabilize the shafts with cement and concrete." (ID05).

With about 60 registered *comptoirs*, gold trading concentrates in Ouagadougou. The *patrons* of the *comptoirs* are those who finally bankroll most ASGM operations. The provision of capital is their key access mechanism. Since the prefinancing loans are arranged in an entirely informal manner, social relations together with access to a large network of gold collectors are paramount for the *comptoirs* to control and maintain access to the upstream part of the value chain. The residual risk that a prefinanced shaft produces only a little or no gold favors the bigger *comptoirs* who are able to diversify their investment across many shafts.

Technology and knowledge are further access mechanisms that *comptoirs* deploy towards the gold collectors. Often, the *patron* provides the equipment to treat the gold, smelt it and cast it into a *lingot*. The *patron* assesses the quality of the gold by weighing the *lingot* on an electric scale and determining its density in a small water basin. *Patrons* also influence measurement results; for example, adding salt changes the density-measurement of the *lingot* in the *comptoir*'s favor. "Even when we buy on the site, everything is done here. [The gold collectors] have to come to Ouaga to determine the value [...]. The price is defined in the office, because only when you melt it can you know the carats". (ID06).

⁴ In the parallel study conducted on the same survey participants on miners' protective strategies when using mercury, it was found that most miners are aware mercury is dangerous but do not sufficiently protect themselves when using mercury. Giving out personal protective equipment in the form of masks and gloves had a significant positive impact on reported usage. Using hair samples from 179 study participants, the authors found that gold collectors and miners who report using mercury often showed higher levels of mercury in their bodies (see Van der Merwe, 2022).

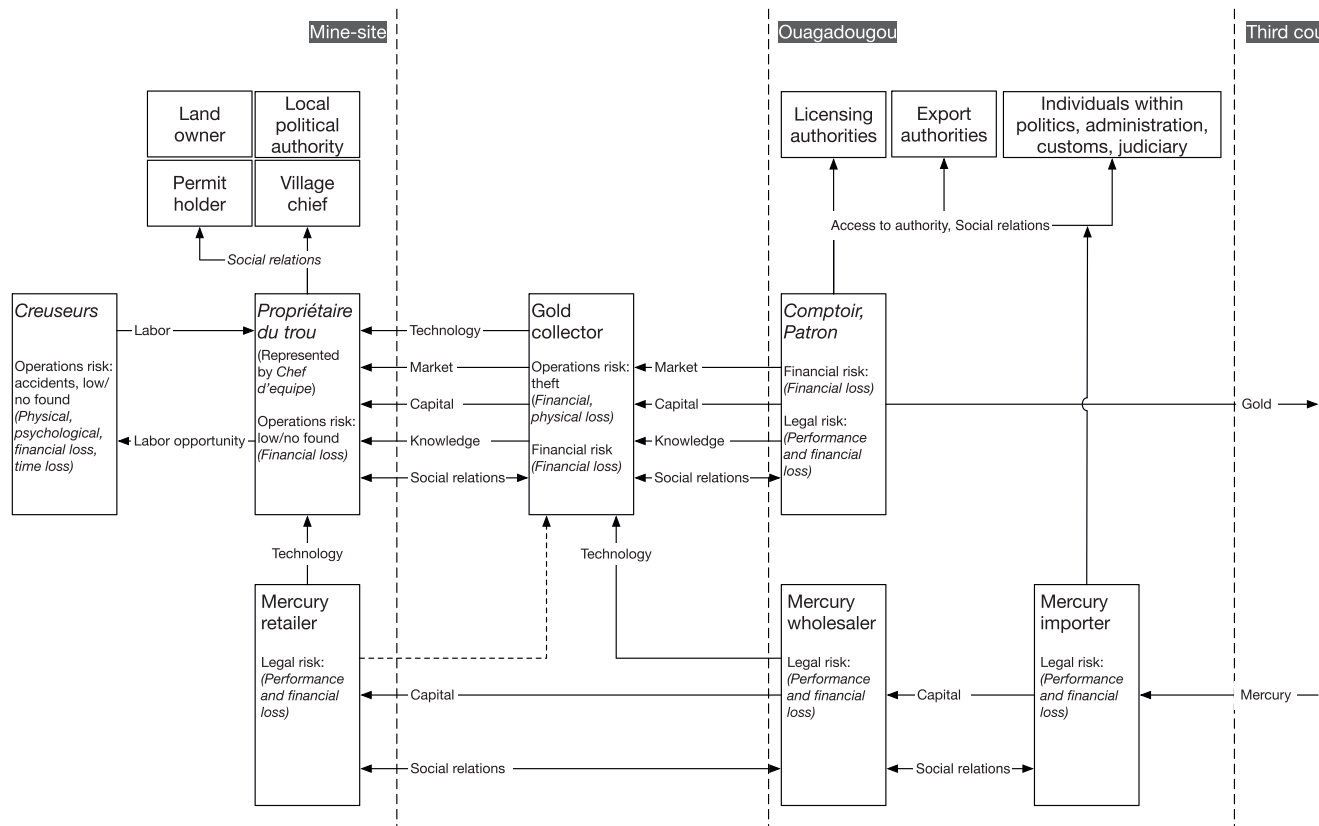


Fig. 5. Means of access and risk exposure. (Source: authors).

Table 1

We do not find a significant correlation between gold collectors providing mercury and lower gold price levels (1) but we do find a negative correlation to lower mercury prices (2). We do not have data on mercury prices for Sandouré. Ordered logit regression showing the odd ratios (<1: negative correlation; >1: positive correlation) with standard errors in parenthesis. Only people who sold gold in the last month (1) and used mercury in the last month (2) were included. *** p < 0.01, ** p < 0.05, *p > 0.1.

	(1)	(2)
	Gold price	Mercury price
Mercury provided by gold collector	1.815 (0.924)	0.261*** (0.113)
Reference mine: Zomnkalgá		
Sandouré	0.674 (0.298)	
Ronguin	2.414* (1.134)	1.164 (0.469)
Galong-Tenga	6.000*** (4.076)	0.695 (0.336)
Observations	153	126

Some *propriétaires du trou* travel to Ouagadougou to sell their gold, which again amplifies the power of knowledge and capital. “It’s with the gold miners who come to the office that the margin is the biggest. The price depends on the day, on his availability of money, on his attitude to it [...]. They can come right away, with 500 g and they ask you: ‘for how much do you take it’? And you say: ‘I don’t have the money so wait.’ Then he’ll say: ‘ok, how much do you have?’ And then it is not about actual gold prices anymore”. (ID07).

Downstream, *comptoirs* as exporters access markets through access to authority. Formally, this is achieved by obtaining an export license. However, there is an understanding among exporters that the official route is financially not sufficiently attractive. “I don’t think there’s

anyone in Burkina Faso who gets rich on the legal route. It’s not possible.” (ID08). To maximize the benefit, *comptoirs* underreport export quantities or smuggle to neighboring countries to avoid export taxes. Access to authority is the key conduit to make this work and manage the legal risks associated: “In the [gold export] chain, you need to have a magistrate with you, a lawyer and a member of the BNAF (Financial Intelligence Unit) – those are the three conditions. If you have those three, they close their eyes. They even tell you how to proceed. A customs officer, you can also put him in the chain”. (ID08).

Another strategy is to sell gold to illegal exporters (mainly Indian, Chinese and Lebanese traders) without recording any transaction: “We’ve already sold to Indians to do internal trading; this means buying and reselling on the same day. Given the high taxes, it’s a nice strategy to abdicate one’s responsibility for everything that is exported and let them do it”. (ID08).

6.2.2. Access to the mercury value chain

The mercury retailers control less of the mercury market than the gold collectors: “[The gold collectors] are the mercury suppliers. Even if you don’t have the money, they give you the mercury, and when you bring your gold, they make a deduction. But you can also have people on the site who just hang it up [physically] and then sell it like this”. (ID09).

Since mercury retailers typically lack the capital, they rely on getting the mercury on credit from the wholesalers in Ouagadougou. A combination of trusted long-term relationships and financial dependency is the access mechanism that links retailers with wholesalers and protects the latter from getting betrayed.

For mercury wholesalers and importers, access to authority and the negotiation of social relations are pivotal access mechanisms that make their business viable: “It’s a bit difficult to go by road. Unless there is corruption. This can’t be denied. The [trafficker] will negotiate, ‘listen, between brothers, we’ll do like this...’[...] The customs officers know that [mercury] is forbidden but eventually...” (ID10). Close personal relations

between authority, wholesalers and importers also mitigate legal risks. Representatives from the local police and the Ministry of Environment explained that they were expected to sanction illegal deforestation caused by ASGM, but they were not supposed to step in against trade or use of mercury. It was risky for them to intervene, and they might lose their job if they would act against the informal political dynamics.

According to our findings, the cross-border trade of mercury is separated from the gold export. For the *comptoirs*, this might be a risk management approach. For the mercury wholesalers, this separation is out of necessity. Many stated that they would like to engage in gold trading if they had the financial means to do so. The mercury and gold chains join up with the gold collector, who uses mercury as a ‘commitment and controlling device’.

6.3. Power relations underlying the mechanisms of access

Power is concentrated with the mercury importers and the gold exporters to which other value chain participants – revealingly – refer to as *patrons*. Through economic cooptation, mercury importers make individuals from the political and administrative system their ‘business partners’ in exchange for political protection. On the other side, through prefinancing wholesalers and – indirectly – retailers mercury importers create a loyal, dependency-based distribution network which provides an additional layer of protection for their operations.

In the case of gold, only about 60 *comptoirs* de facto control a large part of the mining activities in up to 2200 mine-sites across the country through a cascading system of prefinancing arrangements; probably except the mine sites in the North and North-West, which may be under control by armed groups. Without investment from downstream actors, there is no gold production upstream. In a system that lacks formal credit arrangements, long-trusted relationships based on personal relations and reputation replace formal securities and enforcement mechanisms. Downstream the gold chain, access to authorities based on economic cooptation is essential to valorize gold.

Along both value chains, the ability to provide capital makes actors more powerful. In gold, the magnitude of capital investment comes with significant financial risk for the lenders. The diversification of the investment reduces the likelihood that all fail simultaneously, which favors the wealthier financiers. In addition, in the absence of formal credit arrangements and enforcement mechanisms, lenders are putting alternative measures in place to exert control. On the gold sourcing side, this is a combination of controlling knowledge and technology that cascades from *comptoirs* via gold collectors to *propriétaires du trou* and *creuseurs*.

From a controlling perspective, the “mercury-for-free” practice buys the gold collector access to the very moment of gold recovery. The way amalgamation works makes mercury a cheap and convenient recovery method that provides advantages to producers and traders, superior to alternative methods; cyanidization, for example, takes several days to extract the gold from the ore. The benefit for the gold collectors is amplified by the information asymmetry regarding world gold price combined with control over quality assessment and assaying. Survey findings corroborate this dependency. Most respondents (59%) know that cyanide is a more effective method to extract gold compared to mercury, but cyanide is only used as a complementary second step for gold recovery on the four mining sites.

Access to capital separates the gold and mercury chain actors and renders the former more powerful than the latter. In both chains, power also vanishes with distance to the *patrons* while dependency and risk increase in lockstep with smaller financial benefit. To mitigate part of this dependency, most gold collectors channel some gold through other *comptoirs* than their *patrons* while reinforcing dependency towards gold sellers.

The *propriétaires du trou* derive some power from their access to local authority and organizing the extractive work. *Propriétaires du trou* have more autonomy and influence when they finance operations themselves, but this is rather the exception than the norm. Finally, from an investor

perspective, *creuseurs* have the primary function to keep production costs low to maximize benefit. Under the condition of excess labor, *creuseurs* are the rule takers and do not have an option but to accept significant financial risk and to absorb operational health and safety risk fully. The powerless position of *creuseurs* is reflected in their low social status compared to the national average (World Bank, 2021): 71% have not attended any schooling; 75% of male and 83% of female participants cannot read or write (national average: 50% and 67%) and only 1% have completed secondary school (national average: 8.5%).

7. Discussion

Our study contributes to enhancing the understanding of the gold value chain and the persistent use of mercury despite its harmful externalities and the availability of superior alternatives. The combination of access and risk theory proved instrumental to disentangle dependencies on webs of power along the value chain and link artisanal operations with international mercury and gold markets.

Our findings challenge conventional wisdom about poverty-driven ASGM. While ASGM would not be possible without millions of people in search of a livelihood, ASGM would not be a viable livelihood strategy without access to capital and international markets. When the government of Burkina Faso closed borders and suspended international flights during the Covid-19 pandemic in 2020, local gold prices immediately slumped, bringing production to a near halt despite world gold prices climbing an all-time high. Most gold collectors soon run out of cash, putting the few solvent ones in a monopsonist position. *Creuseurs* and *propriétaires du trou* desperate to sell had to accept extraordinarily low prices or even sell on credit while buyers made a fortune. Only after borders opened local gold prices started to recover (Reid and Lewis, 2020; Van der Merwe, 2022; Zongo and Sawadogo, 2020).

The lack of knowledge about the world gold price suggests that the ASGM sector is not primarily driven by jobless youth or gold seekers motivated by raising world gold prices. Instead, ASGM is increasingly the product of capital that is looking for lucrative investment opportunities. The goal is to maximize return on investment by controlling access to markets for upstream gold producers through prefinancing, imposing technological choices, and exploiting information asymmetries. Investors take advantage of the excess labor force in low-income countries such as Burkina Faso to shift operational and financial risk upstream. In this, *comptoirs* have been joined by other Ouagadougou-based investors becoming *propriétaires du trou* more recently. The result is the perpetuation of precarious working conditions for the *creuseurs* while the positive effect that ASGM has on local livelihoods (Bazillier and Girard, 2020; Brugger and Zanetti, 2020) is more a side-effect to facilitate the accumulation of wealth downstream.

Our findings also disprove the argument that formalization would allow miners to invest in more effective methods (Hinton 2006). We find that *propriétaires du trou* do have access to credit, even if it is not a formal loan. Mercury replaces functions that otherwise would be fulfilled by formal arrangements. Whereas gold and mercury value chains seem to be neatly separated, they come together at the point where gold buyers provide mercury. In this case, mercury adopts the function of a ‘commitment and controlling device.’ It enables investment in ASGM and secures the return on investment. Abolishing mercury would undermine the viability of the current system as an interviewee put it: “Doing ASGM without mercury [...] is like trying to make omelets without eggs”. (ID11).

Further, our findings disprove the techno-developmental assumption that miners would switch to improved technology, if available. Most *creuseurs* and *propriétaires du trou* are aware that cyanide has higher gold recovery rates, and many even are involved in cyanide leaching on each site we studied. Yet, adoption remains limited to the processing of tailings.

Despite the importance of mercury in the gold value chain, our findings do not confirm claims made in the literature that the *comptoirs*

are involved in mercury trade (Hendus, 2020). We find the different levels of financial requirements make the chains accessible for different actors and gold traders prefer to avoid the accumulation of risks. Yet, we cannot rule out the option completely that *comptoirs* play a role in e.g., indirectly financing mercury imports due to their interest in a functioning mercury supply.

The widespread use of mercury in ASGM across the Sahel and Sub-Saharan Africa makes our findings relevant beyond Burkina Faso. They can particularly inform the development of National Action Plans for the Implementation of the Minamata Convention. Formalization approaches and the introduction of mercury-free technologies need to be sensitive to the non-technical functions of mercury and the informal governance dynamics along the mercury and gold value chains. Acknowledging the miners' dependency on mercury opens a more constructive starting point than the dominant legalistic attitudes. However, focusing on miners will not be enough. The *comptoirs* that emerged as the power holders and primary beneficiaries of the current system will present a daunting policy challenge when they see their income stream threatened.

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CRediT authorship contribution statement

Bugmann: Conceptualization, Methodology, Investigation, Formal Analysis, Writing – original draft, Supervision, Project administration
Brugger: Conceptualization, Methodology, Writing – original draft, Visualization, Supervision, Funding acquisition, **Van der Merwe:** Formal analysis, Writing – review & editing, Project administration, **Zongo:** Investigation, Writing – review & editing.

Declaration of Competing Interest

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

ID	Actor	Place	Date
1	Gold collector	Ouagadougou	10.12.2019
2	Patron of <i>comptoir</i>	Ouagadougou	30.11.2019
3	Gold collector	Galong-Tenga	08.01.2020
4	Gold collector	Ouagadougou	26.11.2019
5	Gold collector 1	Ouagadougou	09.12.2019
6	Patron of <i>comptoir</i>	Ouagadougou	27.11.2019
7	Patron of <i>comptoir</i>	Ouagadougou	04.12.2019
8	Patron of <i>comptoir</i>	Ouagadougou	07.12.2019
9	Technical Director of DGPE	Ouagadougou	09.12.2019
10	ANEEMAS official	Ouagadougou	03.12.2019
11	Mercury trader	Zomnkalgá	06.01.2020

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