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Examining the linkage and structural transformation effects of nickel industrialization: A case of South Halmahera, Indonesia

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ABSTRACT

The global surge in electric vehicle demand has intensified focus on green economies. Indonesia, home to the world's largest nickel reserves, enacted a nickel ore export ban to maximize domestic value-added through downstream industrialization, notably in South Halmahera, North Maluku. We examine the effects of nickel downstream processing by estimating multiplier impacts for mining and manufacturing sectors at regional and national levels, identifying structural transformation in South Halmahera, and assessing the competitiveness relative to North Maluku Province. Several methods were used, such as the Leontief inverse matrix of updated Input–Output (IO) and Interregional Input–Output (IRIO) tables, shift-share (SS), and location quotient (LQ). We find that manufacturing multipliers have grown substantially, but with significant leakage as benefits largely flow to other provinces. SS analysis also indicates rising productivity, labor reallocation into manufacturing, and the emergence of supporting sectors. LQ results confirm a sharp, although temporary, increase in manufacturing competitiveness that also boosts mining productivity. Despite transformative effects on nickel industrialization, much of the value-added potential remains uncaptured due to weak local integration. Developing reliable supporting industries is crucial to attaining economic diversification for long-term sustainable growth, considering the limited amount of nickel reserves.

Contribution/Originality: This paper serves as an initial exploration of the regional economic effects of nickel industrialization under Indonesia's raw nickel export ban policy. It specifically examines potential multiplier leakage and signs of structural transformation resulting from nickel downstream activities in one of the world's largest nickel-producing areas in South Halmahera Regency, Indonesia.

1. INTRODUCTION

Nickel has recently garnered significant attention as a critical mineral, primarily because of its essential role in the production of batteries for electric vehicles (EVs) and its increasing demand in various industrial applications. However, the widespread discussion and debate surrounding the nickel industry highlight whether it has positive or

negative impacts on sustainable economic development (Golroudbary, Kraslawski, Wilson, & Lundström, 2023; Lo et al., 2024; Pirmana, Alisjahbana, Yusuf, Hoekstra, & Tukker, 2023). Despite this debate, nickel currently is a vital resource for the Indonesian economy, as the country holds over 57.11 million metric tons of nickel reserves as of 2021 (GAI, 2022). Following this, the Government of Indonesia issued Law No. 3/2020, which restricts the export of raw minerals due to their added value in downstream and manufacturing industries. This development has benefited Indonesia as a supplier to nickel downstream businesses, contributing to approximately 50% of global nickel production (Basuhi et al., 2024). Notably, although Indonesia has the largest nickel reserves, these are located only in certain provinces in eastern Indonesia, which are expected to be depleted by 2056 (Sunuhadi, Ernowo, Hilman, & Suseno, 2024; Zuada, Afdalia, Kafrawi, & Nutfa, 2023).

Mineral industrialization in Indonesia aims to reduce economic disparity particularly between the western and eastern regions by developing smelting facilities and their derivative products. However, it has resulted in significant exploitation and environmental damage, such as forest degradation, while the economic contribution of eastern Indonesia remains at 20% (Langston et al., 2015; Resosudarmo & Jotzo, 2009). An appropriate policy design is needed to direct development in eastern Indonesia to avoid the "*Dutch disease*" phenomenon, with the "*resource curse*" being on the horizon. Moreover, the structural changes induced by mineral industrialization can lead to a decline in traditional sectors. As the mining sector grows, labor and capital are drawn away from agriculture and manufacturing, which can suffer from underinvestment and reduced productivity. This shift can exacerbate regional inequalities, as areas dependent on agriculture may struggle to compete with the lucrative mining sector.

What might possibly go wrong when eastern Indonesia still has low economic shares despite having abundant natural resources? We attempt to answer this question by quantitatively exploring the economic linkages and structural transformation following the nickel downstream industry in one of the world's largest nickel production areas in South Halmahera Regency, Indonesia.[1] Since its inception of smelter and industrial operations in 2016, South Halmahera Regency has experienced a dramatic increase in economic growth, and the contribution of the secondary sector (manufacturing, trading, etc.) overlaps with that of the primary sector (agriculture). Given this phenomenon, is the nickel downstream industry noteworthy for bringing in and strengthening domestic economic growth? Moreover, we discuss the effectiveness of policy design and resource management to avoid the pitfalls associated with the Dutch disease. Our investigation focuses on the identification of the economic multiplier and the change in economic structure due to the nickel downstream industry in South Halmahera Regency via input-output (IO), interregional input-output (IRIO), and base sector dynamics (shift share and location quotient) analyses. To operationalize these, we update the IO and IRIO 2016 tables provided by Statistics Indonesia before estimating the economic multiplier and structural change. Finally, our study serves as a foundation for developing a more sustainable development policy to avoid the possibility of the resource curse in the area.

2. LITERATURE REVIEW

Natural resource extraction has long been recognized for its significant economic benefits for developing countries, such as promoting economic growth, attracting foreign investment, and increasing local workers' real wages (Betz, Partridge, Farren, & Lobao, 2015; Dansereau, 2006; Rehner & Rodríguez, 2021). Specifically, mining and mineral processing projects can generate substantial economic inflow. Enormous economic benefits to communities surrounding mining areas come from the construction phase, as many jobs are created during that period, but only for a short duration. Meanwhile, approximately 85% of additional jobs are created during production phases (Clements, Ahammad, & Qiang, 1996). This construction period also increases government revenue, mainly from taxes, reaching its peak during the production phase (Dorin, Diaconescu, & Topor, 2014). In

[1] According to GlobalData (2024) South Halmahera Regency becomes the second largest active nickel mine (mainly through Halmahera Persada Lygend Project, Co. Ltd.) after Weda Bay Project (also in Indonesia) with the estimated 95.18 thousand tones of nickel production in 2023.

addition, Roe and Round (2017) estimated both direct and indirect impacts of mining industrialization on key economic variables, where the multiplier effects of mining business operations were spread to other sectors, such as transportation, energy infrastructure, and the creation of job opportunities for local communities, which eventually increased the human capital quality of local workers. However, in many cases, remote mining areas receive limited multiplier effects. The case in Chile shows that the greater economic linkages from the copper mining supply network mostly benefit the business center, whereas the mining areas receive benefits from basic services with low but long-term linkages, which implies an uneven distribution of multiplier effects (Atienza, Lufin, & Soto, 2021).

Despite its economic multiplier, mineral exploitation is found to generate economic output only in the short term, while it could deteriorate economic development in the long run (Nagwa, 2024). This is likely due to incompetent institutional capacities and capabilities in managing mining areas, resulting in corruption, nonproductive activities, and high economic rents from inefficient markets (Epo & Nochi Faha, 2020; Stijns, 2005). The crowding-out effect in human capital accumulation was also observed since there is limited incentive in labor investments (Gylfason, 2001). The negative effect on human capital accumulation, combined with exchange rate appreciation and considerable energy consumption, will eventually decrease investment in skills, knowledge, and capital in the manufacturing sector (Chan, 2022; Kwakwa, Alhassan, & Adu, 2020; Torvik, 2001). A case study on Singkep Island, Indonesia, revealed that high economic dependency on the mining sector resulted in limited development of skilled workers and public facilities, while migration continued in the area due to the availability of jobs (Syahrir, Wall, & Diallo, 2020). Furthermore, there are limited supporting industries for mining activities, as many are dependent on mining, such as small businesses, machinery providers, and other local suppliers. This also potentially shifts the job recruitment pattern to be more relevant to migrant workers than to local workers and businesses (Fatah, 2008). In addition, environmental degradation occurs because mining areas are remote and have limited monitoring and surveillance (Langston et al., 2015; Resosudarmo & Jotzo, 2009).

The detrimental effects of mining exploitation and industry are thus more concerning than their benefits if there is no mitigation plan in place. The "*resource curse*," often referred to as the "*paradox of plenty*," remains a key consideration in developing mitigation strategies for mining exploitation and industrialization. This paradox is particularly evident in developing nations, where resource wealth can lead to a range of negative effects on economic and social development and does not necessarily translate into economic prosperity or improved living standards in the long run (Brunnschweiler & Bulte, 2008). Mining industrialization typically initiates a series of structural changes in local economies. As mining operations expand, they often dominate the economic landscape, leading to a reliance on a single industry, making the economy vulnerable to global price changes (Rocha & Moreira, 2010), socioeconomic disparities and conflicts over land use (Littlewood, 2014; Loayza & Rigolini, 2016), environmental degradation (Gupta & Paul, 2015) and socioenvironmental conflicts (Özkaynak & Rodriguez-Labajos, 2017; Valle Díaz et al., 2023). Moreover, the economic structure of resource-rich countries often leads to the neglect of other sectors, further increasing their vulnerability. The mining industry can dominate the economic landscape, leading to a phenomenon known as *Dutch disease*, where the growth of the mining sector causes a decline in other sectors, such as agriculture and manufacturing (Briguglio, Cordina, Farrugia, & Vella, 2009). This structural change not only reduces economic diversity but also increases the economy's exposure to global price fluctuations. The mining sector's boom and bust cycles can lead to significant fluctuations in government revenues, which in turn affect public spending and investment in critical areas such as education and infrastructure (Shtangret, Shliakhetko, & Mandzinovska, 2022).

Escaping the "*resource curse*" can be accomplished through promoting diversification to ensure the sustainability of growth. As argued by Ploeg (2011), fostering economic diversification and industrialization can act as a solution to maintain growth in the long run, as proven in Indonesia, Malaysia, and Thailand (Gylfason, 2001). A similar idea was also proposed by Murshed and Serino (2011), where trade specialization in primary products was associated with slower economic growth, and those who succeeded in cultivating the economic trend were able to diversify

their economic structure. While economic diversification might be the solution to the curse, regions that focus solely on primary product manufacturing can also suffer from the curse. This is confirmed by Murshed and Serino (2011), who reported that dependency on resource-based manufacturing had nonsignificant effects on long-term economic growth and tended to be at risk of exchange rate volatility. On the basis of the above discussion, we formulate the following research hypotheses: (1) the mining and manufacturing sectors in South Halmahera generate multiplier effects on particular sectors closely related to the operation process, and (2) nickel downstream activity becomes the leading sector and crowds out other industries.

3. DATA AND RESEARCH METHODS

3.1. Data

We use secondary regional-level economic data, namely, sectoral regional GDP, sectoral employment, provincial-level (North Maluku Province) IO, and IRIO data. All the data are sourced from Statistics Indonesia. These datasets are separated into three periods based on the operationalization phase of the nickel smelter: (1) the pre-downstream period (2011-2015), (2) construction and downstream phase 1 (2016-2020), and (3) downstream phase 2 (2021-2023). One major nickel exploration in South Halmahera Regency started in 2010[2]; Therefore, our pre-downstream period took place between 2011 and 2015, before the construction of the first smelter and nickel processing in the regency in 2016 (the construction and 1st phase of nickel downstream)[3], followed by the full operation of nickel downstream starting in 2021[4]. Notably, the latest IO and IRIO data published by Statistics Indonesia were published in 2016, when the nickel processing industry in South Halmahera Regency had not yet started. On the other hand, the smallest administrative level available for IO data is only the provincial level. In this case, we update and rescale the IO data to obtain relevant analysis, as depicted in Figure 1.

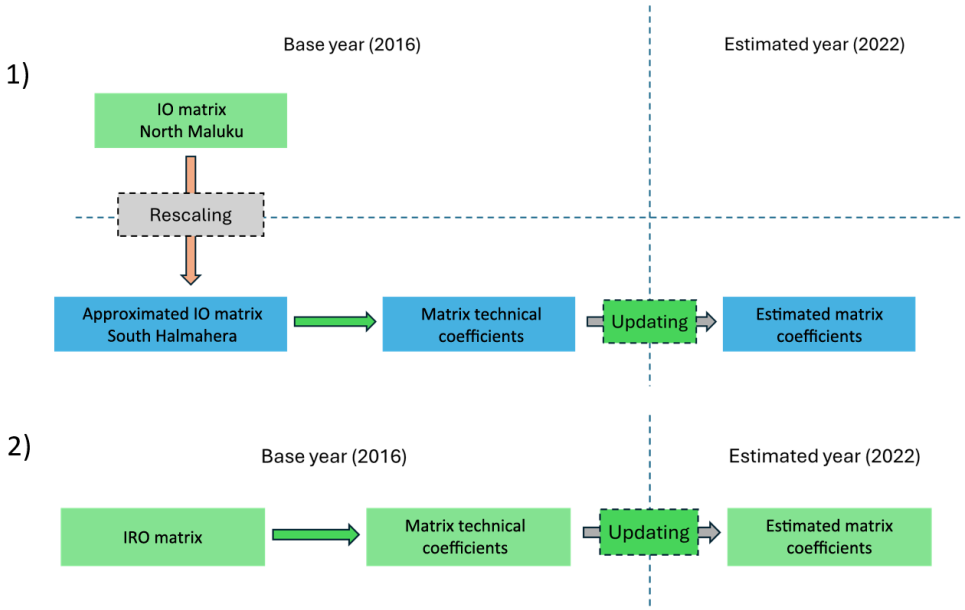

Figure 1. Flow chart for (1) IO rescaling and updating process, and (2) IRIO updating process.

[2] Based on press release of TBP, Co. Ltd. that claim as the first mining company to conserve mineral in South Halmahera Regency through environmental and environmental management permits from the Government of Indonesia. Retrieved from https://tbpnickel.com/media/press-release/operational/harita-nickel-perusahaan-pertama-yang-lakukan-konservasi-mineral.

[3] Based on press release of HPAL, Co. Ltd. as a part of nickel downstream consortium in South Halmahera Regency under the management of Harita Nickel, Co. Ltd. as the holding company. Retrieved from https://hpalnickel.com/media/press-release/the-first-manufacturer-of-battery-raw-materials-for-electric-vehicles-in-indonesia-officially operates.

[4] Based on press release of TBP, Co. Ltd. that is officially opened by the Government of Indonesia. Retrieved from https://tbpnickel.com/media/press-release/operational/resmi-ri-miliki-pabrik-nikel-sulfat-pertama-di-indonesia-dan-terbesar-di-dunia.

We employ the nonsurvey RAS method to rescale and update both the IO dataset and the IRIO dataset (Stone, 1961; Stone & Brown, 1962). RAS tends to perform better than its alternatives when the calculated values in the matrices are all positive (Jackson & Murray, 2004; Okuyama, Hewings, Sonis, & Israilevich, 2002). Moreover, both procedures of the RAS method require only the target value of each IO/IRIO u (intermediate input), v (intermediate output), and q (total output) vector. These values are obtained by calculating the proportion of sectoral output between South Halmahera Regency and North Maluku Province or by estimating the Input-Output (IO) in 2022 through the growth rate across observation years. To this end, we employ the 2016 IO/IRIO analysis as the baseline and compare it with 2022 data to capture changes in the multiplier effect since the construction of nickel smelting facilities in North Maluku Province was initiated in 2016.

This study utilizes sectoral GRDP and employment data, as they directly reflect output changes and labor dynamics as key indicators of structural transformation. Input–output (IO) and interregional input–output (IRIO) tables offer detailed interindustry and interregional linkages, enabling the estimation of economic multipliers. These variables are selected to comprehensively assess both sectoral productivity shifts and the distribution of economic benefits within and across regions.

3.2. Analysis Strategy

This paper employs three approaches to analyze the effects of the nickel processing industry on the sectoral economy, with each approach complementing the others to support the hypotheses. *First*, input–output (IO) and interregional input–output (IRIO) analyses are used to assess the linkage of a sector or, generally, the supply chain network within a single region and across multiple regions (Miller & Blair, 2009). The IO and IRIO models provide quantitative estimates of sectoral and regional multiplier effects, capturing direct and indirect economic linkages.

Specifically, the multiplier effects are calculated using the Leontief inverse matrix (Leontief, 1941). To calculate the Leontief inverse matrix, we must consider the IO (and IRIO) model as follows:

$$X = AX + F \qquad (1)$$

Where x is a vector of $n \times 1$ describing the output of each sector, A is a $n \times n$ technical coefficient matrix depicting the coefficients of the sector's output used as inputs for other sectors, and f is an $n \times 1$ vector of final demand that accumulates outputs that are consumed by the end consumers. Rewriting the above equation and adding the $n \times n$ identity matrix (I) results in the equation below:

$$X = (I - A)^{-1}F \qquad (2)$$

Where $(I - A)^{-1} = L$ is the Leontief inverse that reflects the required input to produce, both direct and indirect, one additional unit of f (Davar, 2005). Therefore, the interpretation of the multiplier effect is straightforward: if the demand for the sector i increases, the total demand increases to a certain number because of the linkage between the sector i and sector j (where $j \neq i$). This tool has been widely implemented to discover the production network and multiplier effect of mining and manufacturing industries across the world, for example, in

China (Zhang, Yao, & Lee, 2022), Europe (San Cristóbal & Biezma, 2006) and Indonesia (Dewi, Wiguna, & Noya, 2023).

The second approach involves measuring the structural transformation of the economic structure in South Halmahera Regency. To accomplish this, we implement a method from Andriansyah, Nurwanda, and Rifai (2023) via the shift-sharing (SS) method. The SS approach enables us to decompose productivity growth and labor reallocation, allowing the identification of structural transformation. Furthermore, rather than presenting aggregated regional data results as described in Andriansyah et al. (2023), this study refines the analysis by breaking down the results at the sectoral level for South Halmahera Regency. This intuitive approach allows us to obtain the dynamic changes in productivity growth while also revealing clear aspects affecting the results. Thus, the SS method is decomposed into three terms:

$$SS_i = \frac{S_{i0}\Delta P_i}{P_0} + \frac{P_{i0}\Delta S_i}{P_0} + \frac{\Delta S_i \Delta P_i}{P_0} \quad (3)$$

Where $\Delta S_i = S_{iT} - S_{i0}$ and $\Delta P_i = P_{iT} - P_{i0}$. S_{iT} denotes the employment share of the sector i at time T, whereas P_{iT} denotes the level of productivity of sector i at time T. Δ describes the change in that mentioned variable from time 0 to time T. The first term, $\frac{S_{i0}\Delta P_i}{P_0}$, is known as the 'within effect' and explains changes in labor productivity sourced from the same sector. The second term, $\frac{P_{i0}\Delta S_i}{P_0}$, is known as the 'static structural effect' and expresses the structural change contributed by labor reallocation between sectors because of the initial level of productivity (at time 0). Finally, $\frac{\Delta S_i \Delta P_i}{P_0}$, known as the 'dynamic structural effect', captures effects sourced from both labor reallocation and productivity growth.

Our *third method* is implemented to discover the dynamics of the "*base sector*" in South Halmahera Regency. The "*base sector*" defines a specialized sector in the given territory that is able to exceed local needs, thus being exported outside and channeling income to the local economy, in contrast to the non-basic sector (Leigh, 1970). In our context, this categorization is useful for measuring the sectoral convergence caused by nickel processing activity; therefore, we use the location quotient (LQ) to quantify the economic base, as suggested in the literature (Alhowaish, Alsharikh, Alasmail, & Alghamdi, 2015; Chiang, 2009; Miller, Gibson, & Wright, 1991). Moreover, we employ two types of LQs: the traditional LQ (or static LQ) and the dynamic LQ (DLQ). Both offer complementary interpretations, where static LQ explains the cross-sectional relative importance of sectors, whereas DLQ identifies base sectors based on growth (Goschin, 2020). The static LQ formula for sector i in region w is defined as:

$$LQ_{iw} = \frac{(E_{iw}/E_w)}{(E_{in}/E_n)} \quad (4)$$

Where E_{iw} is the regional output for sector i in region w; E_w represents the total output of district w; E_{in} denotes the output of sector i in the administrative region above districts (or w), called province n; and E_n represents the total output of province n, while the DLQ for sector i in region w is defined as:

$$DLQ_{iw} = \left\{\frac{(1+G_{iw})/(1+G_w)}{(1+G_{in})/(1+G_n)}\right\}^t \quad (5)$$

Where G_{iw} represents the growth of sector i in region w between observation periods, G_w represents the total output growth of region w, G_{in} represents the growth of sector i in region n, G_n represents the total output growth of region n, and t represents the total number of periods observed. The estimated coefficients of LQ and DLQ indicate if the sector is a "*base sector*" (coefficient above 1), a "*nonbase sector*" (coefficient below 1), or a "*self-sufficient sector*" (coefficient equal to 1).

The combination of these three approaches ensures a robust evaluation of economic change from both macro linkage and microstructural perspectives.

4. RESULTS

South Halmahera Regency experienced significant growth from 2016 to 2023 after stagnant growth despite large-scale nickel mining (Mittermeier et al., 2013). Figure 2 depicts the situation before, during, and after the construction of the nickel smelter in the regency. Following the inception of the nickel smelter between 2016 and 2020, economic growth surged to 19% annually, surpassing that of its peers even during the COVID-19 pandemic. In the full operation phase, growth reached 27% annually, exceeding that of Ternate city, the long-standing economic hub of North Maluku Province. Moreover, in 2021, nickel firms in Central Halmahera Regency expanded and industrialized their operations, driving a sharp regional GDP surge and making it the fastest-growing region.

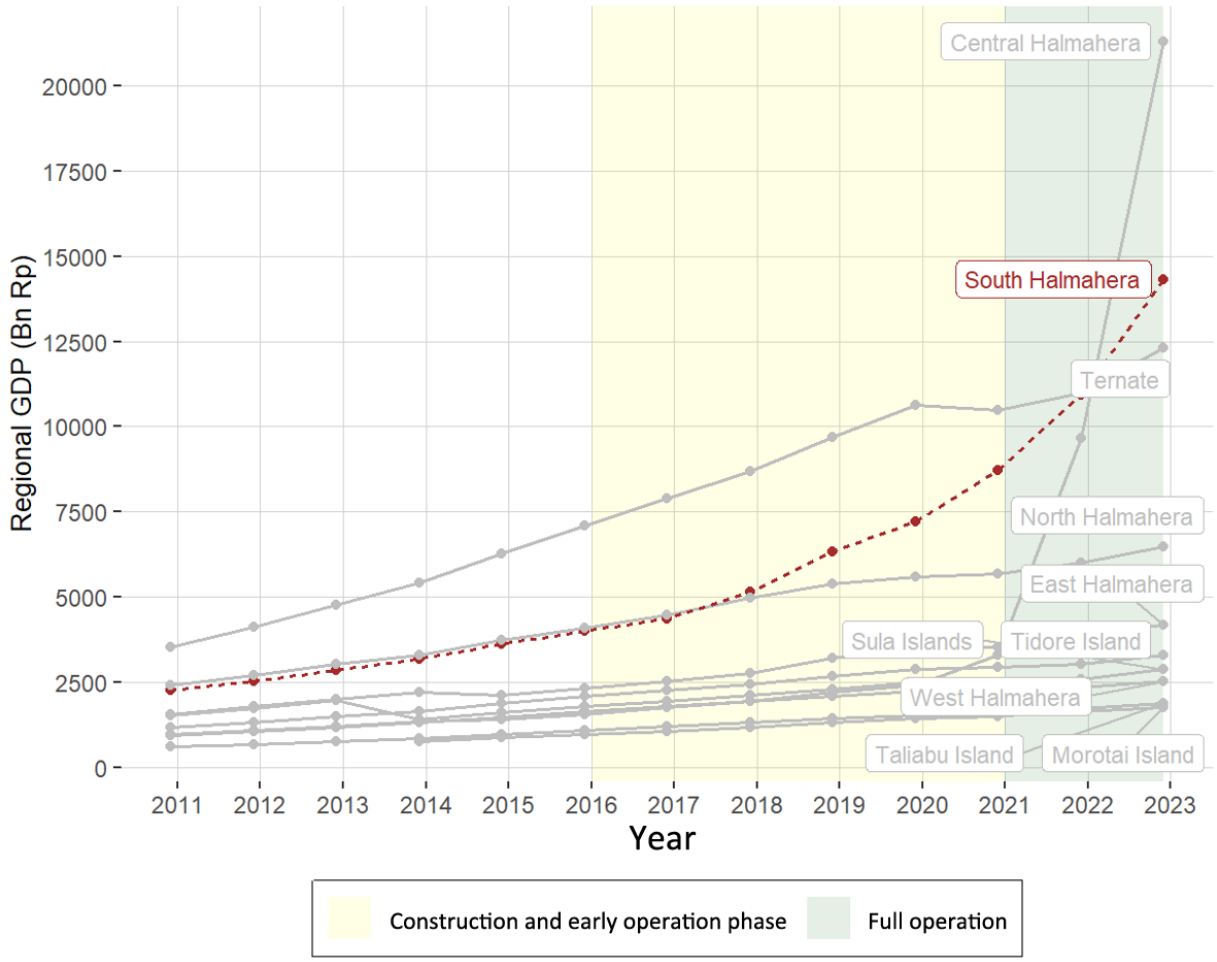

Figure 2. Regional GDP of regencies in North Maluku Province (Current price).

4.1. How the Nickel Downstream Industry Improves Economic Integration but Fails to Utilize Local Industrial Development

IO analysis reveals a stark contrast in multiplier effects between 2016 and 2022. Table 1 presents sectoral multiplier coefficients via Statistics Indonesia's coding (as defined in Appendix A). These coefficients are categorized into direct (sector *i*'s own multiplier), indirect (sector *i*'s impact on sector *j*), and total (sum of both).

Following the standard interpretation, each monetary unit of output generates the corresponding multiplier value. RAS-based Leontief estimates for South Halmahera indicate varied sectoral changes, with the highest gains in manufacturing, followed by financial and insurance, and electricity and gas supply. This finding supports our hypothesis that large-scale nickel downstream activity drives exceptional multiplier effects, whereas mining shows only modest growth.

Table 1. Disaggregated sectoral multiplier coefficient in South Halmahera Regency (2016 & 2022).

Sector	2016			2022		
	Indirect	Direct	Total	Indirect	Direct	Total
A	0.029	1.013	1.042	0.045	1.020	1.065
B	0.011	1.009	1.020	0.030	1.022	1.052
C	0.071	1.031	1.102	0.377	1.163	1.541
D	0.011	1.080	1.091	0.017	1.122	1.139
E	0.031	1.016	1.047	0.029	1.014	1.043
F	0.002	1.000	1.002	0.007	1.000	1.007
G	0.062	1.001	1.063	0.059	1.001	1.060
H	0.020	1.000	1.020	0.039	1.001	1.040
I	0.033	1.000	1.033	0.012	1.000	1.012
J	0.025	1.020	1.045	0.051	1.041	1.092
K	0.030	1.013	1.044	0.079	1.034	1.113
L	0.021	1.000	1.021	0.029	1.000	1.029
MN	0.030	1.011	1.040	0.060	1.021	1.082
O	0.010	1.000	1.010	0.006	1.000	1.006
P	0.002	1.000	1.002	0.002	1.000	1.002
Q	0.006	1.001	1.007	0.005	1.000	1.005
RSTU	0.008	1.001	1.010	0.037	1.006	1.043

We then delve deeper into an estimation of the multiplier network of mining and manufacturing sectors across South Halmahera Regency, as presented in Table 2. We find a quite similar multiplier network, where most of it is the direct multiplier.

However, the manufacturing sector is relatively more dispersed than mining and quarrying, indicating that the production activity of the manufacturing sector is able to help enhance others' productivity. These divergent results are in line with those of Atienza et al. (2021), who showed that the value chain of mining has a limited number of links compared with other industries.

Moreover, in South Halmahera Regency, all nickel downstream firms start with nickel extraction. When the decision is made to build processing facilities, the location is near the mine pit and only supplies the minerals to their own facilities, thereby cutting the processing and distribution chains.

On the other hand, the relatively high multiplier network in manufacturing is attributed to both forward and backward linkages, as described by Bloch and Owusu (2012) and Koitsiwe and Adachi (2017) in other mine processing activities. Notably, our estimated 2022 IO data imply that, for manufacturing, less than half of the inputs were provided by industries within South Halmahera Regency (including the industry itself), and less than 10% of the mining input values were supplied locally. Therefore, we present the estimated 2022 IRIO analysis, which covers interregional trade across provinces in Indonesia.

Table 2. Disaggregated sectoral multiplier coefficient in South Halmahera (2016 & 2022).

Sector	Mining and quarrying		Manufacturing	
	2016	2022	2016	2022
A	0(0%)	0(0%)	0.027(2.4%)	0.139(9%)
B	1.009(98.9%)	1.022(97.1%)	0.001(0.1%)	0.004(0.3%)
C	0.001(0.1%)	0.002(0.2%)	1.031(93.6%)	1.163(75.5%)
D	0(0%)	0(0%)	0.004(0.3%)	0.019(1.2%)
E	0(0%)	0.001(0.1%)	0.002(0.1%)	0.009(0.6%)
F	0(0%)	0(0%)	0(0%)	0(0%)
G	0.001(0.1%)	0.003(0.3%)	0.015(1.3%)	0.078(5%)
H	0.002(0.2%)	0.004(0.4%)	0.003(0.2%)	0.014(0.9%)
I	0(0%)	0(0%)	0(0%)	0.001(0%)
J	0.005(0.5%)	0.013(1.2%)	0.005(0.5%)	0.03(1.9%)
K	0.001(0.1%)	0.002(0.2%)	0.003(0.3%)	0.018(1.2%)
L	0(0%)	0(0%)	0.002(0.2%)	0.012(0.8%)
MN	0.001(0.1%)	0.003(0.3%)	0.001(0.1%)	0.009(0.6%)
O	0(0%)	0(0%)	0(0%)	0.001(0.1%)
P	0(0%)	0(0%)	0(0%)	0(0%)
Q	0(0%)	0(0%)	0(0%)	0.002(0.1%)
RSTU	0(0%)	0(0%)	0.008(0.7%)	0.042(2.7%)
Total	1.02(100%)	1.052(100%)	1.102(100%)	1.541(100%)

Compared with most other provinces, North Maluku Province has an outstanding multiplier effect, which is less than that of Central Sulawesi Province, as displayed in Table 3. Compared with 2016, North Maluku Province also experienced a remarkable improvement in its estimated multiplier coefficient in 2022. There are two possible explanations for this improvement in the multiplier effect in the province, as formulated by Domański and Gwosdz (2010): supply type and income type. The former characterizes multipliers that arise when additional demand is generated, enabling their suppliers to grow as well, and the latter defines them as a result of the increased purchasing power of households caused by relatively high wages offered by the growing enterprise, allowing the growth of consumer goods providers. Each of these types could prompt another cycle of multiplier effects, which Domański and Gwosdz (2010) are called 'second order', 'third order', and so on. In the case of South Halmahera Regency (and North Maluku Province), both supply- and income-side effects cannot be fulfilled locally, which requires it to be imported from other provinces, similar to findings from Atienza et al. (2021).

Table 3. IRIO provincial multiplier coefficients in 2016 and 2022.

No	Province	Multiplier coefficient		No	Province	Multiplier coefficient	
		2016	2022			2016	2022
1	Aceh	1.49314	1.86355	20	West Kalimantan	1.55488	2.00596
2	North Sumatera	2.22443	2.13569	21	Central Kalimantan	1.59391	2.44906
3	West Sumatera	1.51438	1.98035	22	South Kalimantan	1.53601	1.72902
4	Riau	1.79993	2.13252	23	East Kalimantan	1.84482	2.18104
5	Jambi	1.52449	2.30927	24	North Kalimantan	1.3546	2.13501
6	South Sumatera	1.87882	2.65433	25	North Sulawesi	1.52101	2.06825
7	Bengkulu	1.37316	1.85564	26	Central Sulawesi	1.46857	3.25577
8	Lampung	1.61461	2.01463	27	South Sulawesi	1.73457	2.09961
9	Bangka Belitung	1.45212	1.90969	28	Southeast Sulawesi	1.34465	1.89145
10	Riau Island	1.33732	1.42488	29	Gorontalo	1.40813	1.72168
11	Capital Region of Jakarta	2.54076	1.98178	30	West Sulawesi	1.38106	1.73855
12	West Java	2.59749	2.124	31	Maluku	1.28905	1.72492
13	Central Java	2.03592	2.06105	32	North Maluku	1.31763	2.98787
14	Special Region of Yogyakarta	1.4544	1.91056	33	West Papua	1.52564	2.04122
15	East Java	2.71039	2.10158	34	Papua	1.43048	1.76112
16	Banten	1.74568	2.04864				
17	Bali	1.52821	1.61959				
18	West Nusa Tenggara	1.44921	1.61215				
19	East Nusa Tenggara	1.37712	1.62915				

Figure 3 visualizes the input intensity to illustrate the supply- and income-side multiplier effects in North Maluku Province. The graph suggests potential input flows resulting from these multiplier effects. For example, North Kalimantan Province is the primary coal supplier for the captive steam power plant used in nickel smelting. When the demand for processed nickel increases, the demand for coal from North Kalimantan Province will also rise, indicating a supply-side multiplier effect. Additionally, there is a relatively high input intensity on Java Island, particularly in East Java Province, which dominates the logistics flow from western Indonesia, including Java, toward eastern Indonesia (Zaman, Vanany, & Awaluddin, 2015). Therefore, when nickel processing enterprises offer relatively high wages to workers, the demand for consumer goods and services from Java Island will increase, such as garments and electronic goods. This also leads to greater demand for transporting goods through ports and airports in East Java Province, which could explain the income multiplier effect.

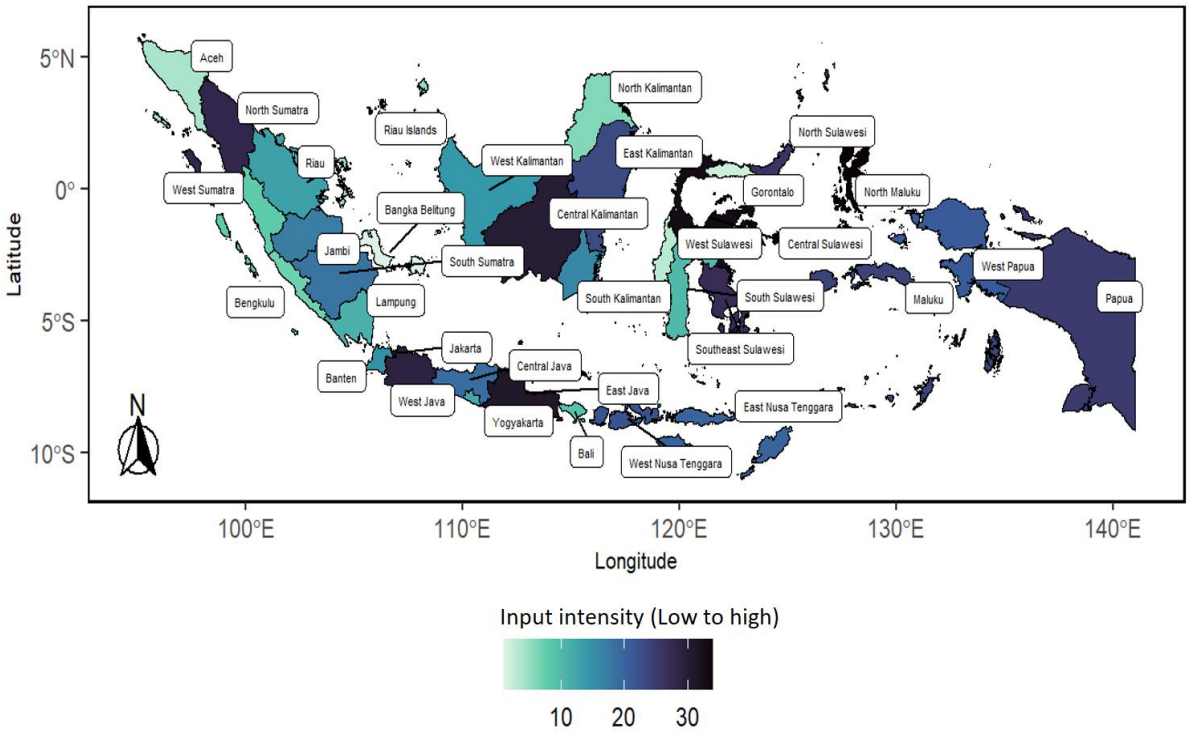

Figure 3. North Maluku trade intensity map.

4.2. Intense Productivity Growth and Labor Allocation toward the Manufacturing Sector

South Halmahera Regency has outperformed other regencies in North Maluku Province in terms of economic growth, with significant structural changes in the manufacturing sector particularly regarding labor productivity during the construction phase until full operation. However, proactive measures are necessary to mitigate the negative impacts of structural changes in the economy, such as the resource curse, since Indonesia has experienced an insignificant correlation between economic growth and the shift from agriculture to manufacturing (Andriansyah et al., 2023). Table 4 examines the sources of structural change in manufacturing, primarily driven by productivity within the sector, followed by changes in employment share and productivity growth, indicating increased productivity and employment absorption compared to other sectors. Conversely, mining activity mainly attracts labor through productivity but has not generated higher productivity than other sectors, although it appears to have improved productivity within the sector above pre-downstream levels. Notably, since the commencement of nickel downstream activities, most sectors have experienced a crowding-out effect, evidenced by declining SS coefficients relative to pre-downstream levels, except for construction, which is highly demanded during the early downstream phase. Nonetheless, this structural change does not necessarily hinder business growth, as there has

been an increase in workers in the electricity and gas supply sector and business services, which did not exist prior to the start of nickel downstream activities.

These findings are relevant to a small open economy model by Matsuyama (2008), who argued that relatively higher productivity growth in a sector results in more employment, especially when the product is highly demanded globally, opening chances for structural change. Moreover, our SS results indicate that South Halmahera Regency is entering the industrialization phase. The enormous disparity in labor productivity growth between mining and manufacturing implies that nickel downstream activity is able to generate a tremendous amount of value added, hire a greater portion of labor, and create a structural change in the district (Schröder & Iwasaki, 2024). On the other hand, the high SS coefficient of the manufacturing sector in the construction and early operation phases is consistent with a report from ICMM (2014) that revealed significant economic activity during that phase. Moreover, the emergence of new related sectors involves local firms' efforts to capture linkages that were previously taken by outside regional firms, specifically upstream linkages (Fessehaie & Rustomjee, 2018). Unfortunately, the downstream linkages in South Halmahera Regency have not yet been developed, and all the processed nickel is exported abroad.

Table 4. SSA result*.

Sector	Pre-Downstream				Construction and early operation				Full operation			
	Within	Static	Dynamic	Total	Within	Static	Dynamic	Total	Within	Static	Dynamic	Total
A	0.2089	-0.0513	-0.0278	0.1298	0.1291	-0.0292	-0.0100	0.0898	0.1428	-0.0330	-0.0548	0.0549
B	-0.0710	0.2015	-0.1332	-0.0027	0.3620	-0.0192	-0.0940	0.2488	0.1480	-0.0244	-0.0439	0.0797
C	-0.0019	0.0377	-0.0008	0.0350	0.4141	0.0534	0.2200	0.6875	0.1718	0.0511	0.0411	0.2639
D									0.0004	-0.0001	-0.0002	0.0001
E												
F	-0.0030	0.0463	-0.0033	0.0400	0.0687	-0.0133	-0.0147	0.0408	-0.0056	0.0250	-0.0078	0.0116
G	-0.0250	0.1688	-0.0280	0.1158	0.0991	-0.0019	-0.0010	0.0963	0.0864	-0.0202	-0.0327	0.0335
H	0.0135	0.0007	0.0004	0.0146	-0.0101	0.0251	-0.0090	0.0060	0.0041	0.0010	0.0006	0.0057
I	-0.0014	0.0059	-0.0033	0.0013	-0.0018	0.0076	-0.0050	0.0008	0.0005	-0.0001	-0.0001	0.0003
J												
K	0.0122	-0.0005	-0.0004	0.0113	0.0168	-0.0045	-0.0038	0.0085	-0.0020	0.0091	-0.0031	0.0040
L												
MN					0.0109	-0.0010	-0.0094	0.0004	-0.0001	0.0007	-0.0003	0.0002
O	0.4402	-0.0729	-0.3046	0.0628	-0.0058	0.0367	-0.0017	0.0292	0.0091	0.0057	0.0019	0.0166
P	0.0105	0.0038	0.0014	0.0157	0.0002	0.0114	0.0001	0.0118	0.0002	0.0046	0.0001	0.0049
Q	0.0375	-0.0088	-0.0163	0.0124	-0.0022	0.0168	-0.0015	0.0131	0.0001	0.0037	0.0000	0.0039
RSTU	-0.0015	0.0051	-0.0021	0.0015	0.0062	-0.0018	-0.0030	0.0015	0.0009	-0.0002	-0.0002	0.0006

Note: Blanks indicate no workers observed in these sectors.

4.3. Strong (but Likely Temporary) Role of Nickel Processing as the Base Industry

In this section, we focus on observing the role of mining and manufacturing in becoming the leading sectors during nickel downstream activities. During the pre-downstream period, manufacturing in South Halmahera was already positioned as the basic sector, whereas mining was below the unitary level for the estimated static LQ, as shown in Figure 4. This indicates that, even though large-scale nickel mining had already occurred, its contribution to the district's GDP was not as high as that of manufacturing, and during that phase, the nickel processing enterprises had not yet operated. During the construction and early operation phases, the coefficient of the manufacturing sector started to increase until it reached above 3 in 2019, indicating a substantial economic contribution to the district relative to other districts. This was followed by the mining sector reaching above the unitary level of coefficients in that year. Finally, in the full operation phase, both the manufacturing and mining sectors gradually reverted to the pre-operation phase. On the other hand, the DLQ results shown in Table 5 also yield similar results, emphasizing the slower growth of all sectors except mining and manufacturing during the construction and early operation phases, turning them into base sectors during the full operation period.

Several factors may explain the emergence of this dynamic. First, the start of operations of the enterprises in Central Halmahera Regency drastically increased both the manufacturing and mining output proportions at the district and provincial levels, decreasing the LQ value of these two sectors in South Halmahera Regency. Moreover, the second factor can be expanded to include the possible structural change phenomenon, as described in the SS results; the coefficients of both sectors decline during the full operation phase.

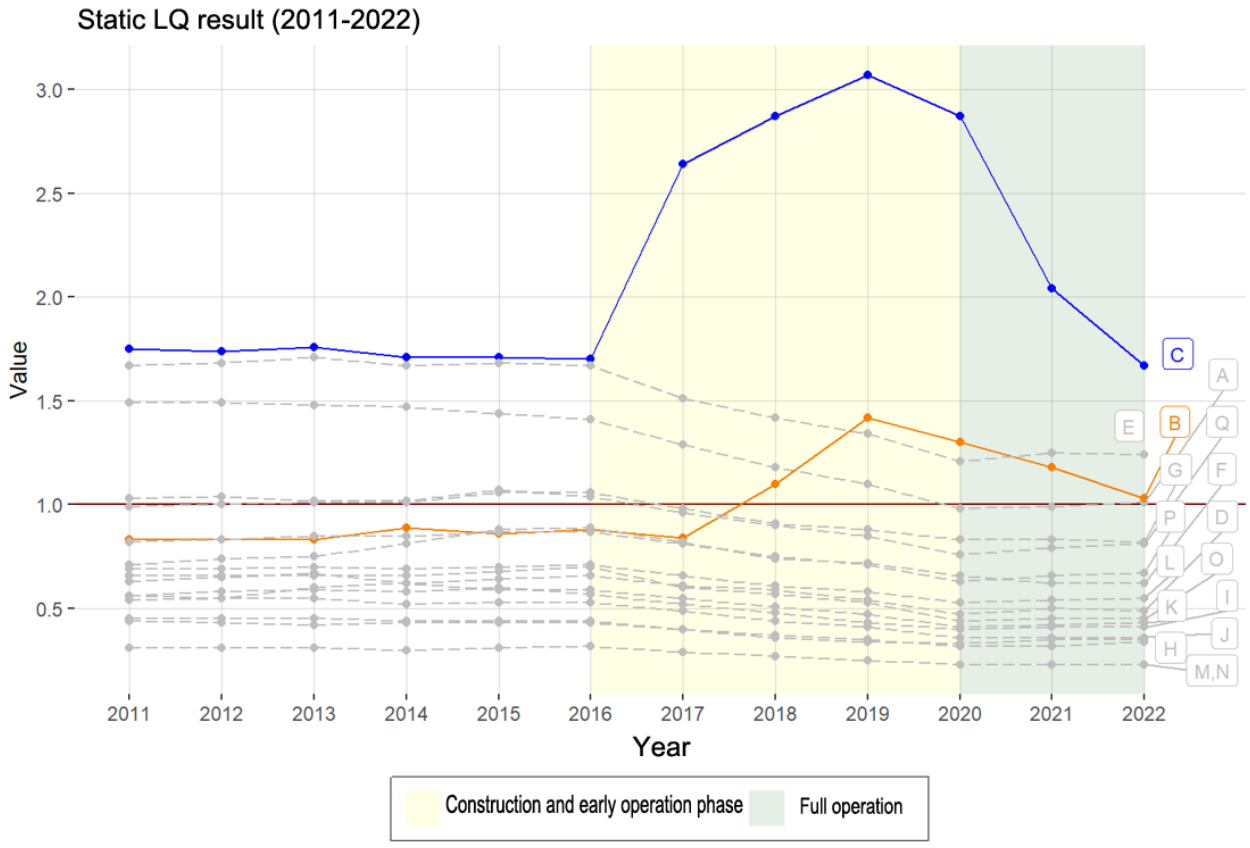

Figure 4. Static LQ result.

Table 5. DLQ results.

Sector	Pre-downstream	Construction and early operation	Full operation
A	0.975	0.719	1.061
B	1.030	1.436	0.848
C	1.021	1.145	0.812
D	1.064	0.734	0.998
E	1.002	0.724	1.008
F	1.190	0.774	1.022
G	1.078	0.797	1.004
H	0.958	0.787	0.998
I	1.051	0.736	0.986
J	0.963	0.740	1.003
K	1.042	0.729	1.044
L	1.033	0.773	1.033
MN	1.020	0.749	1.012
O	0.997	0.664	1.038
P	1.053	0.741	1.032
Q	1.035	0.749	1.032
RSTU	0.994	0.748	1.045

5. DISCUSSION AND POLICY IMPLICATION

Since nickel industrialization began, South Halmahera Regency has transformed into a manufacturing-dependent area with tremendous economic growth, aligning with a "successful" development path, as shown in A. Wood (1999) and Adrian Wood and Berge (1997). Our results show that manufacturing creates greater demand for other sectors than mining does. However, nickel processing lacks vertical integration to end consumers, as products are fully exported after smelting. This paper finds that multiplier effects flow out of South Halmahera Regency and North Maluku Province, and that the regency cannot fulfill upstream linkages between regions. However, there is insufficient empirical evidence on the economic linkages formed by resource-based manufacturing, especially with respect to employment (Neilson, Dwiartama, Fold, & Permadi, 2020). This situation reduces potential value added and hampers dynamic innovation, particularly given limited nickel resources (Kaplan, 2016). An empirical example in Wen and Jia (2022) revealed opposing effects of resource dependence across development phases in China's resource-based cities. Initially, resource abundance significantly increases growth (referred to as "resource browsing") but later becomes a hindrance (known as the "resource curse"), even with greater value-added processing. Our results show that mining and manufacturing weakened as reliable specialized sectors during full operation. Without substantial intervention and amid volatile prices, communities around these facilities risk socioeconomic decline after mining closure, as observed in Singkep Island (Indonesia) and Orkney & Grootvlei Mines (South Africa) (Ackermann, Botha, & Van Der Waldt, 2018; Syahrir et al., 2020).

Economic diversification is necessary for South Halmahera's long-term sustainable growth to avoid the “resource curse” pitfall. Resource-rich regions transitioning to broad-based industrialization achieve greater productivity growth than those focusing solely on resource-based industries (Joya, 2019). Hausmann and Rodrik (2003) stressed "*self-discovery*" in identifying industries with greater economic productivity, as regions have idiosyncratic elements evolving over time. Nurturing local equipment and solution suppliers is an important initial step toward diversification and preserving positive externalities from indirect multipliers. Strong local supplier industries are important for absorbing employment and generating income, arguably equal in importance to nickel downstream firms (Andersen, Marín, & Simensen, 2018). Competitive local supporting industries serve as platforms for diversification, transmitting second-order supply and income multiplier effects (Andersen et al., 2018; Domański & Gwosdz, 2010). Moretti (2010) suggests that employment multipliers can be increased through an enhancement of manufacturing workers' skills, as there is greater elasticity for non-tradable jobs than for unskilled workers.

To transform the economy, strategic steps must be implemented immediately. First, skilled labor for technologically demanding manufacturers and emerging sectors should be developed. Second, innovation systems

connecting institutions, producers, and knowledge-based organizations should be created to support knowledge generation, diffusion, and application (Andersen et al., 2018). Third, institutional quality should be improved, as complex manufacturing relies on strong contract enforcement, the rule of law, and the business environment (Gelb, 2010). Finally, the government should incentivize emerging sectors through tax relaxation and lower logistics costs, which are especially critical for South Halmahera, where mining and processing occur on islands other than the business center (Lashitew, Ross, & Werker, 2021; Ngassam, 2024).

6. CONCLUSION

The objective of this study is to uncover the macroeconomic effects of nickel downstream activity in South Halmahera, measuring the implications for multiplier effects and structural transformation. This provides a preliminary overview of Indonesia's nickel ore export ban using a nickel-rich North Maluku district as a case study. We employ IO and IRIO analysis for the Leontief inverse multiplier, SS, and static LQ and DLQ methods. For IO/IRIO analysis, we use the RAS procedure to rescale South Halmahera and update 2022 tables. IO analysis revealed that mining-based industrialization improved the manufacturing multiplier by 39.8%, with a fourfold increase in indirect multiplier effects between 2016 and 2022, whereas mining improvement increased indirect effects by 170%. IRIO analysis revealed that North Maluku's multiplier growth exceeded South Halmahera's, indicating unfulfilled linkages within the province, possibly biased by Central Halmahera's nickel processing. SS analysis indicates structural transformation in South Halmahera, with consistent positive values across within, static, and dynamic terms during the construction and operation phases, suggesting industrialization with emerging upstream industries and a productivity slowdown in unrelated sectors. LQ analysis quantifies the role of manufacturing as a base sector that brings income to the local economy. Mining only became a base sector after mineral industrialization began. DLQ analysis reveals simultaneous growth inhibition in all sectors except mining and manufacturing relative to other districts, although they later experienced above-average growth during full operation, indicating demand creation for various goods and services.

Our research has several limitations that should be addressed in future work: the nickel mining site in South Halmahera Regency is located in a remote area that is separated from its mainland, and the economic cycle mainly revolves around that island. However, our analysis does not acknowledge this unique geographical context. Furthermore, future research could consider subsector data to capture the growth of manufacturers supporting nickel industrialization activity rather than aggregated manufacturing sectors.

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Appendix

Appendix A. Sectoral code.

No	Code	Sector
1	A	Agriculture, forestry & fisheries
2	B	Mining & quarrying
3	C	Manufacturing industry
4	D	Electricity & gas supply
5	E	Water supply, sewerage, waste & recycling management
6	F	Construction
7	G	Wholesale & retail trade, repair of motor vehicles & motorcycles
8	H	Transportation & storage
9	I	Accommodation & food beverages activity
10	J	Information & communication
11	K	Financial & insurance activity
12	L	Real estate
13	M,N	Business services
14	O	Public administration, defense & compulsory social security
15	P	Education services
16	Q	Human health & social work activity
17	R,S,T,U	Other services