

Foreign investment and structural transformation in mineral-rich emerging economies

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Abstract. The energy transition has intensified competition for critical minerals, but it remains unclear whether foreign capital promotes structural transformation in mineral-rich economies. This paper examines 30 emerging and developing economies from 2000 to 2024, treating Central Asia as a comparative regional group. Economy-wide structural transformation is measured by manufacturing value added as a share of GDP. Two-way fixed-effects models use lagged regressors, country-clustered standard errors, and Driscoll–Kraay inference, while AidData records distinguish upstream extraction from midstream processing finance. Aggregate FDI shows no statistically detectable average association with manufacturing value added; the estimate remains stable across

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robustness checks, and its 90% confidence interval lies within ± 0.10 percentage-point equivalence bounds. A positive interaction with tertiary enrollment appears only in the full sample and is not robust after 2015. Project-stage estimates are exploratory because midstream variation is limited to seven country-year observations and is sensitive to Indonesia. Central Asia does not exhibit a statistically different FDI–manufacturing association despite weaker institutions. The findings indicate that aggregate inflows reveal little about structural transformation and that investment composition and domestic linkages warrant more direct measurement.

Keywords: critical minerals, foreign direct investment, economic diversification, energy transition, mineral value chains, Central Asia, emerging markets

JEL Classification: F21, F23, L72, O13

1. INTRODUCTION

Low-carbon technologies depend on larger and more diverse mineral inputs than the fossil-based systems they replace. Copper, lithium, nickel, cobalt, graphite, manganese, and rare earth elements have therefore become central to the expansion of electricity grids, energy storage, renewable generation, and electric transport (IEA, 2025). Yet the geography of value creation remains highly uneven. Mining is distributed across a relatively broad group of producing countries, whereas refining, beneficiation, and separation capacity is concentrated among far fewer economies (Kim et al., 2026).

This imbalance creates a development problem for mineral-rich emerging economies. Raw materials may be exported at relatively low unit values and later re-enter world markets as higher-value components and manufactured goods. Recent research therefore treats the critical-mineral boom not only as a supply-security issue but also as a possible new form of the resource curse. The risk is particularly pronounced where foreign investment expands extraction without building domestic processing capacity, supplier networks, or technological capabilities (Braunstein & Chuchko, 2025; Boafo et al., 2024). Policy analysis similarly warns that rising mineral demand may reproduce resource dependence unless it is accompanied by stronger governance and domestic value-chain development (Arezki & van der Ploeg, 2025).

Mineral endowments are known to attract resource-seeking foreign capital and may simultaneously crowd out investment in non-resource sectors (Poelhekke & van der Ploeg, 2013). Their effect on production structure is less certain. One pathway links foreign investment to capital formation, technology transfer, workforce development, local procurement, and a broader manufacturing base. Backward linkages to domestic suppliers are especially important for such spillovers (Javorcik, 2004). The alternative pathway is enclave development, in which projects import equipment and specialized labor, repatriate profits, and generate few connections with the wider economy. Aggregate FDI inflows may therefore conceal substantially different structural effects depending on whether investment remains upstream or extends into processing and domestic linkages.

Central Asia provides a useful regional test within a broader comparative sample. Its five economies are landlocked, mineral-rich, institutionally heterogeneous, and differently positioned within mineral value chains. Kazakhstan is a major uranium and chromite producer, Tajikistan has substantial antimony exposure, Uzbekistan combines copper, gold, and uranium resources, and the remaining economies display varying degrees of dependence on individual extractive activities (U.S. Geological Survey, 2025). Kazakhstan and Uzbekistan are also pursuing state-supported processing strategies, although they differ in their inherited

industrial capacity and reliance on foreign capital (Kim et al., 2026; Aubakirova et al., 2025). Examining the region within a comparative panel makes it possible to determine whether its investment–manufacturing relationship is systematically different from that of other mineral-rich emerging economies.

Three gaps motivate the analysis. First, the critical-minerals literature remains dominated by the concerns of importing economies, including supply security, price volatility, and geopolitical competition, while the structural outcomes of producing countries receive less attention (Vivoda et al., 2024). Second, much of the FDI literature relies on aggregate inflows that combine extraction, processing, and unrelated sectors, thereby obscuring the role of investment composition. Third, resource-curse theory was developed largely around hydrocarbons and rent distribution, whereas energy-transition minerals enter manufacturing supply chains and may create different opportunities for domestic value capture (Badeeb et al., 2023). Central Asia is also rarely examined as a regional group within a wider panel of comparable mineral producers.

The goal of the study is to assess whether foreign investment is associated with economy-wide manufacturing development in mineral-rich emerging economies and whether this association varies with investment stage, institutional quality, tertiary enrollment, and Central Asian location. Structural transformation is operationalized as manufacturing value added as a share of GDP. The analysis addresses three tasks. It estimates the average association between lagged aggregate FDI and manufacturing value added, compares upstream extraction finance with midstream processing finance, and evaluates institutional, educational, and regional moderation.

RQ1. Is lagged aggregate foreign direct investment associated with manufacturing value added as a share of GDP in mineral-rich emerging economies?

RQ2. Do upstream extraction finance and midstream processing finance exhibit different associations with manufacturing value added as a share of GDP?

RQ3. Do institutional quality, gross tertiary enrollment, and Central Asian location modify the association between lagged foreign direct investment and manufacturing value added as a share of GDP?

Methodologically, the analysis uses an unbalanced country-year panel of 30 emerging and developing economies observed from 2000 to 2024. The major data sources are the World Bank World Development Indicators, the Worldwide Governance Indicators, and AidData’s Global Chinese Development Finance dataset. Two-way fixed-effects models are estimated with lagged regressors and country-clustered standard errors. Driscoll–Kraay inference is used as an additional robustness check. AidData project records are separated into upstream extraction and midstream processing finance to examine the composition of mineral investment.

The novelty of the study lies in integrating critical-mineral, FDI-spillover, resource-curse, and diversification perspectives within one empirical framework and in treating Central Asia as a testable regional differential rather than a set of country narratives. The comparative design places the five regional economies alongside producers such as Chile, Peru, Indonesia, Zambia, and Mongolia, making the regional claim empirically falsifiable rather than descriptive.

Two principal limitations define the scope of the findings. Manufacturing value added captures economy-wide industrial development rather than mineral-specific processing. In addition, the project-stage data cover Chinese official finance rather than total sectoral FDI and contain limited midstream variation. The results are therefore interpreted as conditional associations. Exposure to global mineral-demand shocks and a harmonized six-digit processed-mineral export indicator remain important extensions for future research.

2. LITERATURE REVIEW

To date, the material intensity of clean technologies has been studied and quantified in considerable detail. Publications by the World Bank (2023) and the International Energy Agency (2024) note that achieving stated climate goals will require a manifold increase in demand for a limited number of metals. Nate et al. (2021) similarly demonstrate that the transition to green energy is directly dependent on a narrow group of critical minerals, the availability of which is determined by rapidly growing demand, limited reserves, highly concentrated production, and supply chain risks. Price dynamics in these markets are entirely consistent with those of developing markets, as evidenced by the sharp spikes in lithium and cobalt prices in 2021 and 2022, followed by a deep decline. Wang et al. (2023) also emphasize that a sharp increase in raw material prices could jeopardize the very decarbonization goals that initially drove this high demand. Finally, Attilio (2025) concludes that price fluctuations in critical minerals are not purely industry-specific but have direct implications for investment decisions in the energy transition as a whole.

The second important structural feature is high market concentration. While ore mining itself is geographically distributed across multiple continents, the processes of refining, beneficiation, and separation are concentrated in a very limited number of regions. This creates a unique hourglass-like structure that simultaneously increases the risk of supply disruptions for importing countries and limits exporting countries' ability to extract added value (Kim et al., 2026). States have responded to these imbalances by introducing export restrictions, legal requirements for mandatory localization of raw material processing, and concluding bilateral agreements. Kalantzakos (2020) interprets these processes not as a typical commodity cycle, but as a fundamental geopolitical restructuring. For producing countries, the practical consequence of this transformation is that pricing for raw ore and refined metal is now subject to completely different institutional rules and regimes.

The theory of investment focused on natural resource exploration has a long history and is considered well-established. Commercial entities direct capital to regions with large raw material reserves, high-grade minerals in ore, predictable tax regimes, accessible logistics, and an acceptable level of political risk. Poelhekke and van der Ploeg (2013) demonstrate that the discovery of new deposits attracts relevant foreign direct investment but simultaneously deters capital inflows into non-resource sectors. Arezki et al. (2017) demonstrate that the discovery of ultra-large reserves begins to change macroeconomic indicators long before the first ore is shipped. Using Mozambique as an example, Toews and Vézina (2022) confirm that a major discovery triggered a significant influx of foreign capital and generated a measurable local multiplier effect. This proves that the investment response is quite real and does not remain merely at the level of declarative statements of intent.

The premise that mineral endowments attract investment is maintained rather than tested here, since the exposure measure needed to identify it cannot be constructed from the available data. The paper takes the investment as given and asks what it does to structure. Energy-sector development should also be evaluated against the industrial outcomes it generates rather than by expansion alone. Ginevičius et al. (2022) demonstrate that the economic significance of energy sector development is largely determined by its relationship with industrial production dynamics. This conclusion is supported by findings of Vasylieva et al. (2025) on relationship between FDI and technological advancements in energy sector. This finding emphasizes the need to clearly distinguish between simply increasing raw material production and qualitatively modernizing the production structure. At the same time, foreign investment can contribute to the diversification of the host economy through several key mechanisms. It relaxes the capital constraint, it imports process technology, it trains workers who later move to domestic firms, it builds power and transport infrastructure that other sectors use, and it creates demand for local inputs. Javorcik (2004) links productivity gains to the formation of feedback loops in the economy, while Alfaro et al. (2004) demonstrate

that the impact of foreign direct investment on economic growth is directly dependent on the level of development of the local financial system. Mangla and Yang (2025) also conclude that positive export spillovers for Indian firms are determined by their own absorptive capacity, not simply the physical presence of foreign capital in the market. Finally, Antonietti and Franco (2021) confirm Granger causality from foreign direct investment to increased economic complexity, providing the closest scientific evidence for the mechanism analyzed in this paper. Recent evidence from Uzbekistan further shows that structural transformation in a late-reforming transition economy can proceed through service-led labor reallocation while manufacturing remains comparatively weak, reinforcing the need to assess industrial upgrading directly rather than infer it from aggregate employment shifts (Tagaev et al., 2026).

The enclave counterargument is equally well grounded. Mineral projects are capital-intensive, import most of their equipment, sit far from population centers and sell into international markets, so their input-output footprint in the host economy can be small. Morris et al. (2012) argue that inter-industry linkages in the resource sector develop only when government policy specifically encourages their formation. Lashitew and Werker (2020), in turn, demonstrate that resource dependence, rather than natural resource abundance per se, is the primary driver of the negative consequences traditionally associated with the resource curse. Recent cross-country evidence similarly shows that natural-resource dependence is associated with lower diversification of non-resource and technologically advanced exports, while institutional quality conditions the ability of resource exporters to diversify (Linh, 2024; Tutar & Korpysa, 2026; Zarach & Parteka, 2023). An additional mechanism in this context is the strengthening of the national currency. Corden and Neary's (1982) analysis of a rapidly growing sector continues to explain why successful development in the extractive segment can lead to a contraction of the tradable manufacturing sector. Finally, Yasin and Esquivias (2023) conclude that spillovers from foreign direct investment in Indonesia's manufacturing sector depend on the specific industry and the level of import competition. This is entirely consistent with the notion that the direction of this influence is not constant.

H1. Lagged aggregate foreign direct investment inflows are positively associated with manufacturing value added as a share of GDP in mineral-rich emerging economies.

The stage composition of foreign investment should determine the extent to which capital inflows contribute to the development of domestic manufacturing. Upstream extraction projects are typically capital-intensive, geographically isolated, and dependent on imported equipment, which limits their linkages with the wider host economy. Midstream processing projects require metallurgical, chemical, logistical, maintenance, and supplier capabilities that may create stronger domestic input-output connections. Backward linkages are a principal channel through which foreign investment generates productivity spillovers, although their strength depends on domestic supplier capacity and sectoral conditions (Bieleń et al., 2024; Javorcik, 2004; Morris et al., 2012; Sokolenko et al., 2026; Yasin & Esquivias, 2023). Processing finance is therefore expected to have a stronger positive association with manufacturing development than finance directed solely toward extraction.

H2. Midstream processing finance has a stronger positive association with manufacturing value added as a share of GDP than upstream extraction finance does.

The direction of investment, particularly whether it remains concentrated at the extraction stage or extends into downstream segments of the value chain, depends partly on the institutional conditions prevailing in the host economy. Recent evidence confirms that resource-curse outcomes are conditional rather than uniform. Destek et al. (2023) show that institutional quality, human capital, and financial development can mitigate the adverse development effects of resource dependence. Chung and Jin (2025) further demonstrate that the direction and magnitude of the resource-curse relationship vary across resource types and stages of economic development, with institutional quality mediating these differences. These findings suggest that the structural consequences of mineral investment depend not only on the volume of

resources or capital inflows but also on the institutional capacity to direct rents toward productive investment and domestic value-chain development.

In the context of mineral processing, four key institutional aspects are particularly important. The quality of regulation determines how predictable licensing and permitting processes are for investors willing to invest in projects with a 30-year payback period, such as the construction of metallurgical plants. The rule of law guarantees the implementation of long-term raw material supply contracts and joint venture agreements. Effective public administration ensures the timely connection of electricity, water, and rail networks to industrial facilities. Finally, control of corruption determines whether localization requirements serve as a viable instrument of industrial policy or merely another mechanism for rent extraction.

H3. The positive association between lagged foreign direct investment and manufacturing value added as a share of GDP strengthens with higher composite institutional quality.

Spillovers require a receiver. Metallurgical and chemical processing needs engineers, laboratory capacity, maintenance firms, and a supplier base capable of meeting specifications, and where these are missing, the foreign investor imports them. Research on the adoption of new technologies similarly shows that the successful adoption and productive use of advanced solutions depend on professional knowledge, the availability of qualified personnel, organizational learning capacity, and complementary institutional support rather than on technology availability alone (Banaitiene et al., 2025; Serhieiev et al., 2025; Tagaev & Bilan, 2026). Gylfason (2001), in turn, demonstrated that resource-rich countries systematically underinvest in education, even though this factor subsequently determines the economy's ability to effectively utilize investments in processing industries. Finally, Lashitew et al. (2021), in an analysis of successful diversification cases in resource-dependent countries, concluded that the most effective strategies combined public investment in skills development with targeted support for local suppliers. Mealy and Teytelboym (2022) show that the capabilities needed for green production are related to a country's existing capability set, which implies that the leap from ore to cathode material is much larger for some producers than for others.

H4. The positive association between lagged foreign direct investment and manufacturing value added as a share of GDP strengthens with increasing gross tertiary enrollment.

Several features could make the region different. All five states are landlocked, so ore must travel far before it reaches a port, which raises the relative attractiveness of processing near the mine but also raises the cost of importing the reagents, equipment and energy that processing requires. Industrial structure inherited from the Soviet period concentrated refining in a few large complexes and left supplier networks thin. Recent evidence on post-Soviet economies similarly identifies limited industrial diversification, natural-resource dependence, weak institutions and human-capital constraints as major barriers to the development of higher-value-added activities (Gasim et al., 2025). State-owned enterprises still dominate the mineral sector, which changes the bargaining problem between host and investor. Domestic markets are small, and regional industrial cooperation remains limited, so a smelter must export nearly all of its output.

Despite these constraints, the region has a genuine processing base for uranium and copper, and both Kazakhstan and Uzbekistan are directing state capital toward midstream capacity (Sagzhanov et al., 2025). At the same time, the capacity to support a green industrial transition remains uneven across the region. Olzhebayeva et al. (2023) show that Green Deal research in Central Asia is expanding but remains strongly conditioned by national differences in R&D capacity, human capital and institutional readiness. Whether that base extends to the separation technologies that carry the highest margins is an open question, and the historical record of the rare earth joint venture at Stepnogorsk suggests that the technical barrier is higher than the reserve statistics imply (Kim et al., 2026).

H5. The association between lagged foreign direct investment and manufacturing value added as a share of GDP is weaker in Central Asian economies than in the comparator economies.

Conceptual framework

Figure 1 summarizes the theoretical channels developed above. The upper path runs from critical mineral endowments through foreign investment into extraction and processing, domestic linkages, and structural transformation. Institutions, human capital, infrastructure, and local supplier capacity moderate this transmission. The lower path represents the failure channel, in which investment remains concentrated in enclave extraction, reinforces raw-export concentration and generates limited structural transformation.

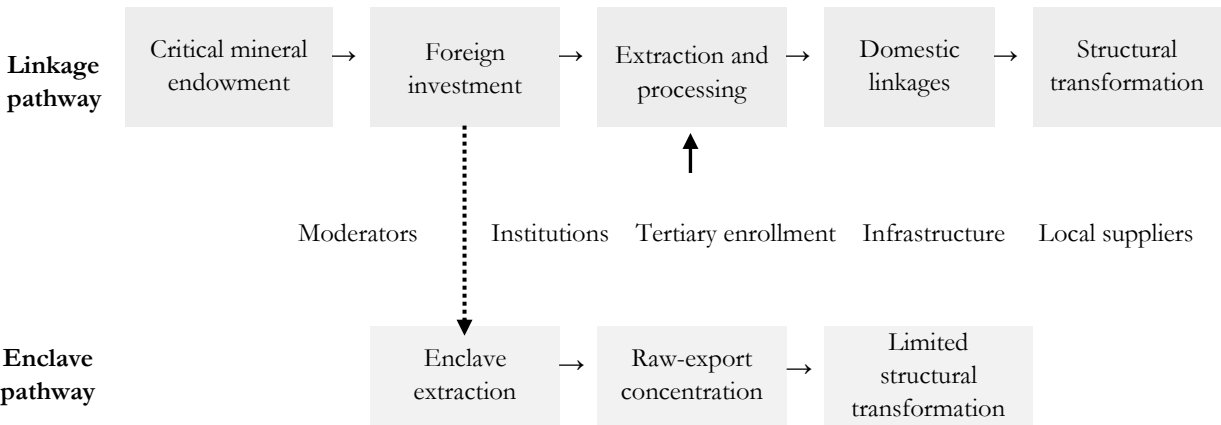


Figure 1. Pathways from critical mineral investment to structural transformation

Note. The linkage pathway captures domestic value creation through processing and supplier linkages; the enclave pathway captures continued dependence on raw mineral exports.

3. DATA AND METHODOLOGY

The sample covers 30 mineral-rich emerging and developing economies observed annually from 2000 to 2024. The resulting country-year frame contains up to 750 potential observations, but the estimation panel is unbalanced because source coverage varies across variables. The study period ends in 2024, as comparable and final statistical series on foreign direct investment for the entire set of countries for 2025 have not yet been published, and extending the time horizon would require combining the preliminary and final data in a single regression equation.

Five Central Asian republics form the focal group: Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. Twenty-five comparators supply the cross-sectional variation that five countries cannot. The comparator economies are drawn from the South Caucasus, East and Southeast Asia, Latin America, Sub-Saharan Africa and the Pacific. They were selected for their mineral exposure, resource dependence, relevance to mineral processing or manufacturing, institutional comparability, and data availability, rather than on the basis of estimated outcomes. Indonesia matters because its ore export ban is the clearest natural experiment in forced downstreaming that the period contains (Guberman et al., 2024). Chile and Peru anchor the high end of mineral governance; the Democratic Republic of the Congo and Zambia anchor the concentrated end; and Malaysia and South Africa provide cases with deeper manufacturing bases. The complete country coverage and the rationale for including each focal economy and comparator are reported in Appendix Table A2.

The design of this study is intentionally two-tiered. Statistical inference is based on a full comparative panel, in which the presence of thirty clusters makes the use of traditional robust standard errors for clustering entirely justified. The analysis for Central Asia is conducted first by assessing differential relationships within this overall panel, and is then supplemented by a descriptive comparison of

development levels and trajectories. Assessing a separate panel consisting of only five countries would yield only five clusters. Cameron et al. (2008) show that asymptotic inference based on robust standard errors for clustering performs extremely poorly with such a small number of groups. For this reason, no causal inference in this paper relies solely on a regional subsample.

Variable definitions, measurement procedures, and data sources are presented in Table 1. All series come from open official sources, and the replication package rebuilds the panel from raw downloads.

Table 1

Variable definitions, measurement and data sources

Variable	Definition	Source
Manufacturing value added	Manufacturing value added, percent of GDP	World Bank WDI, NV.IND.MANF.ZS
Manufacturing value added per capita	Manufacturing value added in constant dollars divided by population, also in log form	World Bank WDI, author calculations
FDI inflows	Net FDI inflows, percent of GDP	World Bank WDI, BX.KLT.DINV.WD.GD.ZS
Extraction finance	Upstream mineral project official finance, count and value	AidData Global Chinese Development Finance
Processing finance	Midstream mineral project official finance, count and value	AidData Global Chinese Development Finance
Institutional quality	Mean of standardized GE, RQ, RL and CC estimates	World Bank WGI
Tertiary enrollment	Tertiary enrollment, gross percent	World Bank WDI, SE.TER.ENRR
Controls	GDP per capita, trade openness, gross capital formation, natural resource rents	World Bank WDI
Export concentration (legacy)	UNCTAD-origin product concentration, secondary check	World Bank, TX.CONC.IND.XQ

Note. WDI denotes World Development Indicators, and WGI denotes Worldwide Governance Indicators. GE, RQ, RL and CC refer to government effectiveness, regulatory quality, rule of law and control of corruption, respectively. Manufacturing value added per capita is calculated by the authors from constant-dollar manufacturing value added and population data.

The assessment panel is constructed using actual observed indicators of value added in manufacturing, foreign investment inflows, four World Bank governance indicators, a standardized institutional index, and macroeconomic control variables. Data coverage for various indicators ranges from 70 to 100 percent. Information on project finance in the mineral resources sector from the AidData database is separated into extraction and downstream processing, and these indicators are then included in the investment structure test in Table 3. A historical series of export concentrations covering nine economies for the period up to 2011 is used as an additional check. Empty cells are classified as missing values rather than zero, and imputation methods are not applied to them.

The main outcome is manufacturing value added as a share of GDP. It captures economy-wide industrial development rather than processing within the mineral value chain itself. The measure therefore addresses whether mineral-related investment is associated with a broader manufacturing base, not whether raw minerals are converted into refined products domestically. It is used because it is consistently available across the full set of countries and years and does not depend on incomplete bilateral trade classifications. A country may expand mineral extraction while manufacturing value added remains stagnant or declines, which is consistent with enclave development. However, the measure cannot identify whether changes occur specifically in smelting, refining, chemical processing, or mineral-based manufacturing.

As a robustness outcome, manufacturing value added in constant dollars is divided by population and entered in both level and logarithmic form. This addresses the possibility that manufacturing value added as a share of GDP falls mechanically when mineral extraction expands the GDP denominator.

A narrower outcome would be a processed-mineral export ratio, defined as processed-mineral exports divided by the combined value of raw and processed-mineral exports at the six-digit product level. Such an indicator would directly measure domestic value capture within mineral supply chains and therefore provide a more precise test of the movement from extraction to processing. Comparable harmonized trade data were not available for the present version of the study. Consequently, the reported results should be interpreted as evidence on economy-wide manufacturing development, while the trade-based processing ratio remains the principal extension for future research.

Foreign direct investment. Aggregate net inflows as a share of GDP are the baseline treatment. Aggregate FDI is a blunt instrument, since it pools mining with telecommunications, finance, and unrelated manufacturing, and this bluntness is central to the argument rather than incidental. If the composition of investment determines structural outcomes, then the aggregate regressor should carry little signal, and testing is one purpose of the design.

Project composition. The composition of investment is derived from project-level official finance data. The AidData record of Chinese development finance identifies each mineral project and classifies it by stage, which allows extraction projects to be separated from processing projects. Four variables follow, namely the value of mineral finance, the count of upstream extraction projects, the count of midstream processing projects and presence dummies for each stage. This split allows the extraction and processing channels to be distinguished, since the two enter the host economy through different input-output footprints. The record is sparse, so the analysis reports exactly how many country-years and economies identify each coefficient, preventing the estimates from being interpreted more strongly than the data support.

Mineral demand exposure. A future extension would construct a shift-share exposure measure by interacting pre-sample country-mineral production shares with global mineral-price changes, following the logic of Goldsmith-Pinkham and coauthors (2020) and the inference results of Borusyak et al. (2022). This measure is not used in the present analysis because compatible pre-sample production shares and complete world-price series are unavailable for the ten minerals. This limitation is discussed in the final paragraph of the Discussion.

Institutional quality. The four Worldwide Governance Indicators most relevant to investment are standardized and averaged,

$$Institutions_{it} = \frac{z(GE)_{it} + z(RQ)_{it} + z(RL)_{it} + z(CC)_{it}}{4}$$

and the index enters both as a direct control and in interaction with foreign investment.

Controls are kept deliberately short, since 30 countries do not support a long right-hand side. The specification includes log GDP per capita, trade openness, gross capital formation as a share of GDP, and total natural resource rents as a share of GDP. Tertiary enrollment enters the tertiary-enrollment specification. Natural resource rents are absorbed by the hydrocarbon channel, so the estimates are not driven by oil and gas exporters, and year fixed effects remove any shock common to all countries.

The estimated models take manufacturing value added as the outcome and two-way fixed effects as the estimator.

Model 1 is the baseline structural-transformation equation.

$$MVA_{it} = \beta_1 FDI_{i,t-1} + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Country fixed effects μ_i absorb geology, geography, and time-invariant institutional inheritance, while year fixed effects λ_t absorb global capital-market conditions. Under the linkage view, β_1 is positive, and under the enclave view, it is zero or negative.

Model 2 adds the institutional moderator.

$$MVA_{it} = \beta_1 FDI_{i,t-1} + \beta_2 Institutions_{it} + \beta_3 (FDI_{i,t-1} \times Institutions_{it}) + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

The coefficient of interest is β_3 , which tests whether the association strengthens with institutional quality as H3 predicts.

Model 3 estimates moderation by gross tertiary enrollment.

$$MVA_{it} = \beta_1 FDI_{i,t-1} + \beta_2 HC_{it}^c + \beta_3 (FDI_{i,t-1} \times HC_{it}^c) + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where $HC_{it}^c(i,t)$ denotes gross tertiary enrollment centered at its sample median. Centering makes β_1 the association between foreign investment and manufacturing value added at the median level of gross tertiary enrollment. H4 predicts that the interaction coefficient is positive.

The marginal association of foreign investment with manufacturing value added is therefore

$$\frac{\partial MVA_{it}}{\partial FDI_{i,t-1}} = \beta_1 + \beta_3 HC_{it}^c$$

The marginal association across the observed tertiary-enrollment distribution is illustrated in Figure 2, with confidence intervals calculated using the delta method.

Model 4 estimates the composition channel from the project data.

$$MVA_{it} = \beta_1 Extraction_{i,t-1} + \beta_2 Processing_{i,t-1} + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

A difference between b1 and b2 is that the stage of investment, not its volume, reaches the productive structure. Model 4 tests H2 by comparing the associations of upstream extraction finance and midstream processing finance with manufacturing value added.

Model 5 estimates the Central Asian differential.

$$MVA_{it} = \beta_1 FDI_{i,t-1} + \beta_2 (FDI_{i,t-1} \times CentralAsia_i) + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

A negative β_2 means investment yields less structural transformation in the region than in comparable emerging markets, as H5 predicts.

The baseline estimator is two-way fixed effects with country clustering and lagged regressors. Driscoll-Kraay standard errors are reported alongside the baseline, since all sample countries face common world prices and cross-sectional dependence is likely (Driscoll & Kraay, 1998). With 30 clusters, the asymptotic cluster-robust approximation is defensible, and Cameron et al. (2008) show that this is the region where it begins to be reliable, which is why the Central Asian result is estimated as a differential inside the full panel rather than on the five-country subsample.

Several robustness and sensitivity checks are implemented. The largest regional economy, Kazakhstan, is excluded because of its potential influence on the estimates. The sample is restricted to 2015–2024, the lag for foreign investment is extended from one to two years, and foreign investment is interacted with natural resource rents. The composition coefficients are also re-estimated after excluding each processing economy in turn, with the results presented in Appendix Table A1. Finally, the legacy export-concentration series provides an alternative outcome for the nine economies and years for which it is available.

To distinguish an imprecise null result from evidence of a substantively small association, the baseline coefficient is additionally evaluated using two one-sided equivalence tests. The equivalence bounds are set at ± 0.10 percentage points of manufacturing value added for a one-percentage-point increase in FDI. Given the sample standard deviations, this bound corresponds to approximately 0.60 percentage points of manufacturing value added for a one-standard-deviation increase in FDI, or about one-tenth of the outcome standard deviation. Equivalence is supported when the 90% confidence interval for the coefficient lies entirely within these bounds.

4. RESULTS

Manufacturing value added is the main outcome throughout. The variable is available for all 30 economies at some point during the 2000–2024 study period, but annual coverage is incomplete: 682 of the 750 potential country-year observations are observed. Because the baseline regression additionally requires non-missing lagged FDI and all control variables, the final baseline estimation sample consists of 541 country-year observations across all 30 economies. It captures whether foreign investment is associated with economy-wide industrial development, but it does not directly measure the domestic processing of specific minerals. Foreign investment enters as the one-year lag of net inflows, institutional quality enters as the standardized mean of the four governance indicators, and each specification includes country and year fixed effects, with country-clustered standard errors. Driscoll-Kraay standard errors are reported alongside the baseline. The baseline estimation sample contains 541 country-year observations across all 30 economies. The institutional specifications use 517 observations, whereas the tertiary-enrollment models use 401 observations due to missing tertiary-enrollment data. The composition analysis additionally uses project-level extraction and processing of finance data from AidData.

Descriptive statistics for the estimation panel are presented in Table 2. Manufacturing value added averages 12.8 percent of GDP, with widespread foreign investment averaging 4.6 percent of GDP, and the institutional index sits below zero for most of the sample, reflecting the developing-economy composition of the panel. The descriptive statistics show substantial variation across the panel and provide the basis for comparing Central Asia with the other economies.

Table 2

Variable-level descriptive statistics for the unbalanced panel, 2000–2024

Variable	N	Mean	SD	Min	Max
Manufacturing value added (% GDP)	682	12.83	5.69	1.63	31.95
FDI inflows (% GDP)	749	4.64	5.96	-37.17	55.07
Institutional index	720	-0.46	0.65	-2.07	1.44
Log GDP per capita	750	7.91	0.99	5.66	9.59
Trade openness (% GDP)	722	77.59	34.06	21.85	220.41
Gross capital formation (% GDP)	697	24.56	8.44	1.52	58.15
Natural resource rents (% GDP)	658	10.04	10.02	0.01	75.37
Tertiary enrollment (%)	526	32.76	22.77	0.60	110.18

Note. The full country-year frame contains 750 potential observations (30 economies $\times$ 25 years). The N reported for each variable is the number of non-missing observations available for that variable and therefore differs across rows. These variable-specific counts should not be interpreted as regression sample sizes. The baseline fixed-effects model is estimated on 541 complete country-year observations for which the dependent variable, lagged FDI, and all baseline controls are jointly available. No missing observations are imputed.

Exploratory estimates of project-stage composition based on Chinese official finance recorded by AidData are presented in Table 3. These estimates do not measure the effect of total sectoral FDI and should not be interpreted as a separate causal test. Total mineral project finance is not significantly associated with manufacturing value added. When projects are separated by stage, upstream extraction coefficients remain statistically insignificant, whereas midstream processing coefficients are negative under the event-count and presence specifications. A Wald test rejects equality between the extraction and processing coefficients in the event-count specification but not at the 5% level in the presence specification.

These differences are identified by an exceptionally sparse midstream record. Processing projects occur in only seven country-year observations across four economies. Moreover, excluding Indonesia reduces the

processing-events coefficient from -1.081 to -0.390 and the processing-presence coefficient from -1.594 to -0.432 , with both estimates becoming statistically insignificant. The project-stage results therefore show that disaggregating finance may reveal patterns hidden by aggregate flows, but they do not establish that processing investment reduces or increases economy-wide manufacturing development. Their principal contribution is to identify a potentially relevant distinction that requires a larger project sample and a mineral-specific processing outcome. Accordingly, H2 is not supported: the estimated processing-finance coefficients are not more positive than the extraction-finance coefficients and are too sensitive to sparse midstream variation to support a general conclusion.

Table 3

Exploratory associations between project-stage mineral finance and manufacturing value added

	(1) Total finance	(2) Event counts	(3) Presence dummies
Chinese mineral finance (t-1), \$bn	0.048 (0.143)		
Upstream events (t-1)		-0.132 (0.153)	
Midstream events (t-1)		-1.081 (0.448)**	
Extraction presence (t-1)			-0.208 (0.387)
Processing presence (t-1)			-1.595 (0.748)**
Wald test, extraction = processing (p)		0.038	0.069
Controls	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	542	542	542

Note. The dependent variable is manufacturing value added as a percentage of GDP. All specifications include log GDP per capita, trade openness, gross capital formation, natural resource rents, country fixed effects and year fixed effects. Country-clustered standard errors are reported in parentheses. Project data refer to Chinese official finance recorded by AidData and are divided into upstream extraction and midstream processing. The Wald row reports the p-value for equality of the extraction and processing coefficients. Midstream variation is identified by only seven country-year observations across four economies. Excluding Indonesia substantially reduces both processing coefficients and renders them statistically insignificant. The estimates should therefore be interpreted as exploratory associations rather than as causal or generalizable effects. ** $p < 0.05$.

The baseline, institutional-quality, and tertiary-enrollment estimates corresponding to H1, H3, and H4 are presented in Table 4. The baseline and institutional specifications indicate a small, statistically insignificant average association, whereas the tertiary-enrollment interaction reveals substantial variation across tertiary enrollment levels. In the baseline two-way fixed-effects specification, the coefficient on lagged foreign investment is -0.029 with a country-clustered standard error of 0.038 , so a one-percentage-point increase in inflows is associated with a change in manufacturing value added that is not statistically distinguishable from zero. The Driscoll-Kraay standard error tightens to 0.018 and still leaves the coefficient short of conventional significance. Adding the institutional index and its interaction with investment does not change the picture, since the interaction is -0.028 with a standard error of 0.061 . The tertiary-enrollment interaction in column 5 is the one specification that departs from the null, since the coefficient on foreign investment interacted with tertiary enrollment is 0.004 with a standard error of 0.001 . Enrollment is centered at the sample median, so the main coefficient of -0.118 represents the association of investment with manufacturing value added at the median level of tertiary enrollment; it is negative and significant. Column 4 estimates the plain baseline on the same 401 observations and returns a coefficient of -0.062 that is insignificant, close to the full-sample -0.029 , which confirms that the interaction and not the change in sample drives the result. This result must be read carefully. At the 10th percentile of enrollment, approximately 6.2%, the marginal association is about -0.21 ; at the median of 29.1%, it is about -0.12 . The point estimate crosses zero at approximately 58% enrollment, while the lower bound of the 95% confidence interval becomes positive only at around 68%, above the sample's 90th percentile of 64.7%. Figure 2 traces

this marginal association across the enrollment range, with confidence bands from the delta method. The interaction is also not robust to the recent window, since it disappears when the sample is restricted to 2015 to 2024. The full-sample interaction is consistent with the mechanism proposed in H4, but it does not provide robust support for the hypothesis. The marginal association remains negative across most of the observed tertiary-enrollment distribution and becomes non-negative only at unusually high enrollment levels. Moreover, the interaction is statistically insignificant when the sample is restricted to 2015–2024. The result should therefore be interpreted as exploratory and sensitive to the estimation period. Overall, H1 and H3 are not supported, while H4 receives only exploratory and period-sensitive support.

The underlying average relationship remains statistically insignificant across all robustness checks. The result remains robust when excluding Kazakhstan from the sample, when limiting the study period to 2015–2024, when replacing the one-dimensional time lag with a two-year lag, and when introducing a variable that interacts investment volume with natural resource rent. None of the resulting coefficients even approach statistical significance, and their point estimates cluster around zero rather than exhibiting dispersion. This demonstrates the stability of the estimated average association across model specifications. The equivalence test further shows that the baseline estimate is sufficiently precise to exclude effects outside the substantively defined ± 0.10 -percentage-point equivalence bounds. The 90% confidence interval ranges from -0.094 to 0.036 and lies entirely within these bounds, supporting statistical equivalence at the 5% level (TOST $p = 0.036$, using 29 cluster degrees of freedom). However, the estimates are not sufficiently precise to establish equivalence under narrower bounds such as ± 0.05 percentage points. Since the share of manufacturing in gross domestic product can decline as the extractive sector grows due to the expansion of the denominator, the manufacturing sector's per capita value added in constant prices, in both absolute and logarithmic forms, was used as an alternative indicator. The identified relationship remains extremely weak and insignificant. The logarithmic coefficient is -0.001 with a standard error of 0.004 , indicating the absence of a denominator effect that would explain the null result.

Taken together, the results indicate that aggregate FDI inflows contain limited information about economy-wide manufacturing development. The project-stage analysis suggests that investment composition may be more informative than total inflow volume, although the sparse midstream record prevents a definitive conclusion. A mineral-specific processing outcome would provide a more direct test of domestic value capture.

Table 4

Aggregate FDI, institutional quality and tertiary-enrollment heterogeneity

	(1) Baseline	(2) + institutions	(3) FDI x institutions	(4) Baseline, enrollment sample	(5) FDI x tertiary enrollment
FDI (t-1)	-0.029 (0.038)	-0.044 (0.048)	-0.044 (0.048)	-0.062 (0.056)	-0.118 (0.021)***
Institutional index		-0.31 (1.42)	-0.31 (1.42)		
FDI (t-1) x institutions			-0.028 (0.061)		
Tertiary enrollment (centered)					-0.031 (0.030)
FDI (t-1) x tertiary enrollment					0.004 (0.001)***
Controls	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	541	517	517	401	401
Within R-squared	0.099	0.073	0.073	0.140	0.148

Note. The dependent variable is manufacturing value added as a percentage of GDP. All models include log GDP per capita, trade openness, gross capital formation, natural resource rents, country fixed effects, and year fixed effects.

Country-clustered standard errors are reported in parentheses. The Driscoll–Kraay standard error for the baseline FDI coefficient is 0.018. Tertiary enrollment in column 5 is centered at the sample median, so the FDI coefficient represents the association at median enrollment. The smaller samples in columns 4 and 5 reflect missing tertiary-enrollment observations.

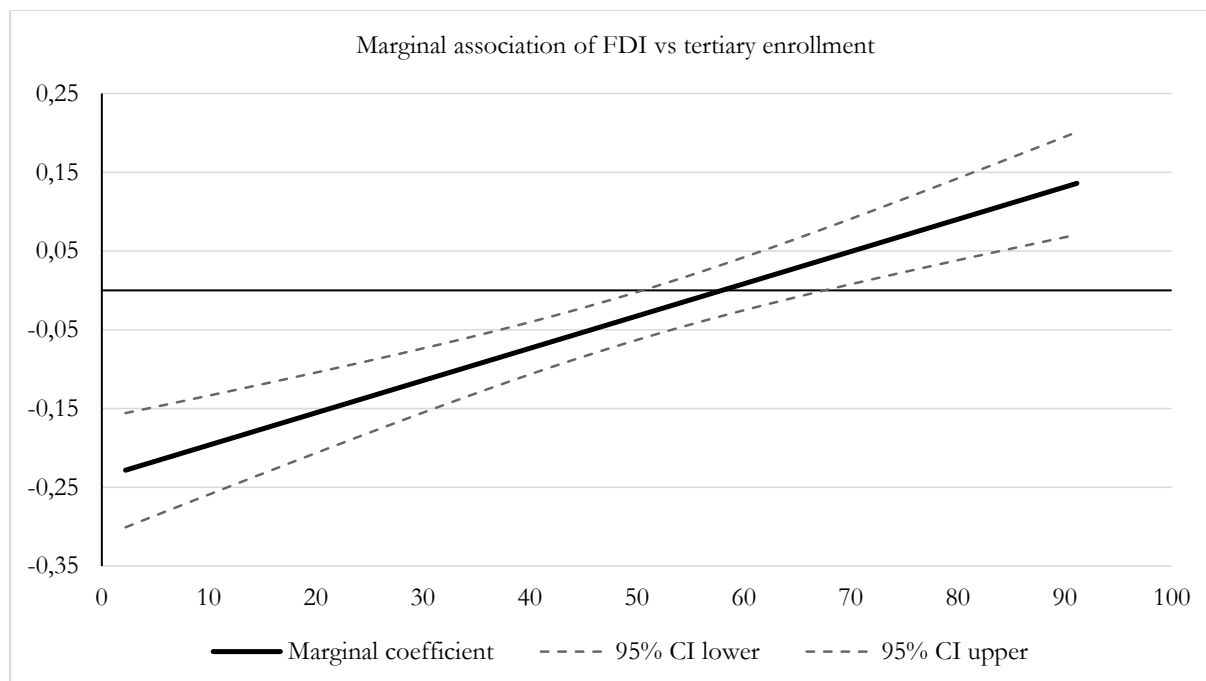


Figure 2. Marginal association of FDI across tertiary-enrollment levels

Note. The central line shows the marginal coefficient on lagged FDI across observed levels of gross tertiary enrollment. The two outer lines report the lower and upper bounds of the 95% confidence interval calculated using the delta method. The interaction is estimated from the full available sample but is not statistically significant in the 2015–2024 subsample and should therefore be interpreted as exploratory.

The estimated Central Asian differential is presented in Table 5. The interaction between lagged FDI and Central Asian membership is 0.029 with a standard error of 0.091, so the region’s structural-transformation response to foreign investment is statistically indistinguishable from that of the comparator group. On levels, the region is unexceptional in two respects and distinctive in one. Mean manufacturing value added over the period is 13.4 percent of GDP in Central Asia, compared with 12.7 percent in the comparators, and mean FDI inflows are 4.7 percent of GDP, compared with 4.6 percent in the comparators, so neither the outcome nor the treatment separates the region. Institutional quality does separate it. The Central Asian mean of the institutional index is -1.01, compared with -0.35 for the comparators, placing the region well below the sample on governance while sitting at the sample average on investment and industry.

H5 is not supported regarding the FDI-manufacturing relationship. The interaction coefficient is positive but statistically insignificant, indicating that Central Asia does not exhibit a systematically weaker association than the comparator economies. The region is nevertheless distinctive descriptively, since it combines approximately average FDI inflows and manufacturing value added with substantially poorer institutional quality. This institutional gap may affect the composition and domestic absorption of mineral investment, but the present aggregate specification cannot establish that mechanism.

Whether the region converts mineral investment into processing at a lower rate than comparators cannot be settled on manufacturing value-added alone; it is the natural next step for the six-digit processing

outcome. The project-level split between extraction and processing records the stage of each investment and offers one way to examine that question directly once the trade-based outcome is available.

Table 5

Central Asia in comparative perspective: FDI, manufacturing and institutions

	(1) FDI association	(2) Group means
FDI (t-1)	-0.030 (0.040)	
FDI (t-1) x Central Asia	0.029 (0.091)	
Mean MVA, Central Asia (N=84)		13.4
Mean MVA, comparators (N=598)		12.7
Mean FDI, Central Asia (N=125)		4.7
Mean FDI, comparators (N=624)		4.6
Mean institutional index, Central Asia (N=120)		-1.01
Mean institutional index, comparators (N=600)		-0.35
Controls	Yes	
Country and year FE	Yes	
Observations (regression)	541	

Note. Column 1 reports a two-way fixed-effects regression with log GDP per capita, trade openness, gross capital formation, and natural resource rents as controls. Country-clustered standard errors are reported in parentheses. Column 2 reports unweighted group means calculated from all available country-year observations; the corresponding numbers of observations are shown in parentheses beside each variable. Central Asia comprises Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. The interaction between FDI and Central Asian membership is statistically insignificant, so H5 is not supported.

Robustness and sensitivity checks for the lagged-FDI coefficient are summarized in Table 6. The null result for aggregate investment holds across all estimated specifications. It survives the exclusion of Kazakhstan, the restriction to the 2015–2024 period, the use of a two-year lag, the interaction with natural resource rents, and the use of alternative outcomes. The point estimates remain concentrated near zero rather than varying substantially across specifications. In the baseline model, the 90% confidence interval (−0.094 to 0.036) lies within the ± 0.10 percentage-point equivalence bounds, indicating that effects outside this range can be rejected at the 5% level.

Table 6

Robustness and sensitivity of the lagged-FDI estimates

Specification	Coefficient	SE	Observations
Baseline, clustered SE	-0.029	0.038	541
Baseline, Driscoll-Kraay SE	-0.029	0.018	541
Add institutional interaction	-0.044	0.048	517
Exclude Kazakhstan	-0.030	0.039	522
Period 2015 to 2024	-0.003	0.017	279
Two-year FDI lag	-0.014	0.032	517
FDI x resource rents	-0.070	0.067	519
Outcome: log MVA per capita (const. USD)	-0.001	0.004	541
Outcome: MVA per capita, level (const. USD)	-0.163	1.050	541
Legacy concentration outcome, 9 economies	0.002	0.003	89

Note. Each row reports a separate regression. Unless otherwise stated, specifications include log GDP per capita, trade openness, gross capital formation, natural resource rents, country fixed effects and year fixed effects. Standard errors are country-clustered, except for the row explicitly using Driscoll–Kraay inference. The reported coefficient is the coefficient on lagged FDI; in interaction specifications, it is evaluated when the relevant moderator equals zero. Manufacturing value added per capita is measured in constant US dollars. For the legacy concentration outcome, higher values indicate greater export concentration, and the sample is limited to nine economies through 2011. For the

baseline specification, the two one-sided equivalence tests use bounds of ± 0.10 percentage points. The corresponding 90% confidence interval is $[-0.094, 0.036]$, and the TOST p-value is 0.036 using 29 cluster degrees of freedom.

5. DISCUSSION

The estimates do not support a general positive association between aggregate FDI and manufacturing development in mineral-rich economies. This finding is consistent with the possibility that foreign capital expands extraction without generating sufficiently strong domestic industrial linkages, although the country-level models do not directly identify an enclave mechanism. A plausible interpretation is that the structural consequences of mineral investment depend on its stage composition, domestic linkages, and the host economy's absorptive capacity.

The tertiary-enrollment interaction provides a plausible but sample-sensitive indication of absorptive capacity. In the full sample, higher tertiary enrollment weakens the negative association between foreign investment and manufacturing value added, and the marginal coefficient becomes non-negative only near the upper end of the enrollment distribution. However, the interaction is not statistically significant in the 2015–2024 subsample. The result, therefore, does not establish gross tertiary enrollment as a robust moderator, although it identifies an absorptive-capacity mechanism that warrants examination using more complete education and sector-specific investment data.

The project-level analysis provides exploratory rather than confirmatory evidence. Aggregate project finance is not associated with manufacturing value added, while the coefficients differ after projects are separated into extraction and processing stages. However, midstream variation is identified by only seven country-year observations across four economies, and the estimates weaken substantially when Indonesia is excluded. The negative processing coefficients therefore should not be interpreted as evidence that midstream investment harms industrial development. They may reflect project timing, construction and commissioning lags, country-specific policy changes, or the mismatch between a narrowly defined mineral project and an economy-wide manufacturing outcome. The analysis nevertheless demonstrates why the stage composition of mineral finance deserves separate measurement in future research.

The findings connect the resource-curse, FDI-spillover and global-value-chain literatures by shifting attention from resource abundance and aggregate capital inflows to the mechanisms through which investment affects productive structure. Consistent with Javorcik (2004), domestic linkages remain central to potential spillovers, while the project-stage results suggest that investment composition deserves separate measurement. The analysis also qualifies recent enthusiasm for mineral-based industrial policy: the construction of processing capacity does not by itself demonstrate broader supplier development, technological learning or economy-wide diversification.

The paper's central claim is therefore narrower than the enthusiasm surrounding critical minerals would suggest. Transition minerals are embedded directly in manufacturing value chains, but they do not escape the developmental risks associated with enclave extraction. Their contribution depends on whether investment generates domestic processing, supplier linkages and technological learning.

The findings, interpreted alongside the prior literature, suggest five policy implications. The first concerns the direct processing of raw materials. It is the transition from concentrate to refined metal, and from there to chemical compounds and finished components, that ensures the main margin. The tungsten industry development program in Uzbekistan and the expansion of copper smelting capacity in Kazakhstan represent steps in this direction, and in both cases the main limiting factor is not ore volume but separation and purification technologies (Kim et al., 2026). Government policy can help with equipment procurement. However, it cannot purchase technological and production knowledge; this must be acquired through the

creation of joint ventures structured for technology transfer, as well as by training specialists who are guaranteed to remain in the country for the long term.

The second concerns local suppliers. Backward linkages are where the productivity spillover from foreign investment actually lands (Javorcik, 2004). A supplier development program needs a registry of qualified domestic firms, certification against investor specifications, working capital finance and procurement rules that give local firms a real chance to bid. Without those instruments, a local content requirement becomes a tax that investors pay in cash rather than in linkages.

The third concerns skills. Metallurgy, chemical engineering, geology, environmental management, and mining data systems are the specific competences the region lacks at scale, and this shortage is evident in the reliance on expatriate technical staff at new processing plants. This is a fifteen-year investment and it competes with nothing else in importance.

The fourth concerns regional cooperation. Five landlocked economies with small domestic markets have an obvious collective interest in shared transport corridors, shared laboratory and certification infrastructure, and coordinated investment rules, and an equally obvious history of not cooperating. The economics here is not subtle. A single certification laboratory serving five countries is affordable, and five national laboratories are not.

The fifth conclusion concerns institutional safeguards. Transparent licensing, stable, publicly available investment agreements, environmental and social standards backed by effective enforcement mechanisms, and a robust public revenue management system are essential conditions for the other four policy areas to yield results. Without these, investment in the mineral resources sector will still flow, but it will inevitably be isolated.

These findings are subject to several limitations. First, the value-added indicator in manufacturing reflects the economy's overall industrial development, not the value-capture processes within mineral supply chains. Using a harmonized indicator for the share of processed mineral exports at the six-digit level would yield more accurate results. Second, the AidData project database covers official Chinese funding, not total foreign direct investment in the industry, and the estimates for the average value chain are based on only seven country-year observations, making them extremely sensitive to Indonesian cases. Third, models with country and year fixed effects and lagged regressors reduce, but do not eliminate, endogeneity between investment and expected structural change. Data coverage is also uneven, particularly for Turkmenistan, while country-level analysis cannot observe the firm-level supplier relationships through which spillovers are expected to occur. The estimates should therefore be interpreted as conditional associations rather than causal effects.

6. CONCLUSION

This paper examines whether aggregate foreign direct investment and stage-specific mineral project finance are associated with structural transformation in 30 mineral-rich emerging economies observed from 2000 to 2024. Lagged aggregate FDI has a small association with manufacturing value added that is statistically indistinguishable from zero across the baseline and robustness specifications. An equivalence test further excludes effects outside ± 0.10 percentage points, although narrower effects cannot be ruled out. Institutional quality and Central Asian membership do not materially modify the average association. The interaction with tertiary enrollment is positive in the full sample, but the marginal association becomes non-negative only at unusually high enrollment levels, and the interaction is not statistically significant in the 2015–2024 subsample. The tertiary-enrollment result should therefore be viewed as exploratory rather than as robust confirmation of H4. Exploratory project-level estimates differ between extraction and processing activities, but the midstream coefficients are identified by only seven country-year observations across four

economies and are highly sensitive to the inclusion of Indonesia. These estimates identify a potentially relevant dimension of investment composition but do not provide generalizable evidence about the effects of processing finance. Overall, the findings show that the volume of aggregate inflows is an insufficient indicator of structural transformation and motivate future analyses that use harmonized trade-based processing outcomes and valid pre-sample mineral exposure data.

Critical mineral endowments create an opportunity for diversification, but their structural consequences depend on investment composition, domestic linkages and absorptive capacity. The exploratory project-stage evidence identifies the midstream as a potentially important channel, but the available data do not conclusively establish its effect.

The strategic objective for a mineral-rich economy should be to maximize domestic value added per unit of mineral investment rather than extraction volumes or aggregate FDI inflows. Attracting foreign capital and expanding domestic midstream capacity can point in opposite directions: the fastest way to attract capital is to offer ore on favorable terms, whereas the fastest way to build midstream capacity is to make that offer conditional. Governments in Central Asia are making this choice with limited evidence about which conditions promote processing without deterring investment.

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APPENDIX

Table A1

Leave-one-country-out sensitivity of the processing-finance estimates

Excluded economy	Processing-events coefficient	SE	Processing-presence coefficient	SE
None	-1.081	0.448	-1.594	0.748
Chile	-1.078	0.480	-1.687	0.848
Kazakhstan	-1.256	0.444	-2.126	0.553
South Africa	-1.399	0.454	-1.723	0.882
Indonesia	-0.390	0.387	-0.432	0.648

Note. Each row re-estimates the project-composition model after excluding the indicated economy. The dependent variable is manufacturing value added as a percentage of GDP. All specifications include the corresponding extraction-stage variable, log GDP per capita, trade openness, gross capital formation, natural resource rents, country fixed effects, and year fixed effects. Country-clustered standard errors are reported. The processing coefficients are not statistically significant only when Indonesia is excluded, with p-values of 0.31 for event counts and 0.51 for presence dummies.

Table A2

Country coverage and sample rationale

Country	ISO3	Region	Mineral or value-chain relevance	Sample role
Kazakhstan	KAZ	Central Asia	Major uranium, chromium and copper producer	Central Asian focal economy
Kyrgyz Republic	KGZ	Central Asia	Small mining economy with strong dependence on gold	Central Asian focal economy
Tajikistan	TJK	Central Asia	Antimony and other non-ferrous metal exposure	Central Asian focal economy
Turkmenistan	TKM	Central Asia	Resource-dependent economy with limited public mineral data	Central Asian focal economy; data-limited case
Uzbekistan	UZB	Central Asia	Gold, copper, uranium and strategic-mineral processing policy	Central Asian focal economy
Mongolia	MNG	East Asia	Landlocked, mining-intensive mineral exporter	Close structural comparator
Armenia	ARM	South Caucasus	Mining-intensive transition economy	Transition-economy comparator
Georgia	GEO	South Caucasus	Transition economy with relatively stronger institutions	Institutional comparator
Azerbaijan	AZE	South Caucasus	Resource-rich transition economy dominated by hydrocarbons	Resource-dependence comparator
Chile	CHL	Latin America	Major copper and lithium producer	Mineral-governance benchmark
Peru	PER	Latin America	Major copper and polymetallic mineral exporter	Strong mineral-export comparator
Bolivia	BOL	Latin America	Large lithium resources and broader mineral potential	Investment-policy comparator
Argentina	ARG	Latin America	Lithium producer with a relatively diversified economy	Macroeconomic and policy comparator
Brazil	BRA	Latin America	Large and diversified mineral-producing economy	Scale and diversification comparator
Mexico	MEX	Latin America	Mineral producer integrated with a large manufacturing base	Manufacturing value-chain comparator

Democratic Republic of the Congo	COD	Sub-Saharan Africa	Highly concentrated cobalt and copper producer	Extreme mineral-concentration case
Zambia	ZMB	Sub-Saharan Africa	Copper-dependent mineral exporter	Resource-dependence comparator
Zimbabwe	ZWE	Sub-Saharan Africa	Lithium, chromium and other mineral production	Emerging critical-mineral comparator
Namibia	NAM	Sub-Saharan Africa	Uranium and other mineral exports	Small mineral-exporting comparator
Botswana	BWA	Sub-Saharan Africa	Resource-dependent economy with comparatively strong governance	Resource-governance benchmark
South Africa	ZAF	Sub-Saharan Africa	Diversified mining and mineral-processing base	Mining-industrial benchmark
Mozambique	MOZ	Sub-Saharan Africa	Rapidly expanding extractive and project-finance exposure	Emerging investment comparator
Madagascar	MDG	Sub-Saharan Africa	Nickel and cobalt mining projects	Project-specific mineral comparator
Guinea	GIN	Sub-Saharan Africa	Highly concentrated bauxite exporter	Raw-export concentration case
Indonesia	IDN	Southeast Asia	Major nickel producer with an active downstreaming policy	Processing-policy benchmark
Malaysia	MYS	Southeast Asia	Manufacturing economy connected to regional mineral value chains	Diversification benchmark
Philippines	PHL	Southeast Asia	Important nickel and other mineral producer	Mineral-policy comparator
Viet Nam	VNM	Southeast Asia	Manufacturing base and significant rare-earth potential	Value-chain comparator
Lao PDR	LAO	Southeast Asia	Landlocked and mining-dependent developing economy	Structural and geographic comparator
Papua New Guinea	PNG	Pacific	Mining-intensive developing economy	Island and logistics comparator

Note. The panel frame covers 2000–2024 for all 30 economies. Actual observations vary across countries and variables due to differences in source coverage; missing values are not replaced by interpolation. The sample combines the five Central Asian focal economies with countries selected for their mineral exposure, resource dependence, relevance to mineral processing or manufacturing, institutional comparability, and data availability. Countries were not selected based on the estimated outcomes.