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Cobalt Extraction in the Democratic Republic of the Congo

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Introduction

In the Democratic Republic of the Congo (DRC), cobalt extraction sets the conditions for modern-day slavery. Cobalt is highly toxic, but entire populations, including trafficked children, work in the mines' subhuman conditions for a dollar a day (Gross). The DRC produces around 70% percent of the world's cobalt, often used in the manufacturing of lithium batteries (Gross). However, the degrading conditions in which miners work illustrate that the enormous wealth from the DRC's cobalt supply may not be distributed equally. In a country that is so resource-rich, why are there some of the highest poverty rates in the world (Gross)?

Professors David Leonard and Scott Straus at the University of California, Berkeley, argue that enclave economies rely on exporting primary products in a small area and that in these economies, production and revenue are disconnected from the mass of societies (66-68). Because governments and rebel groups can predate on these resources without relying on the general well-being of the economy or society, they can wage war and continue corruption at will. Governments are incentivized to continue private patronage rather than use the wealth to invest in the population.

Our research question examines the efficacy of Leonard and Straus's theory in understanding the DRC. The question is twofold: First, has cobalt production and subsequent revenue led to the unequal distribution of wealth among the populations in the Democratic Republic of the Congo? Second, as Leonard and Straus may also predict, does poor governance play a role in the relationship found, if any?

Using Leonard and Straus' analysis, we predict that the revenue generated by cobalt production exacerbates wealth inequality in the Democratic Republic of the Congo, with poor

governance playing a statistically significant role as an intermediary (66). Using data on cobalt production, cobalt revenues, Gross Domestic Production (GDP) per capita, Human Development Index (HDI) scores, and good governance indicators, we determine that cobalt production does lead to the unequal distribution of wealth. The correlation coefficients for GDP per capita are approximately 1.5 times greater than the correlation coefficients for HDI, demonstrating that as cobalt production and revenue increase, GDP per capita increases much more than HDI does. Because GDP is a macro-level indicator of economic performance, and HDI examines measures of human development in society, the stark difference between the correlation coefficients indicates that wealth generated might not used to improve society but is likely for personal gain among elites. However, none of the governance indicators are statistically significant in any models, indicating that governance may not explain the relationship best.

Theoretical Models

Leonard and Straus first differentiate enclave economies from primary product production (66). When the government or rebel groups want to wage war or engage in corruption, they must consider the ability to continue their behavior as society deteriorates. With economies dependent on primary product production, the government or rebel groups depend on economic productivity (Leonard and Straus 66). Thus, any war or corruption they engage in will inevitably hurt productivity and, thus, decrease the ability to continue said war or corruption. After all, the ability to engage in bribery, predatory behavior, and military action requires revenue streams that are damaged when the economy or society is not doing well. However, in enclave economies, the ability to engage in predation, war, and corruption is not reliant on society's overall productivity (Leonard and Straus 66). High poverty rates, economic collapse, or civil war do not limit the ability to continue predatory behavior. Additionally, predation does not

threaten the resource source, as it may in non-enclave economies. For example, while farmers (primary product production) can switch what they grow if their resources are being predated, enclave products like rare earth minerals are not readily adaptable to different uses, are abundantly present, and can be quickly sold internationally (Leonard and Straus 66). Thus, enclave economies encourage patronage politics. The government can predate on resources without contributing to the betterment of the country because the government is not reliant on the well-being of society. As a result, civil conflicts, poverty, and corruption are more protracted and happen at extreme rates (Leonard and Straus 66).

Leonard & Straus's theory can help explain why there are staggering wealth inequities in the DRC even though the DRC has an abundance of mineral resources. Specifically, Leonard and Straus consider the DRC an enclave economy because 93 percent of the exports are enclave products (76). For Leonard and Straus, enclave economies are those where "75 percent of the value of exports was made up of minerals, timber, and estate agriculture" (78). These production forms thrive under limited state control, do not depend on the healthy general economy, and are "weakly integrated with the general economy" (Leonard and Straus 78). Since Leonard and Straus define the DRC as an enclave economy, their theory can help understand wealth and developmental inequities. The second part of the research question connects with how Leonard and Straus predict that the revenue streams can result in greater corruption and predation and, thus, a worse-off population.

To analyze the question, we use data on cobalt production, revenues, GDP per capita, HDI scores, and good governance indicators from 2000 to 2018 in the DRC. First, we analyze the relationship between cobalt production/revenues and GDP per capita. Then, we analyze the relationship between cobalt production/revenues and HDI scores. The first analysis illustrates

how cobalt production/revenues impact state-wide wealth production (macro-level). The second analysis depicts how cobalt production/revenues impact the general well-being of the population. Additionally, we conduct analyses using governance indicators to determine if corruption and patronage could be possible intermediaries in explaining a potential relationship between cobalt production/revenue and wealth inequality.

Our analysis of the research question evidence will test Leonard and Straus's theory, which posits that an enclave economy like the DRC may have a political system in which the state distributes private patronage rather than investing in the population (66). Based on the theory, increased natural resource revenues should result in increased inequality since the rents generated by the resource are distributed only to those in power. The primary relationship addressed by this paper is the causal relationship between the production of cobalt/cobalt revenue and wealth inequality. Poor governance is treated as an intermediary between the variables to ascertain whether or not patronage politics is related to the causal relationship found, if any. Thus, the hypothesis is that the revenue generated by cobalt production does exacerbate wealth inequality in the Democratic Republic of the Congo, with poor governance playing a statistically significant role as an intermediary.

Methodology

The dataset used for quantitative analysis is a time series spanning nineteen years and eight variables. The years for this dataset are 2000-2018. This period was chosen because it theoretically encapsulates the surge in cobalt production due to the increase in lithium-ion batteries, so any causal relationship found might be a more accurate predictor of future years as lithium-ion battery demand increases. Further, these were years when all variables had data available.

Figure 1: Snapshot of Dataset

	year	co_prod	co_price	hdi	gdp_pc	fr_pr	fr_cl	polity	co_rev
1	2000	11000	22.20	0.376	0.2899863	7	6	0	244200
2	2001	12000	15.28	0.374	0.2761422	6	6	0	183360
3	2002	14600	10.25	0.378	0.2760559	6	6	0	149650
4	2003	14800	14.92	0.384	0.2826471	6	6	1	220816
5	2004	20200	31.71	0.390	0.2923509	6	6	3	640542
6	2005	24500	19.71	0.395	0.3005625	6	6	4	482895

The variables included `co_prod`: DRC cobalt mine and refinery production in metric tons, `co_price`: the price of cobalt in 2020 US dollars, and `co_rev`: *co_prod * co_price* for a given year. These variables come from Gulley 2022 and intend to capture cobalt production and subsequent revenue generated in the analyzed years. A significant limitation is that, historically, cobalt has been mined as a byproduct of copper production in the DRC (Gulley). Practically, this means that a miner first decides whether or not to mine the cobalt-containing copper ore depending on the price of copper. If they decide to mine the copper ore, they use the cobalt price to decide whether to recover the cobalt byproduct. If not, they discard the byproduct. This implies that *co_prod* may not accurately represent the work and costs necessary to mine cobalt, and therefore, its impact on inequality might be underestimated.

The outcome variables are `hdi`: Human Development Index (HDI), defined by the United Nations, and `gdp_pc`: gross domestic product (GDP) per capita, scaled by a factor of 10^{-3} to be comparable with HDI. Comparing the movement of these two variables about cobalt production aims to exhibit inequality. Since HDI is an encompassing index that incorporates health, education, standard of living, income, and more, it is a robust measure of individual

well-being. GDP per capita is purely gross domestic product divided by population. Therefore, the idea is that if cobalt's revenue is not distributed evenly, increasing cobalt revenue would increase GDP per capita while HDI remains roughly the same or increase disproportionately. Lastly, three variables aim to quantify "good governance": `fr_cl` represents the DRC's Freedom House civil liberties score, `fr_pr` represents the DRC's Freedom House political rights score, and `polity` is the polity score given by Leonardo Arriola and Martha Johnson that measures the level of democracy, on a scale of −10 (fully autocratic) to 10 (fully democratic).

The data is analyzed using Ordinary Least Squares (OLS) regression. The first step was finding the best-fitting linear model to predict HDI and GDP per capita given the covariates *co_prod, co_rev,* and the governance indicators *fr_cl, fr_pr,* and *polity.* This determination helps to answer two questions: 1) if HDI and GDP per capita are more affected by cobalt production or cobalt revenue, and 2) if including governance indicators as covariates strengthens the linear model. After ascertaining the best-fitting model, we compare the linear coefficients for GDP and HDI to see if there is a significant difference in growth. The models used are below:

*HDI_1: hdi = β_1 * co_prod + ε*

*HDI_2: hdi = β_1 * co_prod + β_2 * co_price + β_3 * polity + β_4 * fr_cl + β_5 * fr_pr*

*HDI_3: hdi = β_1 * co_rev + β_2 * polity + β_3 * fr_cl + β_4 * fr_pr*

*GDP_1: gdp_pc = β_1 * co_prod + ε*

*GDP_2: gdp_pc = β_1 * co_prod + β_2 * co_price + β_3 * polity + β_4 * fr_cl + β_5 * fr_pr*

*GDP_3: gdp_pc = β_1 * co_rev + β_2 * polity + β_3 * fr_cl + β_4 * fr_pr*

Results and Analysis

The key finding of the quantitative analysis is that cobalt production does increase wealth inequality in the DRC. This was determined by the difference in correlation coefficients between cobalt production and HDI and cobalt production and GDP per capita. For every one-unit increase in cobalt produced (tonnes), HDI increased by a factor of 1.297e-06 while scaled GDP per capita increased by a factor of 1.760e-06. For every one-unit increase in cobalt revenue (dollars), HDI increased by 2.839e-08 while GDP increased by 3.641e-08. The correlation coefficients for HDI are approximately 1.5 times smaller than the correlation coefficients for GDP per capita in both cases, exhibiting that as cobalt production and revenue increase, GDP per capita increases more than HDI does. This is direct evidence that cobalt production and subsequent revenue exacerbate inequality since it creates faster growth for GDP than for the citizens' overall well-being. In other words, the citizens do not reap the benefits of increased production proportionally, and is thus evidence for Leonard and Straus' theory, which posits that the public is disconnected from the rents generated by natural resource extraction (66). This finding is also substantiated by our qualitative analysis; for example, Natasha Turak explains how, despite cobalt production increasing, the Congolese people remain poor.

The next step in the analysis was determining if patronage politics was a suitable intermediary variable that explained why cobalt production increased inequality. We found that model *HDI_1*, which models the outcome variable HDI with only cobalt production as a covariate, is a slightly better-fitting linear model than *HDI_2*, including governance indicators as covariates. This same finding applies to GDP per capita; *GDP_1* fits the data slightly better than *GDP_2*. The difference in adjusted R-squared between *HDI_1,* and *HDI_2* is marginal (0.9346 and 0.9253, respectively); the same goes for *GDP_1* and *GDP_2* (adjusted R-squared is 0.8924 and 0.8782, respectively). Furthermore, none of the governance indicators are statistically

significant predictors in *HDI_2, HDI_3, GDP_2,* or *GDP_3*. According to Leonard and Straus'

theory, governance should theoretically significantly impact HDI and GDP per capita, given that

patronage politics drives inequality in enclave economies; however, the data suggests otherwise.

It is important to note that this finding might be due to multicollinearity—the correlation

coefficient between cobalt production and polity is 3.599 and statistically significant. To test

whether multicollinearity may be at play, we ran linear regression models with y = HDI and y =

GDP per capita with x = *fr_cl, fr_pr, polity* to see whether or not governance indicators do

impact inequality without the inclusion of cobalt production. It was found that polity is the only

statistically significant predictor of GDP per capita, and none of the governance variables are

predictors of HDI. Thus, there is robust evidence that governance may not be a strong

intermediary variable in the causal relationship between cobalt production and HDI, GDP per

capita, and inequality. Our analysis actually goes against Leonard and Straus' theory because

they attribute the inequality caused in enclave economies to the government's ability to engage in

corruption and patronage politics unchecked by external factors (66).

Knowing that Leonard and Straus' theory may not be a good predictor in the DRC, yet

cobalt production does increase inequality, the last step was determining whether cobalt

produced in tonnes or cobalt revenue had a stronger causal relationship on inequality. We found

that cobalt produced was a stronger predictor of HDI and GDP per capita than cobalt revenue.

The adjusted R-squared values for *HDI_2* and *GDP_2*, which use cobalt production in metric

tonnes instead as a predictor, are 0.9253 and 0.8782, respectively. The adjusted R-squared values

for *HDI_3* and *GDP_3*, which use cobalt revenue as a predictor instead of cobalt production, are

0.499 and 0.4464, respectively. Thus, the gross amount of cobalt produced has a stronger linear

relationship with HDI and GDP per capita than cobalt revenue. This is an exciting finding

because, as previously discussed, cobalt production generally impacts inequality. However, governance may not be a good indicator of why it is doing so, so Leonard and Straus' theory that government predation leads to unequal revenue distribution may not be a good prediction in the DRC (66). The fact that cobalt produced is a stronger predictor of inequality than cobalt revenue shows that there might be a non-economic explanation for why inequality increases when more cobalt is produced; for example, human rights violations, welfare decreasing, wages decreasing, etc.

Figure 2: Plots of Linear Models
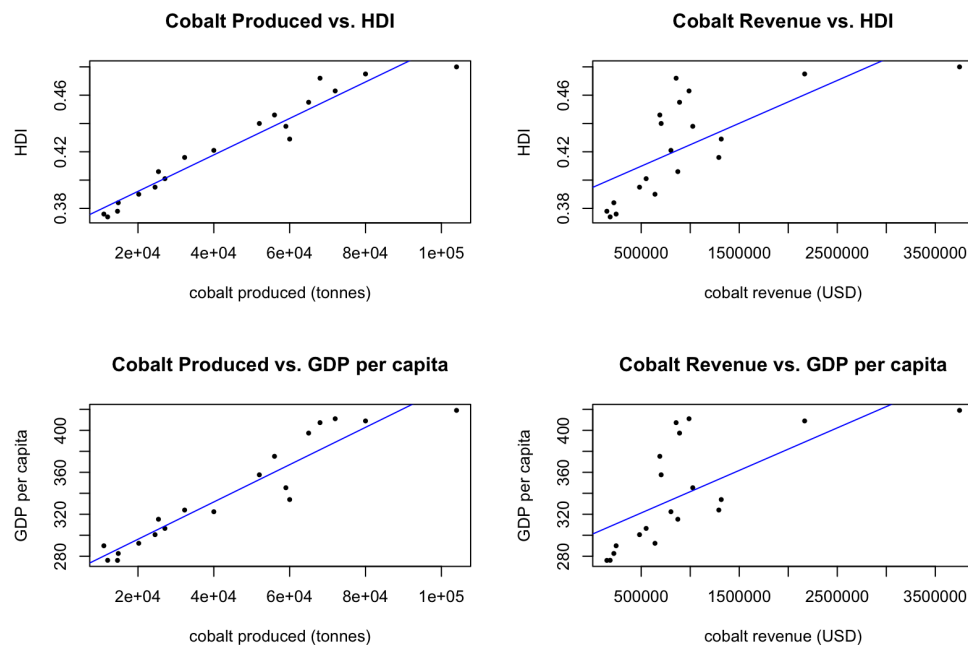
The quantitative analysis has many limitations, the first of which is an underestimation of the impact of cobalt production on inequality due to the mining of cobalt as a byproduct of copper ore. Another key limitation is the sole use of OLS—given the poor fit of the linear model, cobalt revenue and HDI may be better represented by a nonlinear relationship. Lastly, there might be other intermediate factors between cobalt production and inequality that were not explored in this analysis. Considering these limitations, we can tentatively conclude through

quantitative analysis of the dataset that Leonard and Straus' theory was correct because wealth inequality increases in the DRC as more cobalt is produced. However, the evidence shows this may not be because of the government's policies or behavior. Thus, we will explore alternative explanations that may better predict the DRC's case.

Alternative Explanations

One alternative explanation for why the governance indicators are not significant in explaining the relationship between cobalt production/revenue and wealth inequality is the presence of foreign governments (Anderson 8-9). For example, in the past two decades, China has owned almost all of the cobalt mining concessions in the DRC. Even though bribes to former President Kabila allowed China to gain mining rights, most of China's cobalt comes from artisanal miners who work separately from any company (Anderson 1-2). The fact that these small-scale workers do not belong to any company allows Chinese companies to underpay them for their labor. The Chinese companies buy cobalt straight from the artisan miners without the involvement of the DRC's government, which may explain why the DRC's governance indicators may not explain the unequal distribution of wealth (Anderson 1-2). Additionally, Chinese companies have been accused of abusing locals, not implementing any safety standards, and the use of child labor, all of which could also contribute to low levels of HDI independent of the DRC government (Anderson 8-10).

Health hazards could also be responsible for reducing HDI. As referenced above, cobalt is highly toxic, but miners often breathe in fumes and touch cobalt. Mines often collapse onto themselves, injuring or even killing miners (Gross). Choosing mining over education could also contribute to the decrease in HDI. Rather than sending children to school, poverty-stricken families must put everyone to work to stay alive. Additionally, Chinese companies are notorious

for bulldozing villages, city streets, and homes to establish mining sites. Forced evictions could decrease health, education, and income outcomes, all aspects of an HDI score (Amnesty International).

A significant possibility is that the governance indicator scores do not accurately reflect the conditions in the DRC. Many analyses argue that money frequently disappears from taxes, fake taxes are created to continue personal revenue streams, and bribes are frequent (Turak). For example, Global Witness, an ethics watchdog, found that 30% of state mining revenues vanished. Our governance indicators combine scores for political rights, civil liberties, and authoritarian tendencies. While these indicators are good in examining how governments can crack down on citizens and their individual freedoms, it is unlikely that the scores consider instances of tax predation, corruption, and bribery. As a result, using indicators that are better suited to analyzing the level of corruption in the DRC could improve the research design in the future. Similarly, the government indicators could only be a piece of the puzzle explaining how the wealth gap in the DRC came to fruition.

Conclusion

Our research demonstrates that cobalt production/revenue significantly contributes to the unequal distribution of wealth in the DRC. The significant difference in correlation coefficients between GDP per capita and HDI indicates that as cobalt production and revenue rise, GDP per capita experiences greater growth than HDI, illustrating a discrepancy between overall wealth creation and societal well-being. Our findings align with Leonard and Straus's analysis, suggesting that the benefits of cobalt production/revenues are detached from the public and instead funneled to elites (66). While the elites reap the benefits, the rest of society pays the cost with their lives. Even though the country experiences greater economic performance, the wealth

generated does not improve the lives of everyday citizens. Our results depart from Leonard and Straus's when we find that governance might not be the intermediary link between cobalt production/revenues and unequal wealth distribution. However, there are limitations to this research that, if changed or explored in the future, could impact the quantitative result. As referenced above, the presence of foreign governments, the impact of extraction on health and education, and the choice of governance indicators may have all impacted our governance results. Regardless, it is clear that the cobalt extraction in its current form must end because the well-being of the DRC depends on it.

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