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Critical Minerals and Routes to Diversification in Africa: Linkages, Pulling Dynamics and Opportunities in Medium-High Tech Supply Chains

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Abstract

The ongoing global supply chain disruptions, including re-, near-, and friend- shoring, and the shift towards low-carbon future have emphasised the need for resilient, diversified, and sustainable production and supply networks. These evolving scenarios provide a window of opportunity for African countries to reposition and integrate into downstream segments of several 'global' value chains by leveraging their natural resources and renewable energy potential. This paper develops a framework that examines medium-and high-technology value chains and explores the opportunities it offers for critical minerals-led industrialisation in Africa. Taking into consideration the roles of investment, ownership structure and the employment implications of critical minerals-led industrialisation, we discuss the industrial policy lessons for productive transformation across Africa.

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1. Introduction

For a long time, Africa's disadvantaged position in global value chains (GVCs) has been explained by its abundant natural resource capital amid limited productive capability to process them for higher value capture. This has led to limited opportunities for upgrade and capture of significant value and little possibility for innovation or technology transfer (Foster-McGregor et al., 2015; Ndubuisi & Owusu, 2021; Abreha et al., 2021) and industrial development (Andreoni et al., 2021a).

However, the global climate action and the need to transition to low-carbon future and technologies offer the continent new opportunities to upgrade and diversify into medium-and high-technology-intensive GVCs. This is because mineral-rich developing countries have a critical role to play in the supply of critical minerals for a large-scale manufacturing of clean energy transition technologies such as solar panels and batteries. The rapid growth of key clean energy manufacturing industries is projected to significantly drive industrial and employment growth (IEA, 2023).

African countries which are well-endowed with these critical minerals that are pivotal to clean energy manufacturing industries can induce investments in the extraction and processing of these resources as well as in those technology-intensive downstream sectors that depends on them. Therefore, Africa's natural capital presents it an opportunity to play a pivotal role in pulling productive investments to drive domestic and regional industrial transformation and development. Leveraging this opportunity require African countries to improve their manufacturing capacity and scale up production and export through the building of domestic and regional linkages and value chains.

This background paper, therefore, aims to understand Africa's critical mineral endowments, its production and trade, and examines how African countries can potentially localise, diversify and capture value from these supply networks, including building regional value chains. We discuss the industrial policy lessons for productive transformation in Africa are discussed based on the empirical and sectoral case studies.

The remainder of the paper is structured as follows. Based on trade data, Section 2 sets the scene on Africa's participation in GVCs, and the opportunities and challenges it poses for African countries' industrial development. Section 3 discusses the role Africa's natural endowments could play in driving medium-and-high technology industrialisation on the continent, and the implications of investment, ownership structure and employment. Section 4 concludes the paper with policy recommendations.

2. Linkages and Value Addition in Africa

GVCs are essentially about global linkages, with trade in intermediate inputs playing an essential role. In either of these chains, the organization of production for a given product is driven by lead firms exercising power over chain activities of firms from different countries that are knitted in a vertically integrated production system. Firms integrate into such production systems through the so-called backward linkages and/or forward linkages. Firms that integrated through forward linkages are primarily suppliers of intermediate inputs—i.e., they produce and ship inputs that are further re-exported. Conversely, firms that are integrated through backward linkages use imported inputs to produce goods that are shipped abroad.

An inquiry into the opportunities African countries can leverage to diversify into the MHT industries requires first an understanding about the region's existing production structures and network. This section, therefore, provides some basic stylized facts on Africa's participation in

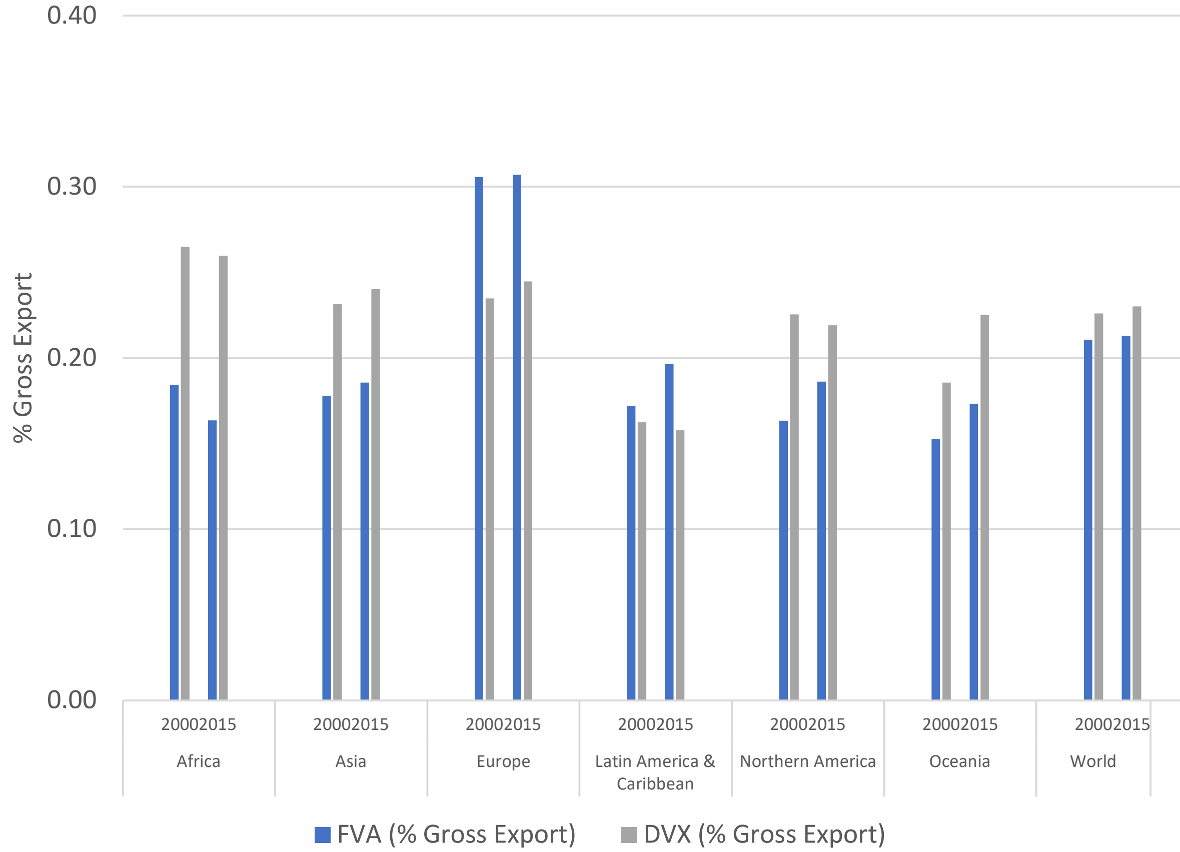
GVCs, using standard GVC measures from the broader literature, and extend the discussion into Africa's participation in medium-and high technology sectors.

2.1 Where value is added, where value is missing in Africa: A country-sectoral analysis based on EORA, 2000-2015

To provide insight on the level and patterns of African countries' GVC integration, we rely on the Eora Multi-Region Input Output (MRIO) database (Lenzen et al., 2013) from 2000 to 2015, which has a wider coverage of African countries and therefore best fit for our purpose. In line with the GVC literature, we compute three GVC indicators that are used in the exercise: forward participation; backward participation; and GVC participation. Forward GVC is measured as the share of a country's value-added exports embodied as intermediate inputs in other countries' exports, thus indicating the extent of GVC participation for relatively upstream firms and industries. Backward GVC linkage is measured as the share of foreign value-added (FVA) used in a country's export. It indicates the import content embodied in a country's gross export, thus indicating the extent of GVC participation for downstream firms and industries. The third is a country's overall rate of linkage to GVCs measured as the sum of the backward and forward linkages in GVC.

There is an expansive literature on the patterns of African's integration in GVCs (Foster-McGregor et al., 2015; Abreha et al., 2021; Ndubuisi and Owusu, 2022). The evidence documented in these studies suggest that Africa is well integrated in GVCs, like most other world regions such as Asia, Europe, and North America. However, Africa's participation in GVCs is largely through the forward linkage where it primarily provides unprocessed raw materials (Figure 1).

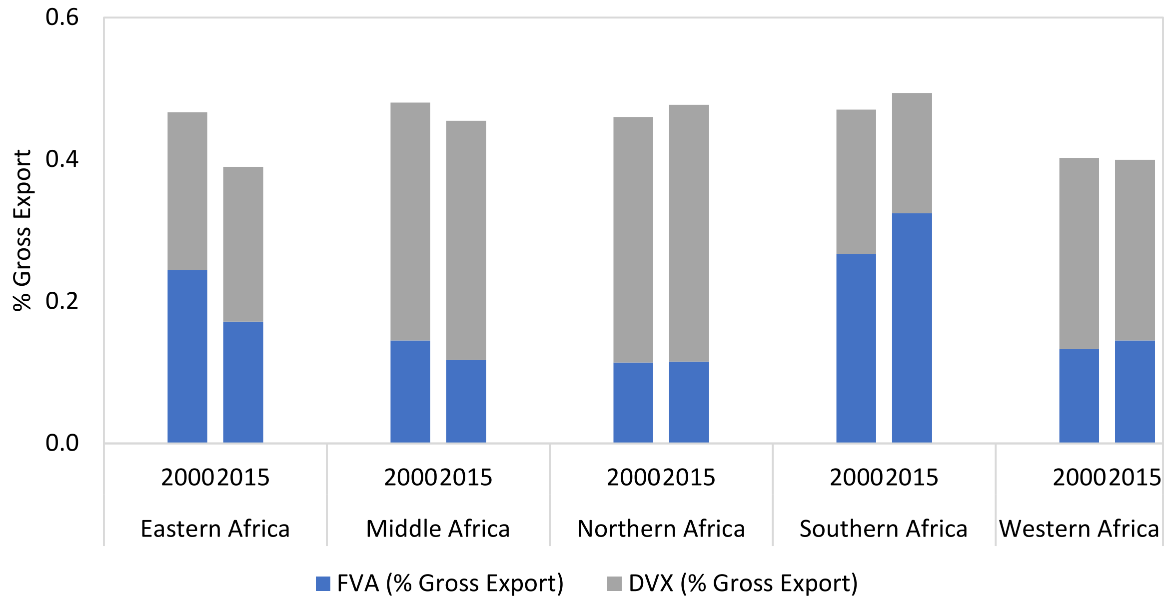
Figure 1: Backward and Forward GVC linkages: Africa compared to other continents.



Source: Authors' computation based on Eora Multi-Region Input Output (MRIO) database.

Even though Africa is highly integrated in GVCs, there is heterogeneity in the overall level of GVC participation and backward and the forward linkages across different regions in Africa (Figure 2). For instance, the data shows that Southern African countries are the most integrated into GVC (48%) while West Africa is the least integrated with an average overall GVC participation level of about 40% between 2000 and 2015.The observed increase in the overall GVC participation for Southern Africa is largely driven by forward linkages, with its level of forward linkage increasing by 5 percentage points which compensates for a 3 percantage point drop observed in the backward linkage within the same period (see Figure 2).

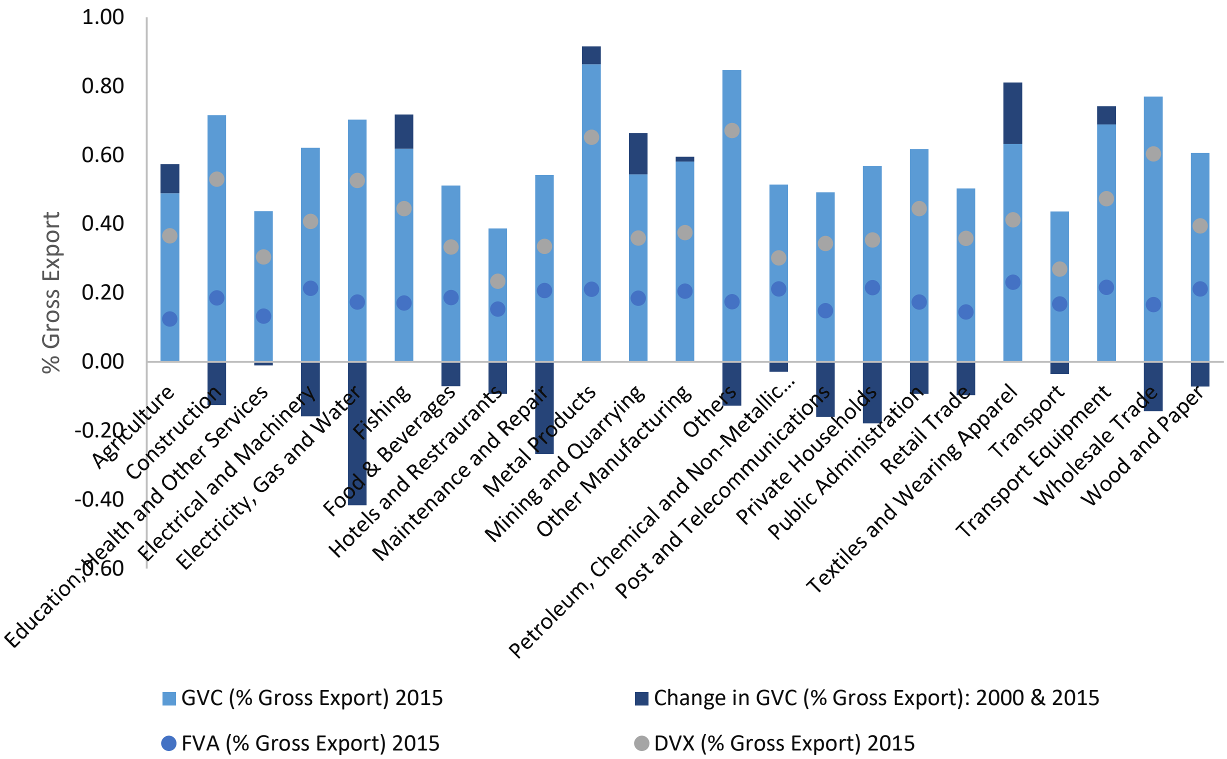
Figure 2: Backward and Forward GVC linkages across regions of Africa.



Source: Authors' computation based on Eora Multi-Region Input Output (MRIO) database.

Also, there is heterogeneity in the overall level of GVC participation, and backward and the forward linkages across different sectors in Africa (Figure 3). Metal product is the sector in which African countries are most integrated (86%), with the sector having the highest forward linkage (65%). However, it has a low downstream specialization (21%). Between 2000 and 2015, its overall GVC participation by 5 percentage points. Other sectors witnessed either a positive or negative change in their overall GVC participation, education and health sectors are the two sectors with no change in its overall GVC participation level across the period.

Figure 3: GVC participation across African countries between 2000 and 2015



Source: Authors' computation based on Eora Multi-Region Input Output (MRIO) database

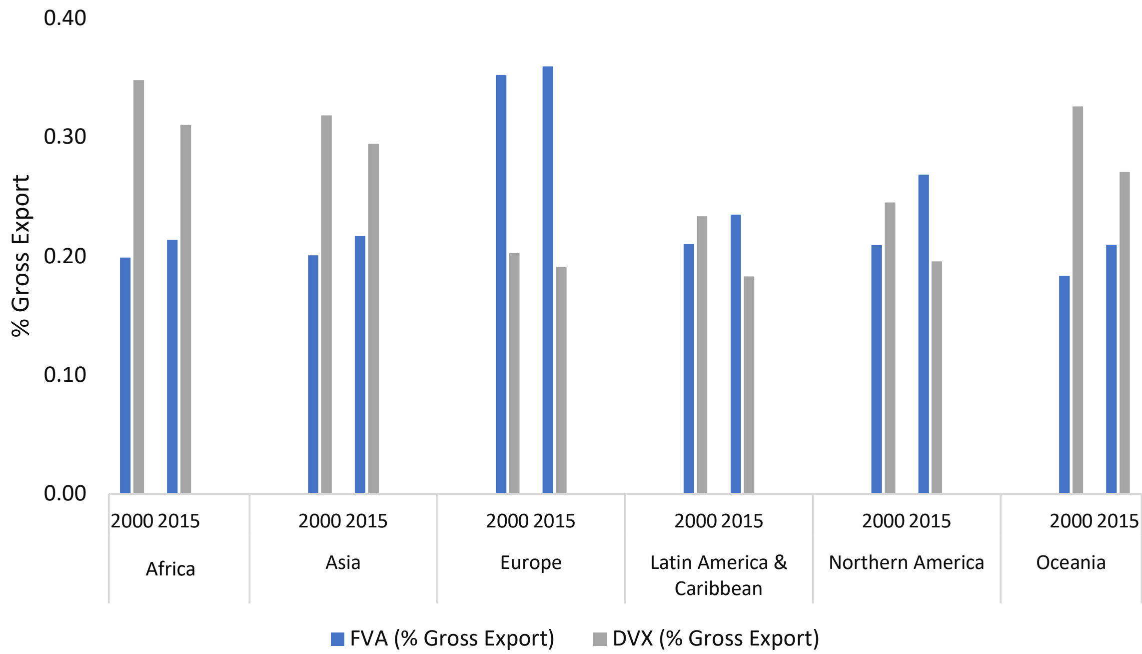
In sum, the foregoing evidence indicates that African countries, on average, participate in GVC mostly through forward linkages. The few countries that participate more in GVC through backward linkage do this largely in light manufacturing sectors such as textiles and wearing apparel, and tradable services such as retail trade, financial intermediation, and hotels.

2.2 Africa in Medium-High Technology (MHT) manufacturing GVCs

For African countries to unlock themselves into high value-added segments of the GVC, where significant opportunities for value capture exists, they need to successfully upgrade into high-value manufacturing activities by keeping pace with technological progress (Andreoni et al., 2021a). Given that MHT-intensive production is now increasingly been organized within value chains that cuts across national borders, it is critical to understand the global fragmentation of MHT production and how Africa is integrated in such production networks. Here as well, we use the GVC indicators discussed earlier. It is, however, important to note that our analysis using the GVC indicators is limited as we observe only three broad sectors that are considered as manufacturing MHT sectors in the Eora Multi-Region Input Output (MRIO) database. This includes transport equipment, electrical equipment, and petroleum and chemical.

Figure 4 shows the participation level in MHT manufacturing GVC across the world region. On average, the data shows that Africa is well integrated in MHT manufacturing GVC. However, Africa's high participation in MHT manufacturing GVC is through the forward linkages. For instance, the region's average level of forward linkage is 33% for both periods while its average level of backward linkage is 20% in 2000 and 21% in 2015, which is lower than the world's average backward linkage that stood at about 24% in both periods. The latter also indicates that the drop in the region's overall GVC participation level is due to a fall in the region's level of forward linkages in GVC.

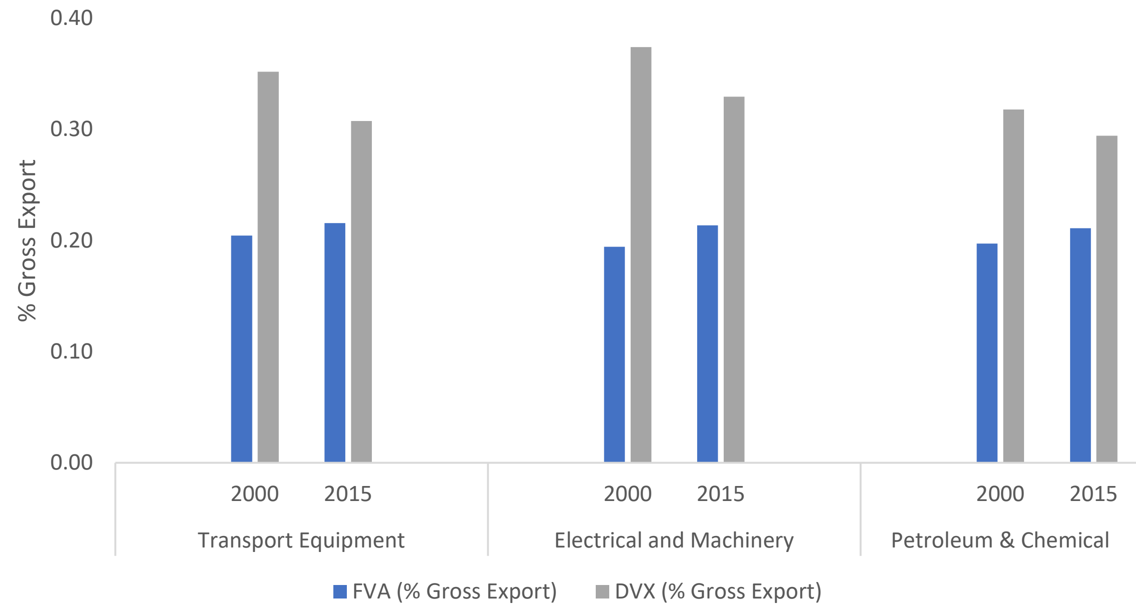
Figure 4: MHT manufacturing GVC participation across the world between 2000 and 2015



Source: Authors' computation based on Eora Multi-Region Input Output (MRIO) database

The level of Africa's MHT manufacturing GVC participation by sector is shown in Figure 5. On average, the data show that Africa has a high overall GVC participation level across the three broad MHT sectors. Overall, Africa's overall participation level in each of these sectors in both periods is above 51%. However, the subcomponents of GVC participation shows a higher DVX shares across the sectors and over the two periods under consideration. This implies that African countries have, on average, largely specialized in the upstream phases of the production in these value chains. This is irrespective of the marginal increase in their FVA share over the two period.

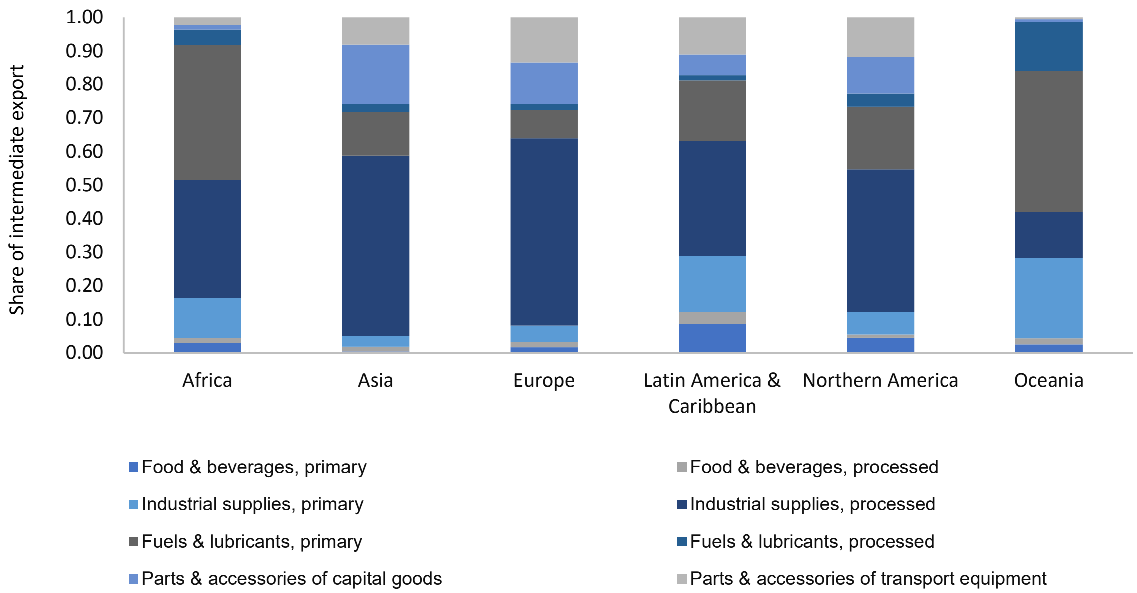
Figure 5: Africa’s MHT manufacturing GVC participation by sector between 2000 and 2015



Source: Authors’ computation based on Eora Multi-Region Input Output (MRIO) database

For the most part, the high upstream specialization that is observed for African countries reflects the region's natural resource abundance amid limited technological and productive capability that limits further processing of these resources to capture higher value. To provide further insights on this, Figure 6 plots the share of intermediate exports by broad end category (BEC). The figure indicates that Africa’s intermediate export is dominated by exports of unprocessed fuels and lubricants (40%). This is then followed by export of processed industrial supplies (35%). The latter is, however, a broad category that includes in addition to manufacturing goods, agricultural products and by-products, crude materials (such as rubber), textiles, cork and wood products, and leather products amongst others that involve relatively simple manufacturing. Hence, they are unlikely to be classified as MHT products. In comparative terms, nevertheless, Africa’s intermediate export share of these processed industrial supplies only managed to top those of Latin America and Caribbean (34%) and Oceania (14%) but lags Asia (54%), Europe (56%) and North America (42%). In terms of parts and components of capital goods and transport equipment, which are where most of the intermediate products with high technology and knowledge contents are, Africa along with Oceania has the lowest share compared to the world region.

Figure 6: Africa's intermediate export between 2017 and 2021



Source: Authors' computation based on BACI-CEPII dataset

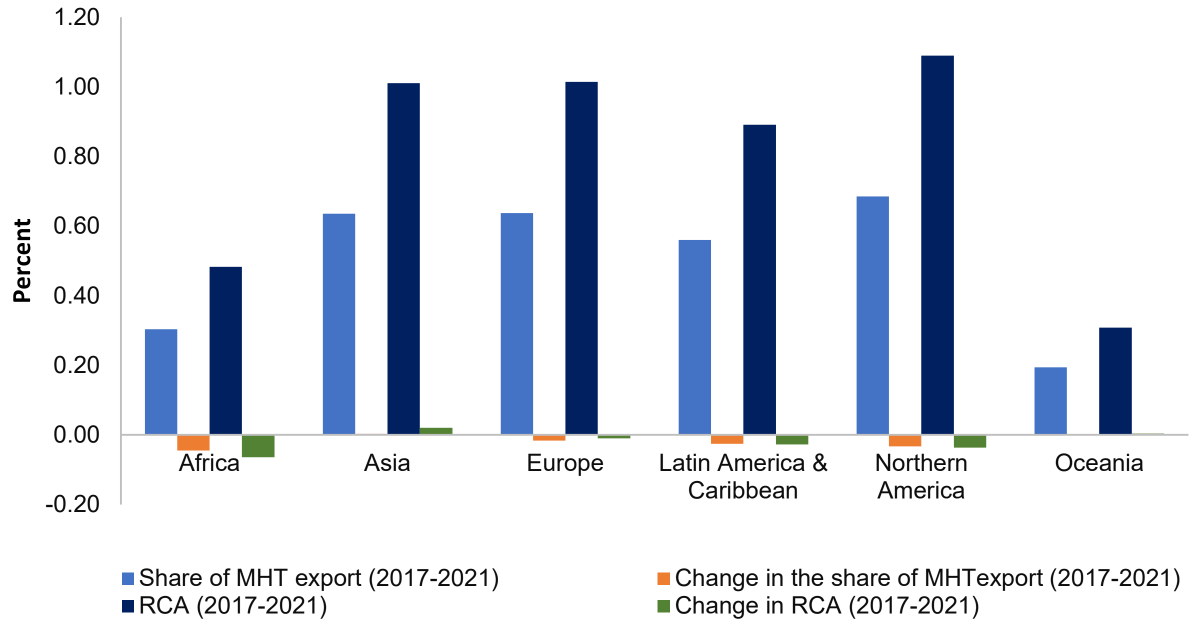
Note: https://unstats.un.org/wiki/display/comtrade/Intermediate+Goods+in+Trade+Statistics

To complement our GVC analysis and to understand the opportunities for local and regional MHT industrial development in Africa, we use the BACI-CEPII dataset to provide further insights on Africa's MHT manufacturing sectors' relative competitiveness. To do this, we explore the shares of Africa's MHT export as well as their relative competitiveness in MHT sectors using the revealed comparative advantage (RCA) index. The latter is computed as a region's share of MHT manufactured exports in total manufactured exports relative to the world's share of MHT manufactured exports in its total manufactured exports. That is, a region with an RCA that is less than unity is said to have a comparative disadvantage in the sector. To ensure our exploration is nascent and capture recent product classification, we recur to the 2017 HS classification, which is available for 2017 to 2021.1

Figure 7 shows the share of MHT manufactured exports in total manufactured exports across the world region. It also shows each region's RCA in the MHT manufacturing sector. Except for Oceania, Africa has the lowest share of MHT manufactured exports across the world region. Particularly, its average share between 2017 to 2021 is 30%. Except for Oceania, with an average share of 19% and Latin American and Caribbean with an average share of 56% for the same period, Africa's share of MHT manufactured exports is twice less than those of North America (68%), Europe (64%), and Asia (63%). The figure also shows that Asia's and Oceania's share of MHT manufactured export remained constant, while those of the other world region declined between 2017 to 2021. The highest in this regard is Africa, with about 5 percentage point drop in its MHT manufactured export between 2017 and 2021. Concerning the RCA, African countries unsurprisingly, on average, has a comparative disadvantage in the MHT manufacturing sector as their RCA index is markedly lower than 1. The region only managed to outperform the Oceania but lags other regions in the world region. Europe, Asia, and North America are the regions with the most competitive position in the sector as their RCA are all above 1, with that of North America topping the list.

[1] To identify MHT sectors, we create a crosswalk between the HS classification and ISIC Revision 3 and MHT sectors corresponds to sectors with the following two-digit ISIC codes, 24, 29, 30, 31, 32, 33, 34 and 35. For the crosswalk see https://unstats.un.org/unsd/classifications/Econ.

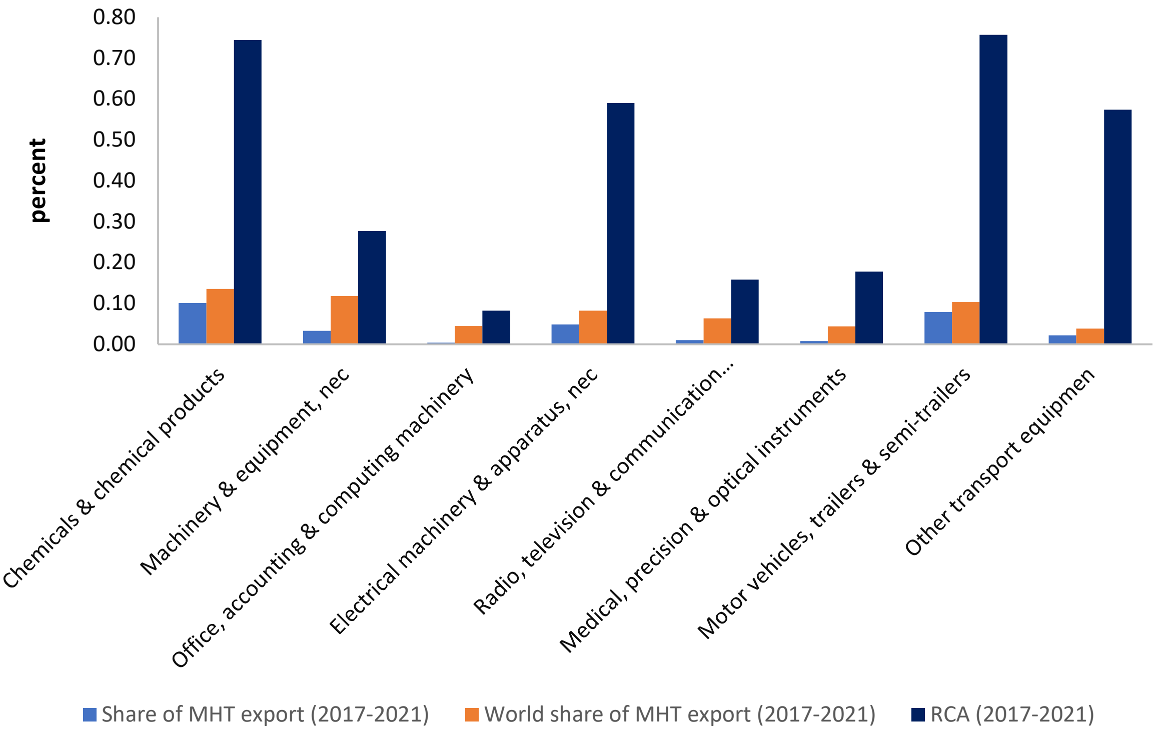
Figure 7: Regional share of MHT export and RCA between 2017-2021



Source: Authors' computation based on BACI-CEPII dataset

To further understand Africa's relative comparative disadvantage in the MHT manufacturing sector, we delve deeper into the different MHT sectors to investigate whether there are some sectors in which Africa performs relatively better in. Figure 8 depicts a picture that is not significantly different from that shown in Figure 7. Particularly, the share of each sector's export in total manufacturing is lower than the world's average. Akin to this, the figure indicates that African countries, on average, has comparative disadvantage across all the MHT sectors as their RCA in each is less 1. At best, the sector where they had the best RCA is chemicals and chemical products and motor vehicles, trailer and semi-trailers with a respective average RCA score of 0.76 and 0.74, respectively.

Figure 8: Africa's share of MHT export and RCA by industry between 2017-2021



Source: Authors' computation based on BACI-CEPII dataset

Overall, the pieces of evidence presented in this section reveal Africa's limited role and uncompetitive position in MHT manufacturing value chain relative to other world regions except for the Oceania. At best, the region's activity is largely in the upstream phase of the production network where it primarily supplies unprocessed raw material.

3. Critical minerals in Africa: Stocks, trade, and emerging industry structures

Clean energy technology manufacturing is at the core of today's energy transition and sustainable development. Most of the minerals critical for the manufacturing of clean energy technologies, such as battery storage and electric vehicles, are held in Africa. For instance, 2023 statistics from United States Geological Survey (USGS) shows that Congo - Kinshasa, Madagascar, and Morocco have about 50 percent of global reserves and produce about 70 percent of cobalt - a critical mineral essential for the production of battery storage and electric vehicles. Bauxite is a key material used in the production of solar photovoltaic (PV) components of which Guinea has about 24 percent of global reserves and produces about 23 percent of global production. Platinum Group of Metals (PGM) is key for abating carbon intensive and root sectors and important for green hydrogen. Of PGM, Africa (South Africa - 90% and Zimbabwe - 2%) holds about 92 percent of global reserves with both countries producing about 82 percent of platinum globally in 2022. Last but not least, chromium is considered a key mineral for the production of low carbon technologies such as geothermal, solar, and wind. South Africa holds about 36% of global reserves and accounts for about 44 percent of global production in 2022. The foregoing highlights Africa's central role in the green energy transition and transformation.

Table A.1 in the appendices shows the distribution of selected critical mineral resources across Africa and their shares by global reserves and global production.

Africa's dominance of global reserves for transition minerals and the rising demand for clean energy technologies to meet the global 'net zero' emissions commitments places Africa 'at the heart of the green energy future, both in environmental and geo-political terms' (Chandler, 2022: p.2) and the transition from fossil -based energy systems (Diene, et al., 2022). The transition presents a unique opportunity for African countries to take advantage of the new global energy economy by re-strategizing and formulating industrial policies that would enable them to develop and diversify their local production processes, reposition, and integrate into downstream segments of existing and new clean energy technology manufacturing value chains. The concentration of some of these key critical mineral resources in Africa gives the continent a natural leverage to tighten and negotiate fair value from related global value chains through the development of local production systems and linkages.

This section situates the foregoing discussion on the possible paths for Africa's MHT industrialisation using its natural endowments. Specifically, the section explores the role Africa's critical mineral resource endowments, key ingredients for the manufacturing of clean energy technologies, could play in Africa's own triple transition from low technology manufacturing processes to MHT manufacturing, energy transition, and environmental sustainability. The discussion recognises the historical paths pursued using fossil fuels and their seeming failure, and the emerging race between developed economies to lead in the manufacturing of transition energy technologies in transition industries, most of which require significant amounts of critical minerals to produce. We propose several ways mineral rich African countries can position and integrate into downstream segments of key value chains of these transition industries, by building local and regional production systems. In section 3.1, we discuss the relationship between mineral resources, manufacturing, and the potential for MHT industrial development. Sections 3.2 and 3.3 bring to fore Africa's position in the exploration and trade of critical mineral resources in global and regional values chains. Section 3.4 discusses the pulling dynamics of these transition minerals through foreign investments and ownership structures.

3.1 The resources-industrialisation nexus: What opportunities for Medium-High Technology manufacturing sectors

For several decades, resource-based industrialization has been argued as a path to economic development for resource-rich countries. This approach to industrialization involves a reliance on natural resources to promote a specific industrial structure aimed at satisfying key national goals (Roemer, 1979). Resource-based industrialization also emerged as a strong alternative to import substitution industrialization and non-resource manufactured exports (Auty, 1991, 1995). Nevertheless, resource-based growth can have both negative and positive outcomes

(Ploeg, 2011), depending on the extent to which natural resources contribute to outcomes in the economy.

However, resource-based industrialization has generally been challenging for developing countries because of over-ambitious strategy design and inefficient implementation and management (Walker, 2001) and damaging effects on the environment. Several theories and empirical studies point to a negative relationship between Africa's economic dependence on mineral resources and its development (Anyanwu, 2017; Sachs and Warner, 2001; Auty, 2001). Thus, the resource curse is often discussed as the bane of developing countries who fail to manage their resources (Barbier, 2010).

Indeed, there are complex set of factors that can affect the success or failure of resource-based industrialization. These include capital market imperfections, human capital, and weak knowledge systems (Stijns, 2005; De Ferranti et al., 2002; Gylfason, 2001). Recently, new literature suggested that resource-based industrialization premised on mining should also account for the importance of energy transition and the protection of the climate. Thus, sustainable mining and energy transition may be key to resource-based industrialization (World Bank, 2020; Diene et al., 2022).

Notable histories of resource-based industrialization can be traced to several developed countries. For instance, through the industrial development of cereal, timber, fish, oil and iron ore resources, Sweden, Finland, and Norway industrialized (Fessehaie and Rustomjee, 2018). The United States also developed by making investments in infrastructure for mining mineral and metals like nickel, zin, copper, lead and iron ore (Andersen, 2012; Wright and Czelusta, 2007). Australia invested heavily in engineering education and mining software systems and is known to be a global supplier of high-technology services that support cleaner mineral extraction and beneficiation. However, the opportunities for developing linkages across industries to support industrialization are known to be country and sector-specific (Morris and Fessahie, 2014; Andersen, 2012) and depend mostly on factors like the industrial and mineral policies, policy frameworks, institutional capabilities, and human capital skills. The reason why resource-abundant developing countries do not exhibit strong and sustained economic growth has to be found in their condition of ‘technological and institutional scarcity’ more than in their inescapable resource curse (Andreoni, 2015).

Unfortunately, there is a patchy attempt at resource-based industrialization in Africa because of poor implementation of linkage development policies (Ado, 2013), weak capacity of the private sector to respond to policy incentives and local demand (Ramdoo, 2015), and uncertain potential of regional value to attract significant investment projects (Fessahie, 2015).

Nonetheless, there are current opportunities to connect resource-based industrialization with environmental sustainability in Africa. The global economy is at the dawn of a new industrial age with focus on clean energy technology manufacturing (IEA, 2023). Given China’s strategic control of the exploitation of critical minerals and the manufacturing of clean energy technology, Western countries are looking forward to diversifying their supply chains and to make it resilient. The call for diversification of these supply chains presents opportunities for African economies.

Clean energy technology manufacturing offer opportunities for Africa to diversify and transition as well as upgrade in MHT value chains. This is because these transition technologies are resource intensive. Africa holds about 19% of the global metal reserves required to make an electric vehicle and at least a fifth of the world’s reserves in a dozen minerals that are critical for the energy transition (Diene et al., 2022). The onset of MHT manufacturing suggests some opportunities for production in manufacturing subsectors that propels growth and development. Recent studies support this assertion by showing that technology-intensive manufacturing can also be less emissions-intensive than low-technology manufacturing (Avenyo and Tregenna, 2022; Altenburg & Assman, 2017; Zhang, 2012), implying its suitability for sustainable industrialization.

Developing these critical minerals for Africa's diversification is critical and can be approached from two perspectives. From a GVC perspective, critical minerals development is about various forms of upstream and downstream integration resulting in further movement along the value chain towards segment with potential for higher value creation and capture. Several African countries such as South Africa, Morocco, and Ghana have started targeting the opportunities arising from critical minerals starting from a GVC diversification perspective. While this is the simplest perspective with some clear focus on specific VC upgrading steps, it has limited focus on structural interdependencies and effect of upgrading for other sectors, with risks for putting resource pressures on other sectors (e.g., water). Also, although direct jobs creation opportunities are targeted (green jobs) in this perspective, there is limited emphasis on broader indirect jobs creation from related sectors.

The structural transformation perspective, where the development of these critical minerals is not simply about increasing quota of processing, emphasises the development of minerals for unlocking opportunities through linkages development and removing bottlenecks that operate as binding constraints in one or more sectoral value chains. African countries are realising the need to take a more holistic approach that integrate the opportunities arising from some GVC diversification for broader upgrading and transformation of other sectoral value chains, including:

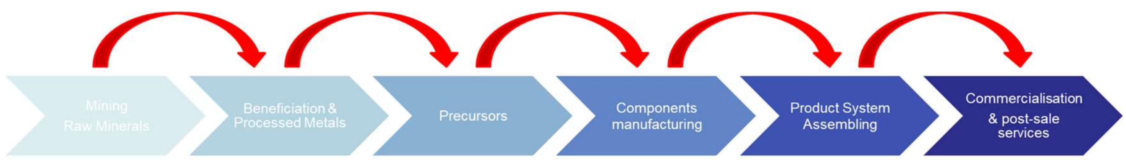
- Mainstreaming greening and energy efficiency across the productive sectors;
- Exploiting investments in certain sectors for unlocking productive opportunities in others;

- Creating and reaching sufficient demand for energy and technologies, so to exploit economies of scale and cost competitive business opportunities;
- Exploiting opportunities for cross-sectoral value chains development, both at the country and regional level.

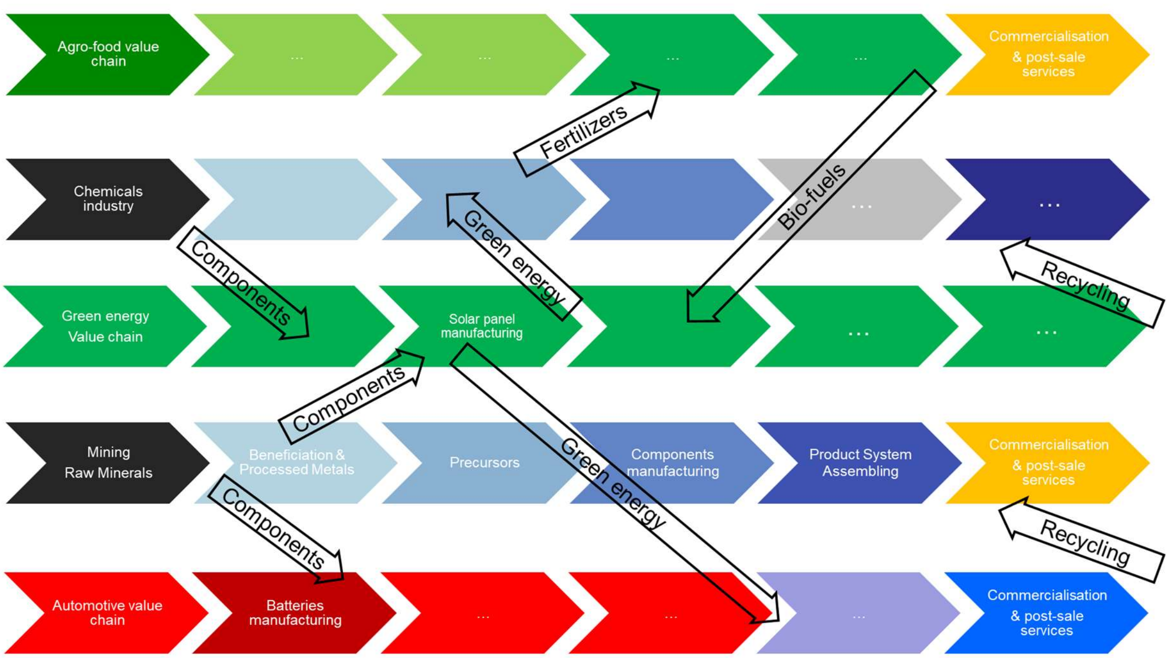
Figures 9 a and b depict these two perspectives schematically.

Figure 9: Diversification from a GVC (a) and Structural Transformation (b) Perspective

a) Diversification from a GVC Perspective



b) Diversification from a Structural Transformation Perspective

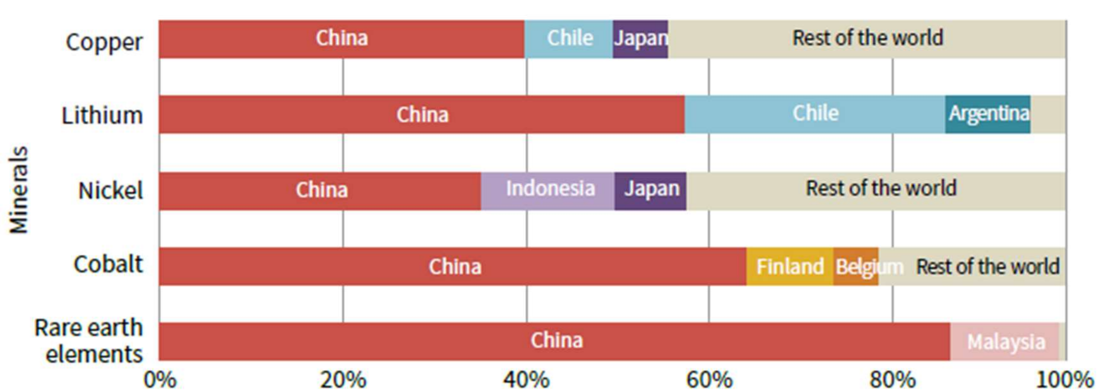


Source: Authors

While several opportunities exist for the development and expansion of these emerging and new manufacturing industries from these perspectives, there are several risks as well. For one, African countries need to expand manufacturing capacities to take advantage of the emerging opportunities. Considering that African countries are likely to enter component supply chains for their exports, it is important that countries appreciate the need to also diversify export supply chains and take new opportunities to maximize rents from resources for the purpose of industrialization.

China and other developed countries have also taken the lead regarding processing of critical minerals by volume. This revelation adds to the political dynamic that minerals are mainly extracted from African countries and sent back to developed countries because of significant investments into mining and extraction. Figure 10 thus shows that countries like China processed large volumes of critical minerals, much of which were exported from several of its mining companies planted across Africa.

Figure 10: Share of processing volume by country for selected critical minerals, 2019



Source: IEA, (2021); Andreoni and Roberts (2022)

Further examination of critical minerals in African countries is considered in the next section to underscore the opportunities available for linking resource-based industrialization and medium- and high-technology manufacturing.

3.2 Critical minerals in Africa: Stock and trade distribution

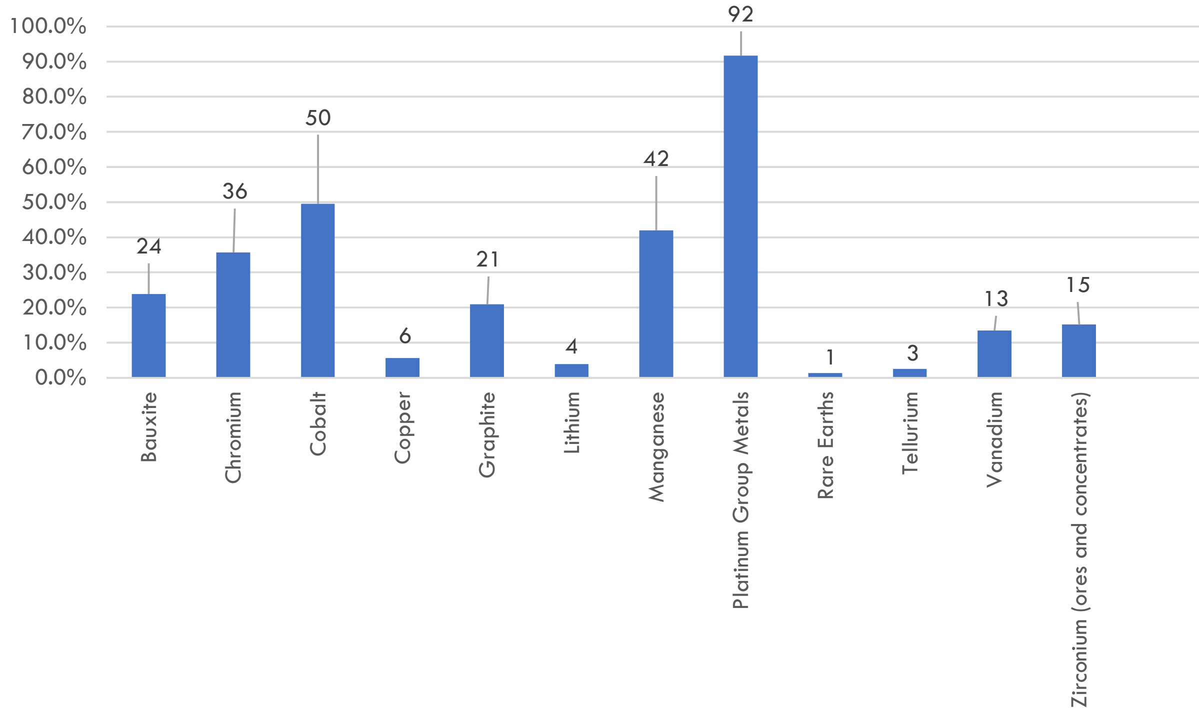
Mineral resource exploitation and trade remain a key feature of African countries' development and integration into global trade networks (Barbier, 2010). This is more so since the mid-1990s, with transnational corporations (TNCs) directing foreign direct investments towards the extractive sector (Andreoni, 2019). While this GVC-led development model has resulted in increases in production and integration of African economies into global value chains, it has led to increases in Africa's dependence on primary commodity exports with limited domestic value addition and capture and little improvement in local manufacturing processes. That is, the integration into commodity based GVCs has not delivered the quality growth Africa needs and requires to overcome its grand challenges.

Given the evidence that Africa's integration into GVCs have so far generated limited quality growth (Andreoni, 2019) and that intra-Africa trade is the least compared with other regions, African countries are re-strategizing to leverage their natural capital and mineral resources to develop their local and regional production systems and to industrialise.

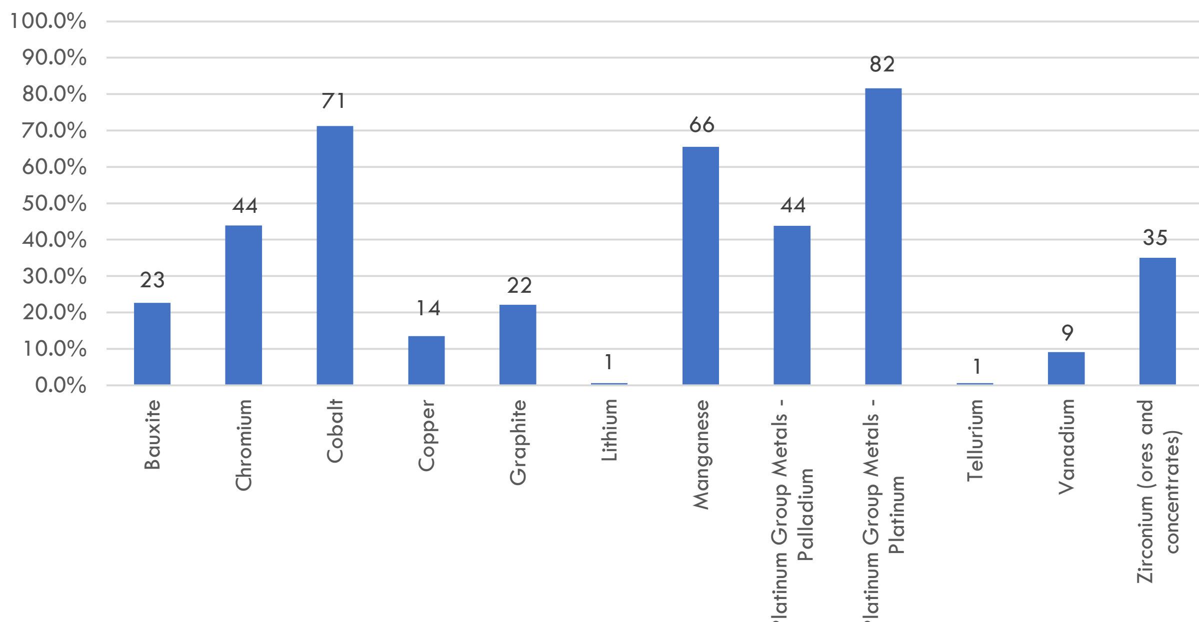
Africa's critical mineral reserves, production, and trade are significant and key for the manufacturing of transition technologies and the transition towards green energy systems. As noted, Africa has significant reserves, and produces and trades a wide array of critical mineral resources. Figures 11a and b show the distribution of selected critical mineral resource reserves and production across the continent respectively.

Figure 11: Distribution of Africa's shares of global reserves (a) and production (b) of selected critical minerals.

a) Distribution of Africa's shares of global reserves of selected critical minerals.



b) Distribution of Africa's shares of global production of selected critical minerals.

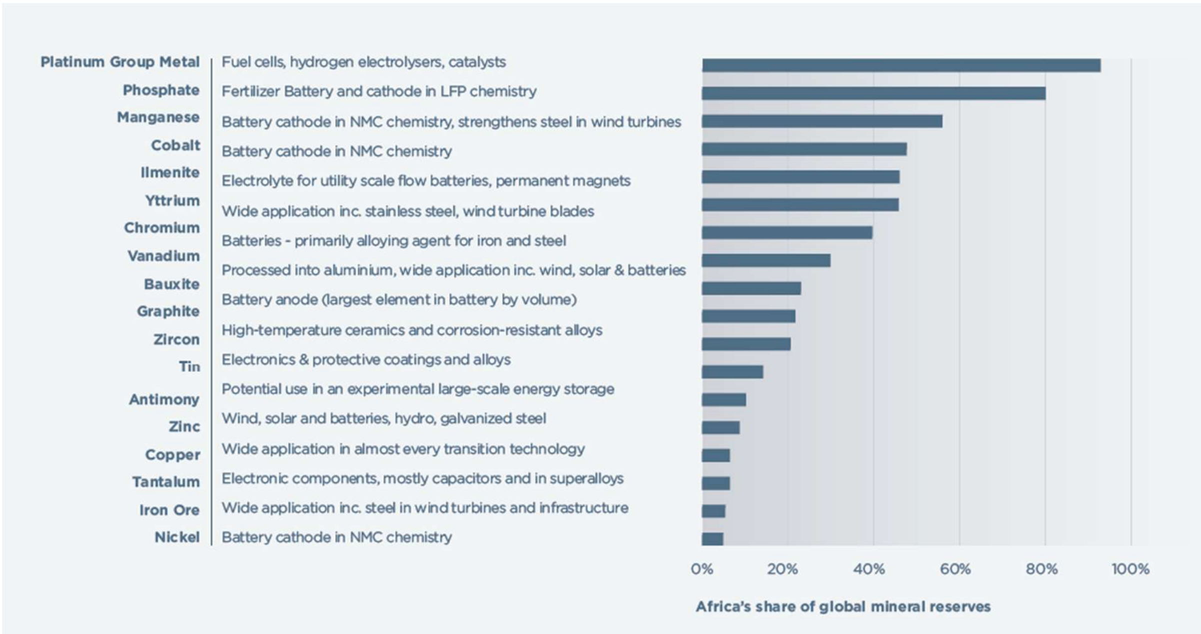


Source: Authors based on data from the United States Geological Survey (USGS) (2023).

A lot of African countries are integrated in the upstream segment of global value chains of these critical minerals, with most countries trading in primary and processed products. Based on trade data from BACI-CEPII database, Figure A.1 in the appendices shows the distribution of critical minerals exported by African countries between 2017 to 2021. The figure shows that most African countries with critical mineral resources export them mainly in their primary form, with a limited number of countries beneficiating these products before exporting in an intermediate form. For instance, of all copper products produced, Democratic Republic of the Congo and Zambia refine about 7% and 1.3% respectively which is lower than the share in global production (10% and 3.5% respectively) (see Table A.1). South Africa holds significant reserves and produces most of the critical minerals, and also well integrated in the beneficiation of these products (see, for instance, TIPS (2021) for a detailed description of each of these sectors in South Africa). Several countries, including those without or with insignificant global cobalt reserves and/or production, export beneficiated cobalt products as well. This suggests re-exportation of cobalt products through regional trade. This hypothesis will be further examined in the preceding paragraphs using the network analysis.

Each of these critical minerals and mix of them find application in a variety of medium-high technologies as illustrated in figure 12.

Figure 12: Africa's share of global reserves: Matching resources and technologies



Source: Diene et al. (2022)

The observed beneficiating activities across the continent, albeit limited, therefore, suggests scattered spots of productive capacity and presents opportunities to have industries with technology-intensive industrialisation. Leveraging these beneficiating opportunities across the continent could kickstart an industrialisation drive that have the potential to generate industrial development and structural transformation of the continent. However, this process requires the deliberate creation and development of horizontal and vertical linkages across firms within a country and/or regions to fundamentally drive African countries' upgrade into medium-and high technological manufacturing activities. The role of effective regional industrial policy that consolidates efforts and the scattered successes across the continent cannot be overemphasized.

3.3 Critical minerals trade: A network analysis of regional and global patterns

To further understand the dynamics of trade in these mineral resources, this section presents and discusses some stylised facts from the global and regional trade (bilateral) patterns of critical mineral resources by African countries. The regional angle is important given the potential for specific beneficiation activities across and between different African countries. This is also important given the emerging evidence of prospects for collaboration across several countries (e.g., collaboration between DRC and Zambia for battery production) with opportunities for developing regional value chains on the continent (Diene et al., 2022).

The network analyses below (figure 13:a-f) show the intra-regional trade and trade with the top five export destinations across selected critical mineral resources. In general, the emerging evidence from the bilateral trade network shows significant heterogeneity across regional trade of mineral products, with different African countries playing different roles in regional and global trade. Intra-Africa trade in mineral products is high, and a bird view of the networks shows that South Africa plays a central role in the trading of several of these mineral products across the African region and the world. This is on the background that South Africa has processing and beneficiating capability and could lead the development of regional value chains in these products. The global trade networks also show the centrality of China in critical minerals trade (mainly primary) with the African continent.

We discuss some of these stylised facts emerging from the regional and global trade (top five export destinations) patterns for six key critical mineral and metal resources (cobalt, graphite, lithium, manganese, phosphorous rock and platinum) that are in abundance on the continent and are critical for the production of transition technologies.

1. Cobalt: We observe interesting cobalt trade dynamics between African countries and top five cobalt export destinations. The top five global destinations of Africa's cobalt

are China (72%), Belgium (2%), Malaysia (2%), Netherlands (2%), and Switzerland (2%). These countries import about 80% of Africa's cobalt export to the top five global export destinations, and have diversified trade links with Zambia, Namibia, Morocco, Congo, Madagascar, South Africa, DR Congo, Mali, Tanzania, Mozambique, Uganda, and Kenya.

Some regional trade of cobalt is evident as well. The countries that export to other African countries include Tanzania, South Africa, Morocco, Botswana, Mauritius, Egypt, Kenya, Zambia, Madagascar, Congo, and DR Congo. Amid these countries, South Africa emerges as the country with the highest intra-African export link, exporting to nineteen African countries over the periods under consideration. This is followed by Zambia with five intra-Africa export links, and Kenya and DR Congo with a respective intra-Africa Cobalt export link of four. However, in terms of intra-Africa export shares, South Africa's intra-Africa cobalt export share is less than 1%. DR Congo tops the list, accounting for 89% of intra-Africa cobalt export, exporting to Zambia, Namibia, Morocco, and South Africa. This is followed by Congo with a share of 4.4%, and Zambia with a share of 3.5%. However, Congo's intra-Africa cobalt export was only to Morocco while Zambia exported to Morocco, Mauritius, Namibia, South Africa, and Zimbabwe (see figure 13a).

2. Graphite: Like copper, graphite also has a dense trade network, but with less complexity (see figure 13b). Top five global destinations for Africa's graphite are countries that emerge China (28%), Germany (15%), India (9%), the United States of America (7%), and Malaysia (5%). These countries account for about 64% of Africa's graphite export outside the region, with trade links with twenty-seven African countries including Nigeria, South Africa, Swaziland, Niger, Guinea, Tanzania, Madagascar, Zimbabwe, Ethiopia, Sudan, Namibia, Tunisia, Morocco, Senegal, Mozambique, Cameroon, Egypt,

Algeria, Côte d'Ivoire, Kenya, Mauritius, Ghana, Botswana, Libya, Sierra Leone, Equatorial Guinea, and Mali.

On the other hand, a total of forty-two countries export to other African countries. Among these countries, South Africa's total intra-Africa graphite export links are thirty-nine, accounting for about 51% of the intra-Africa graphite export share. This makes it the country with the highest intra-Africa export link and shares. Kenya has a total of thirteen intra-Africa graphite export links, making it the second in this regard. This is followed by Morocco with ten intra-Africa graphite export links. These two countries put together, however, only account for about 3% of intra-Africa graphite export shares. The country with the second largest intra-Africa graphite export share is Tanzania, accounting for about 14%, while the third is Seychelles accounting for about 12%. However, these countries export to fewer African countries, with Tanzania only having eight intra-Africa graphite export links (Angola, South Africa, Mozambique , Zambia , DR Congo , Burundi , Comoros and Madagascar), while Seychelles has one (South Africa).

3. Lithium: For lithium, France, the United States of America, Germany, China, and Russia are the top five destinations for Africa's lithium export outside Africa. These countries account for only about 15% of Africa's total lithium export to the rest of the world, with France accounting for about 7%, the United States of America about 3%, Russia about 1%, and Germany and China for about 2% each. The low shares reflect the concentration of the mineral in the region, with most of the part world dependent on the region to source such inputs. Available statistics indicate that between 2017-2021, these five countries sourced this mineral from at least thirty-six African countries.

Within the same period, DR Congo emerges as having the highest intra-Africa export shares for the mineral, accounting for about 77%. However, it has fewer intra-Africa export links for the mineral - only had six export links- implying that its export of these minerals is more with countries outside the region. Within this period, South Africa's total intra-Africa lithium export links are forty-eight, accounting for about 15% of intra-Africa export shares for the mineral. This puts South Africa as the country with the largest intra-Africa export links for the mineral, and the second largest in terms of intra-Africa export shares for the mineral. Kenya and Morocco are the second and third largest in terms of intra-Africa export links for the mineral with Kenya having twenty-one intra-Africa export links, while Morocco has eighteen. Kenya's intra-Africa export shares for the mineral are also higher than that of Morocco with the former accounting for about 1% of the mineral's intra-Africa export shares, while Morocco accounts for less than 1%. Also, countries like Mauritius and Tanzania each account for about 1% of the mineral's intra-Africa export shares. However, their intra-Africa export links are fewer: Mauritius=12; Tanzania=15 (see figure 13c).

4. Manganese: The network plot in figure 13d shows the top five African manganese export destination outside the region as China, India, Norway, Japan, and Russia. These countries account for about 80% of Africa's Manganese exports outside Africa. The highest export destination in this regard is China accounting for about 58%. This is followed by India (10%), Norway (5%), Japan (4%), and Russia (3%). On average, about thirty-one African countries exported to at least one of these countries' top five export destination countries between 2017-2021. Out of these thirty-one countries, China imported from twenty-six countries, India from twenty countries, Japan from five countries, Norway from six countries, and Russia from three countries. Morocco, South Africa, and Zambia (in consecutive order) emerge as countries with the highest intra-Africa export shares for Manganese.

Between 2017-2021, Morocco and Zambia both have eleven intra-Africa export links each for the mineral. However, Morocco accounts for about 42% of intra-Africa export shares for the mineral, while Zambia accounts for about 11%. Within the same period, South Africa has forty intra-Africa export links accounting for 20% of intra-Africa export shares for the mineral. This puts South Africa as the country with the largest intra-Africa export links for the mineral, and the second largest in terms of intra-Africa export shares for the mineral. The country with the highest intra-Africa export link after South Africa is Kenya, with a total of thirteen intra-Africa export links. However, its intra-Africa export shares for the mineral are less than 1%. Ghana also has 11 intra-Africa export links but accounts for less than 1% of the total export shares.

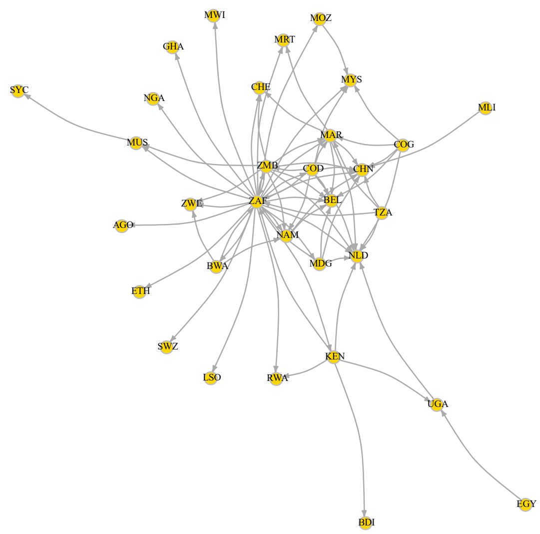
5. PGM: For the Platinum Group of Metals (PGM), the network analysis shows United Kingdom, Japan, Belgium, the United States of America, and Germany as the top five destinations for Africa's PGM export outside Africa. These countries account for about 89% of Africa's PGM export outside the region, with the United Kingdom accounting for about 28%, Japan 17%, Belgium about 15%, United States of America 12% and Germany 9%. On average, forty-five African countries exported to at least one of these countries between 2017-2021.

Within this period, Zimbabwe, although with only two intra-Africa export links for the mineral (this includes Botswana and South Africa), accounts for as large as 86% of intra-Africa export shares for the mineral. Ghana and DR Congo each account for 3% of intra-Africa export shares for the mineral. Ghana exports only to South Africa, while DR Congo only exports to South Africa and Zambia. As per export link, South Africa has the highest intra-Africa export links as it exports to thirteen countries including Nigeria, Zambia, Swaziland, Zimbabwe, Botswana, Mozambique, Angola, Mauritius, Lesotho, Kenya, Ghana, Namibia, and Algeria. This is followed by Swaziland and Malawi that each exporting to three African countries. This includes Tanzania, South Africa, and Mauritius for Swaziland, and South Africa, Uganda, and Rwanda for Malawi respectively (see figure 13e).

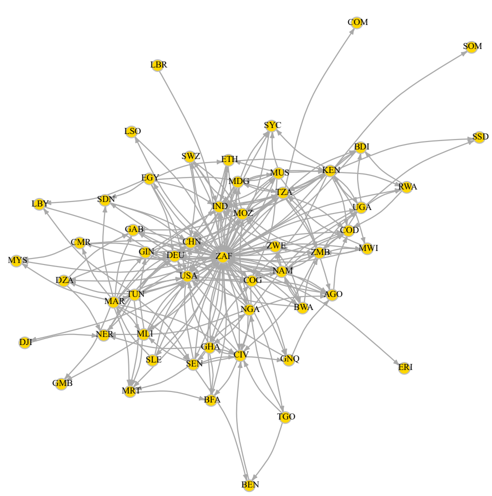
6. Phosphate: Figure 13f shows the network plot of intra-Africa export for phosphate rock as well as the top five African export destination for the mineral outside of the region. The top five export destinations outside Africa include Brazil, India, the United States of America, Bangladesh, and Turkey. These countries account for about 50% of Africa's phosphate rock mineral export outside the region, with Brazil accounting for 17%, India at 13%, the United States of America at 11%, Bangladesh at 5%, and Turkey at 4%. Between 2017-2021, these five countries sourced phosphate rock from about thirteen African countries. This includes Tunisia, South Africa, and Morocco for Bangladesh; Algeria, Nigeria, Tunisia, Morocco, South Africa, Senegal, and Egypt for Brazil; Madagascar, Tunisia, Morocco, Senegal, Seychelles, South Africa, Mozambique, Angola, Egypt, Algeria, and Togo for India; Morocco, Kenya, Tunisia, Egypt, Togo, South Africa, Algeria, and Senegal for Turkey; and Madagascar, Senegal, South Africa, Egypt, Tunisia, Morocco, and Angola for United States of America.

   Morocco and South Africa have the largest intra-Africa export link for the mineral, with each country having a total of thirty-seven intra-Africa export links. However, Morocco accounts for 73% of intra-Africa export shares of the mineral, while South Africa accounts for only 3%. This puts both countries as the countries with the largest intra-Africa export links for the mineral, while Morocco remains the country with the highest intra-Africa export share for the mineral within. The country with the second largest intra-Africa export link and shares for the mineral is Tunisia. It has in total twenty-six intra-Africa export links, accounting for about 7% of the intra-Africa export share for the mineral. This is followed by South Africa as the country with the third largest intra-Africa export shares for the mineral, while Egypt is the country with the third largest intra-Africa export links with a total of eighteen intra-Africa export links.

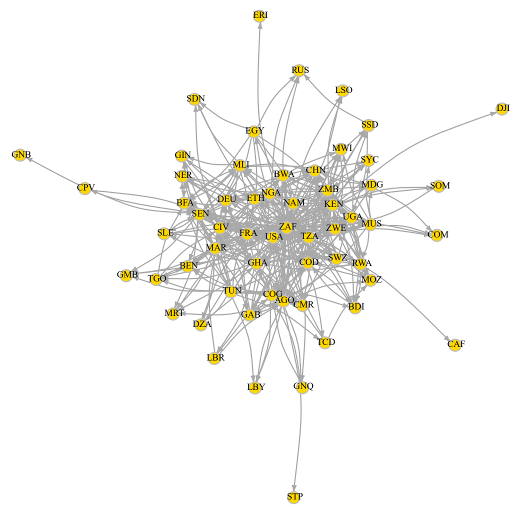
Figure 13: Trade networks of critical mineral resources: regional and global patterns.



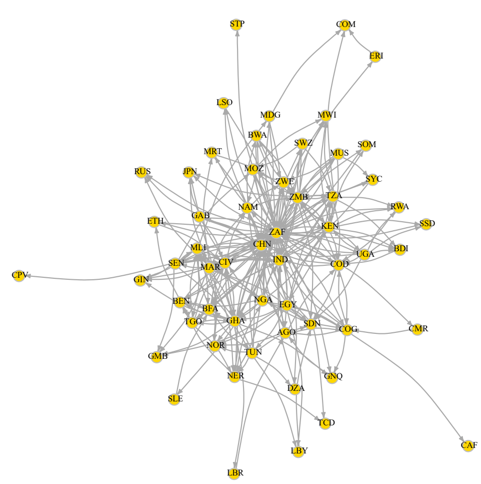
a. Cobalt



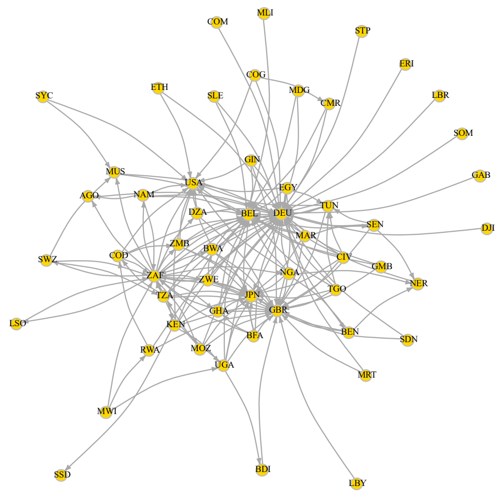
b. Graphite



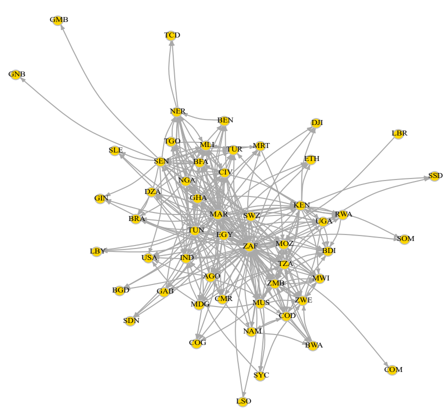
c. Lithium



d. Manganese



e. PGM



f. Phosphate

Source: Authors based on BACI-CEPPI HS 17 database.

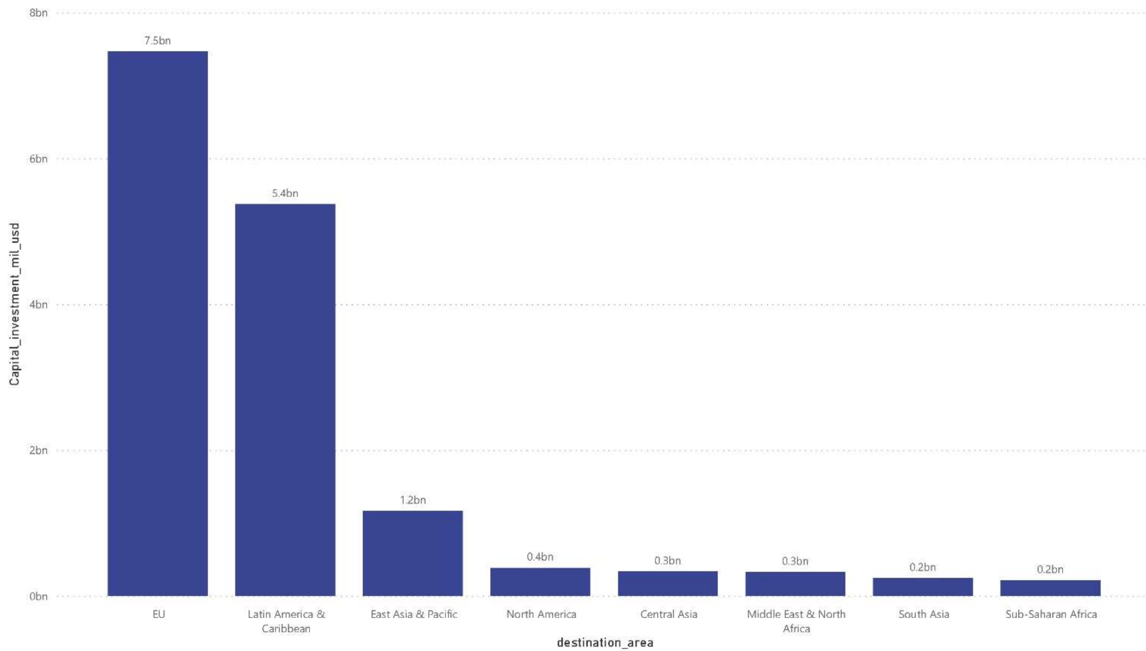
Note: For country codes, see the standard ISO country codes: https://www.iso.org/obp/ui/#search/code/

4. Pulling dynamics, investments, ownership and employment implications: Country and regional level opportunities

As noted, Africa's significant reserves and production of transition minerals are key for the global energy transition and achieving the 'net zero' emissions goal (Diene et al., 2022). To take advantage of the global demand for transition minerals and technologies to develop MHT manufacturing, Africa requires significant investments. The continent still suffers from significant investment gaps, receiving only about 2% of global investments in renewable energy (IRENA, 2022). Figure 14 shows that between 2003 and 2018, sub-Saharan Africa, in particular, received the least capital investment in renewable energy-related industry clusters (environmental technology; ICT and electronics; Industrial; Transport equipment) globally. The European Union, Latin America and the Caribbean, East Asia and Pacific are the top-three destinations for these capital investments.

Capital investments to Africa in renewable energy-related industry clusters as share of total investments between 2003 and 2018 are: Environmental technology (5.81%); ICT and electronics (5.14%); Industrial (1.95%); Transport equipment (3.16%). However, based on data for the four clusters only, capital investments to the continent are noted to fluctuate between 2003 and 2018, with capital investments to Africa peaking in 2012 and dropping thereof (Figure 15). The figure shows some level of recovery in capital investments in 2018, but only at the 2014 levels. Despite the decline in total capital investments in Africa after 2012, the data shows marginal increases in capital investment in transport equipment and industrial clusters, and investments in ICT and electronics also picking up in 2018.

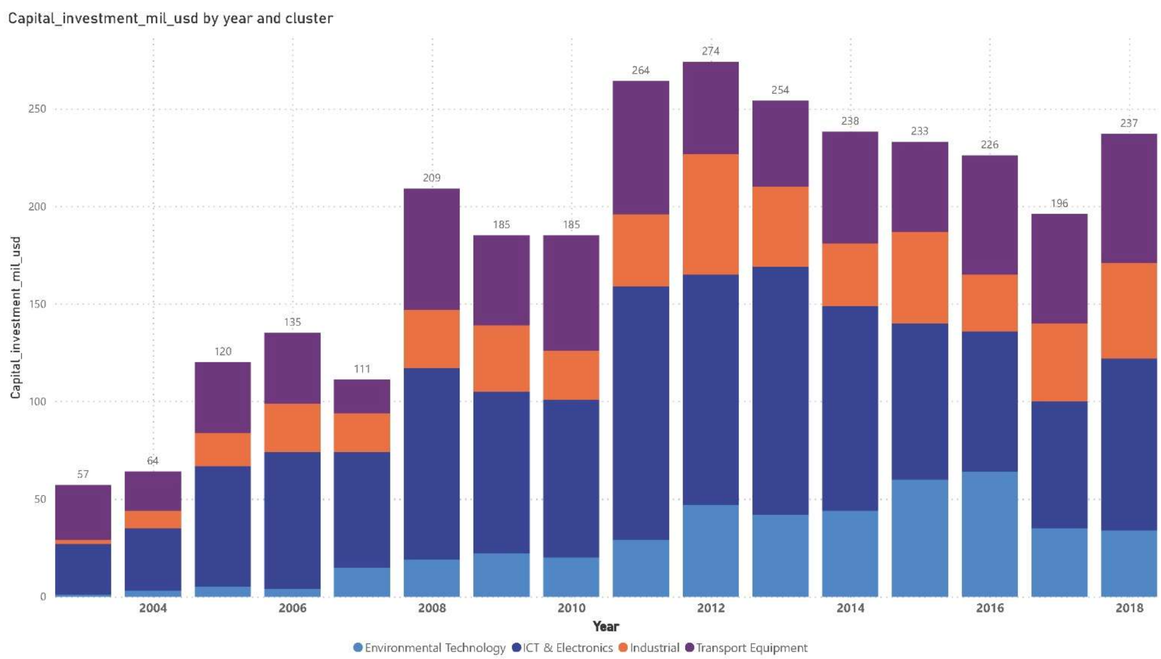
Figure 14: Capital investment across regions (2003 – 2018)



Source: Authors based on data from fdi markets database
Notes: based on four clusters: environmental technology; ICT and electronics; Industrial; Transport equipment.

While these capital investments could play a crucial role in the exploration and refinement of mineral resources for industrial development, most of these investments are from private sector firms in developed countries with specific business interests. The evidence emerging from geopolitics of critical minerals in Africa, for instance, suggests that developed countries have significant investments in mining and extracting critical metals and minerals in several African countries (Andreoni and Roberts, 2022). For instance, China's control over mines in Africa has been growing significantly and reached almost 7% of the total value of African mines in 2018 in countries like Gabon, Ghana, South Africa, Zambia and Zimbabwe. In countries like the Democratic Republic of Congo (DRC), Chinese firms control almost 41% of cobalt extraction and near 28% of copper in the DRC and in Zambia (Ericsson et al., 2020). Other metals like bauxite, manganese, zinc, chromite and uranium are also economically viable and Chinese companies have control over mines in Africa that are mining these minerals. In fact, the Chinese interests or shares seem to be the next largest when compared to those of larger mining companies like Anglo American (from Great Britain), Glencore (from Switzerland) and First Quantum (mostly Canadian) (Ericsson et al., 2020; Andreoni and Roberts, 2022).

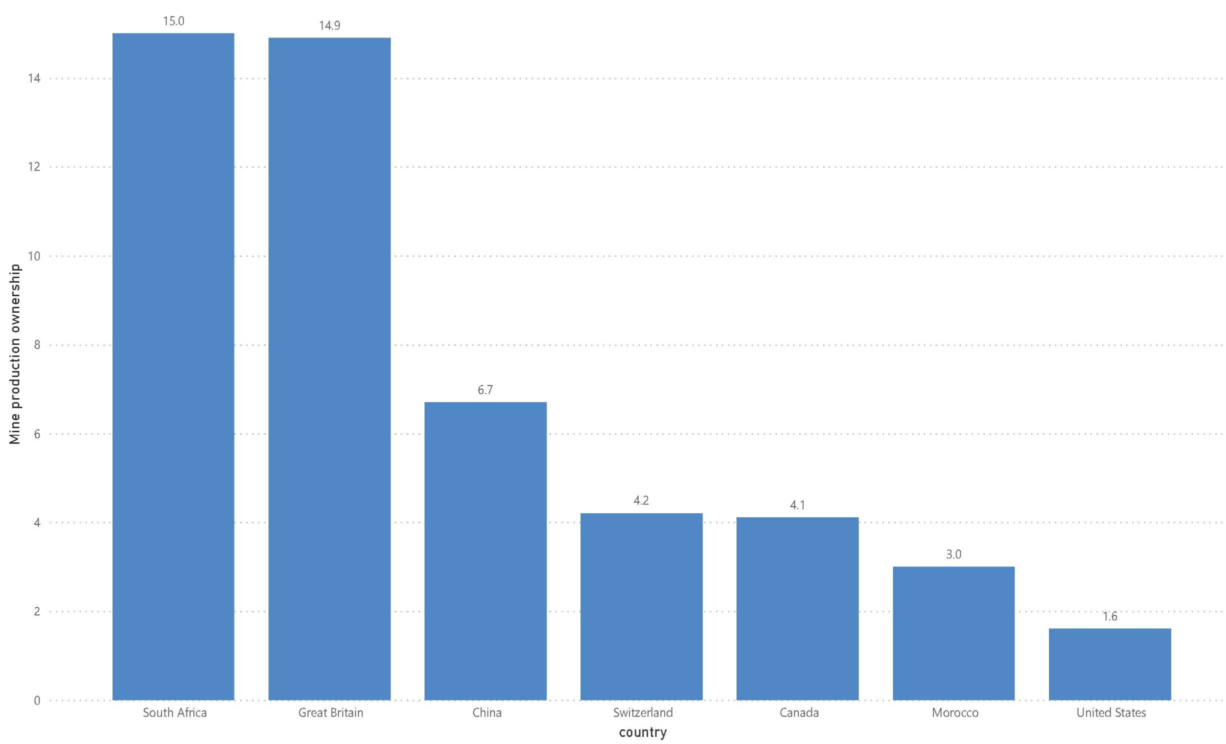
Figure 15: Capital investment to Africa: 2003 – 2018



Source: Authors based on data from fdi markets database
Notes: based on four clusters: environmental technology; ICT and electronics; Industrial; Transport equipment.

Africa's mine productions by large mining companies can be traced to other countries other than China (figure 16). While the activities of Chinese mining firms are focused on young mines in Ghana, Namibia, and South Africa, the major share of resources mined is done by large transnational companies like Glencore and Anglo American. For instance, three large transnational mining companies – Glencore, Barrick and First Quantum – were responsible for much of the copper extracted in 2018 in Zambia, compared to Chinese mining firms. In addition, corporate control over total African mine production is still largely held by companies like Glencore and Anglo American, who are responsible for nearly two-thirds of total mining production (Ericsson et al., 2020) (See figure 16).

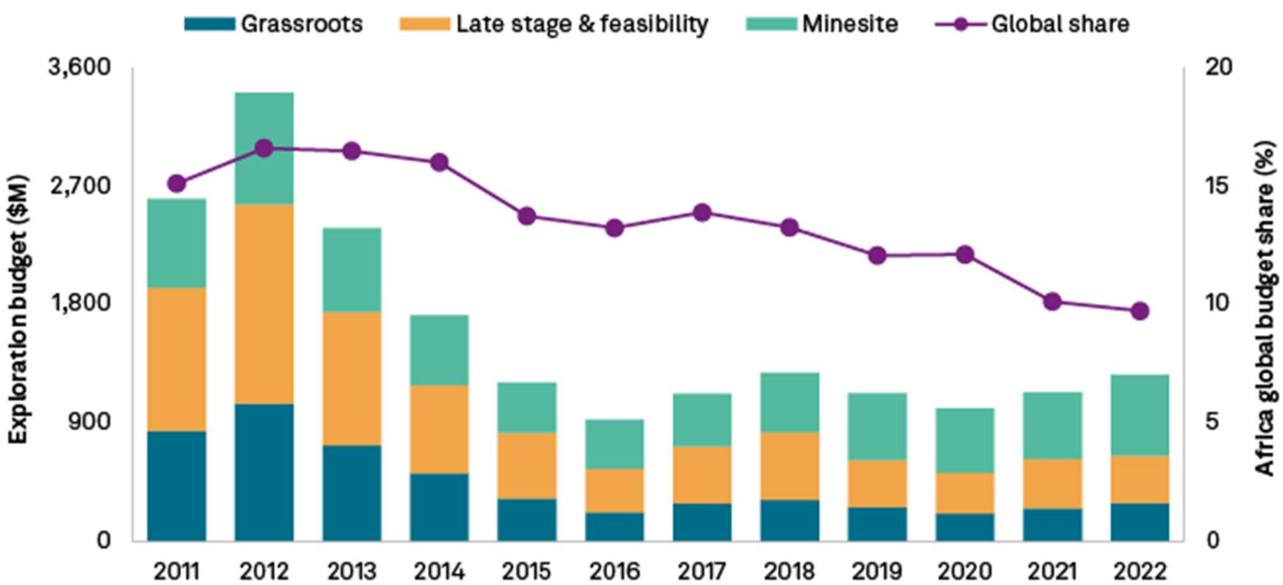
Figure 16: Ownership of total African mine productions in 2018 (in percentages), excluding 'Other.'



Source: Authors elaboration based on data from RMG Consulting.

The increasing demand for critical minerals from Africa is expected to bring in sustainable foreign exchange while developing new supply chains for new technologies that will be required in the transition process. Figure 17 tries to understand the exploration budget for these critical minerals between 2011 and 2022 across Africa. The figure reveals that despite a decline in the total exploration budget since 2012, the budget for mine site activities have been increasing since 2021.

Figure 17: Africa exploration budget as of 17 November 2022



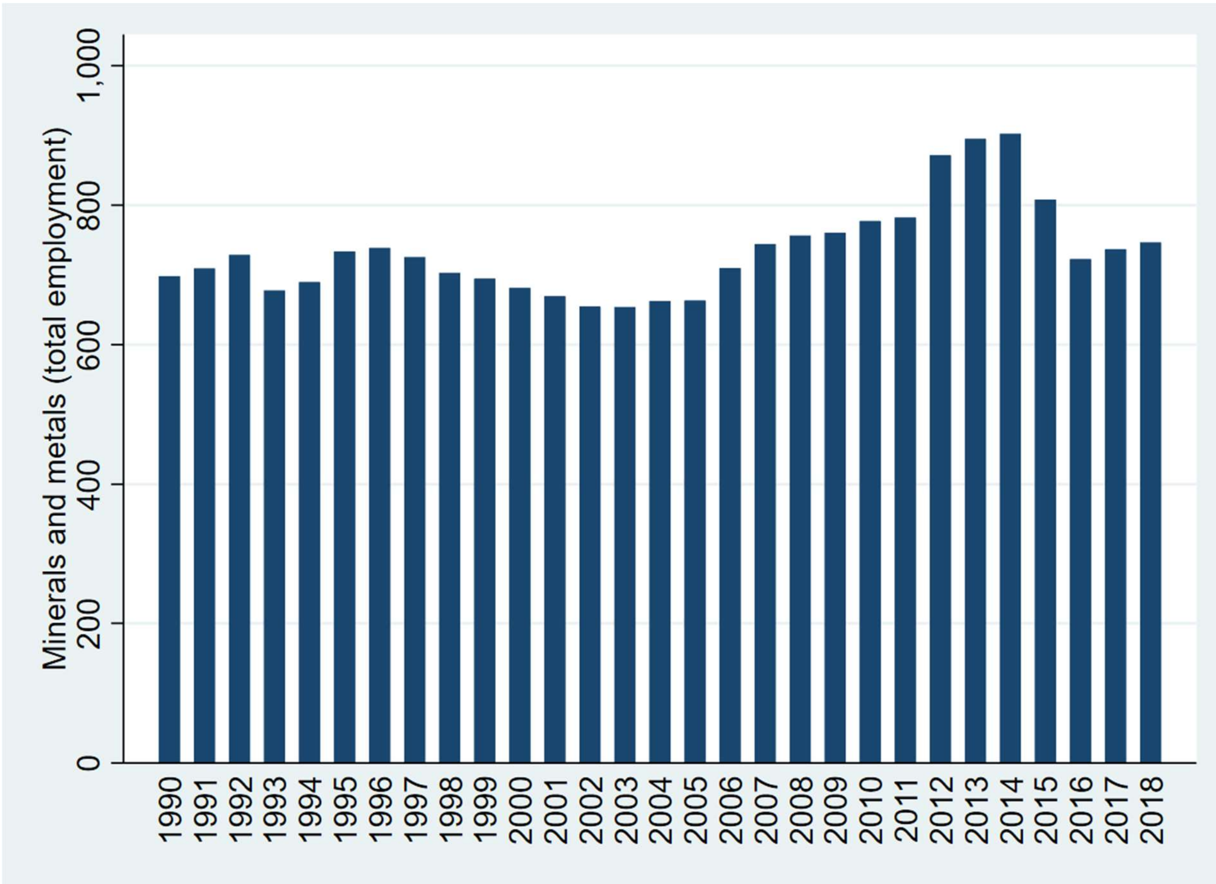
Source: S&P Global Markets Intelligence (https://www.spglobal.com/marketintelligence/en/news-insights/research/africa-mining-by-the-numbers-2022)

Hence, there is the opportunity to leverage these natural resources and the growing levels of international capital in the exploration of these resources to drive resource-based MHT industrialization and integrate into downstream segments of renewable energy technologies production (Andreoni and Roberts, 2022). Also, given the geopolitics and significant investments, there is an opportunity for Africa to leverage its mineral and metal resources to also support energy transition at a global level and industrialize. This is more so given Africa's dominance in the supply of key mineral and metal resources like cobalt, manganese and platinum, required to produce clean energy globally (IEA, 2019; Signé and Johnson, 2021).

More importantly, the exploration of critical minerals in African countries also has some implications for employment. The emerging opportunities from the search for critical minerals present a chance for African economies to structurally transform and create decent employment for its growing young population. We employ data from UNIDO and the fdi markets database to further understand the employment implications of the growing capital investments and ownership structure of the mining industry in Africa.

As noted above, foreign capital investments for the exploration of minerals have been significant in Africa. These investments have created several jobs in the mining sector in Africa over the last two decades. Despite lower employment numbers since 2014, two-digit manufacturing data from UNIDO shows a steady overall increase in employment in the production of minerals and metals in Africa over time (figure 18). It is anticipated that with the global aim of transitioning to clean energy, more employment opportunities may be created in resource-rich countries.

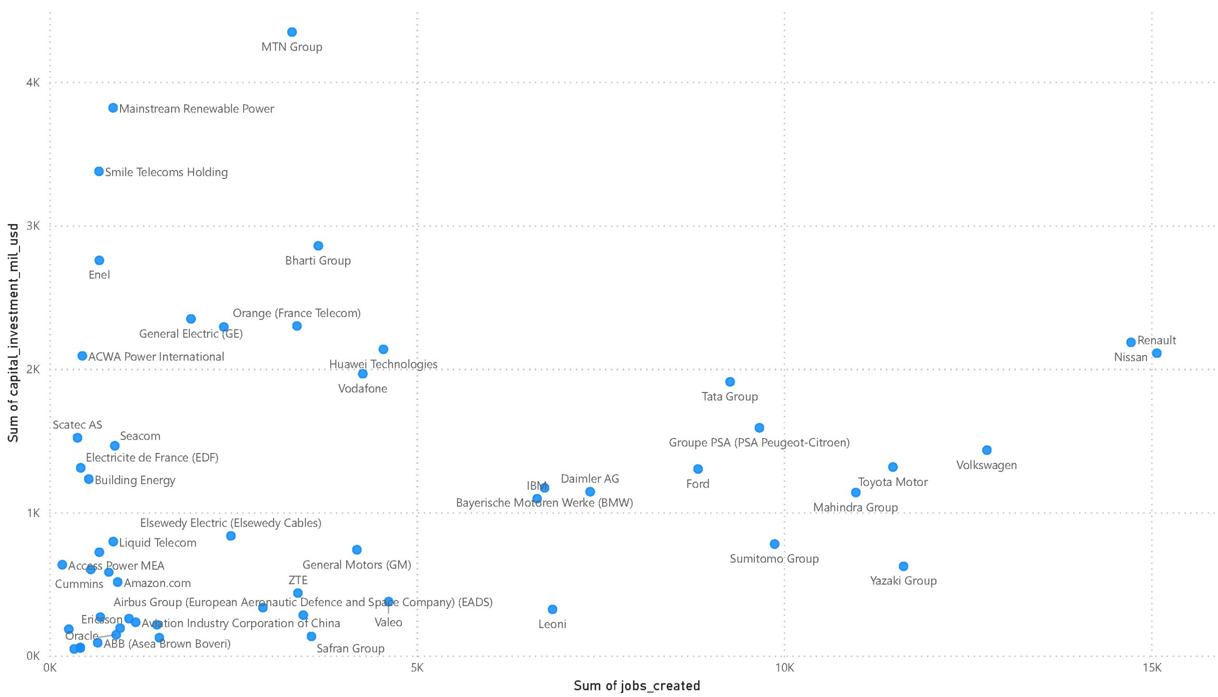
Figure 18: Employment trends in Africa in minerals and metals sector between 1990 – 2018 in ‘000



Source: Authors based on data from UNIDO

Mining of critical minerals contributes directly and indirectly to these jobs created because of the linkages the sector has with other sectors (Addison and Roe, 2018). Linkages between the mining sector and other sectors give room for technology-based companies in other related sectors to enjoy agglomeration economies and hire the required human capital for their operations in African countries. A scatterplot of capital invested by the top 20 firms and the corresponding jobs created using data from fdi markets database reveals that the major automotive manufacturers (Ford, Renault, Nissan, Volkswagen, Toyota Motor, Mahindra, Tata Group, BMW) are some of topmost companies that have created the most of jobs through their capital investments in Africa. Out of this group, Renault and Nissan have created the most jobs with relatively higher capital investments, next to Tata Group and Groupe PSA (PSA Peugeot-Citroen). Telecoms groups like MTN Group have the highest capital investments in SSA but have less than 5,000 jobs created over the last decade or more. The Bharti Group has the next highest sum of capital investments, and yet has created less than 5,000 jobs over the last decade or more. Other telecom giants like Huawei Technologies, Vodafone, Orange (France telecom), General Electric (GE) are found within similar levels. Companies in related industries like renewable energy, aviation and electricity generation are also identified, although these firms have not created many jobs from their investments. Examples include Ericsson, Oracle, Aviation Industry Corporation of China, ZTE and General Motors (see Figure 19).

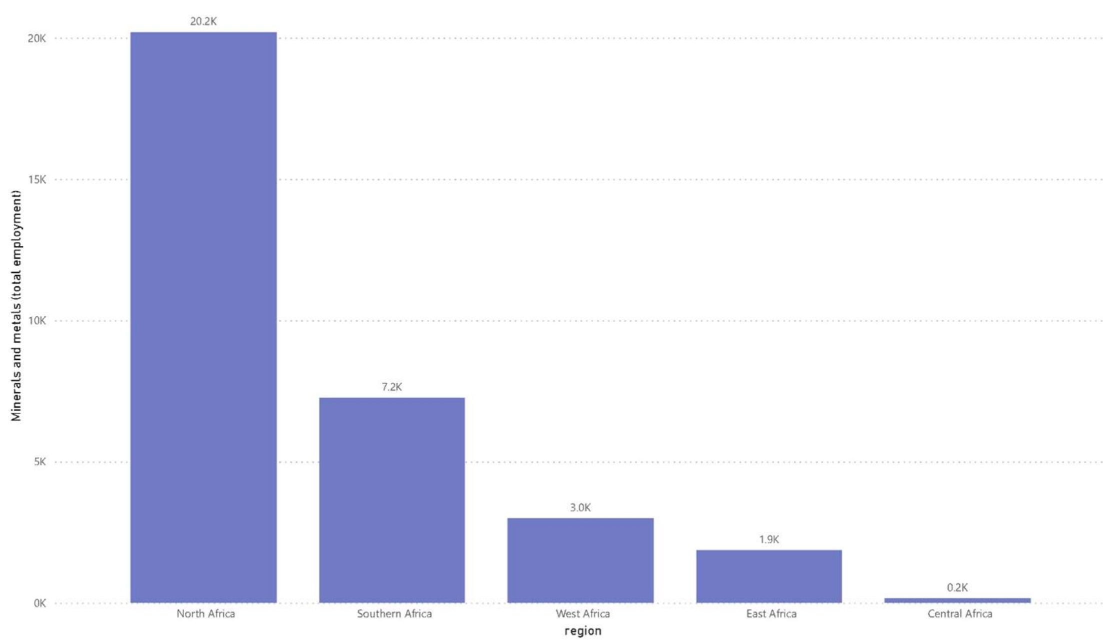
Figure 19: Scatterplot of capital investments and sum of jobs created in Africa between 2003 - 2018.



Source: Authors based on data from fdi markets database

Despite, trends in employment created in the mining sector over the period differ across different regions of the continent. It appears that there is concentration of employment in the minerals and metals sector in North Africa, followed by Southern Africa. The Central Africa is observed to have the least employment concentration in mining and minerals sector on the continent (Figure 20). These suggest that the concentration of employment in the minerals and metals is in regions where the most skills and technological capabilities are present. Thus, based on the two-digit manufacturing data from UNIDO, countries like South Africa and Egypt appear to have a higher workforce in the mining and minerals sectors relative to other countries like Morocco and Nigeria, for instance.

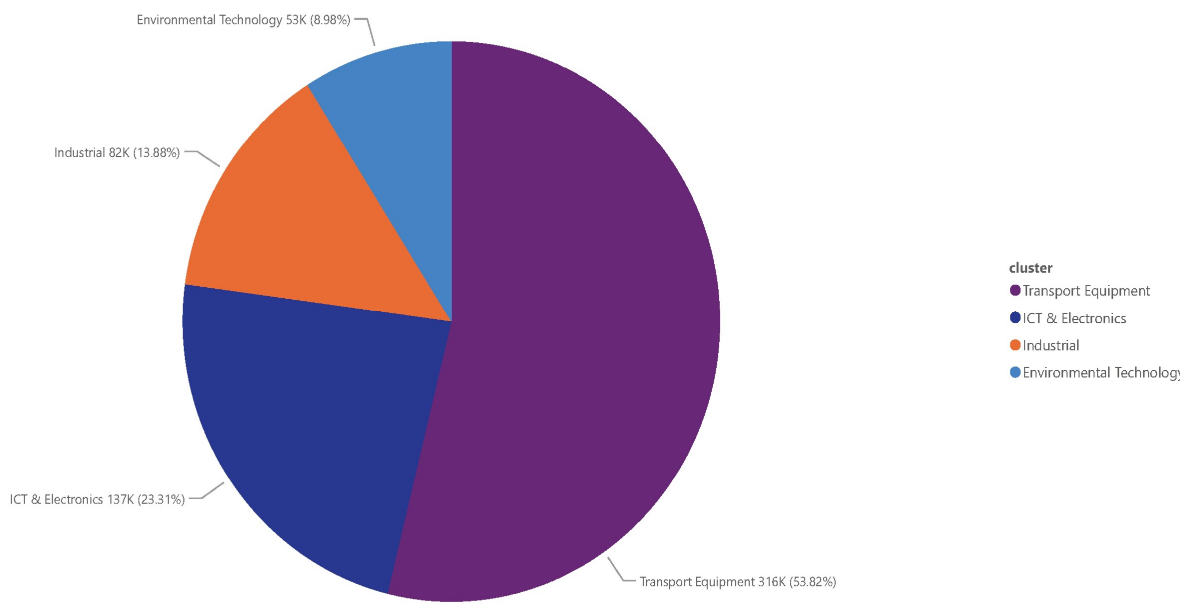
Figure 20: Employment trends in Africa in minerals and metals by region between 1990 - 2018



Source: Authors based on data from UNIDO

Aggregating capital investment in renewable energy-related industry clusters (environmental technology; ICT and electronics; Industrial; Transport equipment) in Africa, the data shows that more than half of the jobs that have been created between 2003 and 2018, by capital investments are in transport and ICT and electronics. Other sectors like industry and environmental technology follow with smaller shares of jobs created (figure 21).

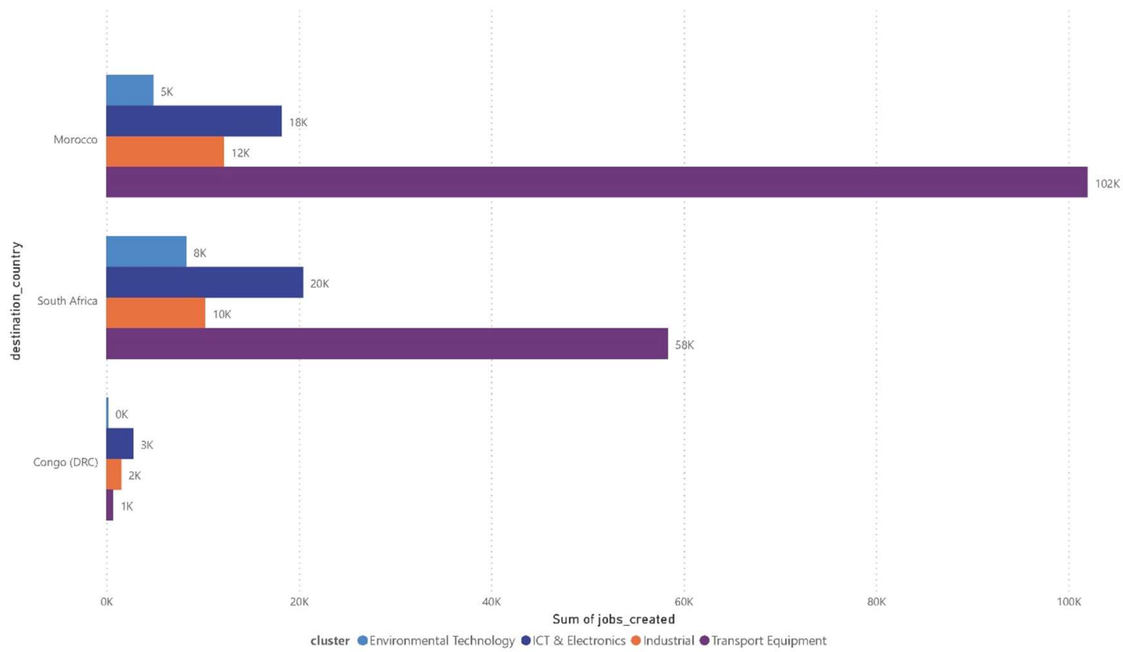
Figure 21: Sum of jobs in Africa created by cluster between 2003 – 2018.



Source: Authors based on data from fdi markets database

Much of the jobs in sectors like transport and ICT and electronics can also be found in African countries that are leading hubs of industrial innovation and technology-based manufacturing. For instance, over the last two decades, jobs created in the transport equipment sector by foreign capital investments amount to about 102,000 jobs in Morocco and about 58, 000 jobs in South Africa. Automotive manufacturers in these countries produce parts and components and assemble already built electric cars for domestic and international markets, which create some demand for human capital with the required skills (Figure 22). Also, over the last two decades, about 12,000 jobs in Morocco and 10,000 in South Africa were created in the ICT and electronics sector by MHT manufacturing companies and their capital investments. In contrast, these investments are relatively small in the Republic of the Congo. Examples from other African countries highlight that, for instance, extraction of critical minerals in Zimbabwe provided jobs for more than 60, 000 people in 2010 and led to the construction of critical infrastructure like roads, railways, telecoms in rural communities (Batanai, 2010).

Figure 22: Sum of jobs in selected African countries by capital investments between 2003 - 2018



Source: Authors based on data from fdi markets database

The foregoing highlights that the implication of the employment opportunities from mining of critical minerals in African countries are dynamic across sectors, countries, and regions. Also, this process depends on the dynamics that exist between ownership of mining companies, investments they make and the forward and backward linkages that owners may want to create at the regional and country levels. The absence of these dynamics and/or lack of forward and backward linkages in most African countries suggest that Africa may have a slimmer chance to promote MHT manufacturing directly from its extraction of critical resource metals. Given that TNCs find it difficult to create linkages (forward and backward) within their local economies, largely due to the lack of local capacity (Andreoni, 2019), creating the economic environment to pull foreign investments and ownership will depend on the extent to which governments in African countries situate the relevance of benefits of new technology manufacturing and supply chain participation in the industrialization path of countries.

The dynamics of governance and the political landscape in several African countries can frustrate potential gains that can be realized from resource-based industrialization and medium - and high-technology manufacturing. According to Andreoni and Roberts (2022), three main factors influence the developmental outcomes of critical minerals industry development in Africa. First, the extent to which governments identify the economic value of critical minerals for regional and local industrialization and production linkages development. Thus, governments who realize the industrial value that critical minerals can bring to the regional and domestic value chains can put measures in place to derive benefits aggregately and through production linkages. Governments may consider certain sector specific legislations that mining companies have to obey to improve the welfare of residents such as? tying road construction, maintenance and social amenities to areas where mining companies operate, establishing binding local content requirements for manufactured goods and services and even binding export performance contracts. This is especially possible when domestic production capabilities are developed to yield cluster and scale economies to give African countries more bargaining power during the extraction stage.

Second, the potential for African countries to capitalize on their critical minerals and advance the development of MHT manufacturing depends critically on the extent to which their governments are not consumed by particular interests and are willing and capable of negotiating mineral rights conditions as part of domestic industrial policy for structural transformation. In effect, governments that are able to align particular interests in mineral resources extraction with the priorities of industrial policy and resource-based industrialization may be on course to drawing out opportunities for medium- and high-tech manufacturing to thrive in their countries.

Finally, the management of geopolitics of critical minerals and the identification of global alliances for domestic productive development can affect the success of resource-based industrialization and medium- and high technology manufacturing in Africa.

Based on the dynamics at the level of mining ownerships, governments in African countries have to be strategic and align with partners that can support the development of domestic production even while mining critical minerals. This will create a win-win situation for African countries, and spur Africa's diversification path towards medium-high tech industries to create the much-needed decent jobs on the continent. In the next section, we present three country case studies to further emphasise the role critical mineral resources could play in Africa's industrial transformation and development.

5. Concluding remarks and policy direction

The growing global demand for critical mineral resources for transitioning into low-carbon future and cleaner energy systems is transforming industries and shaping new technology pathways. The mineral intensity of clean energy technologies offers opportunities and challenges for developing economies, particularly resource-rich developing countries, to diversity, upgrade, and capture value in new emerging value chains. As Africa is well endowed with critical mineral resources that are central to this global transition to a low carbon future, it provides a game-changing opportunity for the region to diversify and industrialize.

In line with the literature, the evidence highlights that Africa is poorly integrated in global trade, that is, trades the least with itself and the rest of the world. In cases where it does with the rest of the world, the trade is dominated by export of primary products with little value addition. These trade dynamics have shaped Africa's structural transformation path. However, our analyses shows that the continent is well-endowed with critical minerals that are pivotal to the green transition. We find that clean energy manufacturing industries can induce investments in the extraction and processing of these resources as well as in those technology-intensive downstream sectors that depends on them for domestic and regional industrial transformation and development. Therefore, Africa's natural capital presents it an opportunity to re-position and transform its production activities, particularly in medium-and high technology sectors.

However, leveraging this opportunity require African countries to improve their manufacturing capacity and scale up production and export through the building of domestic and regional linkages and value chains. Attaining this fit, however, requires active and proactive industrial policies.

First, stakeholders in Africa need to identify the transformative potential of their critical minerals and gradually integrate, upgrade, and diversify into various value chains based on their critical mineral endowments and current technological capabilities and paths. Industrial policy must aim at mitigating the 'dark side of the energy transition' (Marin and Goya, 2021): local pollution of soil, air, and water; the disposal of toxic residuals; intensive use of water and energy (IEA, 2021), work and environmental risks, child labour and sexual abuse (Sovacool, 2021), and corruption and armed conflict. Also, African governments have traditionally struggled to direct mineral rents toward a structural transformation agenda and broader diversification of their economies (Hirschman, 1977). This is due to the fact that, across Africa, the mineral-energy complex remains central to countries' political economy (Page and Tarp, 2020). For instance, there are historical cases showing how abundance of mineral resources does not have to lead to a 'resource curse' (Andreoni, 2016); however, in most African countries the mining sector has so far played a limited transformative role if looked from a structural transformation perspective (Andreoni et al., 2021b). Even in the case of South Africa, a country with a diversified ecosystem of technologically advanced mining equipment companies, the development of this manufacturing sector has been challenged by both domestic and global power asymmetries along value chains and increasing global concentration trends (Andreoni et al., 2021b).

These problems are at the core of the political economy of African countries and state legitimation in the face of geopolitical pressures for Africa's mineral resources. These social and environmental problems, if not well governed and managed, are doomed to become increasingly unsustainable given the increasing pressure on critical minerals extraction from the major industrialised economies.

Creating and capturing value from critical minerals, while addressing the dark side of the energy transition, require a developmental governance framework, government capabilities to design and implement it, and a developmental distribution of power and interests' alignment which makes its enforcement feasible (Andreoni et al., 2021b; Andreoni and Roberts, 2022). In this regard, the African Union in 2009 put forward the Africa Mining Vision to ensure that member countries optimise the opportunities and minimise the challenges of critical mineral resource industrialisation. The vision prioritised several intervention areas including: (i) Improving the quality of geological data; (ii) Improving contract negotiation capacity; (iii) Improving the capacity for mineral sector governance; (iv) Improving the capacity to manage mineral wealth; (v) Addressing Africa's infrastructure constraints; (vi) Elevating artisanal and small-scale mining. However, implementation of the Africa Mining Vision has been slow and there is a low level of awareness of the framework among key stakeholders in the mineral sector (Oxfam, 2017).

Second, at the core of any industrial policy to drive this structural transformation, governments need to set both ‘ex-ante’ and ‘ex-post’ conditionalities which direct, incentivise and regulate the use of natural resources. In the context of critical minerals, directing investments and shaping the mining industry development is particularly important and urgently needed, before market forces, incumbents and rents positions are further consolidated. This involves linking extraction and processing of critical minerals to sustainable industrialisation in Africa. Conditionalities include selection, incentives as well as disciplining mechanisms. They can operate ex ante when they define the specific conditions under which investments can be made, for example, which types of companies can invest, the risks-rewards conditions of the investment, the business model to be followed, which social and environmental standards should be followed, etc. These ex-ante conditionalities are essential as their strategic design can reduce adverse selection in state-companies relationship, hence making enforcement and disciplining more feasible. Given that many of the companies with capabilities in processing and developing critical minerals are international, and often backed up by their governments, ex-ante conditionalities can be used to trigger a ‘race to the top’.

A mix of ex-ante and ex-post conditionalities can be also introduced by the government to give directionality to business technology decisions, incentivise as well as discipline their sourcing and localisation decisions and reward complementary investments. In the mining sector, state-company relationships have been often framed in terms of localisation policies. At national levels, while African governments have increasingly introduced local content requirements, their implementation and enforcement have been limited and conditionalities have been mainly attached to loosen local content requirements without significant strategic vision. Local content requirements in African countries are also not so practical and eventually force mining companies to look elsewhere for their technological and operational needs. This is because some of the requirements demand unrealistic levels of local employment and yet expect mining firms to solely bear the burden of educating or re-educating local employment (AMDC, 2017). This forces mining companies to consider importing technology or skills from their countries of origin. Governments in African countries can give more consideration to available capacity, practicality, evaluation tools and inclusivity so that local content requirements can be more successful (Signé and Johnson, 2021).

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Appendices

Table A.1: Distribution of selected critical minerals in Africa in 2022

Critical mineral (unit)	Countries	Sub-name	Stock (Reserves)	Total global of reserves (rounded)	Share of global reserves (%)	Mine Production	Total global production (rounded)	Share of global production (%)	Refinery Production	Share of global refinery (%)
Alumina (in thousand metric dry tons)	Guinea		NA	NA	NA	440	140000	0,3		
Bauxite (in thousand metric dry tons)	Guinea		7400000	31000000	23,9	86000	380000	22,6		
Chromium (thousand metric tons)	Madagascar**		NA	NA	NA	124	41000	0,3		
	South Sudan**		NA	NA	NA	9	41000	0,0		
	South Africa		200000	560000	35,7	18000	41000	43,9		
Cobalt (metric tons)	Congo - Kinshasa		4000000	8300000	48,2	130000	190000	68,4		
	Madagascar		100000	8300000	1,2	3000	190000	1,6		
	Morocco		13000	8300000	0,2	2300	190000	1,2		
	Zambia***		NA	NA	NA	367	170000	0,2		
	Congo - Kinshasa		31000	890000	3,5	2200	22000	10,0	1700	6,5
	Zambia		19000	890000	2,1	770	22000	3,5	350	1,3

Copper (thousand metric tons)	Eritrea***		NA	NA	NA	21,725	21000	0,1		
	Mauritania***		NA	NA	NA	28,491	21000	0,1		
	Tanzania***		NA	NA	NA	12	21000	0,1		
Diamond (Industrial) (million carats)	Bostwana		300	1300	23,1	7	46	15,2		
	Congo - Kinshasa		150	1300	11,5	11	46	23,9		
	South Africa		120	1300	9,2	6	46	13,0		
Fluorspar (thousand metric tons)	Morocco		NA	260000	NA	77	8300	0,9		
	South Africa		41000	260000	15,8	420	8300	5,1		
Graphite (natural) (metric tons)	Madagascar		26000000	330000000	7,9	110000	1300000	8,5		
	Mozambique		25000000	330000000	7,6	170000	1300000	13,1		
	Tanzania		18000000	330000000	5,5	8000	1300000	0,6		
Iron ore (million metric tons)	South Africa	Usable/Crude ore	1000	180000	0,6	76000	2600000	2,9		
	Mauritania		NA	180000	NA	13000	2600000	0,5		
	South Africa	Iron content	670	85000	0,8	48000	1600000	3,0		
	Mauritania		NA	85000	NA	8100	1600000	0,5		
Lithium (metric tons)	Zimbabwe		310000	26000000	1,2	800	130000	0,6		
	Mali*		700000	26000000	2,7	NA	130000	NA		
Manganese (thousand metric tons)	Congo – Kinshasa***		NA	NA	NA	5	20000	0,0		
	Cote d'Ivoire		NA	1700000	NA	360	20000	1,8		
	Gabon		61000	1700000	3,6	4600	20000	23,0		
	Ghana		13000	1700000	0,8	940	20000	4,7		
	South Africa		640000	1700000	37,6	7200	20000	36,0		
	Zambia***		NA	NA	NA	30	20000	0,2		

Nickel (metric tons)	Madagascar**		NA	NA	NA	9900	2700000	0,4		
	Zambia***		NA	NA	NA	3251	2700000	0,1		
Niobium (Columbium)	Congo - Kinshasa		NA	NA	NA	600	79000	0,8		
	Rwanda		NA	NA	NA	210	79000	0,3		
Phosphate rock (thousand metric)	Algeria		2200000	72000000	3,1	1800	220000	0,8		
	Egypt		2800000	72000000	3,9	5000	220000	2,3		
	Morocco		50000000	72000000	69,4	40000	220000	18,2		
	Senegal		50000	72000000	0,1	2600	220000	1,2		
	South Africa		1600000	72000000	2,2	1600	220000	0,7		
	Togo		30000	72000000	0,0	1500	220000	0,7		
	Tunisia		2500000	72000000	3,5	4000	220000	1,8		
Platinum Group Metals (kilograms)	South Africa	Palladium	63000000	70000000	90,0	80000	210000	38,1		
		Platinum				140000	190000	73,7		
	Zimbabwe	Palladium	1200000	70000000	1,7	12000	210000	5,7		
		Platinum				15000	190000	7,9		
Rare Earths (metric tons of rare-earth-oxide (REO))	Burundi****		100	130000000	0,0	200	290000	0,1		
	Madagascar		NA	130000000	NA	960	300000	0,3		
	South Africa		790000	130000000	0,6	NA	300000	NA		
	Tanzania		890000	130000000	0,7	NA	300000	NA		
Silver (tons)	Burkina Faso***		NA	NA	NA	10	24000	0,0		
	Congo – Kinshasa***		NA	NA	NA	3	24000	0,0		
	Eritrea***		NA	NA	NA	65	24000	0,3		

	Ethiopia***		NA	NA	NA	1	24000	0,0		
	Mali***		NA	NA	NA	3	24000	0,0		
	Senegal***		NA	NA	NA	1	24000	0,0		
	Sudan***		NA	NA	NA	1	24000	0,0		
	Tanzania***		NA	NA	NA	13	24000	0,1		
	Zambia***		NA	NA	NA	9	24000	0,0		
Tantalum. (metric tons)	Burundi		NA	NA	NA	39	2000	2,0		
	Congo - Kinshasa		NA	NA	NA	860	2000	43,0		
	Ethiopia		NA	NA	NA	24	2000	1,2		
	Mozambique		NA	NA	NA	34	2000	1,7		
	Nigeria		NA	NA	NA	110	2000	5,5		
	Rwanda		NA	NA	NA	350	2000	17,5		
	Uganda		NA	NA	NA	38	2000	1,9		
Tellurium (metric tons)	South Africa		800	32000	2,5	4	640	0,6		
Tin (metric tons)	Congo - Kinshasa		130000	4600000	2,8	20000	310000	6,5		
	Nigeria		NA	NA	NA	1700	310000	0,5		
	Rwanda		NA	NA	NA	2200	310000	0,7		
Titanium Mineral Concentrates	Kenya	Ilmenite	390	650000	0,1	180	8900	2,0		
	Madagascar		22000	650000	3,4	300	8900	3,4		
	Mozambique		26000	650000	4,0	1200	8900	13,5		
	Senegal		NA	650000	NA	520	8900	5,8		
	South Africa		30000	650000	4,6	900	8900	10,1		
	Kenya	Rutile	170	700000	0,0	73	9500	0,8		
	Madagascar		520	700000	0,1	NA	9500	NA		
	Mozambique		890	700000	0,1	8	9500	0,1		
	Senegal		NA	700000	NA	9	9500	0,1		
	Sierra Leone		490	700000	0,1	130	9500	1,4		

	South Africa		6500	700000	0,9	95	9500	1,0		
	Tanzania		20	700000	0,0	NA	9500	NA		
Tungsten (metric tons)	Burundi***		NA	NA	NA	165	79000	0,2		
	Congo - Kinshasa***		NA	NA	NA	128	79000	0,2		
	Rwanda		NA	NA	NA	1100	84000	1,3		
	Uganda***		NA	NA	NA	9	79000	0,0		
Vanadium (metric tons)	South Africa		3500	26000	13,5	9100	100000	9,1		
Zirconium (ores and concentrates)	Madagascar***		NA	NA	NA	25,3	1200	2,1		
	Mozambique		1800	68000	2,6	100	1400	7,1		
	Senegal		2600	68000	3,8	70	1400	5,0		
	Sierra Leone***		NA	NA	NA	6,6	1200	0,6		
	South Africa		5900	68000	8,7	320	1400	22,9		

Sources: Authors computation based on data from USGS 2023; *Reserve data from Chandler (2022); ** 2021 data from UNCTAD (2022); ***2020 Production data from 2020 from UNCTAD (2022); **** Global reserve and production data in 2022 from USGS 2023; Country Production data in 2021 from USGS 2023; Production data in 2021 from UNCTAD, 2022.

Figure A.1: Critical minerals exported by African countries, 2017-2021.

Countries	AL	BX	CH	CB	CP	DD	FP	GH	IO	LT	MG	MM	NK	NB	PR	PG	RE	SL	TT	TL	TN	TG	VD	ZN	TN
Algeria	◆		◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆		◆	◆		◆	◆		◆	◆		◆	◆
Angola			◆		◆	◆		◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆		◆	◆		◆	◆
Benin					◆	◆		◆		◆	◆	◆	◆		◆	◆		◆				◆		◆	
Botswana	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆	◆		◆	◆		◆	◆		◆	◆	◆	◆	◆
Burkina Faso	◆		◆		◆	◆		◆	◆	◆	◆	◆	◆		◆	◆		◆			◆	◆		◆	◆
Burundi					◆	◆		◆	◆	◆	◆	◆	◆		◆			◆			◆	◆			
Cabo Verde					◆	◆		◆		◆		◆	◆					◆	◆			◆			◆
Cameroon	◆	◆	◆		◆	◆		◆	◆	◆	◆	◆	◆		◆	◆		◆	◆		◆	◆	◆		◆
Central African Rep.			◆		◆	◆		◆		◆		◆	◆					◆	◆				◆		◆
Chad					◆	◆		◆		◆	◆	◆	◆		◆	◆		◆	◆			◆			◆
Comoros						◆						◆	◆			◆		◆							
Congo			◆	◆	◆	◆		◆	◆	◆	◆	◆	◆			◆		◆			◆	◆			
Côte d'Ivoire	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆	◆		◆	◆		◆	◆		◆	◆		◆	◆
DR. Congo			◆	◆	◆	◆		◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆		◆	◆			◆
Djibouti			◆		◆	◆		◆		◆		◆	◆			◆		◆	◆						
Egypt	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆		◆	◆	◆	◆	◆
Equatorial Guinea		◆				◆		◆		◆	◆		◆			◆		◆				◆			◆
Eritrea					◆	◆				◆	◆		◆		◆	◆		◆							

Ethiopia	♦		♦		♦	♦		♦	♦	♦	♦	♦	♦			♦		♦	♦		♦	♦			♦
Gabon		♦			♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦			♦	♦	♦		♦
Gambia					♦	♦		♦				♦	♦		♦	♦		♦			♦		♦	♦	♦
Ghana	♦	♦	♦		♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	♦
Guinea		♦			♦	♦		♦	♦	♦	♦	♦	♦			♦		♦			♦	♦			♦
Guinea-Bissau		♦	♦		♦	♦				♦					♦							♦			♦
Kenya	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Lesotho					♦	♦		♦		♦	♦	♦	♦		♦	♦		♦			♦	♦			
Liberia					♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦			♦		♦	♦
Libya	♦		♦		♦	♦		♦	♦	♦	♦	♦	♦			♦		♦			♦	♦			♦
Madagascar	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦		♦	♦	♦	♦	♦
Malawi		♦			♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	♦
Mali			♦	♦	♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦			♦	♦			♦
Mauritania		♦			♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦			♦	♦		♦	♦
Mauritius	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦		♦			♦	♦	♦	♦	♦
Morocco	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Mozambique	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦		♦	♦	♦	♦	♦
Namibia	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦		♦	♦	♦	♦	♦
Niger		♦	♦		♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	♦
Nigeria	♦	♦	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦	♦	♦	♦
Rwanda	♦				♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	♦
SaoTome & Principe					♦	♦		♦		♦	♦		♦			♦		♦				♦			♦

Senegal			♦		♦	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦		♦	♦
Seychelles	♦	♦			♦	♦		♦		♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	♦
Sierra Leone		♦	♦		♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦			♦	♦	♦	♦
Somalia			♦		♦	♦			♦	♦	♦	♦	♦		♦	♦		♦			♦	♦			♦
South Africa	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
South Sudan					♦	♦		♦		♦	♦	♦			♦	♦		♦							
Sudan		♦	♦		♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	
Swaziland	♦		♦		♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦		♦	♦
Togo					♦	♦		♦	♦	♦	♦	♦	♦		♦	♦	♦	♦						♦	♦
Tunisia	♦		♦	♦	♦	♦		♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦		♦	♦	♦	♦	♦
Uganda	♦		♦	♦	♦	♦		♦	♦	♦	♦	♦	♦		♦	♦		♦			♦	♦		♦	♦
Tanzania	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦		♦	♦	♦	♦	♦
Zambia	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦		♦	♦		♦	♦	♦	♦	♦
Zimbabwe	♦		♦		♦	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦	♦	♦		♦	♦		♦	♦

Note: AL is Alumina; BX is Bauxite; CH is Chromium; CB is Cobalt; CP is Copper; DD is Diamond (industrial); FP is Fluorspar; GH is Graphite (Natural); IO is Iron ore; LT is Lithium; MG is Manganese; MM is Mixed metal product; NK is Nickel; NB is Niobium (Columbium); PR is Phosphate rock; PG is Platinum group metals; RE is Rare Earths; SL is Silver; TT is Tantalum; TL is Tellurium; TN is Tin; TG is Tungsten; VD is Vanadium; ZN is Zirconium; and TN is Titanium

Source: Authors based on BACI-CEPII HS 17 data.