Nickel Downstreaming, Technology Acceleration, and ESG Implications in Indonesia: A Policy Scenario Analysis

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Abstract
Purpose: This study examines how Indonesia's nickel ore export ban accelerates the transition from Rotary Kiln Electric Furnace (RKEF) technology to High Pressure Acid Leaching (HPAL) technology and assesses whether full downstreaming or partial liberalization is more effective in maximizing value capture within the global Electric Vehicles (EVs) battery supply chain during the period 2026–2030.
Design/methodology/approach: Using monthly time-series data for 2018–2025 (n = 96), the study estimates a log-linear multiple regression via Ordinary Least Squares (OLS) with Newey-West HAC robust standard errors, isolating the export-ban policy shock with a policy dummy. The fitted model is used to project export value under two policy scenarios, complemented by a game-theory framework to assess geoeconomic conflict resolution.
Findings: Foreign Direct Investment (FDI) in base metals is the dominant driver of export performance, with an elasticity of 1.239, compared to 0.555 for the global nickel price. The export ban dummy is statistically insignificant, suggesting that its impact operates entirely through the FDI channel. Among the policy alternatives, the full downstreaming scenario produces the highest projected export value, while the Nash equilibrium of (Full Downstreaming, Cooperation) delivers the highest payoff of (8, 7). The technological transition also reshapes the sector's ESG risk profile: accelerating HPAL adoption trades the carbon intensity of RKEF smelting for long-term tailings-management risk.
Practical implications: Long-term regulatory certainty, fiscal incentives targeting HPAL and Research and Development (R&D) investors, and active bilateral supply-chain diplomacy are recommended over temporary export bans, paired with binding tailings-management standards and community benefit-sharing mechanisms so that FDI-driven expansion satisfies the ESG due-diligence requirements of destination markets such as the EU Critical Raw Materials Act.
Originality/value: The study integrates time-series econometrics, scenario projection, and game theory to quantify the FDI transmission channel of downstreaming policy.
Paper type: empirical

Keywords: nickel downstreaming, foreign direct investment, HPAL technology, environmental, social, and governance (ESG), policy scenario analysis

1. Introduction

The global energy transition toward electric vehicles (EVs) is creating structural changes in the governance of critical minerals. The International Energy Agency (IEA) projects a significant increase in global EV sales, which raised nickel demand for battery production to approximately 30% of total nickel demand in 2023 (IEA, 2024; International Nickel Study Group [INSG], 2024). As the holder of around 21 million metric tons of nickel reserves, accounting for approximately 42% of global reserves, Indonesia faces a strategic challenge to move beyond its traditional role as a raw material exporter (USGS, 2024). This transformation is essential to avoid the resource curse, a condition in which abundant natural resources fail to generate sustainable economic growth unless supported by industrialization and the development of advanced battery-grade nickel processing technologies for the EV battery industry (Auty, 1993; Sachs & Warner, 1995; Zuada & Suaib, 2021).

The downstreaming policy implemented through the nickel ore export ban has increased domestic production by up to 8% in 2024 (USGS, 2025; Ministry of Energy and Mineral Resources,

2019). Strategically, this policy acts as a *forcing mechanism* to accelerate the adoption of High Pressure Acid Leach (HPAL) technology to produce battery raw materials (MHP) from limonite nickel. Various studies have analyzed Indonesia's nickel downstreaming policy from the perspective of *resource nationalism* (Warburton, 2024) and its impact on the domestic industry (Kee & Xie, 2025). Nevertheless, the existing literature still reveals a research gap, particularly the limited quantitative analysis of policy scenarios projecting the impact on value capture, the untested role of the Foreign Direct Investment (FDI) channel as a mechanism for technological acceleration, and the absence of a game-theory framework for resolving geoeconomic conflict in the context of the World Trade Organization (WTO, 2022) and the European Union (EU) Critical Raw Materials Act (European Commission, 2023). Accordingly, this study seeks to bridge the gap between optimizing value capture and accelerating nickel processing technology.

Based on this background, the study addresses two research questions, (1) How does the nickel ore export ban affect the acceleration of the processing technology transition from the Rotary Kiln Electric Furnace (RKEF) to High Pressure Acid Leaching (HPAL), (2) Which policy scenario, full downstreaming or partial liberalization, is more optimal for maximizing value capture in the global EV battery supply chain over 2026–2030.

This study aims to analyze the effect of the nickel ore export ban on the acceleration of nickel processing technology (from RKEF to HPAL) and on the value of Indonesia's processed nickel exports through the base-metal FDI channel, and to evaluate the trade-policy scenario most effective in driving the adoption of battery-grade technology to maximize value capture in the global EV battery supply chain.

2. Literature Review and Hypotheses Development

2.1. Geoeconomic Pressure and Resource Nationalism

Geoeconomic pressure refers to the strategic use of economic instruments to achieve geopolitical objectives, including trade pressure, economic sanctions, and protectionist policies that interact within global governance (Barbieri, 2024). *Resource nationalism*, in turn, denotes policy intervention by resource-rich developing countries to maximize the domestic benefits of resource industries, including through fiscal instruments such as restrictions on raw-material exports (Dou et al., 2024). Although economic openness has been shown to accelerate growth in the ASEAN region, in the context of critical-mineral commodities such as nickel this openness must be balanced with a resource-nationalism strategy so that Indonesia is not permanently trapped as a raw-material exporter.

H_1: The nickel ore export ban, as an instrument of resource-nationalism policy, has a significant effect on the value of Indonesia's processed nickel exports.

2.2. Nickel Processing Technology: From RKEF to HPAL

The global energy transition is changing not only the quantity of nickel demanded but also the quality required. The EV battery industry requires high-grade nickel, whereas the *stainless-steel* industry can still use lower-grade nickel, driving a shift in nickel processing technology at the domestic level (Bappenas, 2026; FEB UI, 2025). In Indonesia, RKEF still dominates smelter operations to produce Nickel Pig Iron (NPI) or ferronickel, while HPAL has become a key technology for producing MHP as an EV battery raw material (FEB UI, 2025). Accelerating HPAL is therefore essential to shift Indonesia's strategic position from a mere supplier to the stainless-steel industry toward a key player in the global battery supply chain (Bappenas, 2026).

International evidence corroborates this technology-transfer channel. Javorcik, Lo Turco, and Maggioni (2018) show that the presence of foreign affiliates stimulates the upgrading of indigenous production capabilities, with Turkish manufacturing firms more exposed to foreign affiliates introducing more complex products. Ni and Kato (2020) similarly find that vertical FDI spillovers raise the productivity of local upstream firms in Vietnam, with the strength of these spillovers depending on investor characteristics; they note that Blalock and Gertler (2008), as cited in Ni and Kato (2020), documented positive vertical spillovers of this kind in Indonesia specifically.

H_2: Foreign Direct Investment (FDI) inflows in the base-metal sector have a significant positive effect on the value of Indonesia's processed nickel exports, reflecting their role as a transmission channel for HPAL technology transfer.

2.3. Scenario Analysis as an Instrument of Policy Innovation

Scenario analysis is a systematic methodology for exploring alternative possible futures to inform policy decision-making, particularly under conditions of high uncertainty and complexity (Wright et al., 2020). A scenario-planning approach in public policy enables the integration of quantitative analysis (time-series econometrics) and strategic analysis (game theory) to evaluate the effectiveness of policy instruments comprehensively.

H_3: Under the geoeconomic conflict-resolution game, the strategy combination of Full Downstreaming and Cooperation constitutes the Nash equilibrium, yielding the highest joint payoff among the available policy-trading-partner strategy pairs.

3. Research Method

This study empirically measures the impact of downstreaming using a Multiple Linear Regression model estimated via Ordinary Least Squares (OLS) on monthly time-series data for 2018–2025 (n = 96 observations). A log-linear specification is chosen so that the regression coefficients can be interpreted directly as elasticities. The regulatory policy shock arising from the nickel ore export ban is isolated using a policy dummy variable to capture the significant difference before and after the intervention. The model specification is as follows:

$$ln(Y_t) = \beta_0 + \beta_1 ln(P_t) + \beta_2 ln(FDI_t) + \delta D_t + \varepsilon_t \quad (1)$$

where $\ln(Y_t)$ is the value of processed nickel exports (UN Comtrade), P_t is the global nickel price (London Metal Exchange, via World Bank Commodity Markets 'Pink Sheet'), FDI_t represents Foreign Direct Investment inflows in the base-metal sector (Ministry of Investment/BKPM), and δD_t is a dummy variable (0 for the export-relaxation period 2018–2019; 1 for the absolute export ban 2020–2025).

Stationarity is examined using the Augmented Dickey–Fuller (ADF) and Phillips–Perron tests. Because all variables are integrated of order one, cointegration is examined before interpreting the level regression. The Engle–Granger residual-based ADF test rejects the null of no cointegration at the 1% level (test statistic −4.32), and the Phillips–Ouliaris test rejects at the 10% level, confirming that equation (1) represents a long-run equilibrium relationship rather than a spurious regression. As a robustness check, long-run elasticities recovered from an ARDL(3,3,3) specification 0.81 for the global nickel price and 1.30 for base-metal FDI, both statistically significant are consistent with the OLS estimates, although the ARDL bounds F-test (Pesaran et al., 2001) is inconclusive, plausibly because the quarterly-to-monthly interpolation of FDI dampens the short-run dynamics on which that test relies.

To ensure valid inference, heteroskedasticity is assessed with the Breusch-Pagan test, while autocorrelation is addressed using Newey-West Heteroskedasticity and Autocorrelation Consistent (HAC) robust standard errors. The estimated model is then used to project export value under two policy scenarios for 2026–2030, complemented by a game-theory framework to analyze geoeconomic conflict resolution.

3.1 Research Framework

The framework links two stages of analysis. The OLS regression stage (H1, H2) traces how the export ban, transmitted mainly through the FDI channel, drives processed nickel export value and accelerates the RKEF–HPAL technology transition. The scenario and game-theory stage (H3) carries the estimated coefficients into a 2026–2030 projection, compares two policy scenarios, and resolves the resulting payoff matrix to its Nash equilibrium, informing the final policy recommendation. As it is shown in figure 1 below.

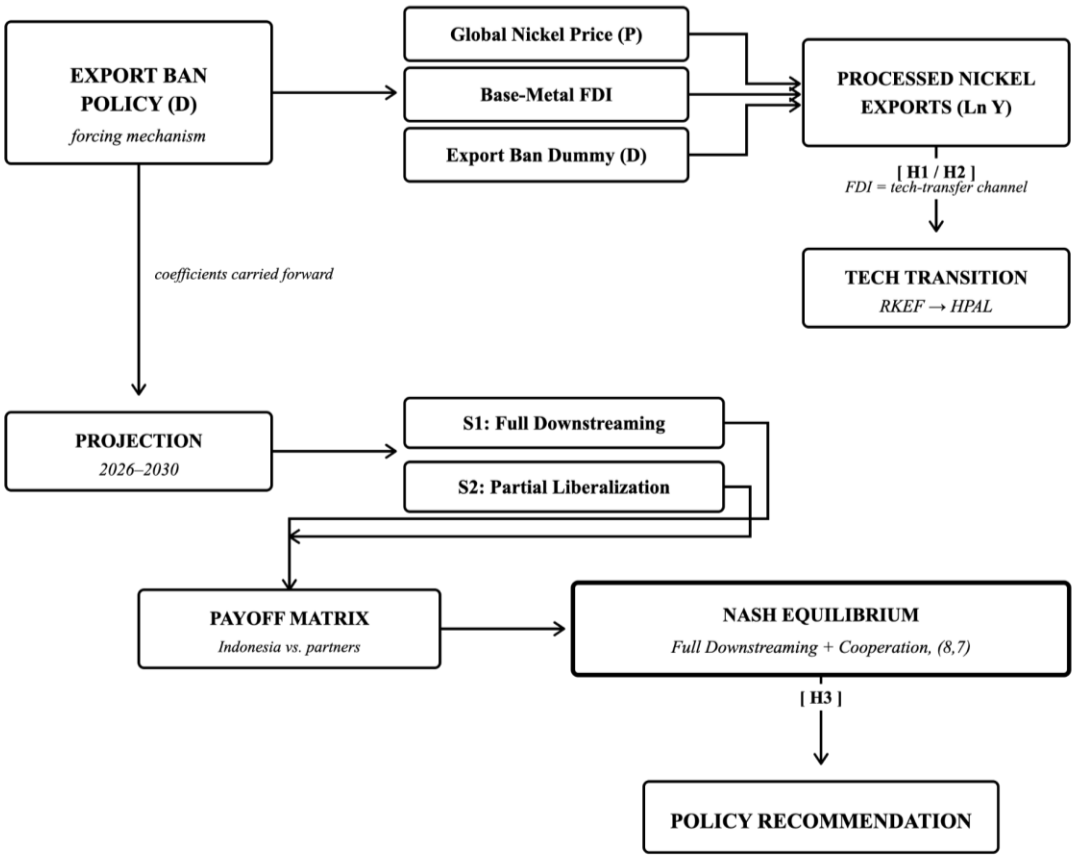

Figure 1. Research Framework of the Study

4. Result and Discussion

4.1. Geoeconomic Pressure and Technology Acceleration

The ADF and Phillips-Perron unit-root tests confirm that all variables are integrated of order I(1), and subsequent cointegration testing (Section 3) confirms a valid long-run equilibrium relationship rather than a spurious regression. The model is free from heteroskedasticity (Breusch-Pagan $p = 0.099 > 0.05$), and autocorrelation is corrected using Newey-West HAC robust standard errors. The OLS estimation produces a model with very high predictive power, and all goodness-of-fit criteria are satisfied, as presented in Table 1.

Table 1. OLS Time-Series Regression Estimation Results

Variable	Coefficient	Std. Error
Ln (Global Nickel Price)	0.555***	(0.130)
Ln (Base-Metal FDI)	1.239***	(0.078)
Export Ban Dummy	-0.091	(0.119)
Constant	-1.339	(1.386)
Observations	96	
R^2	0.922	
Adjusted R^2	0.920	
Residual Std. Error	0.263 (df = 92)	
F-Statistic	362.837*** (df = 3; 92)	

*Note: *** p<0.01; ** p<0.05; * p<0.1. Standard errors in parentheses.*
Source(s): Authors' own creation

4.2. FDI as the Dominant Transmission Channel

Table 2. Regression Coefficient Interpretation and Economic Implications

Variable	Coefficient	Economic Interpretation
Ln (Global Nickel Price)	0.555***	Inelastic (+): a 1% price increase raises exports by 0.56%. Limited response due to smelter-capacity constraints.
Ln (Base-Metal FDI)	1.239***	Elastic (+): a 1% FDI increase raises exports by 1.24%. Dominant variable; downstreaming successfully attracts strategic investment.
Export Ban Dummy	-0.091	Policy effect absorbed through the FDI channel.

Source(s): Authors' own creation

As shown in Table 2, a surge in the world nickel price is not immediately followed by a proportional increase in export volume. A 1% price increase is met with only 0.56% export growth, an inelastic figure that reflects the physical reality of production constrained by domestic smelter capacity. This condition confirms that market-price increases alone are insufficient to drive export performance without physical expansion of the processing industry. By contrast, base-metal FDI shows an elastic response with a coefficient of 1.24, demonstrating the dominance of FDI as the primary driver in raising the scale of production and the value added of Indonesia's nickel exports.

Global Nickel Price (β_1 = 0.555*).** The global nickel price has a positive and significant effect on processed nickel export value, with an elasticity of 0.555. This inelastic value (<1) indicates that although rising international prices encourage exports, the response of domestic producers tends to be limited. This is consistent with domestic smelter capacity still being in an expansion phase, so that price fluctuations cannot yet trigger an optimal supply response. The finding aligns with the highly volatile nickel-price dynamics on the London Metal Exchange (LME), which are not always transmitted directly to export volume in the short run.

Base-Metal FDI (β_2 = 1.239*): Dominant Variable.** Each 1% increase in base-metal FDI inflows contributes to a 1.24% increase in processed nickel export value. This high FDI elasticity reflects not merely capital inflow but also serves as a proxy for technology-transfer capacity. The multiplier effect of FDI is consistent with the empirical findings of Yuliadi et al. (2022), who confirm that FDI and export volume have a highly significant positive effect on the acceleration of Indonesia's Gross Domestic Product (GDP). These investment flows finance the technological transition of domestic smelters from RKEF (pyrometallurgy for ferronickel/NPI oriented toward stainless steel) toward the far more complex, capital-intensive, and high-technology HPAL (hydrometallurgy) process. This finding is consistent with international evidence that FDI drives production upgrading and vertical technology spillovers in host economies (Javorcik et al., 2018; Ni & Kato, 2020). This transition is already underway in practice: an estimated 60% of new smelter capacity currently coming online is HPAL-based and oriented toward battery-grade output (Table 3) [AUTHOR: provide the source for the '60% of new capacity HPAL-based' figure].

Export-Ban Dummy (δ = −0.091, not significant): A Strategic Finding. The insignificance of the dummy indicates that the impact of the export-ban policy has been fully absorbed through the FDI channel, which is highly significant and dominant. By requiring investors to build processing facilities domestically as an operating condition, the export ban indirectly creates a climate conducive to strategic FDI inflows. This is consistent with Ahda's (2021) argument that the export ban functions as a long-term policy instrument to strengthen the industrial structure.

Two auxiliary regressions with Newey–West standard errors substantiate this transmission mechanism. First, regressing ln(FDI) on the export-ban dummy shows that base-metal FDI inflows are significantly higher during the ban period (coefficient = 1.327, p = 0.002), roughly 3.8 times the pre-ban level. Second, the total effect of the ban on export value — estimated by regressing ln(Y) on the dummy alone — is positive and highly significant (coefficient = 1.718, p < 0.001), yet becomes statistically indistinguishable from zero once FDI is controlled for in equation (1). This pattern is

consistent with full mediation: the export ban raises processed-nickel export value indirectly, by attracting strategic investment, rather than directly.

4.3 Scenario Projection and Game-Theoretic Equilibrium

Table 3. Policy Scenario Comparison Matrix, 2026–2030

Indicator	Scenario 1: Full Downstreaming	Scenario 2: Partial Liberalization
Empirical basis	Elastic FDI (β = 1.239) → consistent policy signals are important to sustain investment flows.	Insignificant dummy → partial relaxation does not automatically harm processed exports.
FDI projection 2026–2030	High = regulatory certainty drives HPAL smelter & battery-precursor investment.	Moderate = relaxation uncertainty may dampen long-term investment.
Geopolitical risk	Moderate = WTO pressure continues, but EV-nickel leverage strengthens the bargaining position.	Low in the short run = but risk of lock-in as a low-value intermediate exporter.
GVC value added (Global Value Chain)	High = potential to move up to cathode & battery-cell segments (GVC upgrading).	Medium = limited to the NPI and ferronickel segments.
Technology transition (RKEF→HPAL)	Accelerated: 60% of new capacity HPAL-based for battery-grade.	Slow: RKEF dominance for stainless steel.
ESG risk profile	E: lower carbon intensity than RKEF, but large tailings volumes requiring binding long-term management; S: community benefit-sharing needed as HPAL scales; G: convergence with EU CRMA due diligence strengthens market access.	E: continued reliance on carbon-intensive RKEF pyrometallurgy; S: extraction-pattern livelihood risks persist; G: weak alignment with buyer ESG due diligence risks losing EV-market access.
Tech sovereignty	Gradual technology transfer through joint ventures.	Dependence on imported technology without know-how transfer.
Recommendation	Optimal, consistent with empirical evidence and the National Medium-Term Development Plan (RPJMN) 2026–2029 targets.	Sub-optimal, risk of regressing to an extraction pattern.

Source(s): Authors' own creation

The projection data are analyzed using the following specification:

$$ln\ \hat{Y}t = \hat{\beta}_0 + \hat{\beta}_1\ ln\ Ptproj + \hat{\beta}_2\ ln\ FDItproj + \hat{\delta}D_t \quad (2)$$

where ln Ŷt is the projected value of processed nickel exports, $\hat{\beta}_1$ ln Ptproj is the projected global nickel price under the assumed scenario, $\hat{\beta}_2$ ln FDItproj is the projected Foreign Direct Investment inflows in the base-metal sector, and δ̂Dt is a dummy variable (0 for the export-relaxation period 2018–2019; 1 for the absolute export ban 2020–2025), with all coefficients carried forward from the OLS estimation in equation (1).The exponential back-transformation

$$\hat{Y}_t = e^{(ln\ \hat{Y}t)} \quad (3)$$

follows from the properties of the log-linear model to obtain the projection in US dollars (Wooldridge, 2015). The World Bank Commodity Markets Outlook (2025) projects that nickel prices will grow by an average of 5% per year through 2030, driven by EV battery demand. Annual growth is converted to monthly using continuous compounding:

$$g_{monthly} = ln(1 + g_{annual}) / 12 \quad (4)$$

where gmonthly is the monthly growth rate derived from the assumed annual growth rate g_annual, with the natural logarithm transformation applied to ensure consistency with the log-linear specification of the model. This assumption is applied uniformly across both scenarios to isolate the pure effect of FDI policy.

Scenario 1 assumes base-metal FDI inflows grow at 10% per year over 2026–2030; Scenario 2 assumes 2% per year. The nickel-price path (5% per year, World Bank, 2025) is applied uniformly across both scenarios.

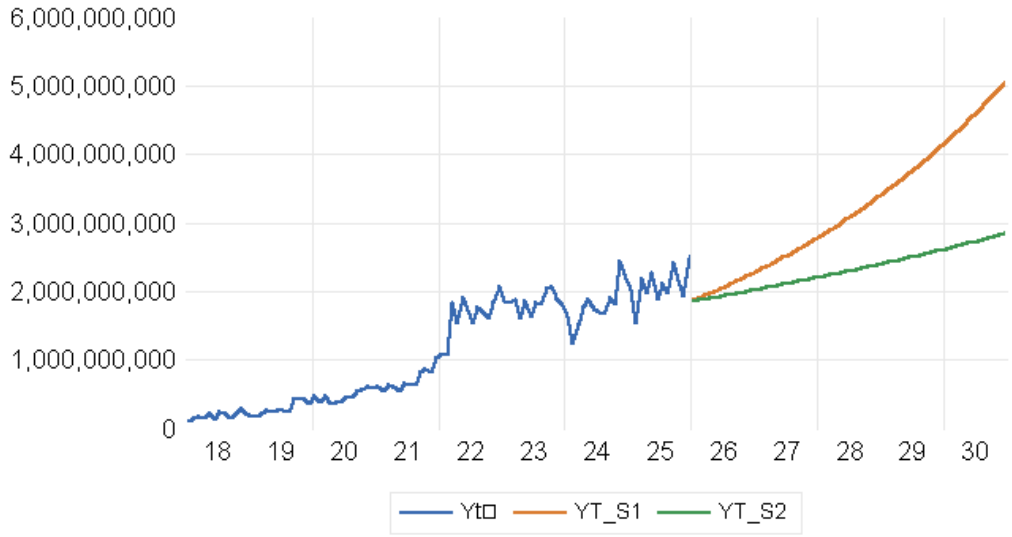

Figure 2. Projection of Processed Nickel Export Value by FDI Policy Scenario (USD). YT0 = historical data; YT_S1 = Full Downstreaming; YT_S2 = Partial Liberalization
Source(s): Authors'

The full-downstreaming scenario is projected to deliver consistently higher processed nickel export value throughout 2026–2030, driven by stronger FDI inflows resulting from regulatory certainty. Based on the FDI elasticity of 1.239, every 10% increase in FDI inflows triggered by policy consistency would drive 12.4% growth in processed exports, a significant *multiplier effect* for the national economy. This projection is consistent with the IEA (2024) report stating that nickel demand for EV batteries will rise by up to 30% by 2030, giving Indonesia an increasingly strong strategic bargaining position if it consistently positions itself as a supplier of high-quality processed nickel.

In the context of technological acceleration, these FDI inflows function as a channel for transferring advanced processing technology, particularly the transition from RKEF technology (producing NPI for the stainless-steel industry) toward HPAL technology (producing MHP as a battery-grade raw material for EVs). The export ban thus acts as a *forcing mechanism* requiring foreign investors to transfer the capital-intensive, high-technology HPAL process as a condition for domestic operation.

4.4 Conflict Resolution: A Game-Theory Framework

The payoff values (1–10) in this matrix are ordinal utilities representing rational preference rankings. The scores are constructed from the accumulation of four main indicators: (1) value capture/FDI (based on the empirical elasticity of 1.239), (2) supply-chain bargaining position, less (3) geopolitical risk/cost, and (4) convergence with trading partners' ESG and supply-chain due-diligence standards. The Full Downstreaming quadrant, with payoffs of (8, 7), where 8 denotes Indonesia's payoff and 7 the trading partner's, indicates that Indonesia's active-diplomacy strategy should shift trading partners from the "pressure" quadrant to the "cooperation" quadrant through bilateral supply-chain agreements, strategic partnerships with battery producers, and convergence of environmental standards with the EU Critical Raw Materials Act.

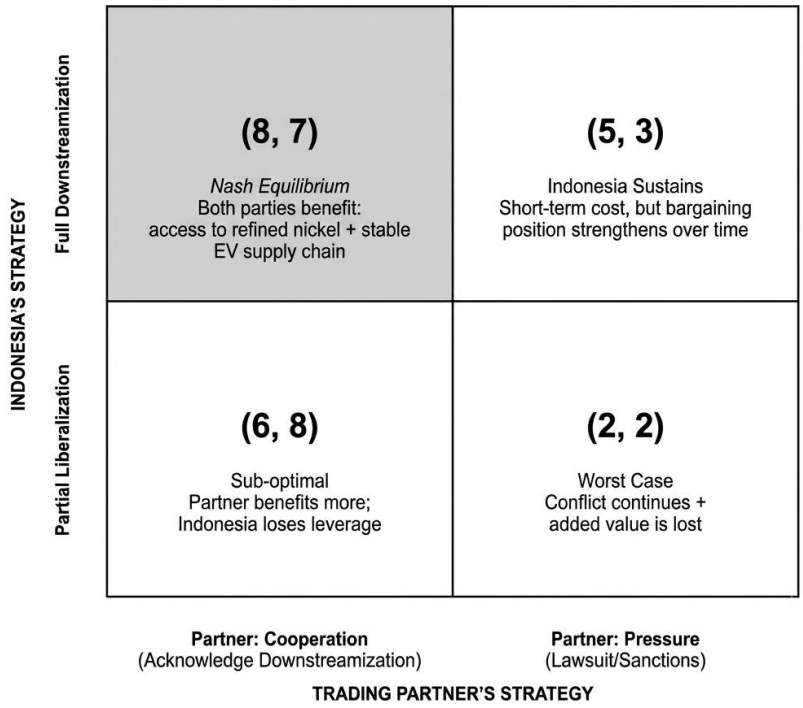

Figure 3. Game-Theory Matrix: Indonesia vs. Trading Partners (Payoff: scores 1–10)
Source(s): Authors'

4.5 ESG and Sustainability Considerations

While the OLS and game-theory results in this study center on value capture through the FDI channel, the two policy scenarios also carry distinct environmental, social, and governance (ESG) implications that lie outside the econometric model itself but merit discussion. On the environmental dimension, RKEF smelting, the pathway associated with the slower, partial-liberalization trajectory is characterized in recent literature as one of the more carbon-intensive nickel processing routes, given its reliance on continuous high-temperature pyrometallurgy (Libassi, 2026). HPAL, the pathway favored under full downstreaming, is comparatively less energy-intensive but generates substantial tailings volumes that require careful long-term management to prevent landslides or water contamination (Libassi, 2026). Accelerating the shift toward HPAL therefore appears to trade one category of environmental risk (carbon intensity) for another (tailings management), rather than eliminating environmental risk altogether.

On the social dimension, life-cycle sustainability assessments of Indonesian nickel operations have documented measurable deforestation and declining vegetation cover around mining and processing sites using remote-sensing analysis, alongside social and economic benefits that remain concentrated in the immediate mining locality rather than distributed to surrounding communities (Agusdinata et al., 2022). Relatedly, the concentration of downstreaming's economic benefits among a narrow set of political and business actors, facilitated by opaque joint-venture structures, has been identified as a persistent feature of the sector's expansion (Warburton, 2024). These findings echo concerns raised regarding the need for a "just transition" that protects local livelihoods as the industry scales (IRID, 2024).

These considerations do not overturn the study's central finding that full downstreaming dominates on value-capture grounds; rather, they suggest that the "Optimal" recommendation in Table 3 is optimal specifically on economic and geopolitical criteria. Realizing this potential sustainably would likely require pairing FDI-driven HPAL expansion with binding environmental safeguards, such as tailings-management standards, and community-benefit-sharing mechanisms. Quantifying these ESG dimensions within the FDI-transmission framework developed here, for example, through a combined econometric and life-cycle-assessment approach, remains a priority for future research.

On the governance dimension, the policy-level analysis connects directly to firm-level ESG accountability. Traceability — the ability to identify the provenance, processing history, and compliance conditions of minerals along the chain — is a precondition for holding companies accountable for environmental and social impacts, and buyer-side due-diligence regimes such as the EU Critical Raw Materials Act and the German Supply Chain Due Diligence Act are raising these requirements for firms sourcing from the Global South (Schöneich et al., 2023). Indonesian issuers, including listed smelter operators, are already subject to mandatory sustainability reporting under OJK Regulation No. 51/POJK.03/2017, making firm-level ESG disclosure the operational mechanism through which state-level downstreaming policy meets destination-market requirements. ESG compliance therefore functions as a determinant of, rather than a constraint on, the FDI-driven value capture identified in this study.

4.6 Synthesis: Evidence-Based Policy Implications

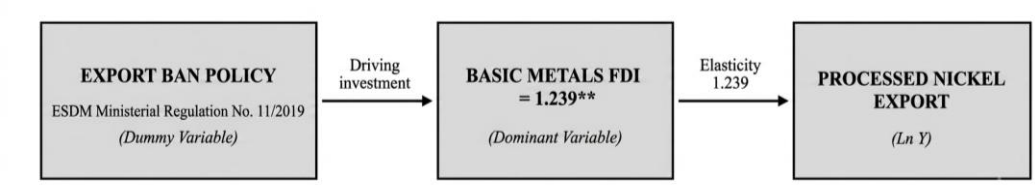

Figure 4. Transmission Channel Diagram of Indonesia's Nickel Downstreaming Policy
Source(s): Authors' own construction based on the estimation results

Overall, the econometric and policy-scenario analysis yields three main policy implications. First, consistency in downstreaming is key: the effectiveness of the export ban works through the FDI channel. Given the importance of mitigating Indonesia's macroeconomic vulnerability to external shocks, consistent downstreaming functions as a buffer for economic and financial stability (Wiranatakusuma, 2018); long-term regulatory certainty is therefore far more crucial than a merely temporary ban. Second, the investment climate and technology-transfer incentives must be strengthened: the FDI elasticity demonstrates that the investment climate is the primary determinant, so the government should provide fiscal incentives specifically targeted at investors bringing R&D technological innovation and HPAL facilities rather than conventional NPI smelters. Third, active diplomacy is needed to shift the Nash equilibrium: initiating bilateral nickel supply-chain cooperation to move trading partners from a "pressure" strategy toward "cooperation" achieves the optimal payoff in the global EV ecosystem.

5. Conclusion

The nickel ore export ban does not directly increase processed nickel export value; rather, it works through the FDI transmission channel. This is evidenced by the insignificance of the dummy variable, which shows that the policy impact has been fully absorbed through FDI inflows with dominant elasticity. In other words, the export ban is effective as a forcing mechanism that attracts strategic investment while accelerating the technological transition from RKEF to HPAL. Consequently, the full-downstreaming scenario proves more optimal than partial liberalization: regulatory consistency drives larger FDI inflows, which in turn generate an export multiplier effect for every increase in FDI. This is reinforced by the game-theory analysis, which places the Nash equilibrium in the (Full Downstreaming, Cooperation) quadrant with the highest payoff (8, 7) as the optimal strategy for Indonesia in the global EV battery supply chain for 2026–2030. Consistent with the broader agenda of advancing inclusive and sustainable economies, the benefits of downstreaming must extend beyond enclave growth to surrounding communities.

This study has several limitations. The FDI variable refers to the aggregate base-metal sector rather than nickel-exclusive data, which may introduce minor bias; the interpolation of quarterly data to monthly may dampen real volatility; and the model has not yet quantified negative externalities such as environmental degradation, the carbon footprint of smelters (particularly the emission-

intensity comparison between RKEF and HPAL technologies), and social conflict in mining areas. Integrating these ESG variables is a priority for future research. In addition, the first-stage evidence for the FDI channel rests on a before–after comparison and therefore cannot fully rule out that FDI would have risen with global EV-demand trends even absent the ban.

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