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# Critical Minerals and the Low-Carbon Transition: Economic Implications for Emerging Markets and Developing Economies

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**ABSTRACT**

The transition toward a low-carbon economy will have important implications for major mineral-exporting countries. We examine the distribution of these minerals across emerging markets and developing economies (EMDEs) and identify potential implications, notably fiscal implication, for these economies due to the shifting patterns of demand that are likely to result from the energy transition. Producers of specific minerals like copper, nickel, and graphite stand to gain from the projected increase in demand for these minerals over the next two decades or so. These countries include Brazil, Chile, China, Mozambique, Peru, Philippines, and Indonesia. Our study emphasizes the need for proactive government planning and policies to seize economic opportunities and mitigate potential risks arising from the low-carbon transition.

**Keywords:** climate change, climate risks, critical minerals, energy transition, fiscal policy, renewable energy resources

## NOMENCLATURE

*Abbreviations*

| | |
|---|---|
| EMDEs | Emerging Markets and Developing Economies |
| EDI | Extractive Dependence Index |
| ETI | Energy Transition Minerals |
| GDP | Gross Domestic Product |
| IEA | International Energy Agency |
| SDS | Sustainable Development Scenario |
| STEPS | Stated Policies Scenario |
| MCI | Mining Contribution Index |

## 1. INTRODUCTION

The transition to clean energy is expected to be accompanied by a significant surge in demand for certain critical minerals used heavily in clean energy technologies such as batteries, solar panels, and wind turbines [1]. Clean energy technologies require fewer fuels but rely more heavily on construction materials, including minerals, than traditional hydrocarbon-based fuels [2]. Due to increased demand and high prices, the market for essential minerals crucial for the energy transition has already doubled in size, reaching a value of USD 320 billion in 2022 [14]. The latest predictions for metal consumption, particularly for copper and nickel, indicate that the demand for these metals will be several times higher over the next few decades than today [3,7,8]. According to the International Energy Agency, critical minerals' markets, including copper, cobalt, manganese, and rare earth metals, are set to grow sevenfold from 2020 to 2030 [2,5,6].

The expected rapid increase in demand for *critical minerals* (also known as *energy transition metals*) raises concerns about their accessibility, reliability of supply, and potentially escalating costs, highlighting challenges to the clean energy transition [13]. While production of some minerals like lithium and cobalt is expected to keep pace with growing demand, others like lithium chemical derivatives, battery-grade nickel, and rare earth elements may become scarce. The IEA predicts that only 50% of lithium cobalt and 80% of copper needs for 2030 will be met by existing mines and projects, even in a scenario that considers stringent climate policies. Current supply and investment strategies will respond slowly to climate change (according to the IEA STEPS

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trajectory) and would need adjustments to achieve a faster transition to low-carbon energy.

While previous research has primarily examined the economic consequences of the transition for oil-exporting countries [9], the fiscal implications of the shift toward low-carbon technologies for countries exporting critical minerals has received little attention. As the global transition toward a low-carbon economy accelerates, the demand for critical minerals in producing renewable energy technologies, energy storage systems, electric vehicles, and other low-carbon technologies could have important fiscal implications for countries with substantial reserves of such minerals. Consequently, once a minor part of the energy market, these energy transition minerals are now becoming a focal point in the mining and metals industry. This shift not only opens up new revenue avenues for the industry but also generates employment opportunities and, in certain instances, aids in diversifying economies that heavily rely on coal.

Against this backdrop, this study has three main objectives: (i) to understand the impact of the low-carbon transition on the demand for critical minerals; (ii) to analyze the variation in demand for critical minerals in selected emerging market and developing economies (EMDEs); (iii) to investigate the fiscal implications for countries due to changes in critical mineral demand. Relying on the methodology described in Section 2, the study's findings emphasize the importance of proactive government planning and policies that leverage the economic opportunities associated with critical minerals while effectively managing potential risks.

Unfortunately, the lack of adequate data prevents a thorough analysis of the expected effects of increased demand and supply of critical minerals. Despite this constraint, it is important to highlight that this study contributes significantly to the existing literature on the macroeconomic implications of the energy transition. It represents a pioneering effort to describe the economic repercussions of the low-carbon transition of critical minerals, drawing upon the information currently accessible. Moreover, it plays a pivotal role by providing a roadmap for forthcoming research initiatives. We emphasize that the future research agenda comprises two core objectives: firstly, the development of a comprehensive database facilitating in-depth fiscal policy analysis, and secondly, conducting country-specific studies to distinguish unique fiscal implications at the national level. These initiatives could help offer nuanced insights, enabling tailored policy recommendations and fostering global economic stability and growth.

The remainder of the paper is organized as follows. Section 2 will present the data and the methodology used. Section 3 will provide the theoretical background necessary for our analysis. Section 4 will illustrate the results derived from our investigation, and Section 5 will place these results in perspective. Finally, Section 6 will offer the concluding remarks of our study.

## 2. MATERIAL AND METHODS

The approach used in this study involves the following steps:

**Step 1: Data collection.**

Our empirical analysis comprehensively examines twelve mineral commodities, specifically chromium, copper, cobalt, graphite, lithium, manganese, nickel, platinum group metals, rare earth elements (REE), silicon, silver, and zinc. This selection aligns with the classification provided by the International Energy Agency (IEA).

We delve into these critical minerals' production and reserve statistics, drawing from the U.S. Geological Survey's 2022 mineral commodities summaries.

Additionally, we explore the global distribution of these major critical minerals across different countries based on information from the IEA's World Energy Outlook Special Report of 2021. Our analysis also includes an evaluation of the Extractive Dependence Index (EDI), a metric established by the Extractive Industries Transparency Initiative (EITI). The EDI offers insights into a country's reliance on the extraction of oil, gas, and mineral resources, considering aspects such as export earnings, revenue share, and their contribution to Gross Domestic Product (GDP).

Moreover, we examine the Mining Contribution Index (MCI) to understand mining's role in national economies and the significance of effective mineral resource governance. This index helps assess how mineral wealth can lead to widespread economic and social development.

Lastly, we assess the future demand for these critical minerals, referring to the International Energy Agency's World Energy Outlook 2021 Special Report. In this context, we particularly focus on the Stated Policies Scenario (STEPS) and the Sustainable Development Scenario (SDS), which provide forecasts under different policy frameworks.

**Step 2: Quantitative analysis. U**sing data collected in Step 1, patterns, and trends in critical mineral production and demand across selected EMDEs is identified.

**Step 3: Comparative analysis**. The cross-country differences between the Extractive Dependence Index (EDI) and the Mining Contribution Index (MCI) are examined to tease out the relationship between mineral dependence and economic development.

**Step 4: Scenario analysis**. Finally, the IEA's scenarios (STEPS and SDS) are used to project future demand for critical minerals in different low-carbon transition scenarios.

## 3. THEORY

This study combines scenario analysis and commodity market dynamics to understand the future demand for critical minerals and its impact on Emerging Market and Developing Economies (EMDEs) fiscal policies. Scenario analysis is used to predict future scenarios like low-carbon technology adoption and geopolitical changes [6,10]. This approach helps anticipate shifts in critical mineral demand, enabling informed decision-making for policymakers and industry stakeholders. The study also examines commodity market dynamics, focusing on the critical mineral sector's demand fluctuations and market concentration. The research uncovers patterns and trends by analyzing these dynamics, offering insights into economic vulnerabilities and opportunities for countries relying on these resources. Integrating scenario analysis with commodity market insights provides a comprehensive framework for understanding critical minerals, aiding sustainable economic development and resource management in EMDEs.

## 4. RESULTS

### *4.1 Distribution of critical minerals in EMDEs*

The production of critical minerals exhibits significant variation across countries, highlighting the specialized nature of the industry. The distribution of the production of selected critical minerals across countries is summarized in Figure 1. The Democratic Republic of Congo (DRC) plays a critical role in global cobalt production, while Chile is the major producer of copper (5,200 tons). China is the major graphite producer (650,000 tons), followed by Mozambique and Brazil (120,000 and 95,000 tons, respectively). China also dominates the production of rare earth minerals (168,000 tons). Indonesia, and the Philippines, are important nickel producers, with production amounting to 1,000,000, and 370,000 tons respectively.

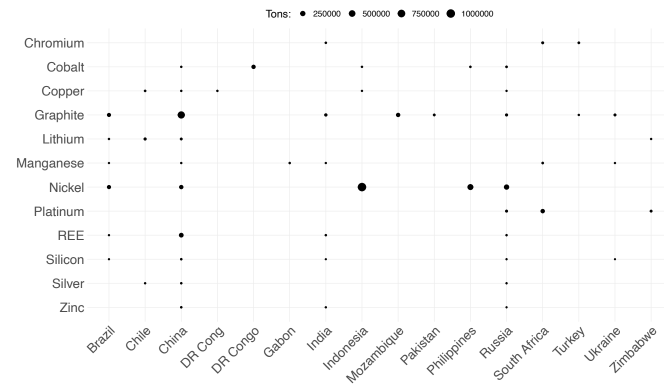


*Fig. 1. Total production (tons) for selected minerals (2022). Source: Authors' elaboration on U.S. Geological Survey data.*

South Africa, Russia, and Zimbabwe play an important role in platinum production, further underscoring the diversity of the mineral production landscape. South Africa is also an important producer of manganese (7,400 tons), followed by Gabon (3,600 tons) and chromium (17,000 tons). China was the biggest producer of silicon (4,500 tons) in 2022, followed by Russia (600 tons). These countries are also major global producers of silver and zinc.

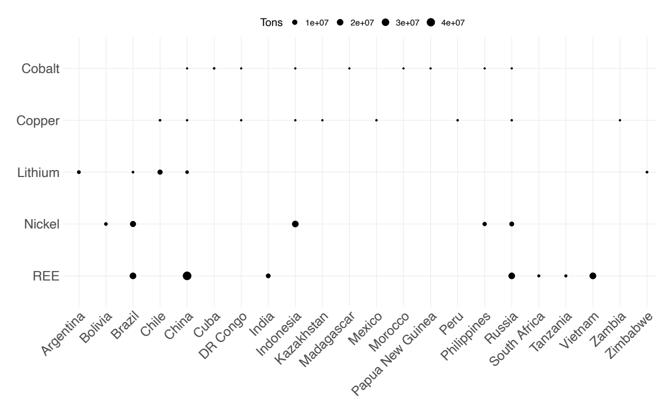


*Fig. 2. Total reserves (tons) of critical minerals by country (2022). Source: Authors' elaboration on U.S. Geological Survey data.*

Some EMDEs are also endowed with substantial reserves of critical minerals, notably Brazil, Chile, China, India, Indonesia, the Philippines, Russia, and Vietnam (Figure 2). According to the 2022 data from the U.S. Geological Survey, China has the largest reserves of Rare Earth Elements (REE), followed by Vietnam, Russia, and Brazil. Chile has the highest reserves of copper (190,000 tons), followed by Peru (81,000 tons) and Russia (62,000 tons).

Cuba and Indonesia have significant cobalt reserves (130,000 and 10,000 tons respectively). Chile also leads in lithium reserves (9,300,000 tons), followed by Argentina (2,700,000 tons) and China (2,000,000 tons). Indonesia and Brazil have substantial nickel reserves (21,000,000 and 16,000,000 tons respectively).

### *4.2 Production and fiscal revenues of critical minerals*

According to EDI data [9], mineral production is a substantial share of economic activity in the Democratic Republic of Congo, accounting for 24.27% of its GDP (see Figure 3). Mineral production is also critical for Chile and Zimbabwe, with a production quantity equivalent to 17.73% and 16.08% of GDP, respectively. Other EMDEs where critical mineral production comprises a considerable proportion of their GDP include Peru, South Africa, Mozambique, Russia, Brazil, Indonesia, and China.

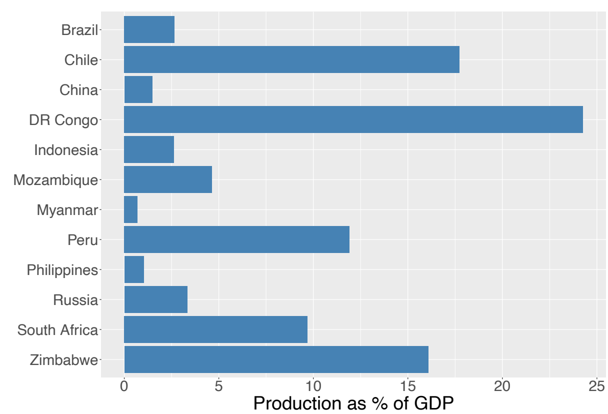


*Fig. 3. Production (as a share of GDP) of critical minerals by country. Source: Authors' elaboration on data retrieved from [10].*

Critical minerals are also an important source of revenues for several EMDEs, representing a considerable share of total fiscal revenues (Figure 4). Revenues from critical minerals constitute as much 53.4% of total fiscal revenues for Myanmar. The corresponding shares for DRC, Russia, and Peru range from about 16% to 38%. Critical mineral revenues also play an important role in fiscal revenues in Zimbabwe, Chile, Mozambique, Brazil, Indonesia, and the Philippines.

### *4.3 Resource dependence and significance of mining for the economy*

EDI data provides valuable insights into the degree of economic diversification and specialization of countries [10]. For instance, countries such as the DRC and Myanmar depend heavily on extractive industries, making them more susceptible to changes in commodity prices. On the other hand, countries like the Philippines have notably lower EDI index values, indicating a more diversified economic base, which could contribute to greater economic stability and resilience to external shocks, including commodity price shocks. The data also hints at regional patterns, with various South American nations exhibiting moderate levels of extractive dependence. The Mining Contribution Index (MCI) ranks countries based on the economic significance of their mining sectors, and can be used to tease out the exposure of countries to potential transition risks [11]. Zimbabwe leads with an MCI score of 92.4, followed closely by the DRC (89.1), Chile (88.2), and South Africa (86.4). Brazil, Mozambique, and Russia also have substantial mining contributions, all have scores above 77, indicating considerable dependence on the extractive industry. China and Myanmar have comparatively lower MCI scores, indicating a less dominant role for mining in their economies.

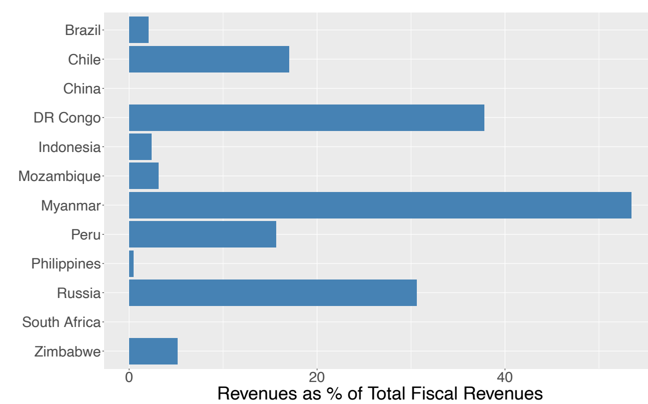


*Fig. 4. Revenues (as a share of total fiscal revenues) of critical minerals by country. Source: Authors' elaboration on data retrieved from [10].*

### *4.4 Projected critical minerals' demand*

We examine the scenarios presented by the IEA to better understand the potential shifts in the demand for critical minerals. As illustrated in Figures 5 and 6, a range of outcomes are plausible, based on the STEPS and the SDS scenario.

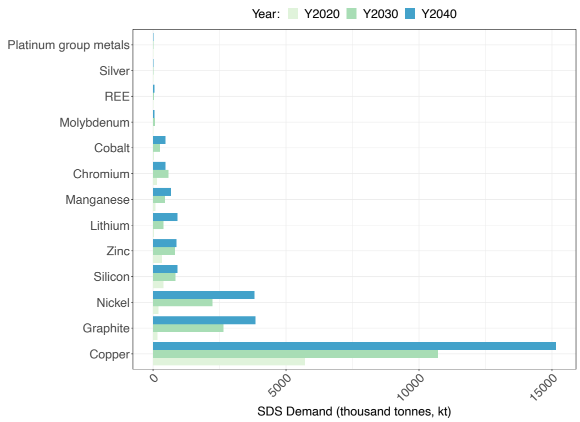


*Fig. 5. Total demand by key critical mineral - Sustainable Development Scenario. Source: Authors' elaboration on IEA [6] datasets on the metal demands requirements to achieve the Paris Agreements global warming targets.*

Our analysis reveals that all critical metals considered in this study will experience higher demand over the coming decades. Copper, graphite, and nickel are projected to undergo the most significant increases in demand by the year 2040, according to both the STEPS and SDS scenarios.

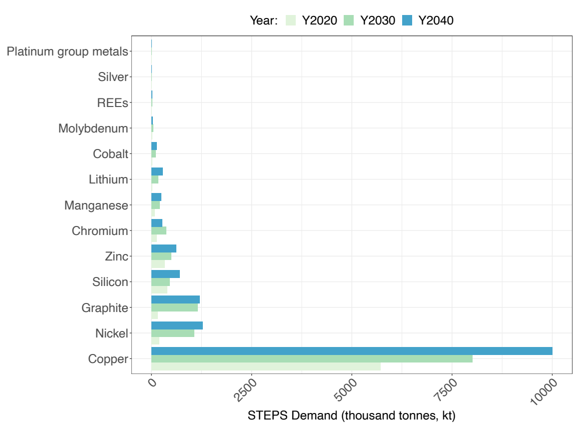


Fig. *6*. Total demand by key critical mineral - Stated Policies Scenario. Source: Authors' elaboration on IEA [6] datasets on the metal demands requirements to achieve the Paris Agreements global warming targets.

## 5. DISCUSSION

The low-carbon transition potentially entails a structural economic change underpinned by shifting consumer preferences and technological change. As the transition proceeds, some sectors of the economy will thrive while others will likely lose their relative importance. Using the IEA scenarios and production patterns for critical minerals across countries, our analysis shows that countries producing cobalt, copper, graphite, lithium, manganese, nickel, silicon, and zinc stand to gain as the demand for these minerals is expected to increase by 2040. Consequently, the impact of the low-carbon transition will be asymmetric across countries because of the geographical concentration of critical minerals. Latin American countries, such as Chile, Brazil, Peru, Argentina, and Bolivia, find themselves in an excellent position to supply the minerals critical for energy transition. With its platinum, manganese, and bauxite reserves, Africa should also serve as a burgeoning market for these resources – notably, the DRC for cobalt and Zimbabwe for platinum. In Asian, China holds a prominent position in both metal production and reserves, making it a crucial player in the global supply of lithium, alongside Chile. India is a major producer of iron and steel while Indonesia and, to a lesser extent, Malaysia and the Philippines are expected to play an important role in bauxite and nickel production.

The shift towards a low-carbon economy is also to have significant fiscal implications. While efforts to combat climate change can increase long-term revenue by reducing damages, such as those resulting from climate-related natural disasters, the accompanying economic transformation might slow growth, especially in resource-rich countries heavily dependent on fossil fuel exports [9]. Similar considerations might apply to countries that will experience increased critical mineral demand, as described in our analysis. These countries need to adopt fiscal policies to maximize economic benefits from this transition. Governments can implement strategic taxation policies on mineral extraction and exports, thus ensuring substantial revenue streams. Investment in infrastructure is equally crucial. Against this backdrop, countries must channel fiscal resources into developing advanced mining operations, robust transportation networks, and sustainable energy systems to capitalize on the demand for critical minerals.

## 6. CONCLUSIONS

Critical minerals are an important source of export and fiscal revenues in EMDEs and offer chances for economic diversification in resource-rich nations. Effectively managing critical mineral resources is thus crucial when considering the environmental and societal impacts of the global shift towards a low-carbon economy. The analysis proposed in this paper emphasizes that the transition will disproportionately affect emerging markets and developing economies, leading to a higher demand for specific minerals by 2040. Governments can derive revenue from mineral extraction through strategic taxation policies, directing funds to public services and infrastructure. Economic diversification is crucial, supported by fiscal policies encouraging education and low-carbon sectors. Environmental conservation is equally critical; taxes can discourage harmful practices and fund conservation efforts.

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**DECLARATION OF INTEREST STATEMENT**

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

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