Motivations and Implications of Electric Vehicle-Spurred Cobalt Mining in the Democratic Republic of Congo

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Beatrice Tremblay

Spring, 2024

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Bryn E. Seabrook, Department of Engineering and Society

STS Research Paper

1. Introduction

The rise of electric vehicles (EVs) is sometimes referred to as a revolution, conjuring images of rebellion, uprising, and conflict. Though the development of vehicle electrification is admittedly (and fortunately) not a literal fight, it does represent a radical change, and is, in many ways, quite an uphill battle. While technical and infrastructural factors associated with EVs are widely discussed, it is equally important to consider the social aspects both affect*ing* and affect*ed by* EV development. As calls for decarbonization rise, particularly in the transportation sector (which accounts for an impressive 36% of energy consumption in the US), the domain of influence of EVs, and thus the importance of the aforementioned non-technical considerations, will only expand (US Energy Information Administration, 2023).

The objective of this analysis is to understand the complex and interwoven relationship between the social and technical aspects of the developing EV market, focusing more narrowly on EV-spurred cobalt mining in the Democratic Republic of Congo (DRC). Implementing Co-production of Science and Social Order (CPoSSO) as a guiding framework, this report will investigate the social factors that have catalyzed the dramatic growth in Congolese artisanal cobalt mining, as well the social impact of this market growth on local communities.

2. Methods

As previously mentioned, the analytical framework employed in this study is the Co-production of Science and Social order, a theory which posits that science and social order are inextricably tied, perpetually and mutually shaping one another. In the context of this investigation, artisanal cobalt mining is taken as the science or technology. On the social side, three specific (non-exhaustive) elements of social order were chosen: economic opportunity,

education, and public policy. The analysis is structured thematically with each co-production pairing being investigated independently. For each of the three, first, an analysis is conducted to assess how a particular social factor has contributed to the development or perpetuation of artisanal mining. Subsequently, the reciprocal impacts of artisanal mining on the same social aspect are investigated.

3. Lithium Ion Battery Demand as a Catalyst of Congolese Artisnal Cobalt Mines

Lithium batteries can be traced back to the 1970s, when chemist Lewis Urry developed the "lithium metal battery" consisting of a metallic lithium anode and manganese dioxide cathode (Lemelson, n.d.). Following safety and efficiency concerns associated with dendrite formation on the lithium anode, however, lithium metal batteries were soon replaced by lithium-*ion* batteries. In 1980, scientist John B. Goodenough proposed the use of cobalt oxide as a cathode material, a significant breakthrough which allowed for higher energy density and improved performance (The Nobel Prize, n.d.).

As the 90s rolled in, so did wider scale commercialization of lithium-ion batteries, notably in laptop computers and camcorders. As portable electronic technologies developed, LIB usage expanded still further as their higher energy density, lighter weight, and longer lifecycle edged out more traditional competitors (Ogumi et al., 2016). The true boom in the LIB market, however, would come in the mid-2000s as LIBs found their niche in the emerging electric (EV) and hybrid electric vehicle (HEV) markets. Intuitively, these rapidly growing EV and HEV markets translated to significant market growth for materials involved in LIB fabrication. For several of these materials, demand quickly overpowered supply and material acquisition efforts were forced to scale rapidly.

Generally considered the least plentiful and most expensive raw material used in LIBs, cobalt rose to particularly high demand (Alves Dias et al., 2018). Demand which the DRC, home to a staggering 48% of global cobalt reserves, took advantage of, and soon began to dominate (Garside, 2023). While this boom promised significant economic growth for the DRC, the intensity of the market paired with volatile governance, economic desperation, and lack of alternative livelihoods, led to unlicensed and risky "artisanal mining." These unregulated practices have brought concerns over working conditions, child labor, and environmental impacts - problems that must be understood and addressed as the EV market continues to grow.

4. Analytical Framework: Co-Production of Science and Social Order

In the late 20th and early 21st centuries, the theory of co-production was simultaneously and independently developed in the fields of public administration, sustainability science, and science, technology, and society studies (STS) (Miller & Wyborn, 2020). In contrast to traditional views of independently developing entities, these co-production theories introduced the idea of mutual constitution, i.e., reciprocally influential entities, each contributing to the formation, adaptation, and maintenance of the other. Within the STS field, Harvard Professor and renowned STS Scholar Sheila Jasanoff led the development of co-production theory. In her early work, Jasanoff explored the intersection of science, law, and society, particularly focusing on how legal institutions shape the production and use of scientific knowledge. This exploration laid the foundation for her later conceptualization of co-production, documented in her 2004 book, *States of Knowledge: The Co-Production of Science and the Social Order*. In this work, Jasanoff posited that scientific knowledge and practices have a significant impact on shaping not only law, but social norms and institutions. In turn, Jasanoff maintained that these norms,

policies, and institutions must also affect the direction and manner in which technology develops (Jasanoff, 2004). In other words, scientific knowledge and social order are *co-produced*.

In the years since its development, CPoSSO has been applied to analyze a wide range of issues, including biotechnology, environmental regulation, AI and beyond. Proponents of CPoSSO laude its emphasis on technology and society as dynamic beings, subject to evolving and interconnected contexts. Conversely, critics argue that CPoSSO's novelty (relative to more established frameworks such as Actor Network Theory and Social Construction of Technology) and ill-defined application methodology limit its consistency and efficacy as an analytical tool (Miller & Wyborn, 2020). Additionally, some have argued that the flexibility of science necessitated by CPoSSO may undermine the credibility of empirical evidence and ability of science to provide objective, immutable insights (Soneryd, 2023).

Though there is certainly room for clearer definitions of scientific flexibility and formalization of how to use CPoSSO, there is still tremendous value in Jasanoff's co-production framework as a lens through which to analyze the complex interactions between science, technology, and society.

5. Research question

How do social phenomena including economic opportunity, education, and public policy both exert influence on and receive influence from the artisanal mining sector in the Democratic republic of Congo?

6. Results and Discussion

6.1 Co-production of Congolese Artisanal Cobal Mines and Economic Opportunity

With immense reserves in cobalt, lithium, gold, copper, tin, tantalum, tungsten, and nickel, the DRC is one of the most mineral-rich countries in the world (De Luca et al., 2012).

Despite this abundance of natural resources, the DRC faces significant economic challenges. In fact, the DRC is currently ranked as the 4th poorest country on the world, with a GDP per capita of merely $577.21, an unemployment percent of 22.6%, and approximately 62% of Congolese people living on less than $2.15 a day (World Bank, 2023). Compared to similarly mineral-rich countries (e.g., Australia, Chile, China, Russia, Canada, Brazil, South Africa), the DRC is incomparably poor, with a GDP per capita 60% lower than the next lowest of the aforementioned countries. Why is this? In large part, the DRC's economic struggles stem from many decades of intense political conflict. The Belgian colonization of the DRC in the late 19th century was marked by exploitation, oppression, and violence. Though the DRC gained independence from Belgium in 1960, the country immediately plunged into political chaos. Power grabs, insurrections, political assassinations, authoritarian rule, corruption, and exploitative leadership for personal gain plagued the newly independent nation, striking down hopes of stability. In the late 90s, regional tensions and internal rebellion led to the First Congo War which brought yet another political ousting and violent transition of power (*Conflict in the Democratic Republic of Congo | Global Conflict Tracker*, 2024). In 1998, the Second Congo War, one of the deadliest conflicts in modern African history, began. Though the war officially ended in 2003, several armed groups remained active, and competition over land, ethnicity, and control of valuable mineral resources have resulted in ongoing violence and humanitarian crises since (*Conflict in the Democratic Republic of Congo | Global Conflict Tracker*, 2024).

In the early 2000's, the push for EVs caused the global demand for cobalt to skyrocket. Home to 70% of global cobalt reserves, the DRC was uniquely poised to serve this growing market, and perhaps in turn, to improve their economic standing. However, with the aforenoted context, it is easier to understand why the DRC has not been able to fully capitalize on this

opportunity. It is difficult to grow one's economy when violence, corruption, external influence, and instability characterize the past several decades – if not centuries – of leadership.

This said, the cobalt mining sector did grow, and quickly. Mining opportunities spurred men, women, and children to flock toward the cobalt-rich "Katanga Copperbelt," hoping to find work in largely Chinese-owned industrial cobalt mines. The conditions in these mines were – are – harsh, but those who found jobs in official mines were considered lucky. Many others fell to unofficial, unregulated, and tremendously risky artisanal mining, either risking violet reprimand by picking through waste on the perimeter of large-scale mines, or hand-digging severely dangerous tunnel mines. Though technically illegal, it is reported that Chinese buyers openly deal with artisanal miners, and presently, is believed that up to 30% of Congo's cobalt is derived from artisanal mines (Umpula & Bisil, 2023). When faced with severe financial hardship, it is easy to understand how safety and legality become non-considerations.

The influence of the DRC's economic opportunities – or lack thereof – on the formation of an abundant artisanal mining market is clear. But how have these mining practices improved the economic standing of the country as a whole? Or perhaps more importantly, how have they improved the livelihoods of the Congolese people? To answer the latter in short, they have not. While the GDP of the DRC has grown significantly in the past 20 odd years (a trend primarily resulting from growth in the mining sector), there is no evidence that profits generated from cobalt mining has benefitted cobalt miners, surrounding communities, or the Congolese lower class in general. This is perhaps best exemplified through the Gini Index, a metric of income disproportionality where a score of 0 represents perfect income equality, and a score of 1 represents one individual or group possessing all the income or wealth. In 2012, the DRC's Gini index was 0.696. Between 2012 and 2019, despite a nearly 40% increase in GDP per capita, the

Gini index *increased* to .755, indicating that while more money was coming in, wealth became more concentrated and disparities were only being exacerbated (World Bank, 2022). So, while the cobalt mining boom may have fed the Congolese economy, it is most certainly not feeding those most involved in mining, nor is it helping those facing the greatest economic challenges. Rather, the rich (namely wealthy foreign powers – primarily China – and corrupt, greedy local officials) reap the reward. The relationship between Congolese cobalt mining and economic opportunity in the DRC is inextricable, and unfortunately, the Congolese lower-class consistently bear the brunt of the disadvantage.

6.2 Co-production of Congolese Artisanal Cobal Mines and Education

The Human Capital Index is a measure that assesses the levels of health, education, and skills among a country's population, indicating the potential for future economic productivity and social development. The DRC's HDI is 0.37 which, in more tangible terms, means that the average Congolese child can expect to achieve merely 37% of the potential that would be attainable with good health and full, quality education. For many, education is seen as a pathway out of poverty, toward higher earning potential and a better livelihood. In the DRC however, education is a luxury few lower-class families can afford.

Congolese public education is severely lacking. Though accessibility has improved significantly in the past 2 decades with primary education enrollment rising to 78% in 2017, only 3 of 4 enrolled students complete their primary education, and 7.6 million children aged 5-17 are still out of school (World Bank, 2023; UNICEF, n.d.). Why is this the case? There are several barriers to education in the DRC. Perhaps most notable is the lack of government financial support. Though the Congolese constitution identifies education as a natural right to be provided at the national level, there is close to no public educational financing (Democratic Republic of

Congo Constitution, 2011, Article 40). Between 1982 and 2006, primary education funding dropped by a factor of 15 and the number of state-employed teachers has decreased by 25% (De Herdt & Titeca, 2016). Government funding all but disappeared, and yet, schools still exist. How is this? Primarily through private financing, but there are no rich benefactors nor philanthropic investors funding the education of Congolese youth. Rather, parents were forced to bear the financial burden of their children's education, paying "school fees" to imburse teachers and purchasing uniforms, books, and other necessary expenses out of their own pockets. This reliance on private funding further entrenched disparities in education accessibility, as families with limited financial means often found themselves unable to afford even basic schooling for their children. Additionally, the proliferation of private schools, both secular and religious, offered an alternative for those who could afford it, further diminishing the incentive for the government to invest in public education.

So, for the majority of recent history, if Congolese parents wanted their kids to attend school, they had to pay. For the most economically disadvantaged families that oftentimes are forced to rely on children as economic contributors, sending children to school not only cuts into limited wages, but also reduces the cashflow coming in. The desire may be strong, but there is a negative economic incentive (particularly for the most impoverished) for parents to send their children to school. It does not matter if education helps in the long-term if short-term barriers are insurmountable. In this way, the ineptitude of the Congolese public education system disincentivizes youth education and clears the path for several thousands of children to enter the "work force." Though Congolese children work across many economic sectors, the mining sector is perhaps the most harrowing. Children are subjected to perilous conditions, including exposure to hazardous substances, long hours of labor, and the risk of accidents or injury due to the

dangerous nature of mining activities. Horrifyingly, an estimated 40,000 kids, some as young as 6 years old, work in Congolese cobalt mines (Melville, 2020). These children account for nearly *16%* of Congolese cobalt miners, and because labor laws are more strictly enforced in official mines, a substantial portion of child miners work in artisanal mines. If children were removed from the cobalt mining labor force, artisanal cobalt production would undoubtedly suffer. In this sense, artisanal cobalt mining – and perhaps cobalt mining period – all but necessitates child labor. Now adding education back into the conversation, a broader causal effect can be observed: educational ineptitudes (paired with aforenoted impoverishment) perpetuate child labor which in turn perpetuates artisanal cobalt mines.

The connection between public education and artisanal mining is nuanced but nevertheless apparent. Now, how is this influence reciprocated? In 2019, the Congolese government implemented an ambitious initiative for free primary education. This effort was supported in large part by USAID. In the 5 years since, the impact of this policy is still unclear. While initial studies indicate an increase in primary school enrollment, independent causality is unclear, perceived effects are heterogenous, and free public education is far from complete realization (Kodila-Tedika & Otchia, 2022). Perhaps more time is required for the feedback loop, but the data have yet to indicate a clear positive correlation between this policy and true improvements in Congolese public education. Until this correlation is clear (and likely not until several years after that), it is difficult to elucidate the impact of artisanal mining on education.

6.3 Co-production of Congolese Artisanal Cobal Mines and Public Policy

Unlike the more nuanced influence of public education discussed above, the effect of public policy on artisanal mining is overt. Insufficient public policy has undoubtedly perpetuated the worst parts of Congolese cobalt mining, or perhaps more accurately, insufficient *enforcement*

of public policy has reinforced these mining practices. To highlight this impact, a series of 3 representative laws will be examined.

6.3.1 Mining regulations

Under Congolese mining law, any "adult natural person of Congolese nationality, who wishes to engage in the artisanal exploitation of mineral substances throughout the national territory, can do so only within an approved mining cooperative in accordance with the provisions of the Mining Code; membership of such cooperative is subject to the possession of an artisanal mining card" (*Mining Laws and Regulations Report 2024 Congo D.R.*, 2023). Of note, to obtain said mining card, one must be over the age of 18. Based purely on the estimated 40,000 cobalt miners under the age of 18, it is clear that this law is poorly enforced. It is challenging to find reliable data on the percentage of unofficial, unregulated mines. That said, first person reports would indicate that they are abundant (ABC, 2022). Unfortunately, unregulated artisanal mines are profitable, which disincentivizes enforcement. Furthermore, officials can achieve even more financial gain by soliciting bribes from illegal miners. There is profit from artisanally mined products and profit in bribery, so if one is willing to set aside their moral compass, where is the incentive to enforce mining regulations?

6.3.2 Community protection and development

Under article 285 of the Mining Code, those who hold mine exploitation rights and employ mine laborers are required to "contribute to the financing of community development projects" (*Mining Laws and Regulations Report 2024 Congo D.R.*, 2023). Community development projects are further defined as those which help to improve the socio-economic and industrial development of local communities, building schools, health infrastructure, etc. There is no evidence that these development projects are being genuinely pursued. Again, the people in

charge of mines (primarily Chinese companies and corrupt local leaders) have no incentive to rigidly enforce this law. Doing so would cut into profits and offer no direct benefit. Conversely, avoiding this law maximizes profits and feeds the cobalt mining industry.

6.3.3 Sale of artisanally-mined cobalt

In a 2019 legal directive, the Congolese government issued a legal directive mandating that artisanally mined cobalt must exclusively be sold to the government, and that foreign purchase would not be permitted (World Economic Forum, 2020). Again, compliance data is all but impossible to find, but first-person accounts would suggest that the directive has had little influence. It is possible that this piece of legislation needs time to permeate into day-to-day practices, but if 5 years isn't enough, without intervention, odds do not look good. Foreign buying power dramatically overpowers the domestic counterpart. Afterall, the DRC has little need for raw cobalt – they have little to no processing or manufacturing capabilities. As such, most of the DRC's cobalt goes to China, which, by continuing to buy cobalt from unregulated mines, perpetuates artisanal mining practices (Hart, n.d.). Similarly, local officials, by not enforcing cobalt sale directives, also feed into the system.

These three examples are part of a vast set of laws whose poor implementation overtly support artisanal mining practices. The influence of mining practices on new policy is less tangible, and the influence of mining on policy *enforcement* is, plainly, non-existent. As media attention and international concern regarding the unsafe, unjust, and unsustainable nature of Congolese cobalt mines grow, so too does the push for amended policy. The issue is, of course, that policy was never really the problem. Without effective enforcement, the letter of the law, frankly, does not matter. The issue with enforcement comes down to power and incentives. Power in the cobalt game is controlled by mine owners, cobalt buyers, and local officials.

Similarly, policy breech identification and correction are controlled by these same individuals. The Ven diagram of controllers and enforcers converges into a circle and it is clear why enforcement suffers so tremendously. If those in control are also those with the power to enforce, but enforcement does not benefit them, there is no incentive to enforce. Laws and mines are surely coproduced, but the failure to actualize policy shifts the balance of influence dramatically.

7. Project limitations

Though the best accessible data was used to support the analysis in this report, reliable comprehensive data was oftentimes lacking. Information regarding China's dealings in the DRC and specific details on unregulated mines were perhaps most difficult to find, and analysis of those are presently limited to individual accounts among a couple more substantial sources.

Through this report, the coproduction of Congolese artisanal cobalt mines with 3 social factors is examined. That said, there are still several co-produced aspects of social organization that are required to fully understand the complex sociotechnical underpinnings of Congolese cobalt mining, and these are not explicitly discussed. These include but are not limited to environmental contamination and gender inequity.

8. Conclusion

Congolese economic opportunity, education, and mining policy mutually *shape* and are *shaped by* the development of artisanal cobalt mines. In terms of economic opportunity and education, deficiencies feed the fire of artisanal mining, but mining practices exert either neutral or negative impact on these in return. Public policy has room for improvement, but it is the poor implementation of these policies that truly shapes the mining sector. Without decoupling those in control over cobalt mining and sale from those with the power to enforce critical legislation, the reciprocal impact of current mining practices on policy execution is stunted.

Source Citations

ABC. (2022, February 24). Blood Cobalt: The Congo's Dangerous and Deadly Green Energy Mines | Foreign Correspondent [Video file]. YouTube. https://www.youtube.com/watch?v=_V3bIzNX4co

Alves Dias, P., Blagoeva, D., Pavel, C., & Arvanitidis, N. (2018). Cobalt: demand-supply balances in the transition to electric mobility. *Publications Office of the European Union*, *10*, 97710.

Conflict in the Democratic Republic of Congo | Global Conflict Tracker. (2024, February 21). Council on Foreign Relations. Retrieved March 28, 2024, from https://www.cfr.org/global-conflict-tracker/conflict/violence-democratic-republic-congo

De Herdt, T., & Titeca, K. (2016). Governance with empty pockets: The education sector in the Democratic Republic of Congo. Development and Change, 47(3), 472-494.

De Luca, G., Maystadt, J. F., Sekeris, P. G., & Ulimwengu, J. (2012). Mineral resources and conflicts in DRC: A case of ecological fallacy. Documento de trabajo CRED No. WP, 1207.

Democratic Republic of Congo Constitution. (2011). Article 40.

Garside, M. (2023a, February 18). *Global cobalt reserves by country 2022*. Statista. https://www.statista.com/statistics/264930/global-cobalt-reserves

Hart, J. (n.d.). Cobalt in China | The Observatory of Economic Complexity. OEC World. Retrieved March 29, 2024, from https://oec.world/en/profile/bilateral-product/cobalt/reporter/chn

Jasanoff, S. (Ed.). (2004). *States of knowledge: the co-production of science and the social order*. Routledge.

Kodila-Tedika, O., & Otchia, C. S. (2022). The effects of free primary education in the Democratic Republic of Congo: A d ifference-in-differences approach. Review of Development Economics, 26(4), 2109-2120.

Lemelson - Massachusetts Institute of Technology. (n.d.). *Lewis Urry*. Lemelson. https://lemelson.mit.edu/resources/lewis-urry

Melville, J. (2020, June 19). From Stone to Phone: Modern Day Cobalt Slavery in Congo – Byline Times. Byline Times. Retrieved March 29, 2024, from https://bylinetimes.com/2020/06/19/from-stone-to-phone-modern-day-cobalt-slavery-in-congo/

Miller, C. A., & Wyborn, C. (2020). Co-production in global sustainability: Histories and theories. *Environmental Science & Policy*, *113*, 88-95.

Mining Laws and Regulations Report 2024 Congo D.R. (2023, September 19). ICLG.com. Retrieved March 29, 2024, from https://iclg.com/practice-areas/mining-laws-and-regulations/congo-d-r

Ogumi, Z., Kostecki, R., Guyomard, D., & Inaba, M. (2016). Lithium-ion batteries—the 25th anniversary of commercialization. *The Electrochemical Society Interface*, *25*(3), 65.

Soneryd, L., & Sundqvist, G. (2023). "5: Co-production of Scientific Knowledge and Societal Order". In *Science and Democracy*. Bristol, UK: Bristol University Press. Retrieved

The Nobel Prize. (n.d.). *The nobel prize in chemistry 2019*. NobelPrize.org. https://www.nobelprize.org/prizes/chemistry/2019/goodenough/facts/

Umpula, E., & Bisil, E. (2023, July 25). Formalising artisanal cobalt mining in the DRC: much work remains. International Institute for Environment and Development. Retrieved

March 28, 2024, from https://www.iied.org/formalising-artisanal-cobalt-mining-drc-much-work-remains

UNICEF. (n.d.). Education. UNICEF. Retrieved March 29, 2024, from https://www.unicef.org/drcongo/en/what-we-do/education

U.S. Energy Information Administration. (2023, August 16). *U.S. Energy Information Administration - EIA - independent statistics and analysis*. U.S. energy facts explained - consumption and production - U.S. Energy Information Administration (EIA). https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=The%20transportation%2C%20industrial%2C%20residential%2C,by%20the%20electric%20power%20sector

World Bank. (2022). World Development Indicators: GDP per capita [GDP data]. World Bank. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=CD

World Bank. (2023, September 23). Democratic Republic of Congo Overview: Development news, research, data. World Bank. Retrieved March 28, 2024, from https://www.worldbank.org/en/country/drc/overview

World Economic Forum. (2020, September). Making Mining Safe and Fair: Artisanal cobalt extraction in the Democratic Republic of the Congo. weforum.org. Retrieved March 29, 2024, from https://www3.weforum.org/docs/WEF_Making_Mining_Safe_2020.pdf