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CENTRE FOR A **People-centric Energy Transition**

Optimizing India's Critical Mineral Import Portfolio: A Forward-Looking Mineral-Wise Assessment of Global Sourcing Partners

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Executive Summary

This report examines how India can optimize its economy-wide import portfolio for critical minerals using a model-based assessment approach of potential sourcing partners. Using a country-mineral-year dataset covering 2019-2023, the analysis distinguishes between three import categories, ores and concentrates, processed mineral products, and waste and scrap. This disaggregation is central to the study, as the determinants of competitiveness differ substantially across these categories. To identify historically relevant sourcing determinants, separate Poisson Pseudo Maximum Likelihood (PPML) models are estimated for ores, products, and scrap. These models relate India's import quantities to supplier-country characteristics such as mineral production, macroeconomic scale, governance quality, infrastructure, energy structure, and trade flows. The estimated relationships are then used to generate model-implied import quantities, which serve as the basis for ranking countries within each mineral. These rankings are interpreted as indicators of sourcing attractiveness rather than exact trade forecasts. A forward-looking partner ranking is then constructed by applying the estimated models to recent average country-level characteristics, thereby identifying mineral-wise supplier countries that appear structurally well positioned for future trade partnerships. The findings show that India's optimal import portfolio is highly mineral-specific and differs sharply across ores, products, and scrap. In the ores category, the rankings are strongly shaped by mineral endowment (or, production capacity), with countries such as Australia, Canada, Chile, the United States, China, and the Democratic Republic of the Congo emerging repeatedly across minerals. This suggests that the ores portfolio remains closely tied to the geography of natural resource availability. In the products category, however, the rankings shift toward countries associated with processing capability and downstream industrial integration, with China occupying a central position across many minerals and countries such as Belgium, Estonia, Japan, South Korea, and the United Kingdom also appearing prominently. The products portfolio therefore reflects the importance of refining, transformation, and manufacturing networks rather than extraction alone. In the scrap category, the portfolio is more concentrated and network-driven, dominated by Russia and China along with several West Asian trade hubs and industrial economies. This indicates that waste and scrap trade follows a different logic, linked more closely to recycling systems, industrial throughput, and secondary-material circulation than to raw mineral production. A key implication of the analysis is that India's future sourcing strategy cannot rely on a single generalized list of partner countries. Instead, it must be designed on a mineral-wise and category-specific basis. Some minerals display relatively broad sets of potential suppliers, creating scope for diversification and resilience-building. Others remain structurally concentrated, limiting diversification options and making long-term strategic engagement with a narrower set of countries more important. The study therefore highlights three broad policy directions - first, consolidating relations with a core group of recurrent high-ranking partners; second, widening engagement with underutilised but structurally attractive suppliers; and third, tailoring sourcing strategy by import category, since ores, products, and scrap each follow distinct global trade logics.

Chapter 1: Introduction

The accelerating global transition toward low-carbon energy systems, digital infrastructure, and advanced manufacturing has fundamentally reshaped the importance of critical minerals in the global economy. Minerals such as lithium, cobalt, nickel, copper, and rare earth elements have become indispensable inputs in clean energy technologies, across solar PV, CSP, on-shore and off-shore wind, electrolysers, electric vehicles, and battery storage. According to the International Energy Agency (2025), demand for key energy transition minerals has grown rapidly in recent years, with lithium demand increasing by nearly 30% in 2024 alone, while several other minerals such as nickel, cobalt, and graphite have also experienced sustained growth. According to a recent NITI Aayog report (NITI Aayog, 2026), under India's Net-Zero Scenario, in clean energy technologies, copper and graphite are projected to have the highest cumulative demand, approximately 66 Mt and 46.6 Mt respectively. Such surge in demand has been accompanied by increasing concerns regarding supply security, market concentration, and geopolitical vulnerability. Critical mineral supply chains are characterized by a high degree of geographic concentration, both in extraction and processing stages. Recent evidence suggests that the majority of refined production for several minerals is concentrated among a few countries, exhibiting dominant average market shares (IEA, 2025). This concentration has intensified risks associated with supply disruptions, export restrictions, and price volatility, thereby elevating critical minerals from a purely economic concern to a strategic and geopolitical priority.

For a rapidly growing economy such as India, the implications of these developments are particularly significant. India's ambitions in clean energy deployment, electric mobility, and industrial expansion are expected to substantially increase its demand for critical minerals. However, the country remains highly import-dependent for most of these minerals (Ministry of Mines, 2023), particularly in processed and high-value forms. Emerging academic work highlights that India's dependence on imports for several critical minerals, especially rare earth elements, poses a significant constraint on its long-term energy security and technological sovereignty (Kumar & Bhattacharyya, 2025). In response, policymakers, with the goal of Viksit Bharat by 2047 (Viksit India, n.d.) and Net Zero Economy by 2070 (PIB, 2023), have increasingly emphasized the need to secure resilient and diversified supply chains. Reports and policy discussions stress that diversification of supply sources, strategic partnerships, and the development of alternative supply streams such as recycling are essential to mitigate risks associated with concentrated supply chains (IEA, 2022). However, much of the existing policy discourse remains focused on broad strategies rather than granular, data-driven assessments of optimal sourcing patterns (Wang & Cheng, 2025).

A key limitation in existing analyses of critical mineral trade is their reliance on observed trade patterns, which may not necessarily reflect optimal or efficient sourcing strategies. Trade relationships are often shaped by historical linkages, logistical constraints, pricing dynamics, and short-term considerations, which may result in suboptimal import portfolios that increase systemic risk exposure (Bhamra et al., 2025; Dou et al., 2023). This raises a critical research question that *are India's current import patterns of critical minerals aligned with an optimal, risk-minimizing sourcing strategy?*

To address these gaps, this study develops a counterfactual framework[1] to evaluate India's import portfolio of critical minerals over the period 2019-2023. The analysis begins by explicitly disaggregating India's economy-wide import quantity of critical minerals over the period of 2019-2023 into three categories - ores and concentrates, processed mineral products, and scrap. These variables are treated as distinct analytical categories. This distinction is critical, as the determinants of supply competitiveness differ substantially across these categories. Aggregating them would obscure structural differences in production, processing capability, and secondary resource availability. Building on this disaggregation, the study employs a Poisson Pseudo Maximum Likelihood (PPML) gravity framework, widely used in trade analysis, to estimate the determinants of India's historical import patterns. The model relates India's import quantities for each mineral-category-country-year observation to a set of country-level characteristics, including production capacity, macroeconomic variables, and other structural factors influencing trade. The estimated model is then used to generate fitted (model-predicted) import quantities for all country-mineral-year combinations. These predicted values form the basis for constructing counterfactual rankings of supplier countries, indicating which countries would emerge as preferred partners under the estimated sourcing relationships. The analysis proceeds by generating annual country rankings for each mineral and category, thereby preserving temporal variation and capturing evolving supply dynamics. These counterfactual rankings are then systematically compared with India's actual import patterns, allowing countries to be classified into three groups:

(i) aligned partners (high in both actual and predicted rankings),
(ii) overrepresented partners (high in actual but low in predicted rankings), and
(iii) underutilized partners (high in predicted but underrepresented in actual imports).

[1] A counterfactual framework is an analytical approach that asks ***what would the outcome have looked like under an alternative but plausible scenario?***
In this study, the counterfactual question is not simply who India imported critical minerals from, but which countries India would likely have imported from if its sourcing had followed the structural determinants identified in the model. The econometric model estimates how country characteristics such as production capacity, governance, and trade frictions are associated with India's imports, and then uses those estimated relationships to generate model-implied import rankings. These rankings represent the counterfactual scenario against which actual sourcing patterns can be compared. In this sense, the counterfactual framework helps identify where India's past import structure aligned with underlying supplier attractiveness and where potentially viable partners may have been underutilised.

To ensure robustness, the study further incorporates a persistence analysis across years, distinguishing structurally competitive suppliers from those driven by short-term fluctuations. Building on this, a forward-looking partner ranking is constructed using averaged recent-period country characteristics, providing a strategic ordering of countries likely to remain attractive under prevailing sourcing dynamics. Finally, these results are synthesized into an optimized import portfolio framework, which evaluates India's sourcing patterns through the lens of diversification, concentration risk, and supply resilience. The outcome is a mineral-wise and category-specific identification of priority partners, underutilized opportunities, and areas where import dependence may warrant strategic reorientation.

1.1. Research Questions

The study addresses the following research questions:

1. What country-level characteristics have historically shaped India's import patterns for critical minerals across ores, products, and scrap categories?
2. Which countries emerge as the most suitable import partners when these relationships are used to construct a counterfactual, model-implied sourcing strategy?
3. What is the degree of deviation of India's actual import patterns from these counterfactual rankings, and how does these deviations vary across different import categories and across the critical minerals?
4. Which countries represent underutilized or overrepresented partners in India's current import portfolio?
5. How can India's import strategy be restructured to enhance diversification, reduce concentration risk, and improve long-term supply security?

1.2. Research Objectives

- To estimate the determinants of India's critical mineral imports using an econometric (PPML) framework.
- To construct counterfactual, model-implied rankings of optimal import partners across ores, products, and scrap categories.

- To compare actual and counterfactual sourcing patterns in order to identify structural inefficiencies and diversification gaps.
- To assess the temporal persistence of supplier attractiveness and distinguish structurally competitive partners from short-term outliers.
- To develop a forward-looking, optimized import portfolio that informs strategic sourcing decisions.

1.3. Contribution of the Study

This study makes four key contributions to the literature and policy discourse.

First, it advances the literature by introducing a counterfactual, econometric approach to import portfolio analysis, moving beyond descriptive trade assessments toward a normative framework grounded in observed data relationships. Second, it incorporates a granular, category-specific analysis by distinguishing between ores, processed products, and scrap, thereby capturing heterogeneity in supply chains that is often overlooked in aggregate studies. Third, the study contributes methodologically by applying PPML to derive model-implied trade flows, enabling the construction of internally consistent country rankings without relying on arbitrary weighting schemes. Fourth, and most importantly, it provides actionable policy insights by identifying underutilized sourcing partners, highlighting concentration risks, and proposing a forward-looking import portfolio aligned with supply characteristics. In doing so, the study bridges the gap between empirical trade analysis and strategic policymaking, offering a robust analytical foundation for strengthening India's critical mineral supply security.

Chapter 2: Data & Methodology

The analytical framework is structured to address two distinct but related questions. The first is counterfactual in nature. Given the factors that historically govern India's import behaviour, which countries represented the most suitable sourcing partners in each year? The second is forward-looking. Which countries exhibit sufficiently persistent attractiveness to warrant inclusion in India's long-term critical mineral sourcing strategy? The workflow therefore proceeds in a logical sequence - from estimating historical sourcing relationships, to generating model-implied rankings, to deriving portfolio-level implications. The variables used in the study, along with their data sources are given in table 1.

Table 1: Variables

Name	Type	Rationale	Source
Production Quantity Data	Independent Variable	Captures the exporting country's physical ability to supply the mineral. Higher production generally indicates greater exportable availability and makes a country a more plausible source for India. Here, "Production" refers to the production of "Mineral Raw Materials", which are mineral constituents of the earth's crust of economic value. This includes the so-called "mine output" as well as the output from processing at or near the mines (for instance, the up-grading of ores to concentrates).	World Mining Data (2025)
Import Quantity of Critical Minerals in Ore & Concentrate form		Captures India's actual sourcing of raw mineral inputs.	UN Comtrade
Import Quantity of Critical Minerals in Product form		Captures India's sourcing of processed mineral goods.	UN Comtrade
Import Quantity of Critical Minerals in Scrap form		Captures sourcing of secondary/recyclable material.	UN Comtrade

Import Value of Critical Minerals in Ore & Concentrate form	Independent Variable	CIF value of Ores	UN Comtrade
Import Value of Critical Minerals in Product form	Independent Variable	CIF value of Products	UN Comtrade
Import Value of Critical Minerals in Scrap form	Independent Variable	CIF value of Scraps	UN Comtrade
Access to electricity (% of population)	Independent Variable	Used as a proxy for the overall level of economic development and infrastructure penetration. It is preferred to total electricity generation because it reflects the breadth of access to reliable infrastructure rather than simply country size.	World Bank Data
Central Govt Debt (% of GDP)	Independent Variable	Captures the fiscal position of the exporting country, which may influence investment, policy stability, and the reliability of long-term supply relationships. A ratio is preferred to absolute debt because it is comparable across countries.	World Bank Data
Electricity from fossil (% of total)	Independent Variable	Included as a proxy for the country's dependence on conventional energy systems. Countries relying more heavily on fossil-based electricity may face weaker domestic transition-related absorption of critical minerals and may therefore be relatively more export-oriented.	World Bank Data
Electricity from renewables (excluding hydropower) (% of total)	Independent Variable	Used to capture the extent of the exporting country's renewable-energy transition. A higher renewable share may be associated with stronger domestic demand for critical minerals, potentially reducing export availability. This variable is used as an indirect proxy, so the expected effect is theoretically plausible but not unambiguous.	World Bank Data
FDI (% of GDP)	Independent Variable	Used as a proxy for the investment climate and degree of integration into global production networks. It is preferred to absolute FDI when the intention is to compare openness across differently sized economies.	World Bank Data
GDP (constant PPP)	Independent Variable	Included to measure the real size of the economy in comparable terms. It serves as a proxy for the country's industrial base and productive capacity. PPP GDP is preferred when real cross-country comparability is important.	World Bank Data
Population (Total)	Independent Variable	Included as a broad structural indicator of country size. Population may influence both production capacity and domestic absorption of minerals.	World Bank Data
Average of World Governance Index	Independent Variable	Captures governance conditions such as regulatory quality, political stability, and institutional effectiveness, all of which influence reliability as a long-term trade partner.	World Bank Data

Whether the exporting country is landlocked (1= yes, 0= No)	Independent Variable	Included to capture whether the exporting country lacks direct sea access, which can raise transit costs, increase dependence on neighbouring transit corridors, and reduce trade efficiency.	(Mayer & Zignago, 2011)
Geographical Distance between exporting country and India	Independent Variable	Included to capture geographic trade cost. Greater distance is expected to increase freight, insurance, delivery time, and coordination costs, making imports less likely. This is an important bilateral variable because sourcing decisions depend not only on supplier characteristics but also on the cost of reaching India.	(Mayer & Zignago, 2011)

Step 1: Disaggregation by Import Categories

The analysis begins by treating the three principal import categories - ores, processed products, and scrap, as distinct variables. This disaggregation is necessary because the determinants of supply competitiveness differ substantially across categories. A country may be an important supplier of raw ore without being competitive in processed products, while another may export scrap with little domestic mining activity. Aggregating across these categories would obscure these structural differences and yield a misleading picture of sourcing potential. Separate exercises are therefore conducted for each category, producing three distinct sourcing maps.

Step 2: Estimation of Historical Import Determinants

For each import category, Poisson Pseudo Maximum Likelihood (PPML) econometric model (Motta, 2019; Dadakas et al., 2020; Prehn et al., 2016; Pfaffermayr, 2020) is estimated in which the dependent variable is India's import quantity (ores/products/scrap) from a given country for a given mineral in a given year. The model is estimated across all country-mineral-year observations and is designed to identify which country-level characteristics are systematically associated with higher Indian imports. These may include productive capacity, economic size, governance quality, geographical distance and energy structure, among other factors. This stage is not concerned with ranking countries directly; rather, it recovers the historical pattern embedded in India's sourcing behaviour, that is, the implicit weights the data assign to various supplier characteristics.

Step 3: Generation of Model-Implied Import Quantities

Once the model has been estimated, it is used to generate fitted import quantities for every country-mineral-year observation. These predicted values constitute the central object of the analysis. A high predicted import value indicates that, under the estimated sourcing strategy, a country presents as a strong candidate for that mineral in that year. This approach has the advantage of being internally consistent with the estimated relationships rather than relying on externally imposed weights.

Step 4: Annual Country Rankings

The predicted import quantities are then used to rank countries within each mineral-year combination. For each combination of mineral and year, countries are ordered from highest to lowest predicted import, yielding a set of counterfactual annual rankings. These rankings reflect which countries the model identifies as the most plausible sourcing partners, conditional on the determinants prevailing in that year. Importantly, conducting this exercise year by year rather than aggregating over a fixed window preserves temporal variation, that is, a country that becomes attractive only in later years is not obscured by earlier periods in which its characteristics were weaker.

Step 5: Comparison with Actual Sourcing Patterns

The model-derived counterfactual rankings are then placed alongside the actual import rankings to generate the core policy insight of the counterfactual exercise. This comparison yields three distinct categories of countries. First, countries that rank highly in both the actual and predicted orderings represent established suppliers whose role is consistent with the estimated sourcing strategy. Second, countries that rank highly in actuality but poorly in the model may reflect import inertia, historical dependencies, or factors not captured by the model's covariates. Third, and most importantly for diversification strategy, countries that rank highly in the model but remain underrepresented in actual imports constitute potential sourcing candidates that India has not yet fully utilised.

Step 6: Assessment of Cross-Year Persistence

Since rankings derived from a single year may be sensitive to idiosyncratic conditions, a persistence analysis is conducted across the full sample period. Countries are assessed on whether they appear consistently within the top ranks across multiple years, whether their attractiveness is concentrated in a particular sub-period, or whether they represent recent entrants into the high-ranked group. This temporal lens distinguishes structurally well-positioned partners from episodic outliers and provides the basis for identifying suppliers with durable comparative advantage.

Step 7: Construction of a Forward-Looking Partner Ranking

Drawing on the persistence analysis, the framework then constructs a forward-looking attractiveness ranking. This is not a strict forecast but rather a strategic preference ordering derived by applying the estimated sourcing model to recent country-level charactersitics. To reduce the influence of year-specific noise, each country's characteristics are averaged over the most recent available period before generating predicted import quantities. The resulting ranking reflects which countries are likely to remain attractive under the assumption that the historical sourcing logic continues to govern India's import behaviour. Countries that rank consistently well in this exercise are identified as priority candidates for future engagement.

Step 8: Optimized Import Portfolio

The ultimate objective of the framework is not to produce country rankings per se, but to derive actionable implications for the structure of India's import portfolio. The rankings from each stage are therefore interpreted through the lens of portfolio risk and diversification. This involves assessing where India's current sourcing is excessively concentrated, identifying minerals for which the pool of viable partners is narrow, flagging high-potential countries that are underutilised relative to their model-implied attractiveness, and distinguishing the optimal partner set for ores, products, and scrap respectively. The output is a mineral-wise sourcing strategy that specifies both where India should consider reorienting existing import relationships and were new partnerships merit priority attention.

Chapter 3: Results & Analysis

3.1. Mineral Intelligence and Decision System (MINDS) Dashboard

A dedicated interactive dashboard has been developed and deployed to complement the analytical framework of this study (Link: https://acpet.thedashboards.in/mineraldashboard/). The primary objective of the dashboard is to facilitate data transparency and usability by presenting country-level and mineral-specific indicators, given in table 1, in a visually coherent format. Rather than engaging with raw datasets, users can interact with structured visualizations that allow for rapid identification of patterns across countries, minerals, and time periods. In this sense, the dashboard functions as a decision-support tool, enabling users to examine key variables underlying India's critical mineral import structure without requiring extensive data processing. More broadly, dashboards are widely recognized as effective tools for consolidating and communicating complex datasets, as they provide an integrated view of multiple indicators in a single interface and support data-driven analysis and interpretation.

Within this study, the dashboard serves two complementary purposes. First, it acts as a descriptive layer, allowing users to visually assess the distribution and variation of key variables, such as import flows and production levels, across countries and over time. Second, it provides an analytical foundation that supports the econometric and counterfactual exercises undertaken in the paper by ensuring that the underlying data is transparent, verifiable, and easily interpretable. Importantly, the dashboard is designed with a focus on simplicity and accessibility, ensuring that it is usable not only by researchers but also by policymakers and other stakeholders engaged in critical mineral strategy. By bridging the gap between raw data and analytical insight, the dashboard enhances the overall utility of the study and supports more informed, evidence-based decision-making in the domain of critical mineral sourcing.

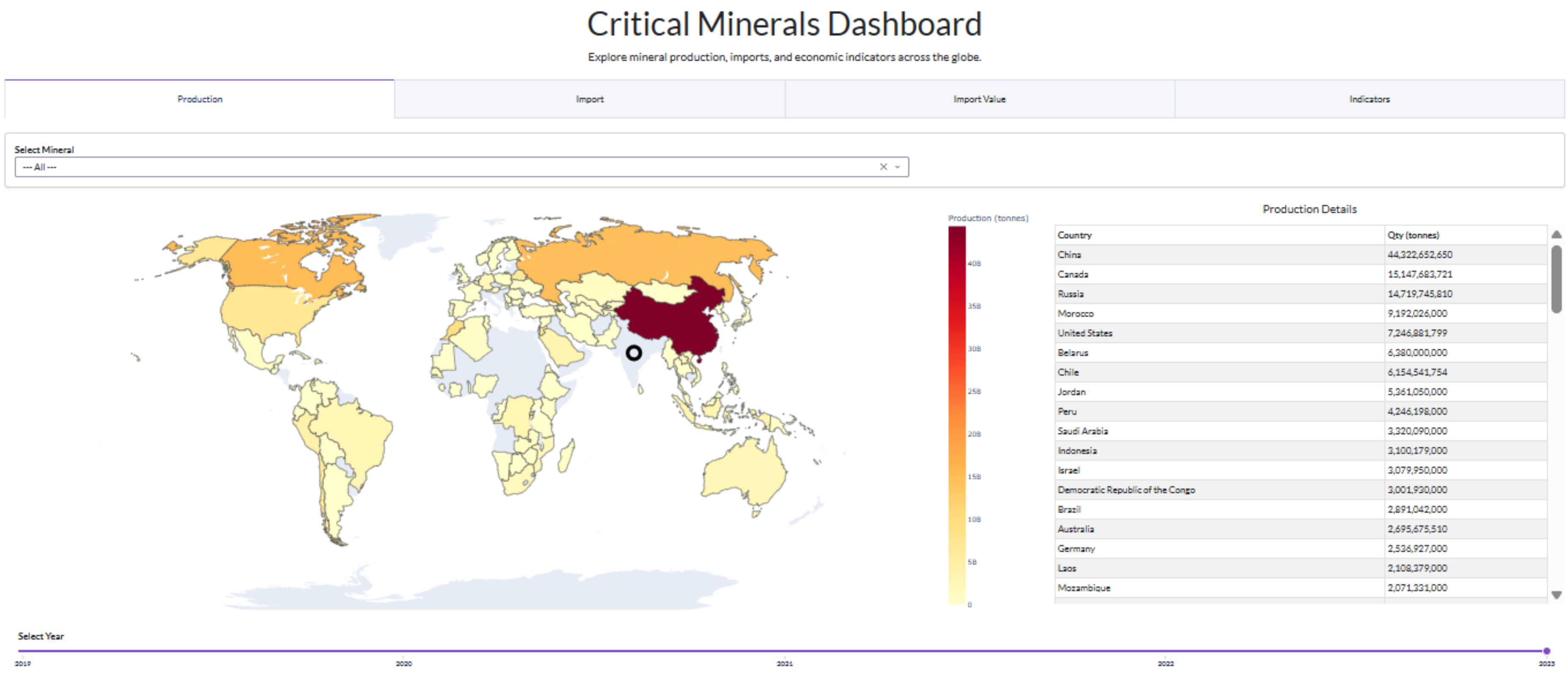

Figure 1: Critical Minerals Dashboard

3.2. PPML Model of Import of Ores

The PPML ores model is statistically significant overall and appears to explain a substantial share of the variation in India's ores imports across country-mineral-year observations. With 3,859 observations, a pseudo R-squared of 0.577, and a highly significant chi-square statistic, the model provides a reasonably strong empirical basis for the subsequent ranking exercise. This is important because the forward-looking partner tables are derived from the model-implied import quantities, so the credibility of the rankings depends in part on the explanatory adequacy of the underlying specification.

Among the country-level regressors, the coefficient on mineral production is positive and weakly significant, which is consistent with the intuition that countries with greater production capacity are more likely to serve as suppliers of raw mineral ores to India. Governance quality, as measured by the WGI average, is positive and strongly significant, suggesting that better-governed countries are more likely to feature in India's ores sourcing pattern. FDI as a share of GDP is also positive and marginally significant, which may indicate that economies that are more open to foreign investment are more integrated into mineral production and export networks. These results are broadly consistent with the expectation that India's ores imports tend to be associated with supplier capacity, institutional reliability, and external economic integration.

At the same time, two results are less intuitive and warrant careful interpretation. First, the coefficient on log distance is positive and statistically significant, which runs against the standard expectation that geographical distance should reduce trade by raising freight and coordination costs. In the context of ores, however, this may reflect the fact that India often sources from geographically distant countries with strong mineral endowments or limited substitutes, so that geological availability outweighs the usual gravity effect of proximity. Second, access to electricity enters with a negative and statistically significant coefficient. While this initially appears counterintuitive for a development indicator, it may reflect the fact that countries with lower levels of electricity access are less industrially diversified and therefore export a greater share of minerals in raw form rather than absorbing them domestically in downstream processing. These interpretations should be treated cautiously, but they are not inconsistent with the structure of global ores trade. By contrast, broader indicators of country size such as GDP and population are not statistically significant in the ores model, nor are most of the year effects. This suggests that India's ores sourcing is driven less by generic macroeconomic scale and more by mineral-specific supply conditions and structural country characteristics. The mineral fixed effects reinforce this conclusion, as they indicate substantial heterogeneity across minerals even after controlling for country-level characteristics. Taken together, the results suggest that the ores category is shaped primarily by supply capacity, governance, and the geography of mineral endowments.

Table 2: PPML - Ores Model

Import_ores_qty	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_production_qty	.287	.162	1.77	.077	-.031	.605	*
ln_gdp	.089	.283	0.31	.753	-.465	.643	
ln_population	.125	.272	0.46	.646	-.408	.657	
ln_distance	1.776	.645	2.75	.006	.511	3.041	***

Access to electricity (% of pop)	-.052	.027	-1.96	.049	-.104	0	**
Central govt debt of gdp	-.014	.012	-1.11	.266	-.038	.01	
Electricity from fossil (% of total)	.01	.008	1.20	.23	-.006	.027	
Electricity from RE, except hydro (% of total)	.021	.021	1.00	.316	-.02	.061	
Fdi (% of gdp)	.01	.006	1.85	.065	-.001	.022	*
Wgi average	1.156	.417	2.77	.006	.338	1.974	***
: base 0	0	.	.	.	.	.	
1	-2.797	1.017	-2.75	.006	-4.79	-.804	***
2019b	0	.	.	.	.	.	
2020	.466	.589	0.79	.428	-.687	1.62	
2021	.376	.91	0.41	.679	-1.408	2.161	
2022	1.085	.875	1.24	.215	-.629	2.799	
2023	-.88	.804	-1.09	.274	-2.456	.696	
: base Antimony	0	.	.	.	.	.	
Beryllium	-14.01	1.264	-11.08	0	-16.488	-11.532	***
Bismuth	-4.584	1.392	-3.29	.001	-7.313	-1.856	***
Cadmium	-2.869	.998	-2.87	.004	-4.826	-.913	***
Cerium	.864	2.6	0.33	.74	-4.231	5.959	
Cobalt	-4.846	1.139	-4.25	0	-7.079	-2.613	***
Copper	1.149	1.468	0.78	.434	-1.729	4.026	
Gallium	-30.834	1.545	-19.95	0	-33.863	-27.805	***
Gallium, Germanium~d	-5.295	2.533	-2.09	.037	-10.26	-.329	**
Gallium, Germanium~b	.061	1.506	0.04	.968	-2.891	3.013	
Germanium	-30.583	1.757	-17.41	0	-34.026	-27.14	***
Germanium and Zirc~m	.986	1.784	0.55	.58	-2.51	4.482	
Graphite	.397	1.055	0.38	.706	-1.67	2.464	
Hafnium	-29.955	3.736	-8.02	0	-37.278	-22.633	***
Indium	-31.928	1.314	-24.31	0	-34.503	-29.353	***
Lithium	-33.738	1.181	-28.56	0	-36.053	-31.423	***
Molybdenum	-1.094	1.153	-0.95	.343	-3.354	1.166	
Nickel	-2.903	1.286	-2.26	.024	-5.425	-.382	**
Niobium	-32.384	.879	-36.86	0	-34.106	-30.662	***
Niobium, Tantalum,~m	1.07	1.075	1.00	.32	-1.037	3.177	
Other Rare Metals	.885	3.031	0.29	.77	-5.057	6.826	
Palladium	-31.531	1.33	-23.71	0	-34.137	-28.925	***
Phosphorous	1.89	1.205	1.57	.117	-.472	4.252	

Platinum	-31.096	1.438	-21.63	0	-33.914	-28.277	***
Potash	-34.293	1.688	-20.31	0	-37.602	-30.984	***
Rare Earths	-33.609	.781	-43.03	0	-35.14	-32.078	***
Rhenium	-31.622	1.163	-27.18	0	-33.902	-29.342	***
Rhodium	-31.607	1.332	-23.73	0	-34.217	-28.996	***
Selenium	-3.02	.994	-3.04	.002	-4.968	-1.071	***
Silicon	.743	1.446	0.51	.607	-2.09	3.577	
Tantalum	-31.825	.88	-36.15	0	-33.55	-30.099	***
Tellurium	-31.633	1.418	-22.31	0	-34.413	-28.854	***
Tin	-8.874	1.06	-8.37	0	-10.952	-6.795	***
Titanium	-.192	1.491	-0.13	.898	-3.114	2.73	
Tungsten	-4.639	1.073	-4.32	0	-6.742	-2.536	***
Vanadium	-31.769	1.014	-31.34	0	-33.756	-29.782	***
Zirconium	.251	1.456	0.17	.863	-2.604	3.106	
Constant	-7.916	9.442	-0.84	.402	-26.422	10.59	

Mean dependent var	1133362.934	SD dependent var	20113370.508
Pseudo r-squared	0.577	Number of obs	3859
Chi-square	235179.486	Prob > chi2	0.000
Akaike crit. (AIC)	18876142182.425	Bayesian crit. (BIC)	18876142507.850

**** p<.01, ** p<.05, * p<.1*

3.3. PPML Model of Import of Products

The PPML products model also appears to perform reasonably well overall and provides a strong empirical basis for the ranking exercise in processed mineral products. With 3,857 observations and a pseudo R-squared of 0.606, the model explains a substantial share of the variation in India's product imports across country-mineral-year observations. Relative to the ores model, the products specification seems to capture slightly more of the observed variation, which is plausible given that product trade is denser and less sparse than ores trade in the dataset. This makes the model-implied predicted imports a useful basis for identifying mineral-wise future partners in processed products.

Among the country-level regressors, production quantity is positive and statistically significant, indicating that supplier capacity continues to matter even in the products category. This suggests that countries with stronger mineral production bases are also more likely to appear in India's processed-product import structure, whether because they possess integrated value chains or because production capacity proxies for broader sectoral strength. By contrast, GDP enters with a negative coefficient and is weakly significant, which may suggest that larger economies retain more output for domestic use or are less reliant on exporting processed mineral products to India. This is an interesting result because it implies that product sourcing is not simply driven by country size; rather, it may depend more on the structure of production and trade orientation than on aggregate macroeconomic scale alone. The products model does not yield statistically robust independent effects for variables such as population, distance, access to electricity, debt, fossil-based electricity, FDI, and governance. This should not be read as evidence that these broader structural factors are irrelevant to processed mineral imports. A more appropriate interpretation is that, once production capacity, mineral fixed effects, and the other included controls are accounted for, the model does not detect a clearly separable partial effect for these variables in the products category. This is plausible because processed-product trade is embedded in more complex downstream supply chains than ores, and the country characteristics that support competitiveness in these markets often operate jointly rather than in isolation. For example, industrial capability in processed products may reflect the combined influence of policy support, infrastructure quality, investment, technological capability, and institutional effectiveness, even if the regression does not identify each of these as independently significant. In that sense, the results suggest not that governance and macroeconomic conditions do not matter, but that their influence may be mediated through broader industrial and production-linked capacities or may be difficult to disentangle empirically in a setting where several structural determinants are closely connected. The insignificance of distance can be interpreted in a similar way. Unlike ores, where sourcing is closely tied to the location of mineral deposits and freight costs may play a stronger role, processed-product trade is often organized through established refining, manufacturing, and distribution networks. Once such networks are in place, proximity to India may become less decisive than the ability to supply usable intermediate or final mineral products reliably and at scale. This interpretation also has implications for understanding India's dependence on imported processed products. One possible explanation is that domestic processing capacity remains limited in relation to India's demand for critical mineral products. At the same time, this dependence is unlikely to be explained by domestic capacity constraints alone. It may also reflect cost differentials, technological gaps, economies of scale in established foreign processing centres, and strategic sourcing choices within global value chains. The products model therefore points less to a single causal explanation than to a broader pattern in which India's imports of processed critical mineral goods are linked to the structure and location of downstream industrial capabilities in the global economy.

The year effects show limited evidence of common time shocks, although the coefficient for 2020 is negative and statistically significant relative to the base year. This likely reflects the disruptive effects of the pandemic period on processed mineral imports, including supply-chain dislocation, logistical interruptions, and temporary trade contraction. The absence of significance for the later years suggests that, after controlling for the other covariates and mineral fixed effects, there is no strong common annual shift in product imports beyond this initial shock. As in the ores model, the mineral fixed effects are highly important and indicate substantial heterogeneity across minerals. The strong positive coefficients on minerals suggest that these products occupy a particularly prominent place in India's import basket, whereas many other minerals remain far less important in the processed-products category.

Overall, the products model suggests that India's imports of processed mineral products are driven primarily by supplier production strength and strong mineral-specific trade structures, rather than by standard macroeconomic size or broad governance indicators. Compared with the ores model, the products model appears less influenced by general country characteristics and more by the organization of downstream value chains. This supports the decision to produce separate rankings for products rather than pooling them with ores or scrap, and it strengthens the interpretation of the forward-looking product rankings as indicators of mineral-specific processing and supply-chain attractiveness rather than simple reflections of country size or distance.

Table 3: PPM L - Products Model

Import_products_qty	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_production_qty	.253	.105	2.42	.016	.048	.458	**
ln_gdp	-.343	.206	-1.66	.096	-.747	.061	*
ln_population	.232	.223	1.04	.298	-.205	.669	
ln_distance	.111	.514	0.22	.829	-.896	1.118	
Access to electricity (% of pop)	.028	.029	0.96	.337	-.029	.084	
Central govt debt of gdp	.002	.012	0.16	.875	-.022	.025	
Electricity from fossil (% of total)	-.003	.006	-0.46	.643	-.014	.009	
Electricity from RE, except hydro (% of total)	.052	.032	1.63	.104	-.011	.115	
Fdi (% of gdp)	-.007	.005	-1.40	.162	-.018	.003	
Wgi average	-.208	.395	-0.53	.598	-.983	.566	
: base 0	0	.	.	.	.	.	
1	-1.455	1.002	-1.45	.146	-3.418	.508	
2019b	0	.	.	.	.	.	
2020	-.734	.317	-2.31	.021	-1.356	-.112	**
2021	.723	.449	1.61	.108	-.158	1.603	
2022	.389	.307	1.27	.205	-.212	.99	
2023	-.175	.529	-0.33	.741	-1.212	.863	
: base Antimony	0	.	.	.	.	.	
Beryllium	-3.811	1.597	-2.39	.017	-6.941	-.682	**

Bismuth	-2.599	.948	-2.74	.006	-4.456	-.741	***
Cadmium	-.193	.784	-0.25	.806	-1.729	1.344	
Cerium	1.273	2.301	0.55	.58	-3.237	5.784	
Cobalt	-2.575	.631	-4.08	0	-3.811	-1.339	***
Copper	1.885	.692	2.72	.006	.529	3.242	***
Gallium	-29.385	1.506	-19.51	0	-32.338	-26.433	***
Gallium, Germanium~d	-.152	1.863	-0.08	.935	-3.804	3.501	
Gallium, Germanium~b	.878	1.905	0.46	.645	-2.856	4.613	
Germanium	-29.102	1.617	-18.00	0	-32.271	-25.933	***
Germanium and Zirc~m	1.873	2.181	0.86	.39	-2.402	6.148	
Graphite	.863	.652	1.32	.186	-.415	2.14	
Hafnium	-8.72	3.66	-2.38	.017	-15.893	-1.547	**
Indium	-29.499	1.615	-18.26	0	-32.665	-26.333	***
Lithium	-1.771	.627	-2.82	.005	-3	-.541	***
Molybdenum	.105	.751	0.14	.889	-1.367	1.577	
Nickel	.205	.635	0.32	.747	-1.039	1.45	
Niobium	-29.747	.79	-37.66	0	-31.295	-28.199	***
Niobium, Tantalum,~m	-5.095	.72	-7.08	0	-6.506	-3.684	***
Other Rare Metals	1.651	2.761	0.60	.55	-3.76	7.062	
Palladium	-28.764	1.454	-19.78	0	-31.615	-25.914	***
Phosphorous	4.236	.63	6.72	0	3.001	5.472	***
Platinum	-4.714	1.512	-3.12	.002	-7.678	-1.751	***
Potash	-3.873	.532	-7.28	0	-4.915	-2.831	***
Rare Earths	-30.494	.878	-34.75	0	-32.214	-28.774	***
Rhenium	-28.709	1.114	-25.78	0	-30.892	-26.526	***
Rhodium	-28.466	1.709	-16.66	0	-31.815	-25.117	***
Selenium	-3.158	1.315	-2.40	.016	-5.735	-.58	**
Silicon	5.548	.941	5.90	0	3.704	7.393	***
Tantalum	-7.171	1.141	-6.29	0	-9.407	-4.936	***
Tellurium	-6.064	1.48	-4.10	0	-8.965	-3.162	***
Tin	-.193	1.047	-0.18	.854	-2.245	1.859	
Titanium	-.971	.788	-1.23	.218	-2.516	.574	
Tungsten	-2.538	.702	-3.62	0	-3.913	-1.163	***
Vanadium	-.166	1.014	-0.16	.87	-2.154	1.821	
Zirconium	-7.744	.804	-9.64	0	-9.319	-6.168	***
Constant	10.133	7.963	1.27	.203	-5.476	25.741	

Mean dependent var	4035581.756	SD dependent var	90391485.419
Pseudo r-squared	0.606	Number of obs	3857

Chi-square	.	Prob > chi2	.
Akaike crit. (AIC)	62990853782.951	Bayesian crit. (BIC)	62990854102.091

*** *p<.01, *** *p<.05, * p<.1*

3.4. PPML Model of Import of Scrap

The PPML scrap model is also statistically significant overall, although its explanatory power is lower than that of the ores and products specifications. With 3,859 observations, a pseudo R-squared of 0.432, and a highly significant chi-square statistic, the model still provides a meaningful basis for analysis, but it also suggests that scrap trade is somewhat harder to explain using the observed structural variables alone. This is not surprising, since scrap flows are often influenced by additional factors such as recycling systems, industrial waste generation, secondary processing networks, and regulatory regimes, many of which are not directly captured in the present dataset. Even so, the model recovers several clear patterns that are useful for interpreting India's scrap sourcing behaviour.

Unlike the ores and products models, the scrap model is dominated by broader macro-structural factors rather than mineral production itself. Production quantity is not statistically significant, which is intuitively plausible because scrap availability is not determined primarily by mining output. Instead, the most important positive coefficient is on GDP, which is strongly significant, indicating that larger economies tend to be more important sources of scrap imports for India. This likely reflects the fact that scrap generation is linked to the scale of industrial activity, consumption, and material throughput rather than to mineral extraction. Population, however, enters with a strongly negative coefficient, suggesting that once GDP is controlled for, more populous countries may retain more recyclable material domestically or may have lower per capita scrap export intensity. Together, these two variables imply that scrap sourcing is associated more with the scale and structure of the industrial economy than with raw resource endowment. Several institutional and macro-fiscal variables are also significant in the scrap model, though in directions that require careful interpretation. Central government debt is negative and statistically significant, suggesting that countries facing greater fiscal stress may be less reliable or less active as scrap suppliers. Governance quality, measured by WGI, is also negative and highly significant, which is notably different from the ores model. One possible interpretation is that better-governed countries have more effective domestic recycling systems or stronger internal demand for recyclable materials, reducing the share of scrap made available for export. Alternatively, this result may indicate that India's scrap imports have historically relied more on countries outside the highest-governance group. This should be interpreted cautiously, but it does point to the distinct political economy of scrap trade as compared with raw ore imports.

By contrast, distance, access to electricity, energy-mix variables, and FDI do not appear to play a statistically significant role in the scrap category. This suggests that the geography of scrap trade may be less sensitive to conventional trade-cost considerations than the ores category, or that such effects are being overshadowed by broader industrial and market-size variables. The year effects are also largely insignificant, implying that once country characteristics and mineral-specific effects are taken into account, there is no strong common annual shift in India's scrap imports over the sample period. This does not mean that scrap trade is stable in an absolute sense, but rather that the observed annual variation is not well captured by common year shocks alone. The mineral fixed effects once again reveal substantial heterogeneity across minerals, confirming that scrap trade is highly mineral-specific. Copper and nickel stand out with strongly positive coefficients relative to the omitted base mineral, which is consistent with the fact that these metals have more established global scrap markets and greater recyclability. Many other minerals are strongly negative, indicating very limited relevance in the scrap trade category. This reinforces the argument that the determinants of competitiveness differ not only across import categories but also sharply across minerals within a category.

Taken together, the scrap model suggests that India's scrap imports are shaped less by mining capacity and more by the economic scale, institutional circumstances, and structural features of supplier countries. Compared with ores and products, the scrap category appears to reflect a more downstream and recycling-oriented sense, in which large industrial economies matter more than mineral-producing ones. This justifies treating scrap as a separate analytical category and supports the use of a dedicated scrap-specific ranking rather than incorporating it into a common sourcing framework with ores and products.

Table 4: PPML – Scrap Model

Import_scrap_qty	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ln_production_qty	.035	.028	1.24	.215	-.02	.091	
ln_gdp	1.522	.228	6.69	0	1.076	1.968	***
ln_population	-1.246	.259	-4.81	0	-1.753	-.739	***
ln_distance	-.169	.293	-0.58	.564	-.742	.405	
Access to electricity (% of pop)	-.012	.012	-1.04	.297	-.035	.011	
Central govt debt of gdp	-.011	.004	-2.93	.003	-.019	-.004	***
Electricity from fossil (% of total)	-.002	.005	-0.34	.731	-.012	.009	
Electricity from RE, except hydro (% of total)	-.006	.013	-0.46	.645	-.031	.019	
Fdi (% of gdp)	-.001	.002	-0.70	.487	-.005	.002	

Wgi average	-.718	.199	-3.60	0	-1.109	-.327	***
: base 0	0	.	.	.	.	.	
1	-2.799	.541	-5.17	0	-3.86	-1.738	***
2019b	0	.	.	.	.	.	
2020	-.557	.47	-1.19	.236	-1.478	.364	
2021	.261	.572	0.46	.648	-.86	1.381	
2022	-.759	.467	-1.63	.104	-1.674	.155	
2023	-1.065	.742	-1.44	.151	-2.518	.389	
: base Antimony	0	.	.	.	.	.	
Beryllium	-29.397	1.039	-28.28	0	-31.434	-27.36	***
Bismuth	-1.324	1.29	-1.03	.305	-3.852	1.204	
Cadmium	-1.153	.559	-2.06	.039	-2.249	-.056	**
Cerium	-29.918	.785	-38.10	0	-31.457	-28.379	***
Cobalt	-2.933	.821	-3.57	0	-4.542	-1.324	***
Copper	2.352	.576	4.08	0	1.223	3.481	***
Gallium	-30.928	1.078	-28.68	0	-33.041	-28.814	***
Gallium, Germanium~d	-4.118	.471	-8.74	0	-5.042	-3.195	***
Gallium, Germanium~b	-29.998	.798	-37.59	0	-31.562	-28.434	***
Germanium	-31.158	1.13	-27.58	0	-33.372	-28.944	***
Germanium and Zirc~m	-30.331	.737	-41.18	0	-31.775	-28.888	***
Graphite	-2.451	1.089	-2.25	.024	-4.585	-.317	**
Hafnium	-29.111	1.202	-24.21	0	-31.467	-26.754	***
Indium	-30.693	1.003	-30.60	0	-32.659	-28.727	***
Lithium	.059	.64	0.09	.927	-1.196	1.314	
Molybdenum	-.942	.975	-0.97	.334	-2.854	.97	
Nickel	1.187	.39	3.04	.002	.422	1.951	***
Niobium	-29.666	1.037	-28.59	0	-31.699	-27.632	***
Niobium, Tantalum,~m	-5.003	1.429	-3.50	0	-7.803	-2.203	***
Other Rare Metals	-29.823	1.539	-19.38	0	-32.84	-26.807	***
Palladium	-30.583	.954	-32.05	0	-32.453	-28.713	***
Phosphorous	-30.226	.64	-47.22	0	-31.481	-28.971	***
Platinum	-30.595	.854	-35.84	0	-32.268	-28.922	***
Potash	-30.574	.779	-39.24	0	-32.101	-29.047	***
Rare Earths	-30.611	.938	-32.63	0	-32.449	-28.772	***
Rhenium	-30.613	1.029	-29.74	0	-32.631	-28.596	***
Rhodium	-30.554	1.139	-26.82	0	-32.786	-28.321	***
Selenium	-3.305	1.24	-2.66	.008	-5.735	-.874	***
Silicon	1.188	.759	1.56	.118	-.3	2.676	
Tantalum	-4.835	.814	-5.94	0	-6.431	-3.24	***

Tellurium	-7.36	.872	-8.44	0	-9.069	-5.651	***
Tin	.963	.999	0.96	.335	-.994	2.92	
Titanium	-.913	.767	-1.19	.234	-2.415	.59	
Tungsten	-3.805	.735	-5.17	0	-5.247	-2.364	***
Vanadium	-30.93	.899	-34.42	0	-32.691	-29.169	***
Zirconium	-6.727	1.01	-6.66	0	-8.707	-4.746	***
Constant	-5.864	3.836	-1.53	.126	-13.381	1.654	

Mean dependent var	157337.618	SD dependent var	1824271.565
Pseudo r-squared	0.432	Number of obs	3859
Chi-square	49099.182	Prob > chi2	0.000
Akaike crit. (AIC)	2847673962.793	Bayesian crit. (BIC)	2847674288.218

**** p<.01, ** p<.05, * p<.1*

3.5. Intuition behind the forward-looking import portfolios

The forward-looking rankings of countries India should potentially import ores, products and scraps of critical minerals are given in table 5, 6 and 7. The import portfolios are to be interpreted as model-based indicators of sourcing attractiveness based on the variables given in table 1, and not as extrapolations of India's past import shares. The econometric framework applied in this study initially identifies the exporting country's characteristics that have historically been associated with higher Indian imports for each import category, that is, ores, products, and scrap. These estimated relationships are then used to identify mineral-wise supplier countries that India has underutilized in the past and should consider becoming partners in the future. The intuition is straightforward. If a country combines the characteristics that have historically made imports attractive to India, such as mineral production capacity, macroeconomic variables (like GDP), governance quality, and lower trade frictions, then the model will assign it a higher predicted import quantity. The top 10 countries of the forward-looking rankings, as portraited in tables 5, 6 and 7, are therefore those that remain structurally well positioned to serve as future partners. These rankings should not be interpreted as forecasts of future trade flows. Rather, they provide a strategic ordering of potential partners that can help identify underutilised suppliers, guide diversification efforts, and inform a more resilient mineral-wise import portfolio for India.

Table 5: Forward-looking portfolio of India's import of Critical Mineral Ores & Concentrates

Mineral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Antimony	Australia	China	Mexico	Canada	Honduras	Guatemala	Turkey	Russia	Germany	Vietnam

Beryllium	United States	Mozambique	Madagascar	Nigeria	China	Brazil	Rwanda	Uganda	Zambia	Mexico
Bismuth	Peru	China	Mexico	Canada	Japan	Vietnam	Netherlands	Germany	Finland	United States
Cadmium	Australia	Germany	Netherlands	Canada	United States	Peru	Mexico	Norway	South Korea	Argentina
Cerium	Germany	United States	Sweden	Switzerland	Estonia	South Africa	United Kingdom	Belgium	China	France
Cobalt	Democratic Republic of the Congo	Papua New Guinea	Australia	Madagascar	Canada	Finland	United States	Indonesia	South Africa	Cuba
Copper	Chile	Australia	Democratic Republic of the Congo	Papua New Guinea	Canada	United States	Peru	Mauritania	Namibia	Mexico
Gallium	China	South Korea	Japan	Ukraine	Russia					
Gallium, Germanium, Hafnium, Indium, Niobium, Rhenium and Vanadium	Germany	Netherlands	United States	Italy	Russia	Estonia	Switzerland	South Africa	Brazil	Israel
Gallium, Germanium, Indium, Niobium and Vanadium	China	Australia	Netherlands	Canada	United States	Japan	Russia	South Africa	Estonia	France
Germanium	United States	China	Japan	Russia	Ukraine					
Germanium and Zirconium	United States	China	Germany	Australia	Russia	Italy	Japan	Switzerland	Sweden	South Africa
Graphite	Madagascar	Mozambique	Tanzania	Canada	Norway	Germany	China	Brazil	Mexico	South Korea
Hafnium	United Kingdom									
Indium	Canada	South Korea	Peru	China	Belgium	Japan	France	Russia	Uzbekistan	
Lithium	Chile	Australia	Argentina	Canada	United States	Nigeria	Portugal	Tanzania	Brazil	China
Molybdenum	Chile	United States	Peru	Canada	Australia	Mexico	China	South Korea	Norway	Russia
Nickel	Australia	Papua New Guinea	Madagascar	Canada	Ivory Coast	Finland	United States	Dominican Republic	Indonesia	South Africa
Niobium	Canada	Democratic Republic of the Congo	Brazil	Nigeria	Mozambique	Rwanda	China	Russia	Burundi	Uganda
Niobium, Tantalum, Vanadium	Canada	Nigeria	Russia	Madagascar	United States	Mexico	Spain	Ukraine	Kuwait	
Other Rare Metals	South Africa	Estonia	United Kingdom	China	Austria					

Palladium	Canada	United States	Australia	South Africa	Finland	China	Russia	Poland	Zimbabwe	Serbia
Phosphorous	Senegal	Australia	United States	Togo	Peru	Finland	Morocco	Chile	Tanzania	South Africa
Platinum	Canada	South Africa	United States	Australia	Finland	Germany	Colombia	China	Poland	Russia
Potash	Chile	Canada	Germany	United States	Australia	Israel	China	Brazil	Spain	United Kingdom
Rare Earths	Australia	Madagascar	United States	Nigeria	China	Brazil	Burundi	Russia	Vietnam	Malaysia
Rhenium	Chile	United States	Poland	China	Russia	United Kingdom	Kazakhstan	Armenia	Uzbekistan	
Rhodium	Canada	South Africa	United States	Russia	Zimbabwe					
Selenium	Chile	Germany	Canada	United States	Finland	Mexico	Peru	Poland	Sweden	China
Silicon	China	Cyprus	Chile	Denmark	Malta	Australia	New Zealand	Germany	Nigeria	Canada
Tantalum	Sierra Leone	Democratic Republic of the Congo	Australia	Nigeria	Mozambique	Brazil	China	Denmark	Rwanda	Spain
Tellurium	Canada	United States	Sweden	China	Japan	Germany	Russia	Bulgaria	United Kingdom	Uzbekistan
Tin	Australia	Democratic Republic of the Congo	Nigeria	Namibia	Peru	Tanzania	Indonesia	Brazil	China	Portugal
Titanium	Sierra Leone	Australia	Senegal	Madagascar	Mozambique	Canada	United States	South Africa	Norway	Kenya
Tungsten	Australia	Democratic Republic of the Congo	Portugal	China	Nigeria	Mexico	Brazil	Spain	Rwanda	Vietnam
Vanadium	South Africa	China	United States	Brazil	Russia	Germany	Argentina	Latvia	Slovenia	
Zirconium	Australia	Sierra Leone	Senegal	Madagascar	Mozambique	South Africa	United States	Nigeria	Kenya	Indonesia

Table 6: Forward-looking portfolio of India's import of Critical Mineral Products

Mineral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Antimony	China	Turkey	Honduras	Russia	Guatemala	Tajikistan	Iran	Australia	Mexico	Vietnam

Beryllium	United States	China	Brazil	Mozambique	Nigeria	Madagascar	United Kingdom	Uganda	Rwanda	Zambia
Bismuth	China	Vietnam	Peru	Japan	Mexico	Russia	Bolivia	Canada	Kazakhstan	Finland
Cadmium	China	Mexico	Brazil	Peru	Netherlands	Germany	Bulgaria	Japan	South Korea	Canada
Cerium	Estonia	Belgium	United Kingdom	Sweden	Germany	Japan	South Africa	France	United States	China
Cobalt	Cuba	Morocco	Philippines	Indonesia	Finland	Australia	Russia	Canada	Democratic Republic of the Congo	China
Copper	Chile	Peru	Brazil	Mexico	Spain	Panama	China	Indonesia	Portugal	Morocco
Gallium	China	Ukraine	Russia	Japan	South Korea					
Gallium, Germanium, Hafnium, Indium, Niobium, Rhenium and Vanadium	Russia	United Kingdom	Estonia	Brazil	Germany	Belgium	Italy	Netherlands	South Africa	United States
Gallium, Germanium, Indium, Niobium and Vanadium	China	Russia	Japan	Thailand	South Africa	Estonia	Spain	Belgium	France	United Kingdom
Germanium	China	Ukraine	Russia	Japan	United States					
Germanium and Zirconium	China	United States	Russia	Japan	Germany	Belgium	Italy	Sweden	United Kingdom	Australia
Graphite	Brazil	China	Turkey	Ukraine	Mexico	Sri Lanka	Russia	Mozambique	Madagascar	
Hafnium	United Kingdom									
Indium	China	Belgium	Japan	South Korea	France	Canada	Peru	Russia	Uzbekistan	
Lithium	Chile	Brazil	Australia	China	Argentina	Portugal	Canada	United States	Zimbabwe	Bolivia
Molybdenum	Chile	Peru	Mexico	China	United States	Iran	Canada	Russia	Australia	Armenia
Nickel	Cuba	Guatemala	Indonesia	Philippines	Brazil	Greece	Finland	Colombia	Australia	Dominican Republic
Niobium	Brazil	Canada	Russia	China	Nigeria	Democratic Republic of the Congo	Mozambique	Rwanda	Ethiopia	Uganda
Niobium, Tantalum, Vanadium	Russia	Canada	Nigeria	Mexico	Ukraine	Spain	Kuwait	United States	Madagascar	
Other Rare Metals	United Kingdom	China	South Africa	Estonia	Austria					

Palladium	South Africa	Russia	Canada	Finland	United States	China	Australia	Serbia	Zimbabwe	Poland
Phosphorous	Cuba	Morocco	Jordan	Brazil	China	Nauru	Peru	Tunisia	Syria	Russia
Platinum	South Africa	Russia	Finland	Canada	Colombia	China	United States	Australia	Zimbabwe	Serbia
Potash	Jordan	Belarus	Brazil	Chile	Canada	Germany	China	Spain	Russia	United Kingdom
Rare Earths	China	Brazil	Australia	United States	Vietnam	Russia	Madagascar	Malaysia	Nigeria	
Rhenium	Chile	Poland	United States	China	Russia	Uzbekistan	Armenia	Kazakhstan	United Kingdom	
Rhodium	Canada	South Africa	Russia	United States	Zimbabwe					
Selenium	Germany	Belgium	Philippines	Chile	China	Finland	Mexico	Japan	Peru	Sweden
Silicon	China	Denmark	Kenya	Greece	Iceland	Chile	Morocco	Marshall Isds	Samoa	Mauritius
Tantalum	Brazil	Denmark	Spain	China	Australia	Russia	Nigeria	Democratic Republic of the Congo	Mozambique	Sierra Leone
Tellurium	China	Sweden	Japan	Russia	Bulgaria	Canada	United States	United Kingdom	Uzbekistan	Germany
Tin	Brazil	Peru	Indonesia	China	Vietnam	Australia	Spain	Portugal	Malaysia	Russia
Titanium	Kenya	China	Ukraine	Brazil	South Africa	Australia	Vietnam	Senegal	Canada	
Tungsten	China	Vietnam	Portugal	Spain	Brazil	Russia	Thailand	Mexico	Australia	Bolivia
Vanadium	Brazil	China	Russia	South Africa	United States	Belgium	Latvia	United Kingdom	Argentina	
Zirconium	Kenya	Australia	Brazil	South Africa	Indonesia	China	Senegal	Ukraine	Vietnam	United States

Table 7: Forward-looking portfolio of India's import of Critical Mineral Waste & Scraps

Mineral	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Antimony	Russia	China	Qatar	Turkey	Hong Kong	Iran	Italy	Oman	Germany	Netherlands
Beryllium	China	United States	Mexico	Nigeria	Brazil	Belgium	United Kingdom	Madagascar	Mozambique	Austria

Bismuth	Russia	China	Italy	United Arab Emirates	Germany	Belgium	United States	Netherlands	Mexico	Vietnam
Cadmium	Russia	China	Germany	Italy	United Arab Emirates	Norway	Poland	Netherlands	United States	Argentina
Cerium	China	Germany	Switzerland	United States	Sweden	France	Belgium	Estonia	United Kingdom	South Africa
Cobalt	Russia	Saudi Arabia	China	Turkey	United Arab Emirates	Italy	United States	Germany	Netherlands	Singapore
Copper	Russia	Saudi Arabia	China	Qatar	Iran	Turkey	Poland	Germany	United Arab Emirates	United States
Gallium	Russia	China	South Korea	Ukraine	Japan					
Gallium, Germanium, Hafnium, Indium, Niobium, Rhenium and Vanadium	Russia	Italy	Germany	Netherlands	Switzerland	Israel	United States	Brazil	Belgium	Estonia
Gallium, Germanium, Indium, Niobium and Vanadium	Russia	China	United Arab Emirates	Netherlands	Singapore	United States	France	Thailand	Canada	Australia
Germanium	Russia	China	United States	Ukraine	Japan					
Germanium and Zirconium	Russia	China	Italy	Germany	Singapore	United States	Switzerland	Bahrain	France	Thailand
Graphite	Russia	China	Saudi Arabia	Qatar	Turkey	Germany	Italy	United Arab Emirates	Norway	Oman
Hafnium	United Kingdom									
Indium	Russia	China	South Korea	Canada	France	Belgium	Peru	Japan	Uzbekistan	
Lithium	Russia	China	United Arab Emirates	Argentina	United States	Germany	Australia	Portugal	Canada	Chile
Molybdenum	Russia	China	Saudi Arabia	Iran	United Arab Emirates	Italy	Turkey	United States	Kuwait	Germany
Nickel	Russia	China	Saudi Arabia	Qatar	Turkey	United Arab Emirates	Italy	Poland	Norway	United States
Niobium	Russia	China	Canada	Nigeria	Brazil	Democratic Republic of the Congo	Mozambique	Ethiopia	Uganda	Rwanda

Niobium, Tantalum, Vanadium	Russia	Kuwait	United States	Canada	Ukraine	Nigeria	Mexico	Spain	Madagascar	
Other Rare Metals	China	Estonia	South Africa	United Kingdom	Austria					
Palladium	Russia	China	United States	Poland	Canada	Finland	Serbia	Australia	South Africa	Uzbekistan
Phosphorous	Saudi Arabia	Russia	China	Qatar	Turkey	Iran	Iraq	Israel	United States	United Arab Emirates
Platinum	Russia	China	United Arab Emirates	Germany	Poland	United States	Canada	Finland	Serbia	Australia
Potash	Russia	China	Germany	Iran	Belarus	Israel	United Arab Emirates	United States	Ireland	Singapore
Rare Earths	Russia	China	United States	Vietnam	Australia	Nigeria	Malaysia	Brazil	Madagascar	
Rhenium	Russia	China	Poland	United States	Chile	United Kingdom	Kazakhstan	Uzbekistan	Armenia	
Rhodium	Russia	United States	Canada	South Africa	Zimbabwe					
Selenium	Russia	China	Germany	Poland	United States	Singapore	Mexico	Sweden	Finland	
Silicon	China	Saudi Arabia	Russia	Hong Kong	Italy	United Arab Emirates	Turkey	Kuwait	Germany	Oman
Tantalum	Russia	China	Italy	Germany	Singapore	United States	Netherlands	Nigeria	Australia	Malaysia
Tellurium	Russia	China	Germany	United States	Sweden	Canada	Bulgaria	Japan	United Kingdom	Uzbekistan
Tin	Russia	China	United Arab Emirates	Italy	Germany	Iran	Bahrain	Poland	Indonesia	Singapore
Titanium	Russia	China	Saudi Arabia	Turkey	Iran	Norway	United Arab Emirates	Italy	United States	Kuwait
Tungsten	Russia	China	United Arab Emirates	Italy	Oman	Germany	Turkey	Poland	Singapore	Netherlands
Vanadium	Russia	China	Saudi Arabia	United Arab Emirates	Kuwait	Germany	United States	Singapore	Argentina	
Zirconium	Russia	China	Italy	United States	Indonesia	Ukraine	Vietnam	Australia	Switzerland	

Chapter 4: Discussion & Policy Recommendations

The forward-looking tables translate the econometric results into a mineral-wise sourcing framework. For each import category (ores, products, and scrap), the estimated PPML model is applied to country-mineral characteristics averaged over the sample period in order to generate predicted import quantities. These model-implied quantities are then used to rank countries within each mineral, yielding a forward-looking ordering of potential partners. The resulting tables should therefore be interpreted not as forecasts of exact future trade volumes, but as strategic indicators of sourcing attractiveness under the historical import logic recovered from the data. In this sense, the exercise is forward-looking but conditional. It uses past relationships to identify which country characteristics have historically been associated with higher Indian imports and then applies those relationships to recent average characteristics. The rankings therefore rest on the assumption that the broad structure of India's sourcing behaviour observed during the sample period continues to remain relevant going forward. This ranking framework is especially useful because it moves beyond a simple description of past import dependence. Countries that rank highly in the forward-looking tables are not necessarily those from which India imported the most in the past; rather, they are countries whose observable characteristics make them structurally attractive suppliers within the estimated framework. At the same time, this should not be taken to mean that the rankings fully capture all dimensions of strategic suitability. The model incorporates several broad factors related to production, macroeconomic conditions, governance, trade frictions, and energy structure, but it does not directly measure some considerations that may also shape future sourcing choices, including processing and refining capacity, bilateral geopolitical alignment, trade restrictions, detailed logistics quality, cost competitiveness, or country-specific regulatory risks. As a result, the rankings are best interpreted as evidence-based signals of potential supplier attractiveness rather than as automatic prescriptions for policy. This also implies that the framework may understate the future importance of factors that were not strongly reflected in past import patterns but may become more salient over time. For example, governance, long-term supply reliability, and energy-transition dynamics may matter more in future sourcing decisions than is directly visible in the estimated coefficients. Similarly, some variables may influence import outcomes indirectly through broader industrial or production-linked capacities rather than appearing as independently significant drivers in the model. The forward-looking rankings should therefore be read as model-based approximations of future sourcing attractiveness under historically observed trade relationships, rather than as unconditional statements about which countries will necessarily be India's optimal partners in the future. From a portfolio perspective, these tables provide a mineral-wise map of where India's sourcing relationships could potentially be broadened or rebalanced. Minerals for which the same small set of countries dominate the forward-looking ranking point to a narrow global supplier base and therefore higher concentration risk. Conversely, minerals with a more diversified set of highly ranked countries indicate greater scope for portfolio diversification. The tables can thus be read as tools for identifying strategic partners, underutilised suppliers, and vulnerabilities in India's current import structure across ores, products, and scrap. Their principal value lies not in predicting exact future trade patterns, but in helping to identify where India's sourcing portfolio appears aligned with underlying supplier characteristics, where it may be overly concentrated, and where additional strategic engagement maybe considered.

In table 5, the forward-looking portfolio on import of ores and concentrates of critical minerals of India, an important pattern observed is the repeated appearance of a relatively small set of countries across multiple ores categories. Australia features prominently across antimony, cadmium, cobalt, copper, lithium, molybdenum, nickel, palladium, phosphorous, platinum, potash, rare earths, tin, titanium, tungsten, and zirconium. Canada also appears frequently across copper, cobalt, indium, niobium, palladium, platinum, potash, tellurium, and several other categories. The United States, China, South Africa, and the Democratic Republic of the Congo also recur across multiple minerals. This repetition suggests that India's future ore-sourcing portfolio may be anchored around a core group of countries (IRENA, 2023). From a policy perspective, this implies that there may be value in prioritising deeper strategic engagement with a handful of recurring high-potential partners rather than treating each mineral relationship in complete isolation. At the same time, the table also reveals considerable diversity beyond this core group. Several minerals have forward-looking partner sets that include countries that are not always central to standard trade narratives. Madagascar and Mozambique appear prominently in graphite, cobalt, nickel, rare earths, titanium, tantalum, and zirconium. Sierra Leone ranks first in tantalum and titanium, while Senegal ranks highly for phosphorous and zirconium. Papua New Guinea appears among the top ranks for cobalt, copper, and nickel. Such cases are especially important for the study's diversification objective, because they point to supplier countries that may not always be at the centre of India's current import structure but are nevertheless identified by the model as structurally attractive. These countries constitute plausible candidates for future portfolio broadening. Another notable feature is the presence of both advanced industrial economies and developing resource-rich countries in the same forward-looking portfolio (Ericsson et al., 2024). Countries such as the United States, Canada, Germany, Japan, Finland, and Australia appear alongside the Democratic Republic of the Congo, Madagascar, Mozambique, Nigeria, Senegal, Tanzania, and Sierra Leone. This mixed composition suggests that ore sourcing is shaped by more than just macroeconomic development. The model points to a combination of production strength, mineral endowment, trade orientation, and structural suitability. In policy terms, this means that India's optimal ore portfolio is unlikely to emerge from a strategy focused exclusively on either advanced economies or developing-country producers. Instead, a balanced sourcing approach may be required, combining reliability and institutional stability with resource access on one hand and diversification on the other.

In table 6, the forward-looking exercise on import of processed critical mineral products reveals a somewhat different sourcing structure. Since processed products reflect a more downstream stage of the value chain, the resulting pattern differs in important ways from the ores portfolio and provides additional insight into how India's future import strategy may need to vary import category-wise. A striking feature of the products portfolio is the much stronger presence of countries associated with processing capability, industrial integration, and downstream manufacturing networks rather than only raw mineral endowments (IEA, 2025). China occupies the top position for a large number of product categories, including antimony, bismuth, cadmium, gallium, germanium, indium, rare earths, silicon, tellurium, and tungsten, while also featuring prominently in many others (IRENA, 2023). This indicates that in the products category, India's potential suppliers are shaped not only by mineral availability but by countries' roles in refining, processing, and manufacturing critical mineral products. The prominence of countries such as Japan, South Korea, Belgium, Estonia, the United Kingdom, and Finland in several product categories reinforces this point, that, unlike ores, where mine output (production of mineral in raw form) and mineral occurrence dominate, processed products appear to reflect broader industrial and value-chain capabilities (Atakhanova et al., 2025). At the same time, it can be observed from the table that some mineral products are led by well-known primary producers that also rank highly in the ores' portfolio, such as Chile in copper, lithium, molybdenum, and rhenium, Brazil in niobium and tin, and South Africa in palladium and platinum. On the other hand, several minerals display very different product rankings from their ores' counterparts. For example, cobalt products are led by Cuba, Morocco, the Philippines, and Indonesia rather than by the Democratic Republic of the Congo; graphite products place Brazil and China ahead of the African suppliers that featured prominently in the ores ranking; and phosphorous products are led by Cuba, Morocco, and Jordan rather than by the broader ores-based group. This divergence suggests that competitive advantage in processed products is often less about extraction alone and more about the presence of midstream and downstream transformation and export capacity. A second important pattern is that the products portfolio appears somewhat more globally networked and geographically diverse than the ores portfolio. While the ores rankings were often anchored in large resource-rich exporters, the products rankings bring in a wider mix of advanced industrial economies, middle-income processors, and specialized trading hubs. Countries such as Belgium, Estonia, Denmark, Portugal, Spain, and the United Kingdom appear repeatedly in specific product categories, even where they are not among the leading global miners of the corresponding raw material. This is consistent with the idea that critical mineral products are embedded in more complex international production systems in which refining, alloying, intermediate manufacturing, and re-export functions matter alongside extraction (Singh, 2025; Vivoda et al., 2024; McCaffrey et al., 2023; Soto-Viruet et al., 2013). For India's import strategy, this means that optimizing the products portfolio cannot rely solely on geological or mining criteria, it also requires attention to industrial capabilities and participation in global value chains. The table further highlights that some countries occupy recurring positions across many products and can therefore be seen as broad strategic partners in the midstream and downstream value chain. China is the most obvious example, but countries such as Brazil, Russia, Canada, the United States, Australia, Belgium, and South Africa also appear across multiple minerals. This repetition indicates that India's future product-import strategy may benefit from distinguishing between two types of partners - first, countries that are systematically important across a range of processed mineral categories, and second, countries that hold strategic relevance in only a narrow set of products. The former are likely candidates for broader trade and industrial engagement, while the latter may require more targeted mineral-specific partnerships.

Table 7 presents perhaps the most distinctive of the three forward-looking portfolios. This is because the geography of waste and scrap imports differs sharply from that of ores and processed products. Whereas the ores portfolio was anchored largely in resource-rich producing economies and the products portfolio reflected midstream and downstream industrial and processing networks, the scrap portfolio is dominated by countries associated with large industrial systems, recycling-intensive economies, trading hubs, and secondary materials circulation. The most striking feature of the table is the overwhelming prominence of Russia and China across a very large number of minerals. Russia occupies the top rank for antimony, bismuth, cadmium, cobalt, copper, gallium, graphite, indium, lithium, molybdenum, nickel, niobium, palladium, platinum, rhenium, selenium, tantalum, tellurium, tin, titanium, tungsten, vanadium, and zirconium, while China also appears consistently within the top positions across nearly all categories. This degree of repetition is much stronger than in the ores and products portfolios and suggests that the scrap category is far more concentrated around a small number of large and structurally important players. From a portfolio perspective, this immediately raises a concentration issue, that India's future scrap sourcing options may be more limited and more dependent on a narrow set of countries than is the case for ores or products (IEA, 2024). A second major pattern is the strong presence of West Asian and transshipment-oriented economies in the upper ranks of several scrap categories. Saudi Arabia, the United Arab Emirates, Qatar, Kuwait, Oman, Iran, Bahrain, and Singapore appear repeatedly across minerals such as cobalt, copper, graphite, lithium, molybdenum, nickel, phosphorous, platinum, silicon, tin, titanium, tungsten, and vanadium. This is an important difference from the ores portfolio and reflects the distinct economics of scrap trade. Scrap flows are often linked to industrial consumption, recycling systems, trade intermediation, and logistics hubs (Sahni & Gutowski, 2011; (Lyons et al., 2009). The appearance of these economies suggests that India's scrap import strategy may need to focus on countries that function as aggregation, processing, or re-export nodes within global secondary-material supply chains. The scrap portfolio also appears more connected to industrial and commercial circulation than to geological endowment. Countries such as Germany, Italy, the Netherlands, Belgium, Switzerland, Poland, and the United States recur across several categories, despite not necessarily being dominant raw-mineral producers for the corresponding minerals. This is consistent with the regression results, which suggested that scrap imports are driven more by broader economic scale and structural characteristics than by mining production itself (Hu et al., 2020). In practical terms, the table indicates that India's future scrap sourcing opportunities lie heavily in industrial economies and trading hubs where recyclable material is generated, collected, processed, or redistributed at scale. At the same time, the table reveals substantial mineral-specific variation within this concentrated overall structure. Copper scrap is led by Russia, Saudi Arabia, China, Qatar, and Iran, while cobalt scrap is headed by Russia, Saudi Arabia, China, Turkey, and the United Arab Emirates. Lithium scrap is dominated by Russia and China but also includes the United Arab Emirates, Argentina, the United States, Germany, and Australia. Palladium and platinum scrap show strong positions for Russia, China, the United States, Canada, South Africa, and Finland, while rare earths scrap introduces the United States, Vietnam, Australia, Nigeria, Malaysia, Brazil, and Madagascar into the ranking. This indicates that although the scrap portfolio is generally more concentrated, there remains meaningful variation across minerals, and some categories offer more diversification space than others.

Compared with ores and products, Table 7 suggests that the scope for diversification in scrap is narrower and more uneven. Many minerals display top 10 lists populated by the same cluster of countries, especially Russia, China, Gulf economies, and a handful of industrial European or North American states (Hu et al., 2020). This pattern implies that India's scrap portfolio may be more vulnerable to concentration risk, geopolitical shocks, and trade disruptions affecting a relatively small set of supplier systems. Consequently, an optimized scrap-import strategy is likely to require more deliberate risk management than simple supplier expansion. For some minerals, it may be necessary to secure access through stable long-term partnerships with a limited set of key suppliers; for others, there may be room to widen the portfolio by engaging more actively with secondary suppliers that appear further down the ranking but still possess structural relevance. This means that India's approach to scrap sourcing may need to involve a different policy toolkit, potentially including engagement with recycling industries, circular economy partnerships, logistics arrangements, and customs/trade facilitation mechanisms rather than only upstream resource diplomacy.

Chapter 5: Conclusion

This report set out to identify how India might optimize its critical mineral import portfolio by constructing a model-based ranking of current and prospective supplier countries. Instead of treating past import patterns as self-evidently efficient, the study estimated the structural determinants of India's imports and used them to derive forward-looking mineral-wise partner rankings across ores and concentrates, processed products, and waste and scrap. In doing so, the analysis moved from a descriptive understanding of import dependence to a strategic assessment of sourcing attractiveness.

5.1. Key Findings

- India's critical mineral sourcing structure is highly heterogeneous across ores and concentrates, processed products, and waste and scrap, which means that a single undifferentiated import strategy is unlikely to be effective.
- The ores portfolio is shaped primarily by mineral endowment and upstream production capacity, with recurrent strategic relevance for countries such as Australia, Canada, Chile, the United States, China, and the Democratic Republic of the Congo, though the exact ranking varies by mineral.
- The products portfolio reflects midstream and downstream industrial and processing capability more strongly than raw geological availability, with China occupying a particularly central role across many product categories and countries such as Belgium, Estonia, Japan, South Korea, Brazil, and the United Kingdom also emerging as important suppliers.
- The scrap portfolio is more concentrated and network-driven than the other two categories, with Russia and China dominating across many minerals and several West Asian and industrial economies functioning as important hubs for secondary material flows.
- The forward-looking rankings show that concentration risk differs sharply by mineral. Some minerals have a relatively broad pool of plausible suppliers, creating scope for diversification, while others remain structurally narrow and therefore more vulnerable to disruption.
- A relatively small group of countries recurs across multiple minerals and categories, indicating that India's future sourcing strategy is likely to depend on a core set of strategically important partners supplemented by a wider set of mineral-specific suppliers.

- The model-based rankings identify both established partners whose importance is broadly supported by underlying supplier characteristics and underutilised partners that may represent missed opportunities for diversification.
- The findings suggest that India's historical import structure does not always fully align with model-implied sourcing attractiveness, implying that some degree of import dependence may reflect inertia, path dependence, or other unobserved constraints rather than optimal portfolio design.

5.2. Key Policy Recommendations

- India should adopt a mineral-wise and category-specific sourcing strategy rather than relying on a uniform policy approach across ores, products, and scrap.
- India should consider deepening long-term engagement with a core group of recurrent high-ranking partners identified by the model through trade diplomacy, commercial partnerships, and strategic cooperation mechanisms. These countries emerge as consistently attractive suppliers across multiple minerals and import categories under the estimated sourcing framework. At the same time, model-based rankings should not be treated as a complete measure of strategic suitability, since factors such as geopolitical alignment, trade restrictions, and certain forms of country risk are not explicitly captured. Similarly, the governance variable included in the model is intended only as a broad proxy for institutional quality and does not fully represent all dimensions of trade reliability or strategic vulnerability.
- India should explore diversification toward underutilised but structurally attractive suppliers, particularly in minerals where the model indicates a broader pool of viable partners and where current import concentration remains high. These countries emerge as promising candidates under the estimated sourcing framework, although further assessment of bilateral political, regulatory, and logistical constraints would be needed before translating model-based attractiveness into concrete diversification strategy.
- For minerals with a narrow global supplier base, policy should focus less on wide diversification and more on securing stable access through long-term agreements, strategic partnerships, and supply assurance arrangements.
- In the ores category, India should give priority attention to resource-rich producer countries that emerge as structurally important suppliers in the model, and consider strengthening upstream access through investment, offtake arrangements, and mineral diplomacy. This recommendation reflects the model's identification of countries with strong supply-side relevance, while recognising that the framework

captures only some dimensions of trade feasibility and risk through broad proxy variables rather than providing a complete cost- or risk-adjusted assessment.

- For processed mineral products, India may need to prioritize engagement with countries that are well positioned in downstream value chains. This interpretation is inferential rather than directly estimated, since the model does not contain an explicit measure of refining or processing capacity, but it is consistent with the finding that product-level sourcing patterns are not reducible to raw mineral production alone.
- In the scrap category, India should complement external sourcing with stronger cooperation in recycling, circular economy partnerships, and trade facilitation with major secondary-material hubs, while also reducing overdependence on a narrow set of suppliers.
- India should incorporate concentration risk more explicitly into critical mineral strategy by identifying minerals where supplier diversity is low and prioritising contingency planning for these categories.
- India should use model-based partner rankings as an indicative decision-support tool for trade negotiations, diplomatic engagement, strategic investment screening, and import diversification planning, rather than relying solely on historical import shares. The rankings are best understood as evidence-based signals of sourcing attractiveness under the estimated framework, not as prescriptive policy choices.
- India should strengthen domestic capabilities in processing, recycling, and secondary material recovery so that external sourcing strategy is complemented by greater internal resilience across the critical minerals value chain.

In conclusion, the report argues that India’s critical mineral import strategy should be reoriented toward a more diversified, mineral-wise, and category-specific portfolio. Such a strategy would strengthen resilience not by abandoning established suppliers, but by complementing them with a broader and more systematically identified set of partners. In this sense, the forward-looking portfolio developed in this study provides a useful foundation for thinking about how India can better secure access to critical minerals in an increasingly uncertain and competitive global environment.

5.3. Way Forward

While the present framework captures several broad determinants of sourcing attractiveness, future extensions could usefully incorporate a wider set of strategic, sector-specific, and policy-sensitive variables. These may include explicit measures of geopolitical alignment, trade restrictions, processing and refining capacity, logistics quality, circular economy capability, cost competitiveness, and political or regulatory risk. Some related dimensions are only indirectly proxied in the current specification through variables such as governance, distance, landlocked status, and FDI. Additional sector-specific indicators, such as mining or manufacturing value added, may also help capture domestic value-addition strategies, resource nationalism, and the tendency of some countries to retain minerals for internal processing rather than export. Incorporating such variables, where feasible, would further strengthen the policy relevance and interpretive depth of the framework.

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