Policy Insights
74
August 2019

Blockchain in the Mining Industry: Implications for Sustainable Development in Africa

FILIPE CALVÃO & VICTORIA GRONWALD

African perspectives
Global insights

SAIIA
SOUTH AFRICAN INSTITUTE OF INTERNATIONAL AFFAIRS

Executive summary

Distributed ledger technologies (DLT) enable the creation of digital databases stored across multiple locations. In the most-advanced design of DLTs, blockchains record and publish transactions through a peer-to-peer and tamper-proof block structure, and operate securely through a consensus-based algorithm. Increasingly, DLTs and blockchain-based initiatives are deployed in the mineral sector to address the problem of conflict minerals, ensure respect for due diligence standards, and improve supply chain management and traceability. The fast adoption of this technology for governing natural resources by creating immutable digital records of sourcing and geological information engenders new opportunities and risks for mining communities across Africa. These include the creation, ownership and access of digital data, the participatory role of upstream actors, and the effects of monitoring and traceability for informal miners and the future of sustainable development in mining communities.

Introduction

The extractive industry sector is undergoing significant transformations in response to tightening financial regulations and divestment in mining activities. These changes are compounded by increasingly ethically aware consumers seeking an assurance that the products they buy do not contribute to the negative environmental and human impacts of mining, as well as by the disruptive effects of synthetic gemstone production in the market. These transformations will significantly impact resource-rich mining economies in sub-Saharan Africa.

The use of blockchain technology in mineral supply chains has been presented as a panacea for some of these problems, including social and environmental issues. At its inception in 2008, blockchain first gained renown as the technology underlying the Bitcoin cryptocurrency.[1] As a decentralised network, based originally on an electronic, peer-to-peer payment system, blockchains serve as a public digital ledger to record transactions without relying on financial institutions or third-party control. Among its core principles, the original decentralised blockchain rests on openness, transparency and security. Specifically, the possibility of an immutable, or tamper-resistant, ledger has generated different applications for managing high-value assets, including minerals.

Unlike public blockchains (fully decentralised nodes not placed under any single authority), consortium or private blockchains (controlled by a select group of approved or permissioned actors, usually private institutions) have been more conspicuous in the mineral sector. Particularly since 2018, these privately distributed ledgers have emerged in proof-of-concept or pilot stages to showcase how mining, manufacturing and jewellery

1 See Nakamoto S, 'Bitcoin: A peer-to-peer electronic cash system', Bitcoin, https://bitcoin.org/bitcoin.pdf?, accessed 29 April 2019.

actors may harness the potential of blockchain technology in the mineral sector. However, the industry is currently grappling with two related challenges: first, the technical difficulty of translating conventional methods of tracking the physical commodity – from tagging to fingerprinting – into blockchain-based solutions; and second, creating incentives for proper data entry and validation, as well as compensating for value and information fragmentation across participants in the supply chain.[2]

This policy insight reviews the main applications of blockchain technology in the mining industry, from mineral traceability to due diligence, as well as the main challenges emanating from its implementation in Africa. While blockchain technology holds the potential to trace and track minerals from point of extraction to the end consumer, the technology alone does not guarantee socially and environmentally responsible practices along the supply chain. Importantly, some of the most expansive traceability initiatives collecting data down to the level of the mining site neglect to record information about ethical labour practices. Any application of blockchain technology that is focused solely on traceability, we suggest, might allow human rights abuses, corrupt practices, environmental damages and health and safety issues to go unchecked. The policy insight concludes by examining the issue of data agency and ownership, as well as the critical problem of exclusion of artisanal miners or other downstream supply chain actors.

Blockchain technology for mineral traceability

Since the early 2000s there has been no shortage of instruments and governance initiatives to trace the provenance of gemstones, and diamonds in particular, to control irregular supplies. The push for global transparency and accountability in the mining sector was largely heralded by the Kimberley Process Certification Scheme (KPCS).[3] The advent of new international standards for mineral supply chains was further consolidated by the Dodd-Frank Wall Street Reform and Consumer Protection Act (Section 1502, 2010), the Organisation for Economic Co-operation and Development's (OECD) Due Diligence Guidance for Responsible Mineral Supply Chains (third edition, 2016), and the EU's forthcoming Conflict Minerals Regulation (2021) meant to regulate the trade of tin, tantalum, tungsten and gold. These initiatives rest primarily on an assessment of provenance or determination of origin, whereby consumers and traders alike take credence in expert reports assessing the country of origin, or otherwise a paper and audit trail capable of fully accounting for a commodity as it moves from production to consumption (chain of custody).

Since 2016 the mining industry has been at the forefront of an alternative to paper certification modelled on the digital-based blockchain ledger. From diamonds to cobalt to

2 For an early overview of these technical obstacles, see Rakic B *et al.*, 'First purpose built protocol for supply chains based on blockchain', origintrail, 5 October 2017, https://origintrail.io/storage/documents/OriginTrail-White-Paper.pdf, accessed 29 April 2019.

3 First established in 2000 after a first round of meetings between Southern African producers, and entered into force in 2003, with the adoption of UN Security Council Resolution 1459.

gold, there has been an explosion in blockchain-based initiatives for traceability purposes in mineral supply chains. These are often presented as the silver bullet to the perennial problem of record-keeping in commodity transactions. Blockchain technology seeks to expand the scope of existing traceability initiatives, including determination of origin and enhanced chain of custody. The digital transparency of blockchain projects offers the potential of a tamper-proof, immutable record of transactions, ownership and origin. Unlike existing chain of custody initiatives, it effectively surrenders the need for intermediaries or trusted partners to verify, audit or certify the supply chain information (although, as discussed in the following section, blockchain technology only guarantees traceability, and additional due diligence is required to ensure the quality of the input data).

The digital transparency of blockchain projects offers the potential of a tamper-proof, immutable record of transactions, ownership and origin

Diamond industry initiatives

Diamonds in particular have seen a plethora of industry-led initiatives designed to enhance traceability. This is so for two related reasons. First, these are meant to mitigate reputational risks associated with the early 2000s 'blood diamonds' scandal and the possibility of fraudulent or manipulated data. This trend is particularly evident with the surge of uncertified lab-grown synthetic diamonds entering the market and unverified claims of provenance supplied by 'ethical' diamond providers. Second, as pure carbon molecules, it is not possible to technically establish a reliable origin 'signature' for diamonds through scientific or purely chemical composition, unlike other gemstones such as rubies or emeralds.[4] In other words, the conventional gemmological solutions to assess origin (including fingerprinting methods, or others based on the qualities and degree of impurities or isotopes from particles with which to identify geographic origin) do not apply to diamonds.

The Kimberley Process (KP) has begun exploring the possible integration of blockchain technology into its certification process to 'eradicate false KP certificates and reduce the impact of human error while uploading data'.[5] Aside from this multi-stakeholder initiative, there are currently a number of blockchain projects geared toward the diamond supply chain that are in different stages of implementation. Everledger has been leading the

4 See Cartier LE, Ali SH & MS Krzemnicki, 'Blockchain, chain of custody and trace elements: An overview of tracking and traceability opportunities in the gem industry', *Journal of Gemmology*, 36, 3, 2018, pp. 212–227.

5 Blockchain solutions were first proposed by the KP United Arab Emirates chair in 2016, according to its mid-term report. See United Arab Emirates, Ministry of Economy, *Kimberley Process Mid-Term Report*, 2016, https://www.kimberleyprocess.com/en/system/files/documents/kimberley_process_mid-term_report.pdf, accessed 12 July 2019.

race for blockchain technology to create a global registry for diamonds. It seeks to digitally certify the provenance of diamonds above 0.25 carats (50mg or 4mm) by creating a digital 'thumbprint'.[6] This thumbprint would include data matrix symbol codes, or a two-dimensional barcode akin to Quick Response codes, with the information duly replicated and stored on the blockchain. This record, however, can only occur at the moment of polishing and would thus not entirely preclude the risks associated with ensuring an authentic provenance through conventional chain-of-custody processes. Everledger has also managed to recruit different partners, from retail operators (Brilliant Earth) to commodity and digital assets exchanges (Singapore Diamond Investment Exchange, Kynetix), straddling the boundaries of conventional mining partners.

Not to be outdone, in early 2018 De Beers unveiled its own blockchain initiative (Tracr). Thus far it has persuaded major mining and trading players to join the pilot stages of its blockchain, namely Alrosa (the world's largest producer of rough diamonds by volume), as well as retail operators Signet Jewelers and Chow Tai Fook. TrustChain, a partnership between IBM and five companies representing the entire supply chain, is still in proof-of-concept stage and has not seen any update since being officially unveiled in April 2018. Unlike its competitors, TrustChain targets both gold and diamonds, sourced respectively by Leach Garner and Rio Tinto Diamonds, as well as different actors representing refinery, jewellery manufacturer, and retail operations. Similar blockchain-based solutions are currently being developed to enhance knowledge about mining sources and the potential for traceability. Lucara Diamond, for example, has acquired Clara Diamond Solutions to ensure diamond provenance from mine to consumer using blockchain-derived technologies.[7]

Aside from diamonds, Gübelin Gem Lab has recently introduced a 'paternity test'[8] to trace the 'provenance of emeralds back to the exact mine'.[9] Each individual stone is soaked with DNA-based, nano-sized particles encoded with information on each specific mine, which would in turn permeate the stone's natural fissures and microscopic crevices. In other words, the lab would physically introduce information about the mine, the mining company, and date of extraction onto the stone itself. The microscopic barcode is practically invisible and non-removable, and would survive cutting, polishing, testing and mounting. This technology, however, is not applicable to diamonds – unlike emeralds,

6 The process would entail a two-step verification process: in actual mines, a composite picture of each stone would be created through HD cameras and a stress map with internal deformations (personal communication, Leanne Kemp, CEO of Everledger, June 2018). The second stage, also designated as the digital incarnation, entails the actual physical inscription on the diamond's girdle, star facet or crown.

7 This is not an exhaustive list. Diamante Blockchain Consortium, for example, presents itself as a 'global diamond consortium powered by blockchain technology', although it does not disclose its consortium members. Unlike some of its competitors, however, it seeks to incentivise participation from industry partners by associating the traceability of diamonds to a native crypto-currency. See Diamante Blockchain Consortium, 'Diamante blockchain authenticates ownership and credibility of diamonds', Press Release, 5 February 2019, https://www.diamanteblockchain.com/media/trending/diamante-blockchain-authenticates-ownership-credibility-diamonds/, accessed 29 April 2019.

8 Gübelin Gem Lab, 'Emerald paternity test', https://www.gubelingemlab.com/en/provenanceproof/emerald-paternity-test, accessed 12 July 2019.

9 Presentation by Daniel Nyfeler, Director of Swiss-based laboratory, KP meeting, June 2018.

which retain microscopic openings, diamonds' polishing would erase this nano-particle DNA information. Building upon its 'paternity test', the Swiss-based laboratory has been the leading actor in developing a blockchain-based solution for coloured gemstones, revealed in early 2019 in technical partnership with Everledger.

The mining industry in the Democratic Republic of Congo (DRC) has also witnessed the appearance of different digital tracking and blockchain-enabled solutions: RCS Global and the Better Sourcing Program have unveiled pilot projects seeking to responsibly source cobalt.[10] This is a particularly relevant project given the fungible nature of raw materials and the risk of mixing cobalt from certified and non-certified sources. Similarly, the non-governmental organisation IMPACT and technology company Consensas have recently partnered to implement a blockchain pilot solution for the sustainability of conflict-free, ethical gold mining in the country's Ituri province.[11] While these are not blockchain projects as such, they seek to digitally monitor the commodity for potential integration in blockchain traceability solutions.

As a new financial and digital technology, the use of blockchain for traceability purposes raises questions regarding the risks and potentials of owning and accessing digital data and the participatory nature of record-keeping monitoring. There are other politically salient risks associated with digital transparency pegged to blockchain technology. Unlike the public oversight associated with multi-stakeholder initiatives, the governance and control mechanisms (ie, the maintenance of consensus protocols) in permissioned private blockchains (ie, not open and decentralised public blockchains) would fall entirely under the purview of private institutions, be they banks or companies.[12] The lack of interoperability across blockchains, moreover, would contradict the open control over digital ecosystems meant to expand transparency and accountability.

Blockchain technology and supply chain due diligence

In order to deliver on the promise of responsibly sourced minerals, blockchain traceability must be implemented along with due diligence practices. Two of the main challenges are the attainment and integrity of environmental and social standards throughout the supply chain, and the reliability of data input into the blockchain.

10 RCS Global & ICMM, *Blockchain for Traceability in Minerals and Metals Supply Chains: Opportunities and Challenges*, RCS Global, 20 December 2017, https://www.rcsglobal.com/wp-content/uploads/2018/09/ICMM-Blockchain-for-Traceability-in-Minerals-and-Metal-Supply-Chains.pdf, accessed 12 July 2019. See also Pinkert D, Tonthat J & R Soopramanien, 'How blockchain can make supply chains more humane', *Stanford Social Innovation Review*, 18 January 2019, https://ssir.org/articles/entry/how_blockchain_can_make_supply_chains_more_humane, accessed 29 April 2019.

11 Consensas, 'Just Gold Case Study', https://www.consensas.com/impact-just-gold-case-study, accessed 12 July 2019.

12 Calvão F, 'Crypto-miners: Digital labor and the power of blockchain technology', *Economic Anthropology*, 6, 1, 2019, pp. 123–134.

In order to deliver on the promise of responsibly sourced minerals, blockchain traceability must be implemented along with due diligence practices

Blockchain technology by itself only guarantees traceability, as previously laid out, but that can also include the traceability of irresponsibly produced or traded minerals.[13] The term 'blockchain' can give a false sense of the integrity and responsibility of the associated production and trading practices. Additional due diligence, meaning assessment of risks and their subsequent mitigation or remediation, must complement any implementation of blockchain technology. In practice this would require that any mine site whose production information will be fed into the blockchain comply with selected responsible mining criteria or an existing standard such as a recognised certification or the OECD Due Diligence Guidance. It would further mean that other supply chain actors on the blockchain, such as dealers and exporters, also operate within the confines of the law and are not involved in any illicit or corrupt practices. A combination of due diligence and blockchain technology would ensure that no actors along the blockchain are linked to armed groups or contribute to conflict financing, human rights abuses, corruption or environmental damage.

Ensuring due diligence

One example of how due diligence and blockchain have been coupled is De Beers' blockchain platform Tracr, used to trace diamonds from site of production to customers. In order to avoid issues related to the participants of the blockchain, Tracr uses Know Your Customer checks on each prospective member of the blockchain. In the GemFair project, sourcing from artisanal and small-scale miners in Sierra Leone, these miners must be certified against a selected responsible mining standard and receive training. RCS Global and the Better Sourcing Program are another example of combining blockchain integration and due diligence. First, they validate and monitor cobalt miners in the DRC for compliance with the OECD Due Diligence Guidance. Second, they use digital monitoring adaptable to blockchain technology to trace the minerals and shield them from supply chain contamination. Similarly, the blockchain company Mintrax, also working on metals trading in the DRC, ensures compliance with the OECD Due Diligence Guidance by collaborating with due diligence firm BetterChain.[14] The European Partnership for Responsible Minerals-funded Sustainblock pilot project for artisanally

13 See, for example, Gobrecht HD, 'Technically correct: Using technology to supplement due diligence standards in eastern DR Congo conflict minerals mining', *Journal of Law, Technology & Policy*, 2, 2011, p. 429.

14 *Engineering and Mining Journal*, 'Blockchain forges links to the mining industry', 219, 9, September 2018, p. 58.

mined tungsten from Rwanda is also only working with OECD-compliant miners. Other options of coupling due diligence and blockchain traceability are outlined by the company White & Case, namely automated due diligence and reporting from the mine site, and recording of environmental impacts on the blockchain.[15] A blockchain can also contain qualitative social, environmental and governance information, based on an agreed-upon certification standard,[16] or certificates of responsible production.[17] Finally, Minespider's due diligence protocol, relying on the Ethereum blockchain, is a particularly promising pilot project currently planned for expansion in West Africa. The due diligence focus of the protocol addresses issues of interoperability across a proliferation of private blockchains, self-sovereign supply chain data for communication across partners, and the inclusion of artisanal miners, although admittedly resting on an inherently unstable and speculative system of tokenised incentives.[18]

There remains the question of who collects the due diligence and other blockchain data and how the reliability and accuracy of that data is assured. Although the decentralised architecture of public blockchains offers a solution to the risk of data tempering, this problem is particularly relevant in the crucial first data entry point. On its own, blockchain technology provides no guarantee for the accuracy of the data entered at any stage of the supply chain, but only protects the data against tampering once it has been uploaded. According to White & Case, echoing a common idea in the industry, the blockchain tool is only as good as the data on it.[19] Wipro confirms that blockchain only has a real influence on how business is conducted if there are participants to validate transactions and certainty that the data source is reliable and truthful.[20] The data entry, however, is still subject to human influence. To address this issue, some blockchain technologies only allow data entry by accredited partners,[21] which can be a type of quality control, or by way of a 'token staking' system to ensure its decentralised governance.[22] Technology provider Consensas uses digital signatures and tracking of identity and location of the contributors to provide data accuracy assurance, in addition to subsequent data validation by other supply chain actors. Additionally, there can be third-party verification of the data through auditors, regulators, or others.[23] RCS Global similarly suggests that there should be an algorithm or a person to validate data in the field, according to a previously agreed consensus and data quality standard. This agreement could be that the data corresponds to a certain

15 White & Case, *Digitalising the Mining & Metals Global Supply Chain: Blockchain Brings Sustainability to the Forefront*. London & Washington DC: White & Case, 2018, p. 2.
16 *Ibid*., p. 3.
17 RCS Global, *op. cit*., p. 12.
18 Williams N, *Protocol for Due Diligence in the Raw Material Supply Chain*, Minespider, 2018, https://uploads-ssl.webflow.com/5bb20121ca2e96ee01db29bc/5c0fa81d4a4585e37ea764b7_Minespider_Whitepaper.pdf, accessed 12 July 2019. Nathan Williams, author of Minespider's protocol, is currently developing an alternative to the token model (personal communication).
19 White & Case, op. cit., p. 4.
20 Wipro, How Will Blockchain Technology Change the Mining Industry?, p. 4, https://www.wipro.com/content/dam/nexus/en/industries/natural-resources/latest-thinking/how-will-blockchain-technology-change-the-mining-industry.pdf, accessed 12 July 2019.
21 White & Case, *op. cit*., p. 4.
22 Williams N, *op. cit*., p. 9.
23 Consensas & IMPACT, *Unlock the Value of Data in Your Supply Chain*. Ottawa & Toronto: IMPACT & Consensas, April 2018.

responsible mining standard.[24] It is also important to identify who can undertake data verification on the ground and how those actors are verified, be it through third parties like local civil society, or community monitoring.

Data agency and artisanal and small-scale mining

Blockchain technology represents the potential for end-to-end traceability and for ensuring social and environmental responsibility. However, it also contains risks. Three of those interrelated risks will be outlined in this last section.

The first question pertains to what blockchain technology actually does for the miners on the ground, typically the most vulnerable actors in the supply chain. While the technology carries the promise of traceability and assurance for downstream companies and consumers that they have not contributed to conflict or human rights abuses, it is not always clear how blockchain technology benefits local communities, or how it contributes to poverty reduction and development or more inclusion. While the benefits of blockchain adoption are more apparent to downstream industry actors, they are less so for upstream participants. One of the benefits for artisanal and small-scale miners mentioned by Everledger is price transparency for miners. Importantly, one benefit derived from coupling blockchain with due diligence for miners would be a better price or working and trading conditions as part of a specific blockchain initiative.

It is not always clear how blockchain technology benefits local communities, or how it contributes to poverty reduction and development or more inclusion

Another issue is the risk of exclusion and further marginalisation of certain groups from the technology. While some blockchain pilots explicitly target artisanal and small-scale mining (ASM), others still lack an answer to how the technology will be made accessible to these miners, and whether it will be available, applicable, relevant and affordable for them. In its most advanced iterations such as Everledger, no low-tech solutions are being adopted to ensure the participation of ASM actors.[25] Aside from the technical difficulties, this may be

24 RCS Global, *op. cit.*, p. 12.

25 For Everledger's CEO, Leanne Kemp, only private organisations are currently being contemplated. Personal communication, June 2018.

related to the costs of covering ASM in blockchain solutions. Moreover, if exporters have to cover the additional costs for the blockchain technology, ASM miners could receive less money for the minerals they sell, as the additional costs would eventually come off their income. This issue could be minimised if downstream actors covered some costs or if some technology products, like the Provenance Proof alluded to earlier, are made free for all supply chain actors.

Exclusion is an issue not only for blockchain participation but also in terms of data agency. An important question when it comes to blockchain in the context of the mineral sector is how to ensure collaboration and participation while avoiding digital exclusion and private data ownership. In other words, how to facilitate the inclusion of artisanal and small-scale miners as active participants in the blockchain while avoiding the risk of digitally excluding those who cannot take part in these digital developments. Finally, as the data is rarely fed back to ASM miners, the minerals industry should clarify the terms of data ownership in blockchain initiatives and expand the potential benefits that artisanal and small-scale miners can derive from it in comparison to other supply chain management tools.

An important question when it comes to blockchain in the context of the mineral sector is how to ensure collaboration and participation while avoiding digital exclusion and private data ownership

If these factors are not taken into consideration, blockchain technology might still achieve its goals of traceability and due diligence, but it would not necessarily be beneficial – or, at worst, be outright negative – for those who ultimately need to be at the centre of any mineral supply chain initiative: the miners and receiving communities in the countries of production.

Conclusion

Blockchain systems can be technically demanding and energy consuming to set up and maintain. Industry actors should reflect on the benefits of blockchain technology when compared to other traceability initiatives and chain-of-custody systems. For example, decentralised distributed ledgers may offer important advantages for scaling up local initiatives without the burden of consensus algorithms or data structured in blocks, and with the added value of safe data storage across different locations. The findings from this policy insight result in the following recommendations, directed at supply chain actors and blockchain technology participants and providers.

To deliver on the promise of responsibly produced and traded minerals, blockchain technology must be combined with due diligence practices (the OECD's Due Diligence Guidance, or another recognised responsible mining standard). Authorised parties should carry out risk assessments, mitigation and remediation actions along all nodes of the supply chain, as well as verifying the quality of data collected and stored on blockchains.

Blockchain-enabled initiatives should ensure full transparency on data collected, including information pertaining to mining sites, companies responsible for cutting and polishing diamonds, price, provenance and ownership history. Self-sovereign data, in which only direct parties can access relevant information, would also help provide solutions that allow for interoperability between private blockchains for open communication across the digital ecosystem and to remedy informational asymmetries among participants in the supply chain.

Alongside quantifiable data most directly useful for supply chain management and mineral traceability, blockchain and DLT promoters should design protocols that are accessible to and inclusive of upstream actors, in particular artisanal and small-scale mining communities.

Authors

Filipe Calvão

is an Assistant Professor in Anthropology and Sociology at the Graduate Institute of Geneva. His research examines resource extraction, the global gemstone industry, and digital economies in postcolonial Africa.

Victoria Gronwald

is a Specialist at Levin Sources, a responsible mining and sourcing consultancy and social venture. She is an alumna of the Graduate Institute of International and Development Studies.

Acknowledgement

This paper has been funded by SIDA. The Governance of Africa's Resources Programme of SAIIA gratefully acknowledges this support.

About SAIIA

SAIIA is an independent, non-government think tank whose key strategic objectives are to make effective input into public policy, and to encourage wider and more informed debate on international affairs, with particular emphasis on African issues and concerns.

SAIIA's policy insights are situation analysis papers intended for policymakers, whether in government or business. They are designed to bridge the space between policy briefings and occasional papers.

Cover image

People working the Kalimbi cassiterite artisanal mining site north of Bukavu, east DRC, 2017
(Griff Tapper/AFP/Getty Images)

African perspectives.
Global insights.

Jan Smuts House, East Campus, University of the Witwatersrand
PO Box 31596, Braamfontein 2017, Johannesburg, South Africa
Tel +27 (0)11 339-2021 • Fax +27 (0)11 339-2154
www.saiia.org.za • info@saiia.org.za