
THE CONTRIBUTION OF METAL MINING TO SOUTHEAST SULAWESI'S ECONOMY: AN INPUT-OUTPUT ANALYSIS

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Abstrak. The metal mining sector, particularly nickel mining in Southeast Sulawesi, Indonesia, plays a crucial role in regional economic growth but faces challenges in achieving sustainable development. Despite contributing significantly to the Gross Regional Domestic Product (GRDP), the sector exhibits relatively low economic multipliers and weak integration with upstream and downstream industries. This study aims to analyze the economic impact of the metal mining sector by quantifying its multiplier effects and sectoral linkages using an Input-Output model. Employing the 2023 Input-Output Table for Southeast Sulawesi and applying Leontief multiplier analysis, the research evaluates income, employment, and surplus multipliers as well as backward and forward linkages within 52 economic sectors. The results reveal that while the sector's contribution to GRDP increased by 40.63% from 2019 to 2023, its multiplier effects remain limited compared to secondary and tertiary sectors. Simulation shows that increasing nickel production could raise regional GRDP by 3% but has minimal national impact. The findings underscore the necessity of strengthening downstream processing, enhancing sectoral linkages, and pursuing economic diversification to maximize benefits and ensure long-term regional economic resilience. This study provides valuable insights for policymakers aiming to foster sustainable development in resource-rich regions.

Keyword: Metal Mining Sector, Input-Output Analysis, Economic Linkages, Gross Regional Domestic Product (GRDP), Multiplier Effect.

INTRODUCTION

The global metal mining industry has experienced significant shifts over the past decade, primarily due to the increasing demand for metals crucial to technological progress and the transition to sustainable energy sources. Nickel (Ni), as a key component in various industrial applications, has become particularly important. Current estimates suggest that global nickel reserves amount to approximately 74 million tons of Ni metal (Shannak et al., 2024). The majority of these reserves are concentrated in Australia (25%), Brazil (16%), and Russia (10%), followed by Cuba (7%) and Indonesia (6%). Other countries with notable reserves include South Africa (5%), as well as Canada and China, each holding between 3.6% and 3.9% (Meshram et al., 2019; Mudd & Jowitt, 2014). Nickel is primarily found in laterite deposits, which account for over 60% of global reserves, while sulfide deposits make up the remaining 40% (Meshram et al., 2019). Furthermore, significant nickel resources exist in deep-sea manganese crusts and nodules, particularly in the Pacific and Indian Oceans (Shannak et al., 2024). Although Indonesia is currently the world's largest producer of mined nickel, concerns persist regarding the environmental and social impacts of its extraction, particularly in industries associated with electric vehicles and broader ESG (Environmental, Social, and Governance) considerations (Shannak et al., 2024). In terms of consumption patterns, nickel demand has seen a geographical shift over the past few decades. In 2017, nearly 75% of global nickel consumption was concentrated in Asia, while Europe accounted for only 16%. This represents a significant change from the 1990s when nickel demand was nearly equal in both

regions, with Europe consuming 38% and Asia 37% (Dilshara et al., 2024).

The urgency of addressing global environmental challenges, particularly climate change and resource depletion, has intensified the need for a fundamental transformation in the world's energy systems. Achieving sustainability requires a substantial shift in the global energy mix, with net-zero projections indicating that the combined share of wind and solar energy must increase from approximately 2% to 45% by 2050 to meet climate targets (Shannak et al., 2024). This transition necessitates a stable supply of critical raw materials, and nickel plays a particularly key role in clean energy technologies, notably in battery production. The increasing adoption of clean energy technologies in the 21st century has further amplified the significance of nickel. Specifically, nickel-bearing batteries play a crucial role in energy storage solutions, thus driving the demand for high-purity nickel and other essential metals. Complementing this, the rapid development of electric vehicles has encouraged manufacturers to explore alternative battery chemistries that enhance energy efficiency and performance (Kotal et al., 2022; Yang et al., 2023). Consequently, these advancements reinforce the critical role of nickel in shaping future technological and energy transitions.

Indonesia has positioned itself as a dominant force in the global nickel industry, accounting for over 48% of the world's total nickel supply in 2022. With an output of 1.6 million metric tons, the country has surpassed other major producers, including the Philippines and Russia (McRae, 2023). Sulawesi Tenggara, in particular, has been central to this achievement, possessing extensive nickel reserves and serving as a major hub for mining and processing activities. The region's contribution is closely aligned with Indonesia's broader industrial strategy, which seeks to expand the downstream nickel sector and increase the production of high-value products, such as nickel sulfate and high-purity nickel for electric vehicle (EV) batteries.

Indonesia's policy landscape has played a crucial role in shaping its global competitiveness in nickel production. In 2014, the government implemented a ban on raw nickel ore exports to encourage investment in domestic smelting and refining infrastructure, particularly from China. This policy has led to a rapid expansion of Indonesia's nickel industry, with the country's nickel export value soaring tenfold within a decade, reaching US\$30 billion in 2022 (Warburton, 2024). The policy has also contributed to substantial economic growth in nickel-rich regions, with local economies growing at rates more than three times the national average. By 2023, Indonesia had achieved record levels of foreign direct investment (FDI), largely propelled by the metals sector (Warburton, 2024). A significant portion of these investments was channeled into large-scale industrial parks in Central Sulawesi, Southeast Sulawesi, and North Maluku (Warburton, 2024). In summary, Indonesia's dominance in nickel production, coupled with progressive policies promoting mineral processing, underscores its strategic significance in the global supply chain for critical metals. These developments emphasize the necessity of ensuring that economic benefits are maximized through sustainable policies while mitigating the environmental and social challenges associated with large-scale mining.

The metal mining industry has become a cornerstone of the regional economy in Southeast Sulawesi, contributing 12.71% to the region's Gross Regional Domestic Product (GRDP) in 2023—an increase from 11.23% in the previous year. This growth has been driven by rising production levels and favorable metal prices (Badan Pusat Statistik, 2023). As a result, the mining sector now ranks as the third-largest contributor to the regional economy, following agriculture and trade. Beyond direct revenue generation, the sector's influence extends to broader economic improvements, fostering productivity and development across various industries.

Beyond its direct economic contributions, the nickel mining industry produces a substantial multiplier effect, generating growth in employment, output, and value-added activities that benefit both regional and national economies (Adidharma et al., 2023). For example, the labor multiplier effect demonstrates that increased activity in the mining sector not only expands employment within the industry itself but also stimulates job creation in supporting sectors such as transportation and manufacturing (Kasnar et al., 2024). To maximize these economic linkages, it is essential to develop policies that strengthen the integration of the mining sector with both upstream suppliers and downstream industries, ensuring a more balanced and sustainable industrial ecosystem.

Despite the metal mining sector's substantial contribution to Southeast Sulawesi's economy, there remains a limited understanding of its broader economic impact, particularly in terms of sectoral linkages and multiplier effects. While studies indicate that the growth of downstream industries has significantly increased regional output, value-added contributions, and employment, these analyses often fail to capture the full scope of intersectoral relationships. For instance, the downstream nickel industry alone has led to a threefold increase in economic output and value-added contributions to Southeast Sulawesi's economy, while employment in the region has expanded to approximately 4.5 million people (Malale & Sutikno, 2014). However, existing research tends to overlook the critical backward and forward linkages that shape the mining sector's role in regional economic diversification. Addressing these gaps, this study examines both the direct and indirect contributions of the mining sector, providing a comprehensive assessment of its potential to drive sustainable economic development. By doing so, it aims to highlight how mining interacts with other industries and identify strategies to maximize its regional economic benefits.

Beyond its empirical findings, this research contributes to the broader discourse on regional economic development. While much of the existing literature on extractive industries focuses on environmental and social impacts, relatively fewer studies explore the quantitative economic linkages and multiplier effects within resource-dependent economies. By employing input-output analysis and multiplier models, this study enhances our understanding of how resource-based sectors, particularly mining, can serve as catalysts for broader economic expansion. Additionally, it contributes to ongoing discussions on economic resilience and the role of extractive industries in advancing sustainable development goals.

From a policy perspective, the insights derived from this research hold significant implications. The mining-driven economy of Southeast Sulawesi faces key challenges, including over-reliance on raw commodity exports and the need to enhance value-added activities. The findings of this study can help inform policies that promote deeper integration between the mining sector and downstream industries, such as refining and battery production, while also encouraging investment in supporting sectors such as logistics, infrastructure, and technology. Strengthening these linkages will be crucial in ensuring that the benefits of the mining industry extend beyond its immediate contributions, fostering broader economic growth and long-term resilience.

Optimizing outcomes from the mining sector is expected to yield substantial benefits not only for metal processing and construction but also for various domestic industries that depend on mineral resources (Purnama et al., 2024b). Conversely, the sector itself requires significant inputs from other industries to generate outputs, creating intersectoral relationships that enhance economic stability and global competitiveness. The presence of strong backward and forward linkages further underscores the mining sector's role within a larger supply chain, driving demand for supporting industries and facilitating the expansion of

downstream production (Purnama et al., 2024a).

From an economic planning perspective, this research highlights the critical need to balance economic growth with sustainability. Southeast Sulawesi's vast nickel reserves, estimated at 3.3 billion tons (Ministry of Energy and Mineral Resources Republic of Indonesia, 2021), present significant economic opportunities but also raise concerns regarding resource depletion and environmental degradation. By quantifying the sector's multiplier effects and economic linkages, this study provides empirical evidence to support long-term economic planning, ensuring that growth remains sustainable and equitable. Additionally, the findings will offer a framework that can be adapted to other resource-rich regions, contributing to both national and global discussions on economic resilience and responsible resource management.

A key contribution of this study is its comparative analysis of sectoral multipliers, providing clearer insights into the economic impact of mining relative to other industries in Southeast Sulawesi (Agustina & Abadi, 2024). Understanding these multiplier effects is essential for designing economic policies that enhance regional competitiveness and diversification—especially in areas heavily dependent on mining activities. In doing so, this research addresses a critical policy gap by examining how mining-driven economies can transition towards more resilient and diversified economic structures. Furthermore, this study aligns with broader regional development goals, offering insights into how the metal mining sector contributes to local economic resilience (Ode Wahiyuddin et al., 2023). By analyzing intersectoral relationships, the research sheds light on how mining activity stimulates growth in related industries, such as manufacturing, logistics, and infrastructure. These findings are expected to support policymakers in crafting strategies for sustainable mineral resource management, ensuring that the benefits of mining extend beyond immediate economic gains to foster long-term development.

In light of these objectives, this study aims to measure and analyze the economic impact of the metal mining sector on Southeast Sulawesi's economy through a multiplier effect approach and sectoral linkage analysis. Additionally, it seeks to identify relevant policy strategies that strengthen the sector's role as a driver of sustainable regional economic growth while mitigating potential risks associated with resource dependency and environmental challenges.

The urgency of addressing these challenges is driven by the global shift towards sustainable energy technologies that require stable supplies of critical metals like nickel. Southeast Sulawesi, as a major nickel producer, has a strategic opportunity to leverage this demand for regional economic advancement. However, current sectoral linkages remain insufficient to maximize these benefits, calling for immediate policy attention to strengthen local supply chains, downstream processing, and workforce development. Without such intervention, the region risks over-reliance on primary extraction activities that offer limited socio-economic returns and pose environmental risks.

Additionally, the socio-economic disparities in the region, such as income gaps and low local employment in mining operations, exacerbate development imbalances. Enhancing backward and forward linkages in the metal mining value chain is critical to fostering inclusive growth, ensuring that economic gains from nickel production translate into broader community development and sustainable livelihoods.

Input-output analyses in regional economic studies have demonstrated the importance of sectoral multipliers in understanding economic linkages. Studies by Miller and Blair (2009) and Szabó (2015) have outlined frameworks for assessing how industries interconnect and impact

broader economic dynamics. Recent work on nickel mining in Indonesia highlights its growing global significance but notes challenges in value retention due to export of raw materials (Meshram et al., 2019; Shannak et al., 2024).

Research specific to Southeast Sulawesi's mining sector (Malale & Sutikno, 2014; Irawati, 2018) has documented its contribution to regional income growth but pointed out weak employment linkages and limited benefits for local communities. Other scholars have emphasized the need for downstream industrial development and local capacity building to improve socio-economic outcomes (Warburton, 2024; Purnama et al., 2024).

Comparative analyses of multiplier effects across sectors further underscore the greater potential of manufacturing and services in driving sustainable growth compared to extractive industries (Agustina & Abadi, 2024; Ode Wahiyuddin et al., 2023). These findings suggest a vital policy focus on industrial diversification and strengthening sectoral linkages.

Although previous studies have highlighted the economic contributions of nickel mining, there remains a significant gap in understanding the full extent of its backward and forward linkages in Southeast Sulawesi. Many analyses focus on direct impacts or aggregate outputs but lack detailed assessments of intersectoral dependencies and multiplier effects that reveal opportunities for integrated economic development. This study aims to fill that gap by employing an input-output framework combined with multiplier and linkage analysis to provide a comprehensive evaluation of the metal mining sector's role in the regional economy.

This research uniquely integrates input-output and multiplier analysis with a focus on both backward and forward linkages within the regional economic context of Southeast Sulawesi's nickel mining sector. Unlike prior studies that emphasize output or employment alone, this study offers a detailed examination of intersectoral interactions, revealing critical structural weaknesses and opportunities for policy intervention. By simulating production optimizations and projecting economic impacts on GRDP and income distribution, it provides actionable insights for enhancing regional economic resilience and sustainable development.

The primary objective of this study is to analyze the economic impact of the metal mining sector on Southeast Sulawesi's economy by quantifying multiplier effects and sectoral linkages using an input-output model. Additionally, the study seeks to identify policy strategies to strengthen the sector's integration with upstream suppliers and downstream industries, thereby promoting sustainable economic growth and reducing regional disparities.

This study offers valuable empirical evidence to policymakers, industry stakeholders, and researchers aiming to optimize the economic benefits of the metal mining sector. By illuminating the strengths and weaknesses in sectoral interactions, it informs targeted interventions in local supply chain development, downstream processing, workforce training, and environmental sustainability. The insights gained can support more balanced regional economic planning, improved income distribution, job creation, and the advancement of sustainable mining practices. Furthermore, the methodological framework can be adapted to other resource-rich regions seeking to leverage extractive industries for inclusive growth.

MATERIALS AND METHODS

This research was conducted using a questionnaire survey design and using research methods in quantitative form. The target population is administrators in universities such as the Chancellor, Vice Chancellor, Faculty Deans, Heads of Study Programs, and Heads of Information Systems Bureaus, so that they have aspects of ease in reaching the information needed, and it is hoped that data collection will be easier, economical, effective, efficient and appropriate. The tests carried out in this study used a data analysis tool, namely Partial Least Square (PLS) using smart-PLS software.

This study employs the **Input-Output (I-O) model**, a well-established economic analysis tool that illustrates intersectoral relationships within an economy by showing how the output of one industry serves as an input for others (Subanti et al., 2018; Tui & Adachi, 2021). The **I-O table** provides a structured representation of transactions involving goods and services, enabling a comprehensive assessment of linkages between economic activities over a specific period (Sarkar & Gupta, 2024; Tohmo, 2018). By leveraging this model, the study identifies key sectors with substantial influence on economic growth and evaluates the flow of commodities and services within the regional economy.

The Leontief multiplier effect has been extensively applied in economic analysis through the use of input-output tables (Feng & Zhang, 2018; Roh, 2023). The **Input-Output model** is a **static equilibrium framework** characterized by a **constant price level** and a **Leontief linear production function**, implying that inputs are used in fixed proportions without substitution (Szabó, 2015). The fundamental goal of **I-O analysis** is to determine the necessary sectoral outputs (**endogenous variables**) required to meet a given final demand (**exogenous variable**) (Tausl Prochazkova & Noskova, 2020).

This research utilizes the 2023 Input-Output Table for Southeast Sulawesi, which is an aggregated version of the 2016 I-O Table, consolidated into 52 economic sectors (BPS Sultra, 2021). The mining sector stands out as a key contributor, accounting for 12.71% of the regional GDP, ranking third among all economic sectors in the province (Statistik, 2023). Through this framework, the study examines the sector's linkages with other industries and assesses the broader economic implications of changes within the mining sector. To quantify these impacts, this study applies the Leontief inverse matrix, which serves as the foundation for Input-Output analysis. The standard Leontief equation is formulated as:

$$X = (I - A)^{-1}Y \quad (1)$$

Where:

- X is the vector of total sectoral outputs,
- I is the identity matrix,
- A is the matrix of technical coefficients, and
- Y is the final demand vector.

The Leontief inverse matrix captures both direct and indirect effects, allowing for a comprehensive evaluation of sectoral dependencies and the propagation of economic changes throughout the regional economy (Leontief, 1986; Wulandari, 2023). Building on this framework, the study calculates three key multipliers:

Income Multiplier

The income multiplier measures the effect of changes in final demand on household income. It indicates the additional income generated for households when final demand in a given sector—such as mining—increases by one unit. This metric provides insights into the direct and indirect contributions of mining to household earnings through wages, profits, and other income sources. The calculation utilizes the income coefficient vector (v), which represents the share of value added per unit of output (Miller & Blair, 2009).

$$M_{income} = v \times (I - A)^{-1} \quad (2)$$

Employment Multiplier

The employment multiplier evaluates the number of job opportunities created for every unit increase in final demand. It captures both direct employment within the mining sector and indirect

employment in supporting industries, such as transportation and equipment manufacturing. This multiplier is particularly useful for assessing the sector's role in reducing unemployment and improving labor market conditions. The employment multiplier is derived using the employment coefficient vector (e), which reflects the number of workers per unit of output (Miller & Blair, 2009).

$$M_{employment} = e \times (I - A)^{-1} \quad (3)$$

Surplus Multiplier

The surplus multiplier reflects the total economic surplus generated by investments in the final demand of a sector. It measures the additional economic value created after essential costs are covered, which can then be reinvested into other industries. The mining sector plays a strategic role in economic surplus generation, as its profits and value-added contributions provide opportunities for investment diversification. This study calculates the surplus multiplier using the surplus coefficient vector (s), representing the proportion of net value added per unit of output (Miller & Blair, 2009).

$$M_{surplus} = s \times (I - A)^{-1} \quad (4)$$

By incorporating this analytical approach, the study systematically evaluates how the mining sector influences regional economic stability, sectoral interdependencies, and long-term development prospects. o better understand how these effects propagate across the economy, it is essential to examine the backward and forward linkages of the mining sector.

Backward Linkages

Backward linkages measure the extent to which a sector relies on inputs from other industries to support its production (Li et al., 2024). In the metal mining sector, this includes dependencies on raw material suppliers, machinery manufacturers, and service providers such as energy, transportation, and finance. A strong backward linkage implies that growth in the mining sector stimulates demand in upstream industries, reinforcing the multiplier effect observed earlier. Mathematically, the intensity of backward linkages can be analyzed using the Leontief inverse matrix which captures how an increase in final demand for mining products propagates through the input-output structure of the economy. The general formula for the backward linkage (BL_j) of sector j is:

$$BL_j = \frac{\sum_{i=1}^n a_{ij}}{\frac{1}{n} \sum_{i=1}^n \sum_{j=1}^n a_{ij}} \quad (5)$$

Where represents the elements of the technical coefficient matrix (A), and n is the number of economic sectors. This equation quantifies how much input sector j sources from other industries compared to the economy-wide average (Bulmer-Thomas, 1982).

Forward Linkages

Forward linkages indicate how much output from the mining sector is used as an input for downstream industries, such as metal processing, manufacturing, and construction (Li et al., 2024). The strength of forward linkages determines the extent of the multiplier effect in these sectors. The forward linkage (FL_j) for sector i is given by:

$$FL_j = \frac{\sum_{j=1}^n a_{ij}}{\frac{1}{n} \sum_{i=1}^n \sum_{j=1}^n a_{ij}} \quad (6)$$

This formula measures the proportion of sector i 's output that serves as input for other sectors, compared to the overall economy-wide input use (Bulmer-Thomas, 1982). By analyzing both forward and backward linkages, this study provides a comprehensive understanding of how the mining sector interacts with the broader economy. These insights help quantify the full extent of

the multiplier effect, revealing potential areas for sectoral synergy optimization, value chain integration, and regional economic diversification. The findings are expected to contribute both theoretically to regional economic literature and practically as a foundation for data-driven policy formulation.

RESULTS AND DISCUSSION

Sectoral Multiplier Effects and Economic Contributions

The economic impact of different sectors varies significantly in terms of income generation, employment, and economic surplus. **Figure 1** illustrates the sectoral multipliers for Southeast Sulawesi, highlighting the relative contributions of each sector to regional economic growth. These multipliers provide insights into the structural dynamics of the economy, identifying key sectors that drive development.

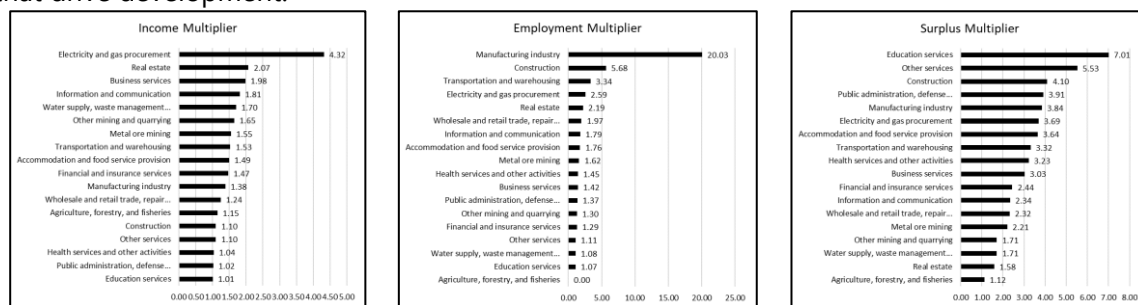


Figure 1. Input-Output Analysis of Southeast Sulawesi Province 2023

Source: Research result

Among all sectors, the electricity and gas procurement sector exhibits the highest income multiplier at 4.32, indicating its substantial capacity to generate regional income per unit of final demand. In contrast, the metal mining sector ranks seventh with a multiplier of 1.55, suggesting that while mining contributes to income generation, other sectors—particularly infrastructure-related industries—play a more dominant role. This finding underscores the need to explore how mining revenues can be leveraged to enhance broader economic growth.

On the other hand, the manufacturing sector emerges as the leading driver of employment, with a multiplier of 20.03, reflecting its labor-intensive nature and ability to absorb a large workforce. In comparison, the metal mining sector ranks ninth with a multiplier of 1.62, indicating a limited capacity for direct job creation. Given these disparities, policies aimed at strengthening employment linkages between mining and other sectors could improve overall labor market outcomes.

Furthermore, economic surplus, which reflects the additional value created per unit of investment, is highest in the education services sector (7.01). In contrast, the metal mining sector ranks fourteenth with a multiplier of 2.21, signifying a lower capacity to generate economic surplus relative to service-oriented industries. This highlights the long-term benefits of investing in human capital, as education and knowledge-driven industries contribute more significantly to economic sustainability.

Overall, the findings indicate that while metal mining remains a vital economic pillar, secondary (manufacturing) and tertiary (service-based) industries exhibit significantly higher multiplier effects. This suggests that although mining can stimulate initial economic activity, long-term growth requires diversification, particularly through investments in manufacturing and education-driven sectors.

Despite its substantial contribution to the regional economy, the metal mining sector, particularly nickel mining in Southeast Sulawesi, faces structural weaknesses. Over the past five

years (2019–2023), the sector has grown by 40.63% (Statistik, 2023). However, its economic impact, as measured by multiplier indicators, remains limited. The sector's surplus multiplier is 2.21, its income multiplier is 1.55, and its employment multiplier is 1.62—figures significantly lower than those of secondary and tertiary industries, which record a surplus multiplier of 7.01, an income multiplier of 4.32, and an employment multiplier of 20.03.

These disparities indicate that secondary and tertiary sectors have a far greater capacity to generate income and employment. A study on nickel mining in Pomalaa, Southeast Sulawesi, found that while mining activities contributed to regional income growth, they had minimal impact on local employment, as most jobs were filled by non-local workers (Irawati., 2018). This suggests that prioritizing the development of secondary and tertiary industries is a more effective strategy for reducing reliance on primary industries like mining.

Moreover, resource-based economies often encounter challenges such as the "resource curse," where over-dependence on natural resources impedes economic diversification and long-term sustainable growth. To address these issues, policies should focus on strengthening local employment opportunities, enhancing value-added processing, and investing in industries with higher multiplier effects.

Backward and Forward Linkages in Regional Economic Development

Beyond multiplier effects, inter-sectoral linkages—both backward and forward—play a crucial role in regional economic integration. These linkages determine how different industries interact, influence supply chains, and create long-term economic interdependencies. Backward linkages measure a sector's ability to stimulate economic activity through its demand for inputs from other industries. As shown in **Figure 2**, the manufacturing sector demonstrates the highest backward linkage multiplier at 6.76, highlighting its role in regional economic integration through strong inter-industry dependencies. This suggests that manufacturing creates significant demand for raw materials, services, and intermediate goods, making it a key driver of local supply chain development.

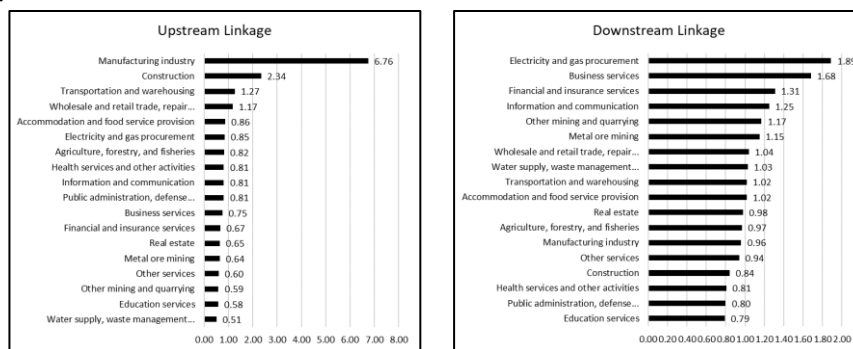


Figure 2. Upstream and Downstream Linkage Analysis of Southeast Sulawesi Province 2023

Source: Research result

Conversely, the metal mining sector ranks fourteenth, with a backward linkage multiplier of only 0.64. This indicates limited integration with upstream industries, suggesting that mining activities in Southeast Sulawesi have not fully optimized local supply chains. The low multiplier may be attributed to a reliance on imported machinery, foreign expertise, and limited local processing capabilities. To maximize its economic impact, policies should encourage domestic procurement, local supplier development, and industrial clustering to strengthen mining's role in regional economic ecosystems.

On the other hand, forward linkages measure a sector's ability to create new economic activities dependent on its output. The electricity and gas procurement sector ranks highest, with a forward linkage multiplier of 1.89, reinforcing its strategic importance in supporting

industrialization, infrastructure development, and technological expansion. The metal mining sector ranks sixth, with a forward linkage multiplier of 1.15, indicating moderate potential for downstream value-added activities. While this suggests some degree of industrial integration, it remains suboptimal compared to leading sectors. Strengthening mineral processing, refining, and manufacturing linkages could significantly enhance mining's contribution to long-term economic development. By promoting downstream industries such as metal refining, alloy production, and mineral-based manufacturing, the sector can move beyond raw material extraction and contribute to higher value-added production.

The analysis of backward and forward linkages in the metal mining sector further underscores its limited contribution to strengthening the regional economic value chain. The backward linkage for the metal mining sector is 0.64, while the forward linkage is 1.15. In contrast, the secondary and tertiary sectors exhibit significantly stronger linkages, with backward linkage values of 6.76 and forward linkage values of 1.89. These figures indicate that secondary and tertiary sectors play a far greater role in stimulating economic interactions and driving regional industrialization.

The relatively low backward linkage of the metal mining sector suggests that its production activities are not well-integrated with supporting industries, limiting its overall impact on the local economy. A study in Konawe Utara, Southeast Sulawesi, found that mining operations engaged minimally with local suppliers, resulting in limited economic spillover effects (Maidina & Tamma, 2023). Similarly, the low forward linkage indicates untapped potential for value-added activities. Enhancing downstream processing—such as smelting and refining—is essential for increasing the sector's value-added contribution. The construction of smelters, as mandated by Indonesian law, represents a critical step in improving the mining sector's long-term economic benefits (Womal, 2023).

Simulation of Production and Contribution of the Metal Mining Sector to the Economy of Southeast Sulawesi

In 2023, Southeast Sulawesi recorded nickel mining production of 65,482,765.79 tons, contributing 12.71% to the regional economy, making it one of the province's strategic sectors (Statistik, 2023). This highlights the sector's pivotal role in driving regional economic activities and attracting investment opportunities.

The Gross Regional Domestic Product (GRDP) per capita at current prices increased from IDR 58,715,000.00 in 2022 to IDR 64,088,000.00 in 2023, reflecting a 9% annual growth (Statistik, 2023). However, real income remains low, reaching only 33% of the Regional Minimum Wage (UMR) of IDR 34,631,568.48 (Statistik, 2020). This significant income gap of IDR 13,466,364.48 highlights structural economic challenges, particularly in equitable income distribution and sustainable livelihood improvements for local communities.

To bridge this gap, increasing per capita income is essential. If additional income of IDR 13,466,364.48 were distributed proportionally across economic sectors, the metal mining sector would contribute IDR 5,291,033,450,000.00 to the regional economy. This would elevate the GRDP from IDR 176,179,907,000,000.00 to IDR 181,470,940,000,000.00, representing a 3% increase. However, this increase alone may not be sufficient to achieve significant socioeconomic transformation. Additional measures, such as workforce upskilling, local business empowerment, and industrial diversification, are required to ensure the mining sector's benefits extend beyond GDP growth.

From a national perspective, the additional economic growth generated by the mining sector appears marginal. In 2023, Indonesia's actual GDP was IDR 20,892,376,700,000,000.00, with a revised estimate reaching IDR 20,897,667,733,000,000.00, reflecting an increase of only 0.03%. This minor contribution highlights the disproportionate impact of mining at the regional versus national level. While nickel mining plays a vital role in local economies, its limited influence on the national

GDP suggests inefficiencies in value retention and economic integration.

This underscores the pressing need to strengthen downstream processing industries and enhance the value-added potential of mined resources. By shifting away from reliance on raw material exports and investing in domestic refining and manufacturing, Indonesia could significantly amplify the economic benefits of its mineral wealth. Additionally, policies fostering industrial diversification, research and development, and workforce skill enhancement are crucial in transforming mining from a primarily extractive industry into a catalyst for broader economic development. Without such initiatives, the national mining sector risks stagnation, failing to translate regional resource wealth into substantial national economic gains. Policymakers must, therefore, prioritize strategies that encourage sustainable industrial growth, ensuring that mining's contributions extend beyond localized economic improvements.

The economic trajectory of Southeast Sulawesi's metal mining sector demonstrates significant growth potential while highlighting important considerations for sustainable development. In 2023, the sector's contribution GRDP reached IDR 22,388,150,000,000.00, with projections indicating potential growth to IDR 27,679,183,450,000.00 following strategic income allocation initiatives. This 23.6% increase reflects the sector's capacity for substantial economic expansion when supported by appropriate policy frameworks and investment strategies.

The anticipated growth in nickel production from 65,482,765.79 tons to 80,958,430.55 tons represents a significant operational expansion driven by three key factors. First, technological advancement and operational efficiency improvements are expected to optimize extraction processes and resource utilization. Second, strategic investment in modern mining infrastructure and equipment will enhance production capabilities while minimizing environmental impact. Third, policy incentives designed to promote sustainable mining practices are anticipated to create a favorable environment for responsible resource development.

Simulation models analyzing the relationship between mining sector performance and regional economic well-being reveal important insights. The current GRDP of Southeast Sulawesi Province, standing at IDR 176,179,907,000,000.00, requires an additional IDR 5,291,033,450,000.00 to achieve minimum living standard targets. This 3% increase, bringing the total GRDP to IDR 181,470,940,000,000.00, represents a critical threshold for social and economic development in the region. The simulation findings align with research conducted in comparable mining regions, which demonstrates the importance of optimizing resource management to enhance socioeconomic outcomes.

However, the national economic impact of this regional growth remains relatively modest. The projected increase in contribution to Indonesia's GDP of 0.03% (from IDR 20,892,376,700,000,000.00 to IDR 20,897,667,733,000,000.00) underscores the need for a more comprehensive development strategy. This limited national impact suggests that regional mining activities must be integrated into a broader economic diversification framework to achieve meaningful long-term growth.

These findings point to several strategic imperatives for regional development. First, policymakers should focus on strengthening backward and forward linkages between the mining sector and local industries to maximize economic multiplier effects. Second, investment in downstream processing capabilities and value-added manufacturing could help capture more economic benefits within the region. Third, environmental sustainability must be prioritized through robust regulations and incentives for responsible mining practices. Finally, workforce development programs should be implemented to ensure local communities can participate more fully in the sector's growth.

The path forward requires a balanced approach that leverages the mining sector's growth potential while actively pursuing economic diversification and sustainable development objectives. This strategy should encompass infrastructure development, environmental protection, skills

training, and industrial policy coordination to create a more resilient and inclusive regional economy. Success in this endeavor will depend on effective collaboration between government authorities, mining companies, and local stakeholders to implement comprehensive development initiatives that extend beyond mere production increases to achieve lasting economic transformation.

Policy Recommendations for Enhanced Economic Impact

To maximize the economic benefits of the metal mining sector in Southeast Sulawesi while ensuring long-term sustainability, a multifaceted policy approach is required. Key strategies include promoting downstream processing, strengthening local supply chains, investing in human capital, ensuring environmental sustainability, and supporting economic diversification.

First, promoting downstream processing is crucial to increasing the value-added contribution of the mining sector. Encouraging the development of local smelting and refining facilities can help shift the industry away from raw material exports toward higher-value production. The government can provide fiscal incentives, such as tax reductions and infrastructure support, to attract investment in mineral processing industries. Additionally, policies that mandate the domestic processing of extracted minerals, as outlined in Indonesia's regulatory framework, should be effectively enforced to stimulate industrial growth.

Second, strengthening local supply chains can enhance the mining sector's backward linkages and its integration with other industries. Policies should prioritize the use of locally sourced materials, machinery, and services, reducing dependency on imports and increasing economic spillover effects. This can be achieved through preferential procurement programs, capacity-building initiatives for local suppliers, and financial support for small and medium-sized enterprises (SMEs) in mining-related industries.

Third, investing in human capital is essential to ensuring that local communities benefit from the mining sector's economic opportunities. Expanding vocational training, technical education, and skill development programs in mining engineering, metallurgy, and environmental management can equip the local workforce with the expertise needed to take on specialized roles. Collaboration between industry stakeholders, educational institutions, and government agencies can help bridge skill gaps and create a pipeline of qualified professionals for higher-value mining-related activities.

Fourth, ensuring environmental sustainability is imperative to mitigate the adverse effects of mining activities and support long-term economic resilience. Stricter enforcement of environmental regulations, along with incentives for adopting green technologies, can help reduce pollution and land degradation. Additionally, requiring mining companies to implement land rehabilitation programs and community-based environmental initiatives can foster more sustainable resource management while maintaining local livelihoods.

Lastly, supporting economic diversification is necessary to reduce the region's reliance on mining and build a more resilient economy. While mining remains a key driver of economic growth, policies should encourage the development of complementary sectors such as agriculture, tourism, and manufacturing. Investment in infrastructure, digital connectivity, and entrepreneurship programs can create new economic opportunities and enhance regional stability beyond the mining industry.

By implementing these policy recommendations, Southeast Sulawesi can leverage its metal mining sector more effectively to drive inclusive and sustainable economic growth. A balanced approach that fosters industrial integration, human capital development, and environmental responsibility will help reduce income disparities, strengthen local economies, and improve overall well-being in the region.

CONCLUSIONS

This study highlights the critical role of the metal mining sector, especially nickel, as a key driver of regional economic activity in Southeast Sulawesi. While the sector significantly contributes to economic growth, it is not the main catalyst for sustainable, long-term development, as secondary and tertiary sectors exhibit stronger multiplier effects in income generation, job creation, and economic surplus, indicating their greater potential for enhancing regional prosperity. Simulation results suggest that increasing nickel production from approximately 65.5 million tons to 81 million tons could boost the regional GRDP by 3%, from IDR 176.18 trillion to IDR 181.47 trillion; however, its impact on the national GDP remains minimal at 0.03%. This analysis assumes *ceteris paribus*, not accounting for external economic factors and intersectoral linkages. Thus, while mining remains vital regionally, its sustainable future depends heavily on economic diversification and better integration into value chains. For future research, it is recommended to conduct dynamic, longitudinal studies incorporating broader economic interactions and external shocks to assess mining's real-time impact more accurately. Additionally, exploring the social and environmental dimensions alongside economic factors could provide a holistic understanding of the sector's sustainability and inform more balanced policy-making.

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