PAYING FOR THE CRITICAL MINERALS OF THE LOW-CARBON TRANSITION

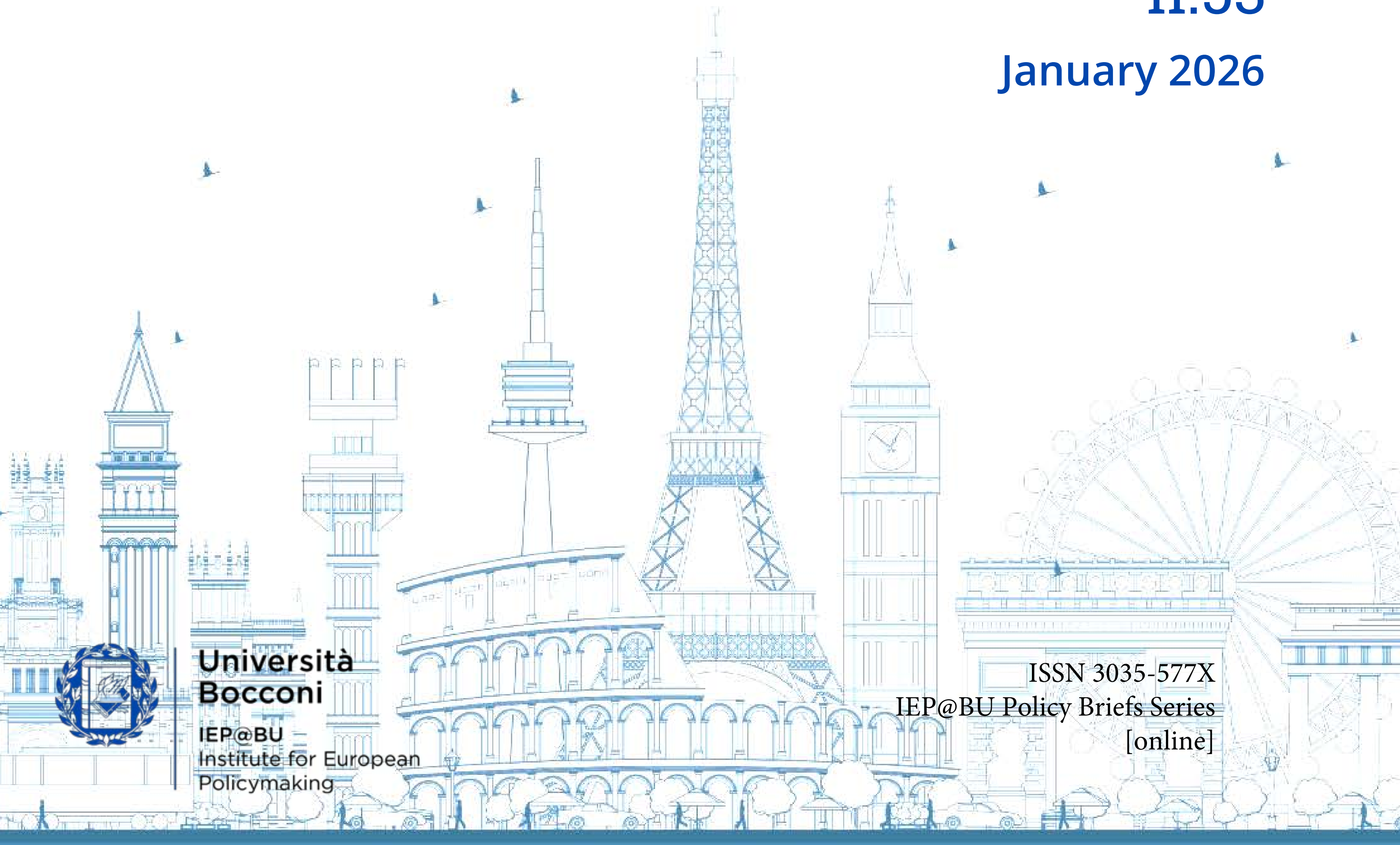
An exploration of the 'viability space' between exporters' fiscal revenues and electric vehicle affordability

ROMAIN **SVARTZMAN**, LEONARD **WEBER**

IEP@BU Policy Brief

n.53

January 2026



Università Bocconi

IEP@BU

Institute for European Policymaking

ISSN 3035-577X
IEP@BU Policy Briefs Series
[online]

Abstract

The low-carbon energy transition is highly dependent on critical minerals (CMs), whose prices are expected to increase. This raises the question of whether higher CM prices could improve fiscal revenues in low- and middle-income countries (LMICs) that export these minerals, and whether such gains would come at the cost of reduced affordability of low-carbon technologies.

This paper contributes to quantifying this trade-off by examining the joint effects of higher prices for four critical minerals – cobalt, copper, lithium, and nickel – on fiscal revenues in exporting LMICs and on the prices of electric vehicles (EVs). Using data on mineral production, current fiscal revenues (including from mining), EV material intensities across battery technologies (NMC 811, NCA, and LFP), and projected CM prices, we construct stylized scenarios in which a 5 percent levy would be applied by the exporting countries to mineral values.

We find that a sizeable viability space exists between exporter revenues and EV affordability: Even under substantially higher CM prices, fiscal revenues in several exporting LMICs could increase markedly while EV prices would rise only modestly.

Despite several methodological limitations, including the omission of the CM processing stage, which is largely controlled by Chinese firms, these results suggest that higher CM prices need not pose a binding constraint on the low-carbon transition and may support policy approaches based on fair trade and international cooperation between mineral-exporting LMICs and importing economies.

Acknowledgments

We thank Daniel Gros for his insightful comments on a previous draft of the paper. We also thank the following people, who provided insightful background for the paper and/or feedback during the early stages of this project: Sarah Ben Bouazza Chabert, Tanguy Bonnet, Andrew Jackson, Dario Leoni, Capucine Nobletz, J.Christopher Proctor, Gabriel Santos Carneiro and Luca Tausch. Potential errors are exclusively our own.

1. Introduction

The low-carbon energy transition requires large quantities of critical minerals (CMs) such as cobalt, copper, lithium, and nickel (Gielen, 2021; Giurco et al., 2019; Watari et al., 2021). The concept of mineral "criticality" refers to a combination of characteristics.

First, these minerals are essential inputs for key technologies and are difficult to substitute (Carrara et al., 2023). Second, their reserves are either scarce, geographically concentrated, or unlikely to be extracted at a pace consistent with the rapid growth in demand associated with the energy transition (IEA, 2023). Third, their extraction and processing can generate significant environmental impacts, creating trade-offs between short-term economic gains and long-term negative externalities (Weber, 2024).

In this context, a growing consensus holds that, absent major technological or social breakthroughs, CM prices are likely to increase in the coming decades. For example, Boer et al. (2021) project in an IMF Working Paper that demand shocks induced by the energy transition could lead to substantial price increases for copper, nickel, cobalt, and lithium by 2040.

Against this backdrop, a growing literature examines whether and how countries with CM reserves could benefit from rising prices, either passively or by proactively seeking to increase them, for instance through coordination mechanisms such as cartels, or by improving their position in global value chains by moving beyond the export of raw materials toward downstream manufacturing (Fang, 2024; Fischer, 2011; Miller et al., 2023; Müller, 2023; Nobletz et al., 2024; Omonbude and Mataba, 2024).

Recent policy developments illustrate these dynamics. China has implemented stricter export controls on several rare earth elements and related products, creating supply bottlenecks for downstream firms (Malik, 2025). Similarly, Indonesia has progressively phased out nickel ore exports, culminating in a full ban in April 2022, alongside regulations requiring domestic processing prior to export (IEA, 2024).

At the same time, higher prices originating in mining or processing countries are often perceived as a threat to the affordability of the low-carbon transition in importing regions such as the European Union, which rely heavily on CMs either as raw materials, processed inputs, or embedded in final goods (Fajgelbaum et al., 2020; Nakhle, 2023). This concern is reflected in the EU Critical Raw Materials Act (CRMA), adopted in 2024, which seeks to expand domestic production, processing, and recycling capacity while reducing dependence on dominant external suppliers.

Despite increasing attention to these issues, a quantified understanding remains lacking of the extent to which higher CM prices generate trade-offs between improving fiscal revenues in exporting LMICs and preserving the affordability of low-carbon technologies. This empirical gap limits the ability of policymakers to design and implement effective CM-related strategies, including those embodied in the CRMA.

Against this backdrop, we assess how potential price increases for four CMs, cobalt, copper, lithium, and nickel, could simultaneously affect fiscal revenues in exporting LMICs and the prices of electric vehicles (EVs). We differentiate across battery technologies (NMC 811, NCA, and LFP) and combine data on the geographical concentration of CM production, the evolution of mineral content in EV batteries, current mining-related fiscal revenues, and scenarios of CM price increases – based on both this historical peak of 2022, and projections from an IMF working paper (Boer et al., 2021).

We find that a large "viability space"[1] exists, meaning that CM prices could increase substantially, thereby benefiting exporting LMICs, without significantly affecting EV affordability. For example, a hypothetical 5 percent levy applied to the four CMs considered could increase mining-related fiscal income by more than 10 percent in countries such as the Democratic Republic of Congo and Zambia, while raising final EV prices by only 0.1 to 1.1 percent, depending on battery technology.

These findings carry important policy implications. In particular, they suggest that high-income countries without CM reserves could pursue forms of "fair trade" with exporting LMICs by accepting higher mineral prices that improve fiscal outcomes in producer countries without jeopardizing the low-carbon transition.

We also discuss key limitations of the analysis, including the omission of downstream processing stages, which remain largely controlled by a small number of firms and countries, particularly China.

The rest of the paper proceeds as follows. Section 2 reviews the literature on the macroeconomic relevance of CMs. Section 3 describes the data and methodology. Section 4 presents the key results. Section 5 discusses policy implications and limitations. Section 6 concludes.

[1] Viability space can be understood as the set of conditions under which a system can function sustainably given existing constraints. In our case, it refers to the extent to which the price of CMs can fluctuate within ranges that make them interesting for both extracting countries and end users.

2. Literature Review: the criticality of minerals and their potential macroeconomic implications

Critical minerals (CMs) are essential inputs for a range of key industries, including low-carbon energy technologies such as electric vehicles, solar panels, and wind turbines, as well as information and communication technologies, drones, and satellites. Demand for these minerals is expected to increase substantially by 2040 (Carrara et al., 2023; Giurco et al., 2019; Lee et al., 2020; Maisel et al., 2023; Marscheider-Weidemann et al., 2021).

For some minerals, including lithium, cobalt, and nickel, projected demand may exceed available supply in the near future (Schlichenmaier and Naegler, 2022; ETC, 2023). Given their importance for military equipment, access to CMs is also increasingly treated as a national security concern (Shiquan and Deyi, 2023).

Production and processing of CMs are highly concentrated at both the country and firm level. Mining deposits are located in a small number of countries, particularly for cobalt, lithium, and nickel. In 2024, cobalt production was dominated by the Democratic Republic of Congo, which accounted for approximately 75 percent of global output, while Indonesia, with a share of around 9 percent, is expected to increase its contribution to 18.5 percent by 2028 (S&P Global, 2024; USGS, 2025a). Indonesia also accounted for around 60 percent of global nickel production (USGS, 2025c).

Over the same period, lithium production was largely concentrated in a small group of countries, including Australia (36 percent), Chile (20 percent), China (17 percent), Zimbabwe (9 percent), and the United States (7 percent) (USGS, 2025b). This concentration becomes even more pronounced at subsequent stages of the value chain, particularly in processing and the production of intermediate goods for low-carbon technologies (IEA, 2022b).

In particular, Chinese firms dominate processing activities, controlling 100 percent of graphite processing, more than 90 percent of rare earth element processing, 93 percent of manganese processing, 43 percent of copper processing, 58 percent of lithium processing, and 70 percent of cobalt processing.

In addition, the mining industry itself is characterized by an oligopolistic structure, dominated by a limited number of large multinational corporations and state-owned enterprises operating across multiple jurisdictions (Eyl-Mazzega and Mathieu, 2019). The five largest mining companies control approximately 61 percent of global lithium output and 56 percent of cobalt output (IRENA, 2023). While ownership of mining companies is formally dispersed across countries, ultimate control is highly concentrated in financial institutions located primarily in the United States (Lapeyronie et al., 2025).

In this context, and against the backdrop of growing geoeconomic fragmentation, new risks related to CM supply may be emerging. For example, global nickel prices rose sharply following the Russian invasion of Ukraine, reflecting the fact that one of the largest global nickel producers is based in Russia (Johnston, 2022).

More broadly, international and domestic conflicts could lead to infrastructural destruction or mine closures, severely disrupting mineral supply and further increasing CM prices (IRENA, 2023; Kalantzakos, 2020; Teer and Bertolini, 2023; Saadaoui et al., 2025). Looking ahead, Boer et al. (2021) project that, even abstracting from geoeconomic fragmentation, demand shocks induced by the energy transition could lead to substantial price increases for copper, nickel, cobalt, and lithium by 2040.

Disruptions or shortages in CM supply could have wide-ranging economic effects, including impacts on energy markets (Chen et al., 2022), industrial production and supply chain management (Dou et al., 2023; Keilhacker and Minner, 2017; Liu et al., 2021; von Dzengelevski and Netland, 2017), financial markets (Chen et al., 2022; Gong and Xu, 2022; Haq et al., 2022; Kamal and Bouri, 2023; Reboredo and Ugolini, 2020), and the pace of the low-carbon energy transition itself (Apergis and Apergis, 2017). For instance, Apergis and Apergis (2017) find that rare earth price fluctuations significantly influence long-run renewable energy consumption. Attílio (2025) shows that, at an aggregate level, CM price shocks negatively affect the low-carbon transition, even though price shocks for individual metals do not always exhibit statistically significant effects.

CM producing countries play an active role in the supply of CMs. In this context resource protectionism refers to policies adopted by mineral-producing countries to enhance domestic value retention and move up global value chains. Shifting from the export of raw materials to higher value-added activities is often pursued as a development strategy aimed at internalizing more stages of production, raising wages, generating specialized employment, and creating demand and productivity spillovers.

These strategies are frequently motivated by efforts to regain control over national resources and increase economic sovereignty, thereby strengthening the position of mineral-rich countries within global supply chains (Crescenzi and Harman, 2022). An increasing number of mining countries have adopted policy instruments that directly influence CM prices, with export taxes among the most prominent measures (Przemyslaw, 2023). Other tools include export quotas, minimum export prices, embargoes, and licensing requirements (IRENA, 2023; Teer and Bertolini, 2023).

Developments often viewed as threats by advanced economies can therefore represent opportunities for countries in exporting LMICs. By creating incentives for local investment and increasing export taxes on CMs, producing countries can attract downstream activities and increase domestic value capture (Müller, 2023). Given the combination of concentrated supply and strong, geographically diversified demand, mineral-producing countries may occupy a relatively strong bargaining position in global markets.

Despite these dynamics, the macroeconomic and financial implications of higher CM prices and resource protectionist policies remain underexplored in the literature. Existing work often remains at a descriptive level and rarely quantifies trade-offs. In particular, little is known about the extent to which there is a "viability space" between increased fiscal claims on CM exports by LMICs and the ability to continue reducing the cost of low-carbon technologies. In other words, the potential trade-offs between the goals of increased financial revenues for LMICs and the affordability of low-carbon goods[2] largely remains to be assessed.

3. Research question, methodology and data

Our study aims to quantitatively assess the potential trade-offs between increasing fiscal revenues in mineral-exporting countries and maintaining the affordability of low-carbon technologies. We seek to identify the "viability space" between these two objectives, defined as the range of mineral price increases that would be beneficial for low- and middle-income countries (LMICs) while not significantly undermining the incentives for households and other economic agents to adopt low-carbon technologies.

We address this question by analyzing the joint effects of potential increases in CM prices on fiscal revenues in LMICs with mineral reserves and on the prices of electric vehicles (EVs) produced using different battery technologies. Our focus on EVs is motivated by their central role in future demand for CMs.

The International Energy Agency projects that approximately 45 percent of mineral requirements for low-carbon energy technologies will be used in EVs and battery storage systems (IEA, 2024). In particular, demand for lithium, graphite, nickel, and cobalt is largely driven by EV battery technologies. To reflect differences in technology choices across regions and evolving market shares, we consider three battery chemistries: NMC 811, NCA, and LFP.

More specifically, we construct a stylized scenario in which a hypothetical 5 percent levy is applied to the future potential value of cobalt, copper, lithium, and nickel mined in each exporting country. We assume that this levy (i) fully accrues as fiscal income to the extracting country, and (ii) is fully passed through to final EV prices.

[2] While some related research examines the inflationary effects of CM price shocks, this literature does not directly address the distributional trade-offs at the core of this paper. For example, Miranda-Pinto et al. (2024) use a production network model to study the effects of metal price shocks on headline and core inflation, finding that metal price shocks may become more persistent and dispersed as global reliance on metals increases. Similarly, Considine et al. (2023) analyze the interaction between CM prices, oil prices, and inflation, showing that oil prices exert a stronger influence on CM prices than vice versa, with asymmetric effects across positive and negative shocks.

We consider two representative vehicle types, in addition to the three battery technologies discussed above: a standard vehicle with an initial price of USD 50,000 and a small vehicle priced at USD 20,000. While deliberately simplified, this scenario allows us to estimate the order of magnitude of the fiscal gains that higher CM prices could generate for exporting countries, as well as the potential affordability impacts for final consumers. In doing so, it provides a transparent way to assess the extent to which the objectives of higher fiscal revenues and low-cost of EVs can be reconciled.

3.1 Data compiled to generate the scenarios

To generate scenarios that jointly capture fiscal gains for exporting countries and price impacts on EVs, we combine four types of data:

(i) The quantities of CMs required for different EV battery technologies and vehicle sizes (Table 1): We derive these quantities from the GREET2 modelling framework (Wang et al., 2024), as reported in Table 1. In line with GREET2, we assume a standard vehicle with an 84 kWh battery and a total weight of 1,800 kg, and we then consider a smaller vehicle with a 67 kWh battery and a weight of 1,435 kg. To calculate the material requirements of the smaller vehicle, we assume that vehicle weight scales linearly with battery capacity;

(ii) Projections of evolution of the price of CMs (Table 2): Our first price is anchored in the historical peak of 2022 – using the annual average of that year's monthly prices, sourced from the S&P mining dataset (S&P Global, 2025) – a period marked by exceptionally elevated commodity costs. Consequently, the 2022 data can be interpreted as representing a plausible short-term "perfect storm" scenario for CM prices. For forward-looking shocks, we employ the 2030 and 2040 price projections modeled by Boer et al. (2021). Their analysis is based on the International Energy Agency’s (IEA) Net-Zero Emissions by 2050 (NZE) scenario. Based on these datasets and the one described above, we calculate the cost share of CMs per EV of different battery technologies (Table 3). For the calculation of the cost share of CMs per EV we assume for the mid-sized EV (84 kWh) a final price of $50.000, and for the smaller EV (67 kWh) a price of $20.000.

(iii) Geographical concentration of CM production (Table 4): To identify which countries stand to benefit from potential increases in CM prices, we rely on data on the geographical distribution of production for each mineral. Specifically, we use 2022 production data from the US Geological Survey (USGS) for the four CMs considered in this study. These data allow us to map mineral production to the battery technologies in which each mineral is used.

(iv) Mining-related fiscal income by country (Table 5): We construct a dataset on mining-related fiscal income for 2022 covering 13 countries, based primarily on country reports from the Extractive Industries Transparency Initiative (EITI). Our sample includes countries participating in the EITI that report fiscal data for 2022. Where data gaps arise, we apply assumptions detailed in the supplementary material.

Table 1: Material quantities of Critical Minerals per vehicle (kg)

	NMC 811	LFP	NCA	NMC 811 (small)	LFP (small)	NCA (small)
aluminium	191.8	191.8	193.4	152.9	152.9	154.3
cobalt	7.2	0.0	11.7	5.7	0.0	9.3
copper	77.2	77.2	77.2	61.5	61.5	61.5
iron	933.9	958.6	933.9	744.9	764.6	744.9
lithium	8.4	9.2	0.0	6.7	7.3	0.0
manganese	6.7	0.0	0.0	5.3	0.0	0.0
nickel	57.2	0.1	61.1	45.6	0.0	48.7

Source: Adapted from Wang et al. (2024), based on GREET 2 model.

Table 2: Price per mineral real[1] and projected[2] (per tonne in US-dollar) for cobalt, copper, lithium, and nickel

	2022[1]	2030[2]	2040[2]
Cobalt	63,269	234,703	64,369
Copper	8,742	8,107	6,398
Lithium	70,142	17,924	12,235
Nickel	25,558	33,079	38,956

Sources: [1]S&P Global (2025); [2]Boer et al. (2021).

Table 3: Material cost share of minerals (cobalt, copper, lithium, nickel) as a percentage of final price of EV, according to different price developments and battery technologies

Battery Technology	2022[1]	2030[2]	2040[2]
LFP standard EV	1.52%	1.6%	1.2%
LFP small EV	3.80%	3.2%	2.4%
NCA standard EV	2.04%	10.8%	7.3%
NCA small EV	5.18%	21.5%	14.5%
NMC 811 standard EV	2.24%	8.7%	6.6%
NMC 811 small EV	12.67%	17.3%	13.1%

Note: Underlying material per technology taken from Table 1, based on Wang et al. (2024). Underlying prices are taken from Table 2 ([1]S&P Global (2025); [2]Boer et al. (2021)).

Table 4: Distribution of the extraction of the four critical minerals considered in our study (2022)

Country	Cobalt	Copper	Lithium	Nickel
Argentina			8,630	
Brazil			10,000	88,500
Chile		5,330,000	49,000	
Côte d'Ivoire				
DRC	130,000	2,350,000		
Gabon				
Ghana				
Guinea				
Indonesia	10,000	941,000		1,580,000
Kazakhstan		593,000		
Madagascar	3,000			
Mexico		734,000		
Mozambique				
Papua New Guinea	3,000			
Peru		2,450,000		
Philippines	3,800			345,000
Ukraine				
Zambia		797,000		

Source: USGS (2023)

Table 5: Fiscal income from mining of 13 countries in 2022 (based on EITI country reports)

	Income from minerals (Mio. $)	Fiscal income from minerals	Fiscal income from total mining (including coal, gas, and oil)
Argentina	451	0.5%	3.8%
Chile	6961	8.9%	8.9%
Cote d'ivoire	306	2.4%	5.5%
DRC	7038	38.2%	40.0%
Gabon	163	4.5%	68.0%
Ghana	1041	6.7%	6.7%
Guinea	458	17.1%	17.1%
Indonesia	7787	5.1%	8.2%
Madagascar	15	1.7%	1.7%
Papua New Guinea	500	3.0%	26.7%
Peru	7337	13.0%	18.4%
Philippines	563	1.5%	2.2%
Zambia	1266	40.0%	44.0%

Source: EITI country reports (2023)

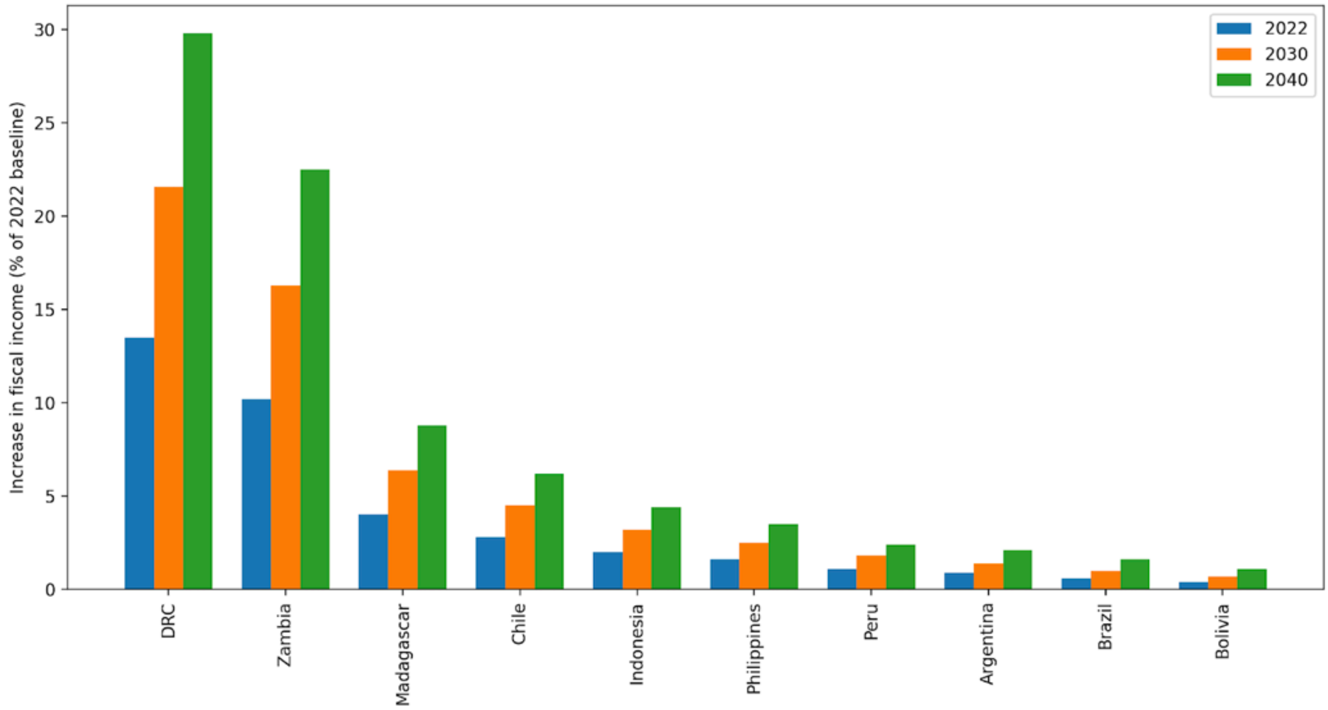
4. Key results

This section presents the core results of the paper. We first examine the fiscal impacts of a hypothetical 5% levy on CM production under 2022 price levels – a year in which the price of several CMs significantly increased. We then extend the analysis to projections of higher CM price scenarios for 2030, and 2040 (note that all fiscal impacts are expressed relative to observed fiscal income in 2022, rather than projected future revenues). Finally, we assess the implications of these price increases for electric vehicle (EV) affordability and synthesize the results through the concept of a 'viability space'.

4.1 Fiscal impacts of a potential levy on the value of critical minerals

Figure 1.A presents the impacts of a 5% levy on the value of cobalt, copper, lithium, and nickel production under 2022 prices, and under theoretical prices for 2030 and 2040 as projected by Boer et al. (2021). The results reveal substantial heterogeneity across the countries considered (countries for which the impact is null or marginal not being listed in the figure), reflecting differences in mineral endowments and production profiles. Countries with strong specialization in one or more of the four minerals experience sizable fiscal gains relative to their observed mining-related revenues.

Figure 1: Fiscal income impact of a 5% levy on critical minerals exports under three price scenarios (2022, 2030 and 2040)



Source: Fiscal income data: EITI country reports (2023), IMF and World Bank; CM price data: S&P Global (2025) and Boer et al. (2021); EV material data: GREET 2 model (Wang et al. 2024); Resource production data: USGS (2025).

In particular, the Democratic Republic of Congo (DRC) and Zambia stand out, with fiscal gains exceeding 10% of their 2022 mining-related fiscal income (blue bars). These large effects reflect both the importance of cobalt and copper – which are abundant in the EV battery technologies considered – in their export baskets and the relatively limited size of existing fiscal revenues from the mining sector.

Other countries, such as the Philippines, Brazil and Bolivia would experience more moderate gains from our scenario. This reflects the fact that our study covers only four CMs and their use in three EV battery technologies. In other words, while fiscal revenues in these CM-extracting countries could also be positively affected by a levy on rising CM prices, such effects are not necessarily captured within the narrow set of CMs and technologies assessed here.

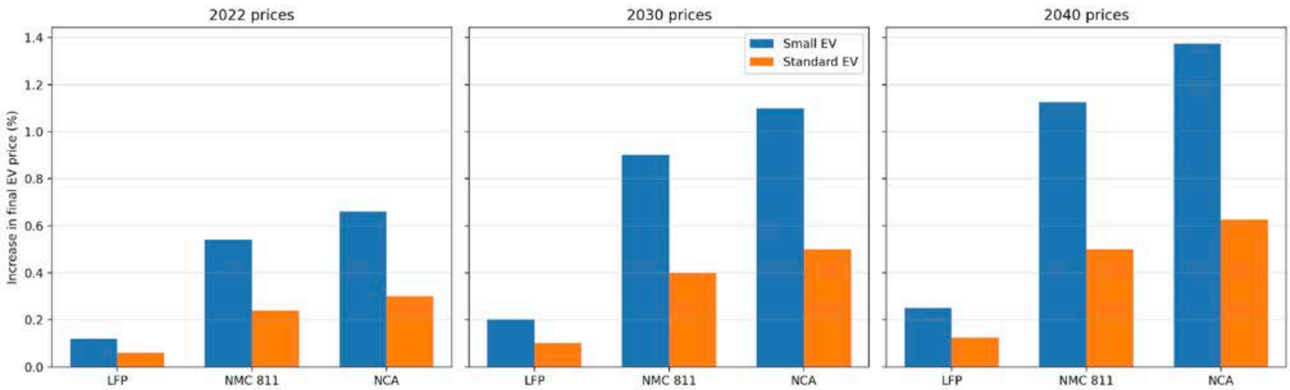
When extending the analysis to projected CM price levels for 2030 (orange bars) and 2040 (blue bars) – based on the Net Zero Emissions scenario projections of Boer et al. (2021), and while holding fiscal baselines constant at their current levels – the fiscal gains generated by the same 5% theoretical levy rise mechanically. By 2024, fiscal gains for highly specialized exporters are already noticeably larger than in the 2022 baseline. By 2030, these gains increase substantially, and by 2040 they can reach several tens of percent of current mining-related revenues in the most exposed countries.

While such gains are purely theoretical – given that fiscal incomes are kept constant – these results highlight the strong sensitivity of exporter fiscal outcomes to CM price dynamics. Even without changes in production volumes, tax rates, or institutional arrangements, rising CM prices alone could significantly expand fiscal space for some exporting low- and middle-income countries.

4.2 Impacts on electric vehicle prices

We now turn to the implications of higher CM prices for EV affordability. Figure 2 shows the effect of a 5% levy on CM prices of cobalt, copper, lithium, and nickel on final EV prices, differentiated by battery technology (LFP, NMC 811 and NCA) and vehicle size (small and standard EV), based respectively on observed prices for 2022 and on Boer et al.'s (2021) price projections for 2030 and 2040. In our scenario, we assume that the increase in price due to the levy is simply passed through to final prices, with an initial EV price of USD 20K (small EV) and USD 50K (standard EV) respectively.

Figure 2: Increase in EV prices resulting from a 5 percent levy on 2030 prices (as projected by Boer et al., 2021), by battery technology and vehicle size



Note: we assume a standard EV (84 kWh) at the final price of $50.000 and a smaller EV (67 kWh) at the price of $20.000.

Source: Fiscal income data: EITI country reports (2023), IMF and World Bank; CM price data: S&P Global (2025) and Boer et al. (2021); EV material data: GREET 2 model (Wang et al. 2024); Resource production data: USGS (2025).

Across all scenarios, the impact on EV prices remains modest. Depending on battery chemistry and vehicle size, a 5% increase in CM prices raises final EV prices by between approximately 0.1% and 1.4%. Even in the upper range, these price increases remain small relative to total vehicle costs. For instance, even if prices were to increase as much as projected by Boer et al. (2021) by 2040 with the technological developments projected by the IEA, the maximum increase in EVs would be of less than 1.4% for small vehicles produced with the NCA technology (last blue bar in Figure 2). Moreover, LFP-based vehicles are the least affected, reflecting their lower reliance on cobalt and nickel, while NCA-based vehicles display the highest sensitivity.

Taken together, the results presented above point to the existence of a large 'viability space' between exporter fiscal revenues and EV affordability. On the one hand, rising CM prices can generate substantial fiscal gains for exporting LMICs. On the other hand, the corresponding impact on EV prices remains limited.

This asymmetry suggests that higher CM prices do not necessarily constitute a binding constraint on the deployment of EVs or, more broadly, on the low-carbon transition. Instead, they open scope for policy approaches that reconcile development objectives in exporting countries with climate mitigation goals in importing regions.

5. Policy implications and limitations

5.1 Policy implications

We find that higher CM prices can be associated with a moderate increase in the final price of EVs alongside a substantial rise in fiscal revenues for mineral-exporting countries. These results have important policy implications. In particular, they suggest that high-income countries without CM reserves could pursue partnerships with exporting countries by accepting higher mineral prices, thereby establishing a form of "fair trade" that supports fiscal outcomes in producer countries without materially undermining the affordability of low-carbon technologies.

Such an approach would need to be embedded in a broader strategy. High-income countries without domestic CM reserves could employ stockpiling, targeted industrial partnerships, and measures aimed at reducing demand. Each of these approaches entails specific challenges.

First, in addition to fair trade arrangements, countries lacking domestic CM reserves may pursue stockpiling strategies (Gros, 2023). Australia, for example, has committed AUD 1.2 billion to establish a flexible CM reserve, including pre-purchase agreements and selective stockpiling, with potential access for international partners. However, there is limited evidence that stockpiling alone can provide sufficient guarantees or flexibility to respond effectively to material supply crises (Hache et al., 2023; Hache and Jeannin, 2023).

Where production volumes are low, stockpiling may significantly distort markets and push prices upward, generating higher costs and increased volatility for importing regions such as the EU. In addition, countries with substantial market power could respond strategically to such measures, potentially necessitating complex and politically sensitive stockpiling strategies (Bourgery-Gonse, 2025).

Second, rather than setting broad and uniform objectives across all CMs, as is currently the case in both the EU[3] and the United States, a more effective approach may involve focusing on a limited number of strategic technologies through targeted industrial policy. From this starting point, governments could then develop tailored strategies to secure the specific minerals required for these technologies.

Such an approach would challenge the prevailing reliance on market mechanisms, particularly within the EU, and would also need to acknowledge the central role of China. Over several decades, China has treated mineral resources as a matter of national security and has pursued a comprehensive strategy spanning extraction, processing, advanced manufacturing, and downstream products such as rare earth magnets, batteries, and electric vehicles. Given the dominant role of Chinese firms in CM processing, a pragmatic strategy to secure supply may need, under certain conditions, to include Chinese investments accompanied by negotiated technology transfers. It should also build on existing strengths in research and development, consider medium-term demand trends, explore the use of price floors, and strengthen partnerships with third countries (Massot, 2025).

Third, some countries and regions, including the EU, could seek to reduce demand for CMs by promoting sufficiency. Sufficiency is defined as a set of policies and practices that limit demand for energy, raw materials, land, and water while ensuring wellbeing and respecting planetary boundaries (IPCC, 2021). According to Hache (2023), sufficiency measures could play a central role in addressing CM supply challenges while simultaneously reducing environmental externalities associated with large-scale deployment of low-carbon technologies, yet they remain largely absent from European policy debates.

Designing lighter EVs, for instance, would reduce battery size and therefore lower dependence on CMs used in transport and electricity generation. At the same time, reducing the EU's critical raw material footprint through lower and more efficient consumption would require a profound rethinking of material use patterns.

Such a shift would need to embed considerations of environmental and economic justice to ensure that lower-income households are not excluded from access to essential technologies for housing, mobility, and heating. Moreover, manufacturing industries may resist the transition toward more resource-efficient products, as it could imply lower sales volumes and reduced turnover.

[3] The EU's Critical Raw Materials Act (CRMA) was formally adopted by the Council of the European Union in March 2024 (*CRMA*, 2024). The CRMA establishes three ambitious benchmarks for the EU's annual consumption of raw critical materials, to be achieved by 2030: 10% of critical raw minerals should be extracted locally, i.e. within the EU; 40% should be processed in the EU; 25% should come from recycled materials; no more than 65% of the EU's annual consumption of any single strategic raw material should come from one single third country.

5.2. Limitations

Our approach is limited by data availability and some key assumptions.

Publicly available data that we're using has a time lag. To provide a broader base of countries, we decided to select 2022 as a base year as for this year most countries of the EITI initiative provide data. Newer data becomes available with time and should be used in further research.

In order to provide a more realistic estimation of the effects of changes in the input prices on final prices, detailed supply chain data would be essential. However, detailed data on the supply chain of electric vehicles is only available at high cost. To still allow for a more realistic approximation of costs, a general multiplier could be applied to the price increase.

To calculate the effect of a hypothetical levy on CMs we assume that 100% of the revenues obtained become fiscal income. In reality, the collection of taxes or tariffs is not as efficient. First, mining is mostly controlled by transnational companies. As a result, the effective level of taxes paid can significantly lower than legally prescribed. Second, the collection of taxes requires administrative capacities which represent a cost and which are sometimes lacking in those countries considered. Both considerations would reduce the effective increase in fiscal income.

Lastly, our study focuses on mining countries which does not account for risks and actors along the remaining supply chain. As the processing of CMs is strongly concentrated among a few firms and countries, most particularly Chinese ones (as discussed in Section 2), prices and the supply of CMs are subject to actors there.

6. Conclusion

This paper shows that rising prices of CMs need not represent a binding constraint on the low-carbon transition. By jointly analyzing fiscal impacts for exporting LMICs and affordability effects for electric vehicles, we identify a substantial viability space in which higher mineral prices can generate meaningful fiscal gains for producers while only modestly affecting EV prices.

This suggests that policies allowing for higher CM prices, including through forms of fair trade and international cooperation, could reconcile development objectives in exporting countries with climate mitigation goals in importing regions. Future research should extend this analysis to downstream processing stages and broader low-carbon technologies.

References

Apergis, E., & Apergis, N. (2017). The role of rare earth prices in renewable energy consumption: The actual driver for a renewable energy world. *Energy Economics*, *62*, 33–42. https://doi.org/10.1016/j.eneco.2016.12.015

Attílio, L. A. (2025). Impact of critical mineral prices on energy transition. *Applied Energy*, *377*, 124688. https://doi.org/10.1016/j.apenergy.2024.124688

Boer, L., Pescatori, A., & Stuermer, M. (2021). IMF working paper: Energy transition metals. *IMF Working Papers*.

Bourgery-Gonse, T. (2025). Experts: Stockpiling may be EU's blind spot in critical raw materials debate. *Euractiv*. https://www.euractiv.com/news/stockpiling-may-be-eus-blind-spot-in-critical-raw-materials-debate-experts-say/

Carrara, S., Bobba, S., Blagoeva, D., Alves, D. P., Cavalli, A., Georgitzikis, K., Grohol, M., Itul, A., Kuzov, T., Latunussa, C., Lyons, L., Malano, G., Maury, T., Prior, A. A., Somers, J., Telsnig, T., Veeh, C., Wittmer, D., Black, C., … Christou, M. (2023). *Supply chain analysis and material demand forecast in strategic techno logies and sectors in the EU – A foresight study*. https://publications.jrc.ec.europa.eu/repository/handle/JRC132889

Chen, J., Liang, Z., Ding, Q., & Liu, Z. (2022). Extreme spillovers among fossil energy, clean energy, and metals markets: Evidence from a quantile-based analysis. *Energy Economics*, *107*, 105880. https://doi.org/10.1016/j.eneco.2022.105880

Crescenzi, R., & Harman, O. (2023). *Harnessing Global Value Chains for regional development: How to upgrade through regional policy, FDI and trade* (1. Aufl.). Routledge. https://doi.org/10.4324/9781003356141

Dou, S., Xu, D., Zhu, Y., & Keenan, R. (2023). Critical mineral sustainable supply: Challenges and governance. *Futures*, *146*, 103101. https://doi.org/10.1016/j.futures.2023.103101

Dzengelevski, O., & Netland, T. (2017). *Tracing The Impacts Of Rare Earth Element Shocks On High-Tech Industry Performance And Relocation*. 10 p. DOI.org (Datacite). https://doi.org/10.3929/ETHZ-B-000193155

EITI country reports. (o. J.). EITI. Abgerufen 18. März 2025, von https://eiti.org/eiti-country-reports

ETC. (2023). *Material and Resource Requirements for the Energy Transition*. Energy Transitions Commission. https://www.energy-transitions.org/publications/material-and-resource-energy-transition

Eyl-Mazzega, M.-A., & Mathieu, C. (2020). The European Union and the Energy Transition. In M. Hafner & S. Tagliapietra (Hrsg.), *The Geopolitics of the Global Energy Transition* (Bd. 73, S. 27–46). Springer International Publishing. https://doi.org/10.1007/978-3-030-39066-2_2

Fajgelbaum, P. D., Goldberg, P. K., Kennedy, P. J., & Khandelwal, A. K. (2020). The Return to

Protectionism*. *The Quarterly Journal of Economics*, *135*(1), 1–55. https://doi.org/10.1093/qje/qjz036

Fang, M. M. (2024a). *Climbing up the Critical Mineral Value Chains: The Global South and Green Industrialization in an Era of Disruption*. papers.ssrn.com. https://papers.ssrn.com/abstract=4800350

Fang, M. M. (2024b). *Climbing up the Critical Mineral Value Chains: The Global South and Green Industrialization in an Era of Disruption* (SSRN Scholarly Paper No. 4800350). Social Science Research Network. https://papers.ssrn.com/abstract=4800350

Fischer, A. M. (2011). Beware the Fallacy of Productivity Reductionism. *The European Journal of Development Research*, *23*(4), 521–526. https://doi.org/10.1057/ejdr.2011.25

Gielen, D. (2021). *Critical Materials for the Energy Transition*. International Renewable Energy Agency. https://www.irena.org/Technical-Papers/Critical-Materials-For-The-Energy-Transition

Giurco, D., Dominish, E., Florin, N., Watari, T., & McLellan, B. (2019). Requirements for Minerals and Metals for 100% Renewable Scenarios. In S. Teske (Hrsg.), *Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C* (S. 437–457). Springer International Publishing. https://doi.org/10.1007/978-3-030-05843-2_11

Gong, X., & Xu, J. (2022). Geopolitical risk and dynamic connectedness between commodity markets. *Energy Economics*, *110*, 106028. https://doi.org/10.1016/j.eneco.2022.106028

Gros, D. (2023). Letter: How Europe can avoid the weaponization of rare earths. Financial Times (September 28).

Hache, E., & Jeannin, F. (2023). *A return of strategic stocks of critical metals in the low-carbon transition dynamics? 669*, 7–12.

Hache, E., & Normand, E. (2024). *Critical materials: Assessing the EU strategy*.

Haq, I. U., Nadeem, H., Maneengam, A., Samantreeporn, S., Huynh, N., Kettanom, T., & Wisetsri, W. (2022). Do Rare Earths and Energy Commodities Drive Volatility Transmission in Sustainable Financial Markets? Evidence from China, Australia, and th e US. *International Journal of Financial Studies*, *10*(3), 76. www.mdpi.com. https://doi.org/10.3390/ijfs10030076

IEA. (2021a). *Minerals used in electric cars compared to conventional cars*. IEA. https://www.iea.org/data-and-statistics/charts/minerals-used-in-electric-cars-compared-to-conventional-cars

IEA. (2021b). *Net Zero by 2050—A Roadmap for the Global Energy Sector*. International Energy Agency. https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf

IEA. (2022). *Global Supply Chains of EV Batteries*. International Energy Agency; Zotero.

IEA. (2024a). *Global Critical Minerals Outlook 2024*.

IEA. (2024b). *Global EV Outlook 2024*. International Energy Agency. https://www.iea.org/reports/global-ev-outlook-2024

IPCC. (2021). *Special report: Global warming of 1.5 °—Summary for policymakers*. IPCC. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

IRENA. (2023). *Geopolitics of the energy transition: Critical materials*.

Kalantzakos, S. (2020). The Race for Critical Minerals in an Era of Geopolitical Realignments. *The International Spectator*. https://www.tandfonline.com/doi/full/10.1080/03932729.2020.1786926

Kamal, E., & Bouri, E. (2023). Dependence structure among rare earth and financial markets: A multiscale-vine copula approach. *Resources Policy*, *83*, 103626. https://doi.org/10.1016/j.resourpol.2023.103626

Keilhacker, M. L., & Minner, S. (2017). Supply chain risk management for critical commodities: A system dynamics model for the case of the rare earth elements. *Resources, Conservation and Recycling*, *125*, 349–362. https://doi.org/10.1016/j.resconrec.2017.05.004

Lee, J., Bazilian, M., Sovacool, B., Hund, K., Jowitt, S. M., Nguyen, T. P., Månberger, A., Kah, M., Greene, S., Galeazzi, C., Awuah-Offei, K., Moats, M., Tilton, J., & Kukoda, S. (2020). Reviewing the material and metal security of low-carbon energy transit ions. *Renewable and Sustainable Energy Reviews*, *124*, 109789. DOI.org (Crossref). https://doi.org/10.1016/j.rser.2020.109789

Liu, W., Liu, W., Li, X., Liu, Y., Ogunmoroti, A. E., Li, M., Bi, M., & Cui, Z. (2021). Dynamic material flow analysis of critical metals for lithium-ion battery system in China from 2000–2018. *Resources, Conservation and Recycling*, *164*, 105122. https://doi.org/10.1016/j.resconrec.2020.105122

Maisel, F., Neef, C., Marscheider-Weidemann, F., & Nissen, N. F. (2023). A forecast on future raw material demand and recycling potential of lithium-ion batteries in electric vehicles. *Resources, Conservation and Recycling*, *192*, 106920. https://doi.org/10.1016/j.resconrec.2023.106920

Malik, M. (2025). Géopolitique des minéraux critiques. *Le Grand Continent*. https://legrandcontinent.eu/fr/2025/08/28/le-fantasme-americain-face-a-lhegemonie-chinoise-geopolitique-des-mineraux-critiques/

Massot, P. (2025). Critical minerals: "We need a finer understanding of China's vulnerabilities". ESSEC Institute for Geopolitics and Business, available at: https://institute-geopolitics-business.essec.edu/blog/critical-minerals-we-need-afiner-understanding-of-china-s-vulnerabilities.

Miller, H., Dikau, S., Svartzman, R., Dees, S. (2023). "The stumbling block in 'the race of our lives': transition-critical materials, financial risks and the NGFS climate scenarios". Centre for Climate Change Economics and Policy Working Paper 417/Grantham Research Institute on

Climate Change and the Environment Working Paper 393. London School of Economics and Political Science.

Marscheider-Weidemann, F., Langkau, S., Eberling, E., Erdmann, L., Haendel, M., Krail, M., Loibl, A., Neef, C.,

Neuwirth, M., Rostek, L., Shirinzadeh, S., Stijepic, D., & Espinoza, L. T. (2021). *Raw materials for emerging technologies 2021*. German Mineral Resources Agency. https://www.deutsche-rohstoffagentur.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen/rohstoffinformationen-50-en.pdf;jsessionid=106B570EE5DB4A92CA3FD224ECF11770.internet942?__blob=publicationFile&v=3

Müller, M. (2023). The 'new geopolitics' of mineral supply chains: A window of opportunit y for African countries. *South African Journal of International Affairs*, *30*(2), 177–203. Taylor and Francis+NEJM. https://doi.org/10.1080/10220461.2023.2226108

Nakhle, C. (2023). *Resource nationalism stunts low-carbon solutions – _GIS Reports. 2024/11/11/*. https://www.gisreportsonline.com/r/resource-nationalism/

Nobletz, C., Svartzman, R., Dikau, S. (2024). "The EU's dependency on critical materials: meeting decarbonisation targets in the context of geopolitical risks". Joint Policy Report, CETEx and Institute for European Policymaking at Bocconi University. September.

Omonbude, W. E., & Mataba, K. (2024). *Financial Benefit-Sharing Issues for Critical Minerals: Challenges and opportunities for producing countries*. IISD.

Przemyslaw, K. (2023). *OECD TRADE POLICY PAPER N°270*.

Reboredo, J. C., & Ugolini, A. (2020). Price spillovers between rare earth stocks and financial markets. *Resources Policy*, *66*, 101647. https://doi.org/10.1016/j.resourpol.2020.101647

Saadaoui, J., Smyth, R., & Vespignani, J. (o. J.). *Ensuring the security of the clean energy transition: Examining the impact of geopolitical risk on the price of critical minerals*.

Schlichenmaier, S., & Naegler, T. (2022). May material bottlenecks hamper the global energy transition towards the 1.5 °C target? *Energy Reports*, *8*, 14875–14887. https://doi.org/10.1016/j.egyr.2022.11.025

Shiquan, D., & Deyi, X. (2023). The security of critical mineral supply chains. *Mineral Economics*, *36*(3), 401–412. https://doi.org/10.1007/s13563-022-00340-4

S&P. (2024). *Lithium and Cobalt Commodity Quarterly Q2 2024*.

Teer, J., Bertolini, M., Ritoe, J. A., Heyster, S., Sweijs, T., de Wijk, R., Vlaskamp, M., Patrahau, I., Thompson, J., Kim, S., Minicozzi, R., Meszaros, A., Cisco, G., & Gorecki, M. (o. J.). *The semiconductor and critical raw material ecosystem at a time of great power rivalry Full version*.

USGS. (2025a). *Cobalt 2025*. https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-cobalt.pdf

USGS. (2025b). *Lithium 2025*. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-silicon.pdf

USGS. (2025c). *Nickel 2025*. https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-nickel.pdf

Wang, M., Cai, H., Ou, L., Elgowainy, A., Alam, M. R., Benavides, P., Benvenutti, L., Burnham, A., Do, T., Farhad, M., Gan, Y., Gracida-Alvarez, U., Hawkins, T., Iyer, R., Kar, S., Kelly, J., Kim, T., Kolodziej, C., Kwon, H., … Zhou, J. (2024). *Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model ® (2024 Excel)*. DOI.org (Datacite). https://www.osti.gov/doecode/biblio/148070

Watari, T., Nansai, K., Nakajima, K., & Giurco, D. (2021). Sustainable energy transitions require enhanced resource governance. *Journal of Cleaner Production*, *312*, 127698. https://doi.org/10.1016/j.jclepro.2021.127698

Weber, L. (2024). *The potential environmental impacts of mining required for future electric vehicle production* [Master's Thesis]. Wu Vienna.