

# Critical Minerals, Critical Taxation

Grégoire ROTA-GRAZIOSI



Université Clermont Auvergne, CNRS, IRD, CERDI and FERDI.

Contact: [gregoire.rota-graziosi@uca.fr](mailto:gregoire.rota-graziosi@uca.fr)

## Abstract

The surging global demand for critical minerals has sparked a renewed scramble for these strategic resources, posing significant challenges for producing countries as they seek to capture a fair share of the economic rents generated. Critical minerals differ from conventional extractive commodities in that the location of rent generation is moving downstream—from the mine to the plant—and toward intangible assets, including proprietary technologies, patents, and digital servitization platforms. Following a brief review of standard mining taxation instruments, this paper turns to China's fiscal approach, which is central in the global critical minerals' ecosystem. Drawing on this case, the paper outlines potential tax policy reform options for resource-rich economies. These include: (i) anchoring production pricing to transparent international benchmarks to mitigate transfer pricing abuses; (ii) establishing ring-fencing provisions for critical minerals produced predominantly as by-products; (iii) reasserting the source principle in bilateral and multilateral tax arrangements; (iv) revisiting the strict application of the VAT destination principle, particularly for unprocessed mineral exports; and (v) exploring the potential role for regional cooperation and international institutions.

**Keywords:** Critical minerals; tax system; China; Profit shifting; Value Added Tax.

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## 1. Introduction

The accelerating demand for critical minerals is reshaping both industrial strategy and public finance for resource-rich countries. These minerals such as lithium, cobalt, rare earths, graphite, and copper have become indispensable for decarbonization technologies (electric vehicles, solar panels, wind turbines), advanced electronics (semiconductors, fiber optics), and defense applications (missiles, satellites, jet engines). The International Energy Agency (IEA) projects that demand for critical minerals could quadruple by 2040 to meet net-zero targets.<sup>1</sup>

Designing an ideal fiscal regime for mining is theoretically straightforward but practically complex. In principle, a neutral tax system would tax only economic rent – the surplus above a normal return on investment – thereby maximizing public revenue without deterring investment. In practice, however, implementing pure rent taxes is difficult. Most countries rely on hybrid regimes combining mining royalties, Corporate Income Tax (CIT), and other capital income taxation.

For critical minerals, these traditional approaches face new pressures and may become obsolete. First, many critical minerals pose challenges in their valuation for taxation purposes: they are either by-products of major base metal mining operations, or they lack liquid spot markets and recognized international transparent benchmarks, or both. Second, their value chain rent shifts primarily from the mine to processing and refining stages, often dominated by different countries —led by China — and by proprietary technologies. This shift in the locus of value creation means that the rent may accrue not where the ore is extracted, but where it is processed.

Tax policy must adapt to these realities. The rise of intangible assets and vertically integrated global value chains in the critical minerals sector blurs the line between mining and manufacturing. Tax authorities in resource-rich countries must grapple not only with taxing the physical extraction of ore, but also with capturing profits derived from intellectual property, engineering services, and downstream processing – activities often undertaken abroad. Issues such as transfer pricing, where multinational firms may undervalue mineral exports or overstate costs to shift profits to low-tax jurisdictions, pose a significant risk to the tax base. In addition, new business models like digital servitization of mining (e.g. foreign firms providing mining services or technology), add further complexity.

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<sup>1</sup> See: <https://www.iea.org/energy-system/industry/critical-minerals>

This paper investigates how tax regimes can be adapted to meet the emerging challenges posed by the critical minerals sector. It presents policy responses, examining both defensive measures to protect existing tax bases (transfer pricing enforcement techniques, ring-fencing provisions, etc.) and strategic repositioning opportunities arising from the fact that the criticality of minerals may enhance the bargaining power of resource-rich countries through the review of Double Tax Agreements (DTAs) to better promote the source principle or through the implementation of a hybrid Value Added Tax (VAT) system modeled on China's approach.

The analysis contributes to several literatures. First, it extends natural resource taxation theory—traditionally focused on upstream rent extraction through royalties and resource rent taxes (Boadway and Keen, 2010)—to address midstream value concentration and the implications for fiscal instrument design. Second, it connects extractive taxation to global value chain literature (Antràs, 2020) by documenting how governance structures and rent distribution in critical mineral chains differ fundamentally from conventional commodities, requiring corresponding fiscal adaptations. Third, it contributes to debates on strategic trade policy and industrial upgrading (Rodrik, 2007) by analyzing how fiscal instruments—particularly hybrid VAT systems—can serve dual objectives of revenue generation and industrial policy without direct spending or tax expenditure. Finally, it informs practical policy discussions on critical mineral governance by identifying specific vulnerabilities in existing fiscal frameworks, concrete policy responses adapted to critical minerals' structural particularities, and the role of regional cooperation and international institutions.<sup>2</sup>

The remainder of the paper is organized as follows. Section II provides an overview of the taxation of economic rents, both in theory and in practice. It identifies the principal risks associated with base erosion and profit shifting (BEPS) in the mining sector and reviews current countermeasures, including reference pricing mechanisms and anti-abuse provisions. Section III turns to critical minerals, highlighting the key distinctions between this sector and conventional extractive industries. It outlines the specific fiscal challenges that arise from the relocation of rent from the pit to the plant, and from tangible to intangible assets, particularly in the context of processing, proprietary technologies, and global value chains. This section also

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<sup>2</sup> We acknowledge that taxation is not the unique way to capture economic rent from these non-renewable resources. Alternatives may be quantity-based instruments such as production-sharing contracts (well developed in the oil sector) or other forms of contract such as long-term offtake agreements or strategic partnerships between resource producers and buyers.

draws on insights from China’s tax architecture, especially its hybrid VAT system. Section IV concludes.

## **2. Tax Regimes for Extractive Industries and their Enforcement**

Tax regimes for the mining sector reflect the dual imperative of mobilizing rents from non-renewable resources while attracting investment in a capital-intensive and high-risk industry. From an efficiency standpoint, the ideal system taxes economic rent—the surplus above the normal return to capital—while avoiding distortions to investment and production decisions. Yet, in practice, political constraints and enforcement challenges have led to hybrid fiscal regimes that combine multiple tax instruments to balance neutrality, stability, and progressivity<sup>3</sup> (Otto et al., 2006; Boadway and Keen, 2010; Calder, 2014). Moreover, Arezki and Rota-Graziosi (2026) underline the risk of misalignment—or even outright competition—between the Ministry of Finance and the Ministry of Mines in shaping the effective tax policy applied to the sector. Such institutional rivalry often leads to an inefficient tax regime, thereby discouraging investment in mining activities.

Because mining projects typically unfold over several decades, investors in this sector are exposed to a classic form of time inconsistency in the sense of Kydland and Prescott (1977)<sup>4</sup>: once capital has been committed, it becomes irreversibly tied to a particular geological deposit, leaving investors vulnerable to shifting policy conditions over time. This dynamic undermines the credibility of policy commitments and can deter investment in capital-intensive sectors like mining. As Boadway and Keen (2010) observe, stabilization clauses operate as a contractual commitment device, locking in key fiscal parameters or guaranteeing compensation in the event of adverse legal changes. While such clauses enhance intertemporal credibility, they may also reduce the host government’s flexibility to respond to evolving economic or political conditions (see Hogan and Sturzenegger, 2010). Their design thus embodies a fundamental trade-off between policy commitment and flexibility—a tension particularly acute in extractive industries, where political pressures typically intensify with rising commodity prices. Notably,

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<sup>3</sup> In the extractive sectors, progressivity denotes the extent to which government fiscal revenues increase with project profitability — notably when commodity prices rise, production levels expand, or cost structures improve.

<sup>4</sup> Governments in resource-rich countries may design investor-friendly fiscal regimes *ex ante* to attract capital, but once irreversible investments have been made, the incentive to revise tax terms *ex post*—through increased royalties, profit taxes, or new environmental levies—can be strong.

progressivity enhances fiscal regime stability by dampening demands for renegotiating fiscal terms during commodity price booms.

### **Current Mining Tax Regimes**

Mining typically involves two distinct stages with different fiscal implications: exploration and extraction (also termed exploitation). For critical minerals, a third stage – processing or refining – is particularly salient. Exploration is characterized by high geological risk and uncertain returns; extraction (and processing), by contrast, generate substantial rents once a deposit becomes profitable but also involve significant upfront costs (Garnaut and Ross, 1983). Consequently, each stage requires a differentiated tax regime.

During exploration, the tax objective is to encourage risk-bearing investment without eroding the future tax base. Most regimes therefore allow immediate expensing or accelerated depreciation of exploration costs and loss carry-forwards with an uplift rate to preserve neutrality (Daniel, Keen and McPherson, 2010). Some countries go further by granting investment allowances, super-deductions, or refundable tax credits, as in flow-through share schemes for junior explorers. Once production begins, the fiscal regime shifts from investment promotion to rent capture.

Mining projects yield diverse revenue streams—from turnover and profits to production factors such as labor, land, and capital. These are captured primarily through royalties and CIT, with supplementary mechanisms including rent-based levies and withholding taxes.<sup>5</sup> While indirect fiscal instruments—customs duties, excise taxes, and VAT—traditionally play a marginal role in resource extraction, the Chinese case discussed below demonstrates an innovative exception: the strategic use of VAT to incentivize in-country value creation.

Mining royalties take two principal forms: *ad valorem*, assessed as a percentage of gross sales or net smelter return or *ad quantum* (or equivalently *specific*), imposed per ton or ounce extracted. While unit-based royalties provide early and stable revenue—especially advantageous for administrations with constrained institutional capacity, they may be regressive, burdening high-cost or low-grade mines. Progressive or profit-linked structures

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<sup>5</sup> Resource rent taxation has been advocated as an alternative fiscal instrument to replace conventional CIT and royalty regimes. It taxes only the economic rents—or super-normal profits—generated by extractive projects, while allowing companies to fully recover all costs plus a normal rate of return before any tax liability arises (Boadway and Keen, 2010). However, despite their theoretical quality, resource rent taxes have rarely been implemented beyond Australia’s short-lived experiment (2014-2016).

align more closely with commodity cycles but require stronger monitoring capacity (Otto et al., 2006). In Africa, countries such as Burkina Faso, Ghana and Tanzania have moved toward sliding-scale royalties tied to price thresholds, seeking both stability and responsiveness (IMF, 2012).

CIT constitutes the primary fiscal instrument revenue in mining tax systems. It is typically levied on net accounting profits, with mining-specific provisions such as accelerated depreciation, immediate expensing for exploration, and loss carry-forwards with uplift. CIT rates may be aligned with the general rate or differentiated for mining; some countries, like Botswana, apply progressive CIT rates based on profitability ratios (Calder, 2014). To capture excess profits, many jurisdictions supplement CIT with additional profits taxes.

Some resource-rich countries (e.g. Nigeria, Indonesia, Ecuador) have implemented poorly designed tax incentives—such as CIT holidays or reduced tax rates—instead of investment-targeted tax credits. Dama et al. (2024) highlights the regressive nature of CIT holidays. These preferential regimes, arising from inter-ministerial competition (see Arezki and Rota-Graziosi, 2026) and reinforced by stability clauses, significantly undermine governments' ability to capture a fair share of mining rents.

Indirect taxes include excises, tariff duties, and VAT. Excises and import duties on key inputs raise production costs. They are usually cancelled through exemptions or refund mechanisms specified in mining codes.<sup>6</sup> VAT is a broad-based consumption tax levied on the value that each firm adds along the production and distribution chain. VAT is ultimately borne by the final consumer. Following the destination principle (Ebrill et al., 2001; OECD, 2017), extractive operations—which are characteristically export-driven—are zero-rated for VAT purposes, resulting in no net tax collection from the sector.

Finally, contemporary fiscal regimes increasingly integrate environmental and social considerations. Tax-deductible rehabilitation and closure funds, provisions for restoration, and carbon or energy taxes aim to internalize environmental externalities (OECD, 2020). In several African jurisdictions, companies are required to pre-fund rehabilitation obligations through financial guarantees or trust funds, whose contributions are treated as deductible expenses

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<sup>6</sup> As an illustration, mining lists may grant total exemption from taxes and customs duties applicable to the construction of a mining facility. That said, the definition and oversight of such lists can be administratively burdensome, technically complex, and a potential source of corruption. These challenges are further amplified when these tax advantages are extended to mining subcontractors, a category whose legal and operational boundaries may remain fuzzy.

(Calder, 2014). These mechanisms align fiscal and environmental policy objectives while reducing the risk of orphaned mine sites.

### **Navigating the Tax Complexities of Extractive Industries**

Profit shifting erodes revenues from both CIT and mining royalty, constituting a critical challenge for fiscal governance in extractive industries, especially in resource-rich developing countries. Mining exhibits structural vulnerabilities to tax planning abuses: intensive capital requirements, widespread intra-group cross-border trade, complex value chains involving processing and marketing affiliates, and significant information asymmetries between firms and tax administrations (UN, 2021a,b). These features enable multinational enterprises (MNEs) to exploit numerous channels for shifting profits from extraction jurisdictions.

Tax base erosion occurs through three principal channels. First, transfer pricing manipulation allows multinationals to distort valuations of intra-group transactions, especially cross-border commodity flows. Second, multinationals can shift profits through the thin capitalization of subsidiaries in the resource-rich (high tax) country and borrowing from subsidiaries in low-tax countries (see Huizinga, Laeven, and Nicodeme, 2008). Third, intangible asset relocation permits the transfer of intellectual property rights—patents, trademarks, proprietary technologies—to favorable tax environments (see Dischinger and Riedel, 2011; Griffith, Miller and O’Connell, 2014).<sup>7</sup>

A prevalent mechanism for tax planning involves transfer pricing manipulation in the sale of commodities to related parties. By underpricing concentrate exports or inflating smelting and refining deductions, companies can effectively transfer value to offshore affiliates located in low-tax marketing hubs such as Switzerland, Singapore, or Dubai (see the case of Glencore in Zambia<sup>8</sup>). Similar effects arise from the use of non-comparable benchmark prices, selective

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<sup>7</sup> Using European MNE data, Dischinger and Riedel (2011) show that intangible holdings are disproportionately placed in lower-tax affiliates. Griffith, Miller and O’Connell (2014) document that IP regimes and patent boxes shape where IP is owned and where income is booked, confirming relocation rather than purely new innovation.

<sup>8</sup> In 2010, a pilot audit for the Zambia Revenue Authority (ZRA) and a coalition of NGOs alleged that Mopani Copper Mines (MCM)—then owned by Glencore and First Quantum—sold copper to the Swiss parent at below arm’s-length prices, overstated costs, and used intragroup arrangements to shift profits out of Zambia. After a long dispute (including Tax Appeals Tribunal stages), Zambia’s Supreme Court (May 2020) upheld ZRA’s position in a landmark ruling and imposed penalties (≈ US\$13 million), signaling judicial backing for arm’s-length pricing on commodity sales to affiliates.

quotation periods, or opaque adjustments for quality and impurities (OECD, 2017; IGF–OECD, 2020).

Tax planning strategies may become more sophisticated—and potentially more aggressive—in the context of servitization, particularly in its digital forms. Servitization refers to the transformation by which firms shift from product-centric offerings toward integrated bundles of products and services, often structured as product–service systems (see Vandermerwe and Rada, 1988; Baines et al., 2009; Raddats et al., 2019). This model reconfigures the cost structure of industrial activity by converting part of fixed capital expenditure (CAPEX) into variable operating expenditure (OPEX), thereby enhancing operational flexibility. This transformation creates opportunities for aggressive tax structuring by reshaping (i) cost recognition patterns and timing, (ii) geographic profit allocation within multinational enterprises, and (iii) payment characterization for tax purposes (services, royalties, or financing arrangements), each bearing distinct implications for taxable income determination and withholding tax exposure. It may also reduce long-term ownership control over critical production assets with important implications for tax base allocation.

In mining, this transition increasingly involves digital servitization. Technologies such as the Internet of Things (IoT) and the Industrial Internet of Things (IIoT) facilitate the interconnection of physical assets—machines, sensors, and infrastructure—via the internet, enabling continuous data collection, remote monitoring, and real-time process optimization (see Nobahar et al., 2024). The integration of such high-value, intangible services—often sourced cross-border from technology affiliates—raises complex transfer pricing questions and may provide additional channels for profit shifting, especially when performed by related entities in low-tax jurisdictions.

A telling example of digital servitization in mining is the replacement of truck purchases (CAPEX) with remotely operated vehicle services (OPEX). Rather than buying equipment, mines sign service contracts under which autonomous, sensor-equipped trucks are operated from remote control centers managing dispatching, safety, and performance in real time. Value shifts from physical assets to digital capabilities — algorithms, networks, and remote expertise — allowing suppliers to charge on a consumption basis (truck-hours, tonnage, licensing fees). Mines no longer buy assets; they purchase guaranteed outcomes such as productivity, reliability, and safety — a textbook case of digital servitization. This shift carries a risk of value delocalization, as the high-value digital components tend to be located — and taxed — elsewhere.

## Standard Approach to Curb Profit Shifting

To face aggressive tax planning, governments and international organizations have developed a broad toolkit to curb profit shifting in extractives. A noteworthy—and relatively straightforward—instrument is the so-called sixth method, which determines the transfer price of mineral exports based on publicly quoted benchmark prices rather than internal contract terms between related entities (IGF, 2022).<sup>9</sup> This approach mitigates the risk of transfer pricing manipulation through undervaluation and the corresponding systematic erosion of reported mining turnover and profitability, thereby protecting revenues from both royalties and CIT. Several countries have adopted reference pricing systems for key minerals—such as copper, gold, bauxite, and iron ore—anchored in publicly quoted market benchmarks (OECD, 2017b; IGF–OECD, 2020). These rules standardize quotation periods and penalty adjustments, thereby limiting manipulation of concentrate values.

Many countries have strengthened corporate transfer pricing rules following OECD/G20 BEPS guidelines. Actions 8–10 emphasize the delineation of actual economic functions and control over risk, while Action 13 introduces Country-by-Country Reporting and transfer pricing documentation. Complementary interest limitation rules—such as earnings-stripping rules and thin-capitalization ratios—reduce the scope for debt shifting (OECD, 2015). In parallel, new treaty anti-abuse provisions, including principal purpose tests and limitation-on-benefits clauses, help constrain treaty shopping and the misuse of conduit jurisdictions.

Withholding taxes on dividends, interest, and technical services help protect the CIT base but are constrained by DTAs, which allocate taxing rights between residence and source countries.<sup>10</sup> Many African countries face treaty-based revenue losses due to reduced withholding rates and limited negotiation capacity (Hearson, 2018, Feng, et al., 2024<sup>11</sup>). Beer and Loeprick (2021) establish empirically a negative effect of DTAs for African countries. The latter did not trigger any additional Foreign Direct Investment (FDI) in these countries, but

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<sup>9</sup> The sixth method—initially developed in Argentina—has gained broader international recognition, notably following its application in high-profile disputes such as the Mopani–Glencore case in Zambia.

<sup>10</sup> In line with the standard terminology in international taxation, we define the residence country as the jurisdiction in which the owner of capital is tax-resident, and the source country as the jurisdiction in which that capital is invested and generates income. Consequently, the residence country is the capital-exporting country, while the source country is the capital-importing one.

<sup>11</sup> Feng, et al. (2024) measures treaty imbalances between capital-exporting and capital-importing countries by building a source tax index, an aggregate indicator that measures the degree to which a tax treaty preserves the source country's right to tax cross-border income.

induced revenue losses (around 5 percent for CIT on average and even 15 percent for countries having a DTA with Mauritius).<sup>12</sup>

A mining-specific tax avoidance mechanism involves the strategic misallocation of costs across projects at varying development phases. Exploration expenditures incurred at prospective or pre-production sites may be improperly charged against the taxable profits of established, income-generating mines. To counter this practice, certain resource-rich countries have enacted ring-fencing rules requiring that each mining license, concession, or project maintain separate tax accounts, thereby precluding the consolidation of losses and expenses across operations.

Despite these advances, implementation challenges remain acute. Many resource-rich developing countries continue to face information and expertise asymmetries vis-à-vis large multinational operators. The complex valuation of mineral concentrates, limited access to international price data, and difficulties in auditing hedging and marketing arrangements constrain enforcement capacity. As a result, even well-designed fiscal regimes risk failing to capture economic rents if profit-shifting practices persist.

### **3. Taxation of Critical Minerals: Structural Shifts and the Chinese Experience**

#### **Particularities of Critical Minerals**

All minerals and more broadly commodities can be critical. The notion of criticality is not new. It was already present in the seventeenth century with saltpeter (potassium nitrate), indispensable for gunpowder—and thus for warfare—and imported on a large scale from India. To administer this strategic resource, the Council of Namur in the Spanish Netherlands adopted a Placard (ordinance) on saltpeter as early as 1627, and England enacted the Gunpowder Act in 1640. Over subsequent centuries, other resources came to be regarded as strategic or “critical,” such as hemp and flax for eighteenth-century navies, and guano and Chilean nitrates for nineteenth-century agriculture.

Recent exogenous shocks—including the COVID-19 pandemic, renewed interstate conflicts, and unilateral policies such as Chinese export controls in some minerals—have fractured just-in-time global value chains revealing the vulnerability of some economic sectors and even some

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<sup>12</sup> Rwanda (in 2013), Senegal and Zambia (in 2021) terminated their DTA with Mauritius (see Erokhin, 2024).

national economies. Several countries (United States,<sup>13</sup> EU Commission,<sup>14</sup> Japan,<sup>15</sup> China<sup>16</sup> ...) have developed their own methodology to establish a list of critical minerals. Their respective definitions may differ slightly but they converge in assessing the risk of potential minerals' supply shortages and their consequences for their national economy.

Critical mineral lists encompass a wide range of materials whose modes of production and commercialization differ substantially (see Table 1). Some, such as aluminum, copper, or nickel, are conventional industrial minerals produced almost exclusively through large-scale operations and traded with well-established global benchmark prices, for example on the London Metal Exchange (LME). Others—such as bismuth, gallium, germanium, hafnium or niobium—are predominantly by-products of others minerals' industrial processing and lack transparent or universally recognized world market prices. Finally, certain critical minerals, including cobalt and tantalum, are also extracted through artisanal and small-scale mining, which introduces additional variability in production conditions, supply reliability, and market behavior.

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<sup>13</sup> Under the Energy Act of 2020, a mineral is critical if it is essential to economic or national security, faces a vulnerable supply chain, and lacks adequate substitutes.

<sup>14</sup> The European Union methodology defines criticality along two dimensions: economic importance and supply risk.

<sup>15</sup> Japan establishes a list of critical minerals with priority placed on battery inputs and rare earths central to automotive, energy, and electronics value chains.

<sup>16</sup> On 30 November 2023, China's Ministry of National Security defined critical minerals as irreplaceable metals and mineral deposits used in advanced industries—such as new energy, information technology, AI, biotechnology, equipment manufacturing, national defense, and military sectors.

**Table 1. Critical minerals, production (type and geographical distribution), prices, and values**

Critical material	Artisanal vs industrial production	By-product	Main product (if by-product)	Top producer (country)	Share of Top Producer (%)	World reference price	If not LME, which agencies	Indicative price (2025)	Annual traded value (bn USD)
<b>Aluminum (bauxite)</b>	Industrial	No	–	China	35	LME	–	2,200–2,400 USD/t	160–190
<b>Antimony</b>	ASM + industrial	Yes	Gold / Lead	China	55–60	No	Asian Metal	12–14k USD/t	1–2
<b>Arsenic</b>	Mostly by-product	Yes	Cu/Pb/Zn	China	65	No	Asian Metal	Highly variable	<0.1
<b>Baryte</b>	Industrial	No	–	China	30–35	No	Fastmarkets	150–200 USD/t	2–3
<b>Beryllium</b>	Industrial	No	–	USA	60–65	No	Fastmarkets	800–900 USD/kg	0.3–0.4
<b>Bismuth</b>	By-product	Yes	Lead / Copper	China	70–75	No	Asian Metal, Fastmarkets	10–13 USD/lb	0.4–0.6
<b>Boron</b>	Industrial	No	–	Turkey	60–70	No	Fastmarkets	700–900 USD/t	2–3
<b>Cobalt</b>	ASM + industrial	Yes	Copper / Nickel	DRC	~70	LME	–	~50,000 USD/t	9–12
<b>Copper</b>	ASM + industrial	No	–	Chile	~27	LME	–	~11,000 USD/t	250–280
<b>Fluorspar</b>	Industrial	No	–	China	55–60	No	Fastmarkets	350–450 USD/t	3–4
<b>Gallium</b>	By-product	Yes	Bauxite / Zinc	China	80–90	No	Asian Metal, Fastmarkets	350–450 USD/kg	0.1–0.2
<b>Germanium</b>	By-product	Yes	Zinc	China	60–70	No	Asian Metal, Fastmarkets	1,300–1,400 USD/kg	0.3–0.4
<b>Natural graphite</b>	Industrial + minor ASM	No	–	China	65–70	No	Fastmarkets, Benchmark	1,300–2,000 USD/t	3–5
<b>Hafnium</b>	By-product	Yes	Zirconium	France / USA	60–70	No	Fastmarkets	1,000–1,200 USD/kg	<0.1
<b>Helium</b>	Industrial	Yes	Natural gas	USA	~50	No	Argus, Platts	7–10 USD/m <sup>3</sup>	1–2
<b>Lithium</b>	Mainly industrial; some ASM	No	–	Australia	50–55	No (index-based)	Benchmark, Fastmarkets	10–13k USD/t	45–60
<b>Magnesium (metal)</b>	Industrial	No	–	China	85–90	No	Asian Metal	3,000–3,500 USD/t	5–7
<b>Manganese</b>	Industrial	No	–	South Africa	25–30	No	Fastmarkets, Argus	~800 USD/t (battery sulfate)	30–35
<b>Nickel</b>	Industrial	No	–	Indonesia	~50	LME	–	14–15k USD/t	55–65
<b>Niobium</b>	Industrial	Yes	Iron	Brazil	~90	No	Fastmarkets, Argus	45–55 USD/kg	3–4
<b>Platinum Group Metals</b>	Industrial	Partial	Nickel / Chrome	South Africa	70–75	No	LBMA, Johnson Matthey	Pt ≈ 1,000 USD/oz	30–35
<b>Phosphate rock</b>	Industrial	No	–	China	30–35	No	Fastmarkets	150–200 USD/t	12–15
<b>Silicon metal</b>	Industrial	No	–	China	60–70	No	Asian Metal, Fastmarkets	2,000–2,500 USD/t	15–20
<b>Tantalum</b>	Very high ASM	Yes	Tin	No country	–	No	Asian Metal, Fastmarkets	>150 USD/kg Ta <sub>2</sub> O <sub>5</sub>	0.3–0.4
<b>Rare Earth Elements (REE)</b>	Industrial; ASM historically	Often	Iron / Phosphates	China	80–83	No	Asian Metal, Fastmarkets	Nd–Pr oxide = M USD/t	10–15
<b>Tungsten</b>	ASM + industrial	Partial	Tin	China	80–83	No	Asian Metal, Fastmarkets	600–700 USD/mtu APT	2–3

ASM: Artisanal and Small-Scale Mining

LME: London Metal Exchange

Source: International Energy Association (2023); USGS (2025).

Given their multiple forms of production and commercialization, there is not a single tax system for all critical minerals. However, we may emphasize several common characteristics. First, the criticality of minerals arises directly from underlying market failures and the associated risk of supply shortages. In theory, competitive markets equilibrate supply and demand through the price mechanism, ensuring efficient allocation. In practice, however, this mechanism may fail when production is highly concentrated in a small number of countries—most prominently

China—within an increasingly fragmented geopolitical and economic environment. Extensive empirical works show that such concentration substantially heightens supply risk for many minerals essential to modern technologies (Graedel et al., 2015; Nassar et al., 2020). These vulnerabilities are further compounded by the lack of transparent, globally accepted benchmark prices for many critical minerals and the reliance instead on privately reported assessments that often diverge across agencies<sup>17</sup> (IEA, 2023). The coexistence of multiple price references limits the capacity of prices to signal scarcity or incentivize timely investment. As a result, the criticality of minerals reflects not only geological or geopolitical constraints but also systemic imperfections in market functioning.

Second, markets for critical minerals are overwhelmingly demand-driven: their offtake is closely linked to the pace of the energy and digital transitions, as well as to potential shifts in underlying technologies. Demand can therefore expand rapidly in response to technological adoption curves, policy incentives, or innovation in low-carbon technologies (Graedel et al., 2015). By contrast, supply tends to be far more rigid, requiring long lead times, high capital expenditure, and significant regulatory and social approvals before new production capacity can come online (Nassar et al., 2020). This structural imbalance—between a sluggish supply response and highly dynamic demand—is further exacerbated by the by-product nature of many critical minerals. For metals such as cobalt, germanium, gallium, or rare earths, production is tied not to their own market fundamentals but to the extraction and processing trends of major host metals such as copper, zinc, or bauxite (Nassar, Graedel and Harper, 2015).

Where economic rents exist in critical mineral chains—despite opacity in pricing and costs, particularly for by-products—they concentrate in midstream processing rather than extraction. Table 2 shows this structural shift: energy commodities (oil, coal) capture value upstream, while critical minerals generate surplus in refining and chemical conversion, where scale, technology, and regulation form barriers. This reflects broader value chain restructuring toward firms controlling technological upgrading and intangible assets (Antràs, 2020). Digital servitization and processing IP further concentrate value in transforming concentrates into battery-grade

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<sup>17</sup> Private agencies such as Fastmarkets, Benchmark Mineral Intelligence, and Asian Metal publish reference prices for critical minerals, yet their assessments may diverge by 10 to 30 percent for materials like lithium, graphite, or rare earths due to differing purity specifications, geographic baselines, and access to transaction data.

materials,<sup>18</sup> consistent with evidence that intangibles drive market power (De Loecker and Eeckhout, 2017).

**Table 2. Value-Added Allocation by Stage (Exploration, Extraction, Refining) and Key Producing Countries**

Mineral / commodity	Value Added Share			Main extraction countries (recent)	Main refining / processing countries
	Exploration	Extraction	Smelting / refining / chemical conversion		
<b>Non critical resource</b>					
<b>Iron ore</b>	1–2%	25–45%	10–25%	Australia, Brazil, China, India	China, India, Japan
<b>Crude oil</b>	3–8%	60–85% ( <i>upstream lifting+transport</i> )	10–25% ( <i>refining margin/throughput</i> )	United States, Saudi Arabia, Russian	United States, China, India
<b>Coal</b>	1–2%	70–90%	5–20% ( <i>washing/coking</i> )	China, India, Indonesia	China, India, Japan
<b>Critical minerals</b>					
<b>Cobalt</b>	1–4%	15–30%	35–60%	DR Congo, Indonesia, Russia	China (dominant), DR Congo/Indonesia intermediates
<b>Lithium</b>	1–4%	10–25%	40–70%	Australia, Chile, China	China (major converter), plus Chile/Argentina (brine chemicals)
<b>Nickel</b>	1–3%	15–30%	30–55%	Indonesia, Philippines, Russia	Indonesia & China (major class-2 refining and intermediates)
<b>Copper</b>	1–3%	20–35%	25–45%	Chile, DR Congo, Peru	China, DR Congo, Chile
<b>Natural graphite</b>	1–3%	10–25%	40–70% ( <i>battery-grade shaping/coating</i> )	China, Madagascar, Mozambique	China
<b>Rare earth elements</b>	1–4%	10–25%	45–75% ( <i>separation is the bottleneck</i> )	China, Australia, Myanmar	China

Source: International Energy Association (2025); U.S. Geological Survey (2025); UN DESA (2025); World Bank (2023).

China's industrial strategy has systematically capitalized on this value chain reconfiguration by amassing both refining infrastructure and processing IP—segments exhibiting markedly greater geographic concentration than upstream mining.<sup>19</sup> Through this dual consolidation, China has secured a dominant position in critical mineral rent extraction (cf. Table 1). Rare earths demonstrate this dynamic most clearly: although China produces roughly 60 percent of mined output (2024), it controls 91 percent of separation or refining and 94 percent of permanent magnet manufacturing—establishing market power at precisely the stages generating maximum margins and presenting the most important entry barriers.

To sum up, in the case of critical minerals, the locus of rent generation shifts from the pit—where extraction occurs—to the plant, where processing and refining take place. Coupled with the rise of digital servitization and IP rights, this transformation also entails a shift from tangible assets, such as mining equipment and deposits, toward intangible assets, notably patents and

<sup>18</sup> In lithium, proprietary extraction or crystallization IP yields higher margins than concentrate sales.

<sup>19</sup> This outcome is aligned with theories of global production networks and market power in vertically fragmented industries (Grossman and Helpman, 2002; Antràs and Chor, 2013)

proprietary technologies for processing and refining. These evolutions and specificities of critical minerals increase significantly the risk of profit shifting with regards to standard mining sector.

### **Insights from China's Tax System in the Extractive Sector**

Given China's central role, its extractive sector tax regime warrants particular examination. Taxation, however, represents only one instrument within a broader policy architecture encompassing industrial policy, export controls, and supply agreements —whose comprehensive analysis exceeds this paper's scope.

Following the 1994 fiscal reform, the government introduced provisional resource-tax rules (per ton or per unit). In parallel, a mineral resources compensation fee operated alongside a variety of local taxes, resulting in considerable administrative complexity and overlapping burdens. Subsequent reforms progressively modernized China's mining tax regime. First, the system transitioned from *ad quantum* (specific) taxation toward *ad valorem* taxation, thereby enhancing price sensitivity and improving the neutrality of the fiscal framework. Second, many ad hoc resource-related fees imposed by local authorities were abolished. This consolidation process culminated in the adoption of the Resource Tax Law in 2019–2020, which codified a unified nationwide resource tax covering crude oil, natural gas, coal, metallic and non-metallic minerals, and salt. The law also granted provincial governments the authority to select tax rates within centrally defined bands, adding a degree of decentralization to fiscal design. A further revision of the Mineral Resources Law in July 2025 reinforced the State's strategic oversight of stockpiling and critical mineral management, including the use of tax incentives and differentiated rates. Complementing these developments, the Environmental Protection Tax Law, enacted in 2018, replaced pollutant discharge fees with a tax regime for mining and processing facilities with significant emissions.

In addition to sector-specific taxes, mining enterprises in China are subject to national taxes such as CIT and VAT. The standard CIT rate is 25 percent and applies to the global income of resident firms. However, preferential treatments exist, including a reduced rate of 15 percent and temporary exemptions for up to five years, primarily aimed at stimulating innovation and promoting industrial upgrading.

As the world's second-largest economy, the largest global trader in goods, and one of the leading sources and recipients of FDI, China is also exposed to international tax planning practices that erode its CIT base. Using firm-level data, Ma et al. (2025) examines the extent of profit shifting by Chinese and foreign MNEs. The authors highlight several country-specific features that differentiate China from advanced economies such as the United States and EU members. First, since the 2008 tax reform, the statutory CIT rate in China has remained relatively low, and a range of preferential tax regimes—particularly in Special Economic Zones—has created opportunities for internal profit shifting toward lower-taxed affiliates. Second, transfer pricing enforcement remains less developed than in many OECD jurisdictions, contributing to base erosion. Third, Hong Kong plays a unique role as both a major source of FDI into China (accounting for 40 to 60 percent of total inflows) and as a conduit for round-tripping strategies, whereby Chinese firms cycle capital offshore and reinvest it domestically to benefit from incentives (Luo et al., 2022).

Ma et al. (2025) estimates that annual CIT revenue losses due to profit shifting amount to approximately 3 percent of total CIT receipts during 2000–2013. Following a macroeconomic approach, Tørsløv et al. (2022) arrives at a close figure of 4 percent for 2015. While these estimates are not negligible, they are notably lower than those reported for other advanced and emerging economies—such as 18 percent in high-tax European countries, 14 percent in the United States, 9 percent in India and Brazil, and 6 percent in South Africa (see Tørsløv et al., 2022).

China has not been a simple rule-taker of the Western led regulations of international taxation (see Christensen and Hearson, 2022). Avi-Yonah and Xu (2018) describe the active role of China in developing OECD BEPS tools and their rapid implementation in the country. Historically a capital-importer, China has pushed for greater taxing rights for source jurisdictions. Following the UN Model, Chinese DTAs have higher withholding tax ceilings, broader permanent establishment definitions including services' provision, and wider capital gains taxing right for the source (see Li, 2010). As China became a net capital exporter and home to major digital firms, its preferences diversified—but its diplomacy in the BEPS Framework remains geared to re-balancing taxing rights toward market jurisdictions.

Besides CIT and taxable base protection, the Chinese VAT system<sup>20</sup> offers another salient illustration of a hybrid solution serving both revenue and development objectives. China deviates from the full destination principle.<sup>21</sup> Since introducing VAT in 1994 at 17 percent, China has adjusted refund policies to advance fiscal and industrial goals.<sup>22</sup> From 1996, refunds on certain exports were limited: only 3, 6, or 9 percent of input VAT is refunded, by product type, generating implicit export tax.<sup>23</sup>

The selective application of export VAT refunds thus operates as a hybrid mechanism situated between destination-based and origin-based taxation, enabling China to retain a portion of tax revenue on exported goods while stimulating and steering industrial upgrading. In December 2024, for instance, the government eliminated VAT refunds entirely for copper and aluminum exports and reduced refund rates from 13 to 9 percent for batteries, photovoltaic products, and certain mineral inputs. Though these measures explicitly increase effective taxation on raw material exporters —eroding their competitiveness in international markets — they simultaneously establish implicit incentives (without tax expenditures) favoring domestic processing and industrial transformation, since finished goods incorporating these inputs retain eligibility for full VAT refund treatment.

In this way, China’s tax policy—through both CIT and VAT instruments—serves a dual function: protecting tax revenues and increasing the domestic value added embodied in exports. By selectively departing from the strict application of international norms such as the residence and destination principles, China has developed a hybrid framework that enables it to capture a larger share of the rent generated by critical minerals, while simultaneously reinforcing its strategic position in global value chains.

### **Policy Implications for Critical Mineral-Rich Economies**

Given the structural particularities of critical minerals and the illustrative case of China, critical minerals-rich countries may consider a range of tax policy reforms aimed at enhancing rent

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<sup>20</sup> China operates the world largest VAT, given its absence in the United States.

<sup>21</sup> The destination principle taxes goods and services where consumed, requiring zero rated exports and full input VAT refunds.

<sup>22</sup> China’s VAT export rebate approach has mainly drawn attention for trade implications (see Chandra and Long, 2013; Chor and Manova, 2012).

<sup>23</sup> This implicit export tax applies to production costs, not export values. The mechanism originated in 1980s’ turnover taxes (Chandra and Long, 2013). Rebate rates increased during the 1998 Asian financial crisis (reaching 5, 13, 15, and 17 percent), fell in 2004, rose after the 2008 global financial crisis, were simplified in 2012, and adjusted in 2018 with VAT rate cuts (from 17 percent to 13 percent).

capture and protecting their tax bases—especially CIT revenues vulnerable to profit shifting. As the locus of value creation for these minerals shifts—from the mine to the processing plant, and from tangible assets to intangible ones—the relevance of the OECD/G20 Inclusive Framework on BEPS, with its 15 Action Plans, becomes even more pronounced in this sector than in conventional mining. In particular, robust transfer pricing rules and reliable reference pricing mechanisms are essential to prevent the mispricing of mineral exports. Instruments such as interest deduction limitations (Action 4) and anti-abuse provisions targeting treaty shopping (Action 6) serve to safeguard source-country revenues from erosion via excessive debt loading and the use of conduit jurisdictions.

Following China's precedent, critical mineral-rich developing countries can also strengthen their fiscal position by reinforcing their taxing rights and pursuing DTA renegotiation. The strategic value of critical minerals in global supply chains provides them with leverage in treaty negotiations with capital-exporting partners. Importantly, this bargaining advantage can be magnified through regional cooperation: since multiple producing countries negotiate with the same multinational enterprises, coordinated approaches prevent companies from playing jurisdictions against one another and enable collective demands for fairer revenue-sharing arrangements.

Several critical minerals—including aluminum, cobalt, copper, and nickel—are actively traded on the LME, producing transparent and verifiable benchmark quotations. The existence of such market-based reference prices substantially enhances the applicability of the sixth method discussed earlier for transfer pricing validation and enforcement. Nonetheless, this mechanism offers limited utility for critical minerals that lack liquid trading platforms or widely accepted pricing indices (see Table 1).

For critical minerals produced mainly as by-products (arsenic, bismuth, gallium), ring-fencing provides a practical method to estimate and protect their taxable profitability. Ring-fencing at the license level may prevent profit-and-loss consolidation across activities—not only between exploration and extraction but also across product types—directly addressing the core challenge of allocating shared costs and revenues in integrated operations (OECD, 2025). Once ring-fenced, the split-off point methodology values each output at a consistent stage: using comparable uncontrolled prices (CUP) where market quotes exist, or residual pricing for products not traded at mine gate (World Bank, 2013; OECD, 2023; IGF, 2022). Joint costs can be allocated via methods such as net realizable value or relative sales value at split-off,

producing auditable by-product profit estimates testable through sensitivity analysis (Deevski, 2016; Valero, Valero and Calvo, 2015).

China's VAT architecture for cross-border mineral transactions offers three strategic advantages to producing countries. First, it enables partial taxation of mineral-embedded value, albeit by elevating production costs and reducing exporter profitability. This functions as a complementary—though potentially distortionary—instrument for taxing multinational profits. Second, it incentivizes domestic processing without revenue loss: exclusive provision of full VAT refunds to refined exports (while denying refunds on concentrates) creates costless implicit subsidies for local value-adding transformation. Third, it addresses structural inequities in global value-added taxation. Copper supply chains exemplify this imbalance: Chile, Peru, and the DRC provide complete input VAT refunds to exporters. Chinese refiners are subject to VAT at the border upon importation of copper. No VAT refund is available when they export their production directly — whether in the form of concentrates or anodes.<sup>24</sup> Where production is sold domestically, however, they may collect VAT and remit the net amount between VAT collected and input VAT deductible. Downstream firms that process these intermediate copper goods and export their output are entitled to a full refund of their accumulated VAT credits. This configuration penalizes explicitly the exports of intermediate goods while rewarding high-value-added manufactured products—aligning with China's industrial strategy of maximizing export sophistication.<sup>25</sup>

State capacity constraints are not a side issue but a first-order determinant of what constitutes "good" tax policy in critical minerals. In many smaller emerging markets and developing economies, the binding constraint is not the statutory design of the fiscal regime, but rather the ability to administer and defend the tax base under intense bargaining pressure, limited information, and highly sophisticated corporate structures. In such settings, a pragmatic strategy is to combine (a) a simple, enforceable revenue backstop—for instance, a well-calibrated ad valorem royalty or a minimum-tax element—with (b) a targeted CIT enforcement agenda that concentrates scarce audit capacity on a few high-risk areas: export pricing of mineral products, intra-group service and management fees (including CAPEX-to-OPEX servitization contracts), and debt-related deductions. The principle is to shift from a comprehensive-but-unenforceable approach to a risk-based compliance model that prioritizes transactions with the highest

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<sup>24</sup> These products fall under Harmonized System (HS) codes 7401, 7402, 7403, and 7404.

<sup>25</sup> Notably, if Chile, Peru, or the DRC chose to withhold VAT refunds from their exporters to China, they could legitimately characterize this as implementing a Chinese-style VAT system—effectively turning China's own policy logic against it to retain a greater share of value-chain taxation.

expected revenue impact and the greatest scope for mispricing, consistent with practical guidance on administering extractive fiscal regimes.

Regional cooperation may complement the previous approach by offering an underexploited avenue for mutualizing administrative capacity in critical-mineral taxation. Because many producing countries face similar counterparties, contract structures, and pricing challenges, there are potentially high returns to pooling scarce expertise: regional centers of excellence for extractives auditing; shared databases on mineral export terms and benchmark adjustments; coordinated training and secondments; and, where legal frameworks allow, forms of coordinated or joint audits for cross-border groups. Regional tax organizations can also disseminate operational tools that make enforcement more realistic, such as structured transfer-pricing risk assessment frameworks tailored to mining-related transactions (Readhead et al. 2023). International organizations can complement these efforts by reducing duplication and lowering the fixed costs of reform through standardized toolkits, guidance, and capacity development.

#### **4. Conclusion**

Critical minerals have rapidly emerged as the focal point of a 21st-century resource boom, with governments around the world striving to secure supply chains essential to the clean energy transition, digital infrastructure, defense, and aerospace technologies, advanced manufacturing, telecommunications, and medical applications. This paper has examined the fiscal challenges and opportunities presented by critical minerals in the context of global value chain reconfiguration and increasing geopolitical competition.

We began by reviewing the tax architecture of the standard mining sector, including its core instruments—namely CIT and mining royalties—as well as the principal risks to the tax bases, such as production underreporting, thin capitalization, transfer pricing abuses, and the growing influence of digital servitization. We then surveyed a set of policy responses aimed at mitigating tax base erosion, including project-level reference pricing mechanisms and anti-abuse provisions embedded domestic legislation.

We turned then to the specificities of critical minerals, emphasizing the downstream relocation of resource rents to processing and refining stages. The combination of absent spot markets, the by-product nature for many minerals, and the rising importance of intangible assets—proprietary technologies and intellectual property—complicates tax administration and erodes

resource-rich countries' capacity to capture equitable rent shares. In light of China's pivotal role in the global critical minerals supply chain, we examined its evolving tax regime in the extractive industries. China has developed a strategic and distinctive tax framework—what Li (2012) evocatively terms a “Great Fiscal Wall”—that selectively integrates features of Western tax systems, including OECD-aligned anti-BEPS instruments, while adapting them to serve its own industrial policy and geopolitical ambitions.

We have outlined a number of fiscal policy options for critical mineral-rich economies. Among these, the adoption of the OECD/G20 Inclusive Framework on BEPS remains fundamental to protect the CIT base. The use of the “sixth method”, which anchors production pricing to observable international benchmarks when available, could be relevant for certain critical minerals. For those produced predominantly as by-products, ring-fencing provisions provide a complementary mechanism to isolate and estimate attributable profits, preventing their dilution through consolidation with primary product revenues. China's hybrid VAT system, which selectively withholds export refunds on unprocessed minerals, offers another policy option worthy of consideration. Such an approach, which departs from the strict application of the destination principle advocated by international institutions (OECD, IMF ...), could allow resource-rich countries to capture a greater share of the value added along the mineral value chain while simultaneously promoting domestic processing and refining. We also emphasize that the binding constraint in many critical mineral-rich countries is not tax regime design but rather its effective implementation, and a pragmatic approach should combine simple enforceable revenue backstops with targeted enforcement on high-risk transactions. Regional cooperation can mutualize these scarce administrative capacities through shared expertise, databases, and coordinated audits supported by international organizations.

Finally, taxation is not the only instrument for sharing resource rents. If taxes are powerful, decentralized tools, their effectiveness depends on the presence of relatively competitive markets and moderate uncertainty. However, the critical minerals market is highly uncertain. In addition to the geological and technological risks inherent to mining, the sector faces acute geopolitical pressures: demand is rising in Western economies, while supply chains remain heavily concentrated in China. This imbalance defines the criticality of minerals and increases the risk of strategic disruptions and price volatility. In this context, alternative mechanisms for rent sharing, such as production-sharing contracts (widely used in the oil sector) and broader forms of contractualization (e.g. long-term offtake agreements, strategic partnerships...) between resource producers and buyers, are gaining relevance.

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**Pascal**

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