SOCIOECONOMIC AND HEALTH IMPACT OF NICKEL DOWNSTREAMING:

CASE OF MOROWALI INDUSTRIAL PARK

ENR80436 Master Thesis Environmental Economics and Natural Resources

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1. Introduction

1.1 Background

As one of the countries with the largest nickel reserves, Indonesia continues to hold a significant share in the global supply chain. By 2030, Indonesia's projected share in the global nickel supply chain is 62% for mining and 44% for refining (IEA, 2024). In light of the rising demand of nickel products for electric vehicle (EV) battery, the downstreaming of nickel resources has become a key national agenda to foster Indonesia's economic growth.

Strategic move towards nickel downstream industrial development started from the 2009 Mining Law. The law prohibited the export of raw mineral and mandated that all commodities mined within the country to undergo domestic processing (Camba, 2023). However, the policy was only effectively implemented in 2014 for nickel and bauxite (Abdurrachman, 2023). Currently, almost 10 years after the policy implementation, Indonesia has steadily increased its annual nickel production. The export of nickel products, such as battery materials and stainless steel, valued to a total of USD30 billion, represents an almost 5-fold increase from the export of unprocessed nickel ore in 2013 (The Economist, 2023).

Indonesia's nickel hotspots are concentrated in the eastern part of Indonesia, specifically in regions of Sulawesi and North Maluku. These areas collectively account for 90% of the country's total nickel reserves (Ministry of Energy and Mineral Resources, 2022). The downstreaming process of nickel production is realized through the construction and operations of new nickel based industrial park in these regions. There are eight nickel-based industrial park at various stages of planning and/or development spread across Sulawesi (CGS Industrial Park Dashboard, 2024). All these nickel industrial parks are powered by newly constructed off-grid coal power plants, adding pollution to a myriad of problems the mining industry inherently possess.

Indonesia Morowali Industrial Park (IMIP) serves as the key site of Indonesia's ambitious nickel downstreaming agenda. IMIP is the integrated industrial zones for nickel ore mining, nickel smelting, and nickel manufacturing. Compared to other nickel industrial park spread in the nickel hotspot island of Sulawesi and Maluku, IMIP is the oldest and longest running industrial park in the country. It is located in Morowali, Central Sulawesi. In 2018, it was estimated that 50% of Indonesia's nickel products was mined and produced in IMIP (Saleha, 2021). IMIP originally built for nickel pig iron and stainless-steel production, but with the rise of EV market, the park focus has expanded to producing battery material by adding High Pressure Acid Leaching (HPAL) plants and battery cathode factories (IESR, 2023).

The government's ambition to move upward in the global nickel supply chain has come at a cost to the local community. In recent years, the rapid expansion of nickel processing activities has led to a rise in of air pollution. According to local residents with close proximity to the industrial park, dust particles often visible as smoke are causing children to cough and feel dizzy, and even led to infant deaths from respiratory problems (Liljas, 2024). The primary contributor to these health issues is the exposure to emission of particulate matter from coal-fired power plants, exceeding the safe levels recommended by health organizations and national air quality standards (CELIOS & CREA, 2024).

While anticipated economic gains are often emphasized, the accompanying pollution and health burdens are frequently overlooked in discussions of Indonesia's nickel downstreaming ambition. Moving up in the global nickel supply chain should signify not only a shift in higher value-added exports, but also a consideration of the long-term impacts on the community. Recent studies highlighted that the potential gains from the industry may be overshadowed by the negative impacts on the environment, public health, and local livelihoods (CELIOS & CREA, 2024). Indonesia's nickel industrialization strategy should move beyond a narrow focus on economic gains and acknowledges the complex interplay between pollution and well-being.

1.2 Problem Statement and Research Questions

Indonesia's current strategy for nickel industrialization relies on coal-fired power plant as its primary energy source. The lack of environmental safeguarding through the mining and production process is causing air pollution accumulation and negatively impact local communities' well-being. Such impacts remained unaddressed in the current nickel industrial development planning. This research then aims to study the effect of nickel industrialization on local communities' health and socioeconomic outcomes, using a quasi-experimental approach and drawing comparisons with a similar non-industrialized region. With a number of nickel industrial parks in the development pipeline, this study serves as a crucial case study to examine the implications of industrialization practices in Indonesia.

Based on the problem statement above, the following general research question is formulated:

What are the impacts of nickel industrialization on local communities in Morowali?

From the general research question, two sub-research questions are derived as follows:

1. *What is the impact of nickel industrialization on key socioeconomic outcomes?*
2. *What is the impact of nickel industrialization on air pollution-related health outcomes?*

This study will compares Morowali with Banggai regency, a region with similar characteristics without a major nickel industrial park to examine the effects of large-scale nickel industrialization on health and socioeconomic indicators, using a Difference-in-Differences (DID) approach.

1.3 Outline

The thesis will be organized as follows: Following the introduction, Section 2 lays the theoretical foundation for the analysis and reviews existing literature on the health and socioeconomic impacts of industrial activity. Section 3 explains the methodology and datasets used in the analysis. Section 4 presents the empirical results and evaluates them through hypotheses and robustness testing. Finally, Section 5 discusses the findings in relation to broader policy implications, and offers recommendations for future research.

2. Theoretical Background

This section provides a theoretical foundation from existing literature on the relationship between industrialization, public health, and broader socioeconomic implications, focusing on the regional impact of the nickel industry in Morowali, Indonesia.

2.1. Industrialization and Economic Growth

With several nickel-based industrial park under development, the government's ambition for nickel downstreaming is evident, emphasizing on its potential economic and welfare benefits of industrialization. Over the past decade, regions like Central Sulawesi have experienced significant economic growth driven by nickel mining and processing, leading to a shift away from agricultural sector (Sangadji & Ginting, 2023).

One of the issues with Indonesia's nickel processing is the reliance and high use of coal to fulfill its energy demand. Captive plants, also known as off-grid captive coal-fired power plants (CFPPs), are constructed specifically to provide power to new industrial parks rather than feed into main electricity grid (Jong, 2023). Captive CFPPs constitute 18% of the country's total coal-fired power capacity. These plants were built from 2016 onwards to support domestic metal processing facilities (Zhu et al., 2023). More than 75% of the total operating capacity of captive coal power plants is utilized for metal processing, a significant share of 67% is powering nickel smelters (CREA, 2023). Indonesia Morowali Industrial Park (IMIP) is currently the most hydrocarbon emission-intensive nickel processing industrial are in Indonesia, relying on the 4000 MW captive CFPP (Sangadji & Ginting, 2023).

Theoretical and empirical evidence have shown a positive relationship between manufacturing sector and economic growth, particularly in low-income countries with higher human capital (Fagerberg & Verspagen, 2002; Szirmai, 2011). However, the rapid growth of nickel industry is inseparable from its massive energy consumption and generated pollution. Exposure to environmental pollution from industrial activities is a key source of health hazard, making it a severe public health concerns (Briggs, 2003).

2.2. Socioeconomic Impact

The impact of industrial progress and manufacturing on economic growth has been extensively studied in the literature. Manufacturing is considered a major engine of growth in the economy (Lavopa & Szirmai, 2012). Manufacturing uses machinery, enabling low-income countries to compensate for limited skilled labor. Additionally, manufactured goods are traded more freely on the global market compared to services (Studwell, 2013). Industrialization also drives economic growth by boosting production capacity, generating employment, fostering innovation, and promoting efficient resource utilization (Elfaki et al., 2021).

The efficacy of Indonesia's nickel industrialization policy will be contingent upon the balancing of economic objective and social outcomes.

Socioeconomic status can be operationalized in a variety of ways, with education, social class, and income being the most common measures (Darin-Mattson et al., 2017). The following socioeconomic outcomes are the generally accepted indicators used in industrial development literature and are also among the social indicators used in the National Socio-Economic Household Survey (SUSENAS).

Economic Growth

Gross Domestic Product (GDP) or Gross Regional Domestic Product (GRDP) per capita are the most common measure of income in the economy and hence, economic performance. There are myriad factors that can affect economic growth, but it is broadly concluded that growth is basically determined by the ability to produce goods and service (Kusumawardhana & Chen, 2017).

To expand production capacity and facilitate technological advancement in the sector, the government is working with multinational corporations to obtain foreign direct investment (Sangadji & Ginting, 2023). This strategy aims to increase real output and improve living standards, as reflected in real income per capita. These goals align with the neoclassical production function, which posits that output (GDP) is generated by the combination of capital, labour, and technology (Solow & Swan, 1956). Solow describes how this production function shows these factors combine to generate output. Similar to the findings of Katuria & Raj (2009) in sub-national level in India, the case Central Sulawesi as a nickel producer, suggests that industrialization has contributed to its rapid economic growth.

Poverty and Income

Poverty typically analyzed through measures of income, consumption, and some human welfare aspect, with the concept of economic well-being rooted in the ability to purchase basic consumption and achieve a minimum standard of living (Hagenaars, 1991). Indonesia's National Statistics Bureau (BPS) defines poverty using a consumption-based poverty line/threshold. This threshold represents the minimum amount of money required to purchase goods and services necessary to meet basic food and non-food needs for a minimum standard of living (BPS, 2022). Generally, lower incomes are associated with higher rates of poverty.

Additionally, industrialization, particularly in sectors like nickel mining and processing, should create higher-paying and more stable jobs compared to traditional agriculture (Kumar & Hidalgo, 2012). Indeed, prior to the development of nickel industrial park, agriculture was the dominant sector in Morowali's economy. However, after the operation of IMIP, manufacturing and mining sector have now become the primary drivers of the region's GRDP (Rauf et al., 2021).

While a high GRDP may indicate overall economic activity, it doesn't necessarily translate to improved living standards for all individuals. GRDP per capita provides a more accurate measure of a region's economic welfare, as it reflects the average purchasing capacity of residents (Rahmawati & Intan, 2020). However, whether higher GRDP per capita actually leads to poverty reduction is still uncertain.

Research on the relationship between GRDP per capita and poverty rate in Indonesia yield mixed results. Rahman et al. (2021) found a negative correlation, suggesting increased individual production or real income can lead to lower poverty risk. Wau (2022) found no significant effect of GRDP per capita on poverty in Indonesia's underdeveloped regions. This suggests that the benefit of industrialization in these regions may not necessarily translated into poverty reduction. Additionally, following Kuznets (1955) hypothesis, regions sustained by the agricultural sector are likely to see income inequality rise during early industrialization.

Labor

There are overarching arguments that manufacturing offers greater opportunities for job creation, exhibits higher labour productivity, provides an important channel mechanism for social upgrading, and promotes opportunities to close the gender gap (World Bank, 2012). Additionally, compared to the agriculture sector, the manufacturing industry is considered to be more productive in labour absorption (Alisyahbana et al., 2022).

Cobb-Douglas theory suggests that economic growth results from increased labor, capital, and technology inputs. As economic growth is often prioritized in development, it is expected to drive increased demand for these inputs, including labor. It is estimated that between 38,000 and 80,000 people work at IMIP, with approximately 5,000 skilled workers from China and the majority of low-skilled workers being Indonesian (ABC News, 2023). This significant skill gap between foreign workers and the Indonesian workers raises questions about labor absorption and productivity of local communities.

2.3. Health Impact

Industrial activity, especially a fossil-fuel reliant one, emits various pollutant such as particulate matter, carbon dioxide, nitrogen oxide, and sulfur dioxide. Fine particulate matter or PM2.5 are particles with various chemical components such as sulfate, nitrate, ammonium, organic and inorganic carbons with a diameter equal to or less than 2.5 µm (US EPA, 2024). Due to its size, it infiltrates deep into the respiratory system and is recognized as one of the leading causes of cardiopulmonary morbidity and mortality (Dockery et al., 1993; Dominici et al., 2006; Pope et al., 2002). Considering these significant health impacts, PM2.5 is a key pollutant regulated by environmental agencies and governments in many countries.

Amin et al. (2024) did a comprehensive review of PM2.5 concentration studies in different areas in Indonesia. According to the study, PM2.5 concentration measurement from anthropogenic sources (industrial emission and vehicle exhaust) in Indonesia are mostly conducted in major cities. Research on PM2.5 concentration and its effect on public health is particularly limited in the eastern part of Indonesia, especially rural and industrial areas. This limits the ability to assess and mitigate the health risks faced by nearby communities, especially in industrial areas. The review of air pollution research in Indonesia indicates that PM2.5 level are often high, frequently exceeding World Health Organization and National Ambient Air Quality Standards (Amin et al., 2024).

Exposure to PM2.5 can have short-term (acute) and long-term (chronic) impact on human health. Short-term impacts can be defined as health burdens attributable to daily changes in exposure to air pollution (Syuhada et al., 2023). Short-term PM2.5 impact studies rely heavily on data from local monitoring facilities, and the limited availability of spatially resolved daily PM2.5 data restricts the scope of these studies (Kloog et al., 2013). Other studies have linked short-term exposure to PM2.5 to cardiopulmonary disease related hospital admission (Chang et al., 2015; Groves et al., 2020).

This study will focus on the long-term health impact on PM2.5 pollution, mainly to capture the chronic health conditions that develop gradually to prolonged exposure to pollutant over the years. Hereinafter, the effects of air pollution on public health will refer specifically to those caused by industrial activities. Long-term health impacts including morbidity and mortality will be explained in the next sub-sections.

Morbidity

Morbidity refers to the presence or rate of disease and illness in a population, usually presented or estimated in prevalence or incidence (Hernandez & Kim, 2022). Empirical studies have linked air pollution exposure to child stunting, adverse birth outcomes such as low birth weight (Liu et al., 2019; Pun et al., 2021), and increased risk of pneumonia (Lu et al., 2014). Children are particularly vulnerable to the effects of air pollution, due to their underdeveloped organs (e.g., heart and lungs) and physiological systems (e.g., respiratory and cardiovascular) that eventually will caused prolonged impacts throughout their lives (Syuhada et al., 2023). Such impacts will ultimately represent a significant public health and societal burden, making the assessment critically important in considering the trade-offs of industrial progress in a region. This study will analyse the impact of nickel industry pollution on infant and children's morbidity, examining the prevalence of PM2.5 exposure related illnesses over the years.

Mortality

Mortality in the context of this study refers to number of deaths attributed to air pollution. It can be presented as a rate or as absolute number (Hernandez & Kim, 2022). Recent estimates of the global burden disease suggest that exposure to PM2.5 causes 4.2 million deaths annually, representing 7.6% of total global deaths (Cohen et al., 2017). All studies of the mortality impacts of air pollution considers exposure to particulate matter (Roser, 2021).

Epidemiological studies have shown that air pollution is associated with several diseases, with the strongest evidence for: lower respiratory infections, strokes, ischemic heart disease, chronic obstructive pulmonary disease, and lung cancers (World Health Organization, 2024). These diseases are included in Sustainable Development Goals (SDG) indicator 3: Good Health and Well-being to track global mortality attributed to air pollution. More recent research such as the Global Burden Disease study, is incorporating type 2 diabetes and neonatal deaths into its analysis. This study utilizes newly developed risk curves derived entirely from outdoor air pollution studies, indicating emerging evidence of causality (Burnett et al., 2018; Vodonos et al., 2018).

2.4. Literature Review

This section synthesizes empirical studies on industrialization and its impacts, highlighting the diverse scope and findings (Table 1). The health impacts explored in the literature review are those that particularly result from air pollution. Due to the limited number of studies specifically focused on regional level in Indonesia, this review also includes relevant empirical research from other contexts.

Table 1. Literature review of the impact of industrialization on socioeconomic and health aspect

No	Author, Year	Scope	Method	Key Findings
1	Rivai et al., 2024	Cement industrial area in South Sulawesi, Indonesia	Cross-sectional study on health risk analysis	PM2.5 in the industrial area exceeds the WHO standards (>10 µg/m3) significantly increase carcinogenic risks on local community, decreasing life expectancy
2	Rambe R.A. et al., 2023	Sumatera, Indonesia (2013 to 2018)	Regression analysis	- Worker's education, type of employment, gender, and industrialization level positively affected the poverty rate - Unemployment rates did not influence poverty significantly
3	Bensaul-Tolonen et al., 2019	Ghana	Difference-in-Differences	- Infant mortality rates decrease significantly in industrial area - Mining industrial activity leads to structural shift in local labour market

				- There is an increase in household expenditure on housing and energy in mining communities
4	Nkwocha E. & Egejuru R. O., 2008	Port Harcourt industrial area, Nigeria	Mixed-effect model	- A strong association was found between air pollution and respiratory symptoms/diseases in children - High positive correlation between pollution levels and morbidity rate
5	Muslimin et al., 2024	Jepara, Central Java, Indonesia	Regression analysis	- Industrialisation has positive impact on social mobility, economic growth, and more opportunities for education and health for local communities - Negative impacts on industrialization including environmental damage, social inequality and unemployment
6	Leogrande et al., 2019	Industrial area in Taranto, Italy (2008 to 2014)	Difference-in-Differences	Exposure to particulate matter increased risk of mortality by respiratory causes in elderly people

3. Methodology

3.1. Research Design

The Difference-in-Differences (DiD) method is used to compare health and socioeconomic outcomes in area with nickel industrial park (treatment group) to health and socioeconomic outcomes in area without nickel industrial park (control group). The did model employs a quasi-experimental research setup with two distinct groups observed across two distinct time periods.

To understand the effects of an intervention on a particular outcome, the did method compares the change in the average outcome between treatment group and control group before and after the intervention began (Li et al., 2021). Did model validity rely on the assumption that, in the absence of intervention, the average outcomes for both the treatment and control groups would exhibit a parallel trend over time (Abadie, 2005) (Figure 1).

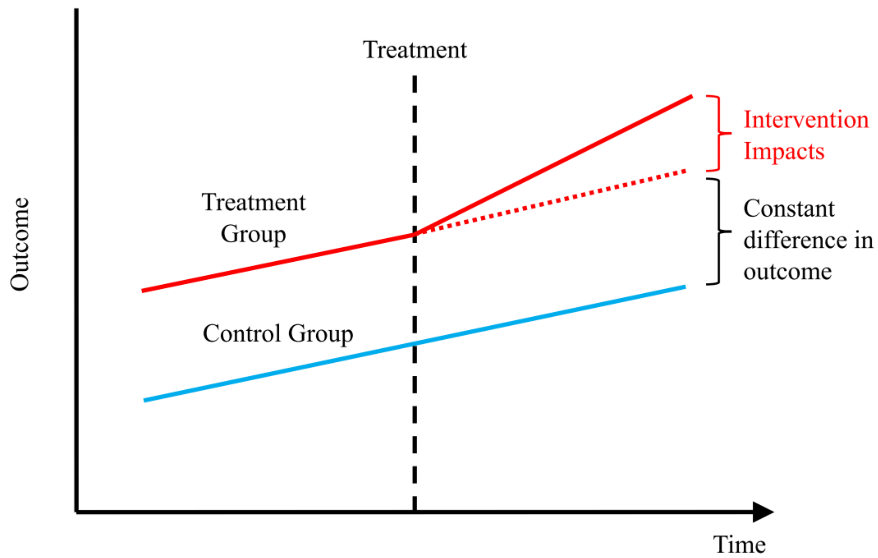

Figure 1. Difference-in-Differences (DiD) graph

The figure shows that without intervention, the difference between two groups is constant overtime. This assumption cannot be verified with the observed data, so the plausibility must be evaluated theoretically (Li et al., 2021).

3.2. Study Area and Population

Morowali is purposively selected based on the presence of Indonesia Morowali Industrial Park (IMIP). IMIP is the integrated industrial zones for nickel ore mining, nickel smelting, and nickel manufacturing. Operating since 2015, Morowali is serving as the key site of Indonesia's ambitious nickel industrialization agenda. Comparative analysis will be conducted with

Morowali as the treatment group and Banggai as the control group. Banggai is chosen as the area without a massive nickel industrial development.

Administratively, Morowali and Banggai are regencies (typically rural areas), which are at the same level as cities (urban areas) and are directly below the province level (Figure 2). The study population consists of residents of Morowali and Banggai. Panel data from two distinct period will be observed: before the industrial park operation (2010-2014) and after the industrial park operation (2015-2023).

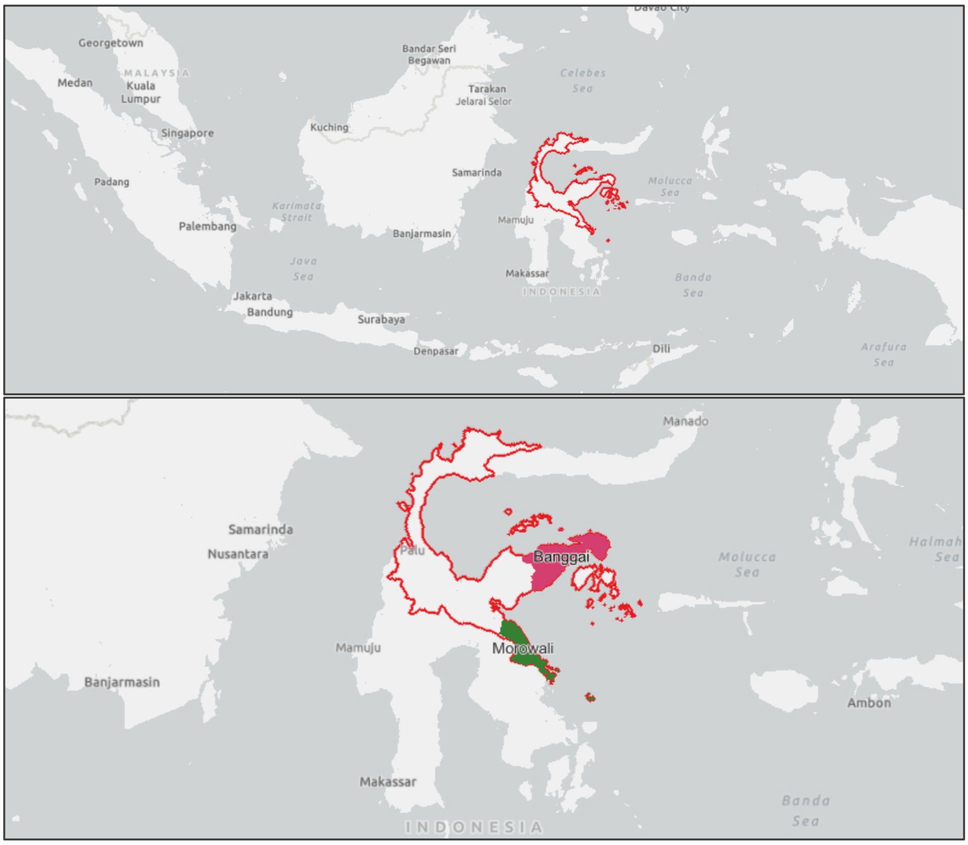

Figure 2. Map of Morowali and Banggai located in Central Sulawesi, Indonesia

Parallel trend assumption

Geographically, Morowali and Banggai are located on the eastern coast of Central Sulawesi, with similar coastal landscapes, climate, and environmental conditions. Before the establishment of IMIP in 2015, both Morowali and Banggai historically relied on the same economic sectors, primarily agriculture, fisheries, and forestry (BPS Central Sulawesi, 2013). Before the establishment of IMIP, both regions were not subject to major industrial-driven economic changes.

Between 2015 and 2019, Morowali and Banggai stood out as significant economic contributors within Central Sulawesi. Out of the 13 regencies/cities, only four surpassed the regional average GRDP. Notably, Morowali and Banggai accounted for on average 14.52% and 18.21% of the total GRDP, respectively, highlighting their substantial economic impact (BPS Central Sulawesi, 2023).

Figure 3a. Parallel trends in socioeconomic indicators pre-industrialization: GRDP per capita, average household expenditure, unemployment rate, and poverty rate

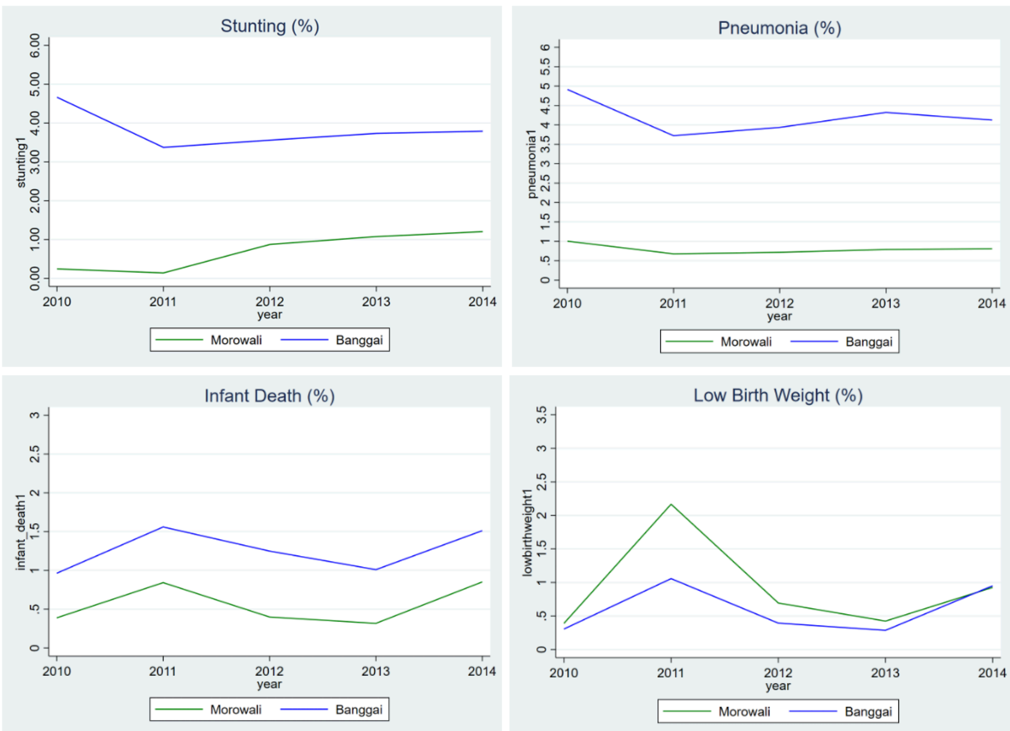

Figure 3b. Parallel trends in Health Indicators pre-industrialization: prevalence of stunting, pneumonia, infant death, and low birth weight

Figure 3a and 3b presents pre-treatment trends for key socioeconomic and health indicators in both Morowali and Banggai. While these graphs offer a helpful visual indication that the treatment and control regions may have followed parallel trajectories before 2015, the validity of the parallel trends assumption will be formally tested in the robustness checks section of the analysis.

3.3. Data Sources and Variables

This study utilizes secondary panel data collected from various reports published by the National Statistics Bureau (BPS) and mortality data from the Institute of Health Metrics and Evaluation (IHME).

Socioeconomic Data

The selected socioeconomic indicators are based on widely accepted indicators in industrial development literatures and are also included in the National Socio-Economic Household Survey (SUSENAS). Table 3 shows the list of socioeconomic indicators observed in Morowali and Banggai.

Table 3. Socioeconomic indicators for nickel industrialization impacts

Indicator and Unit	Definition	Source
Economic Growth		
GRDP per Capita (IDR)	Total Gross Regional Domestic Product (GRDP) divided by the population	BPS Regional Economic Data
Poverty and Income		
Mean Household Expenditure (IDR)	Average per capita household spending on goods and services. This serves as a proxy for income and standard of living	National Socio-Economic Household Survey (SUSENAS)
Poverty Rate (%)	Percentage of the population below the poverty line, based on a consumption-based threshold	National Socio-Economic Household Survey (SUSENAS)
Labor		
Unemployment Rate (%)*	Percentage of unemployed individuals in the labor force	Labor Force Survey Report (SAKERNAS)

*No data is available for 2016 because only a provincial-level survey was conducted.

Health Data

The specific health outcomes observed are all related to PM2.5 exposure based on a study by Syuhada et.al (2020) on long-term health impact of air pollution in Jakarta, Indonesia. Morbidity was observed in children, the most vulnerable demographic, while mortality was observed in the adult population. Table 2 shows the list of health indicators observed in Morowali and Banggai.

Table 2. Long-term health impacts and mortality from nickel industrialization

Indicator	Observed Age	Source
Stunting	< 5 years old	Regional Health Profile report
Pneumonia	< 5 years old	Regional Health Profile report
Low Birth Weight	At birth	Regional Health Profile report
Infant Deaths	0-12 months	Regional Health Profile report
Mortality*	> 5 years old (adult)**	Global Burden of Disease 2021 report

*Total mortality includes deaths from ischemic heart disease, stroke, COPD, type 2 diabetes, lower respiratory infections, and lung cancer (IHME, 2021)
**excluding infant deaths

Adverse health outcomes in children including: infant deaths and adverse birth outcomes such as low birth weight and preterm births. Stunting was selected as a primary child health outcome due to its national priority status and the identification of air pollution as an attributable risk factor in a recent meta-analysis (Syuhada et al., 2020). Morbidity is calculated using prevalence for the observed age groups detailed in Table 2.

$$Prevalence = \frac{Number\ of\ subjects\ having\ the\ disease\ at\ a\ time\ point}{Total\ number\ of\ subjects\ in\ the\ population}$$

Mortality outcome in adults includes six cause-specific mortality from PM2.5 exposure based on literature review. The total mortality caused by those six specific diseases were calculated by multiplying the total population of Morowali and Banggai with the Central Sulawesi's mortality rates estimated by the Global Burden of Disease 2021 study by IHME.

3.4. Summary of Datasets

The model utilizes socioeconomic and health indicators as dependent variables to assess the impact of nickel industrialization in Morowali. The independent variables include region type (treatment vs control), time period (pre- vs post-industrialization), and additional covariates/control variables such as healthcare access and education levels. These factors are included to control for other influences on the observed health and socioeconomic outcomes.

Table 4 provides an overview of mean values of 28 observed indicators of health and socioeconomic outcomes for both Morowali and Banggai for initial comparison.

Table 4. Descriptive statistics of full sample (2010 – 2023)

Variables		Mean	Median	Std. Dev	Min	Max
Socioeconomic Indicators						
GRDP per capita	Morowali	184.86	107.88	155.26	32.83	498.61
	Banggai	39.171	45.81	14.259	18.645	55.187
Poverty Rate	Morowali	15.208	14.76	2.289	12.31	20.29
	Banggai	9.129	9.235	1.534	6.94	9.84
Avg. Household Expenditure	Morowali	11.89	14.73	6.124	2.661	20.733
	Banggai	9.433	11.79	4.515	2.344	14.650
Unemployment Rate	Morowali	3.566	3.073	1.008	2.290	5.207
	Banggai	3.818	3.29	1.423	2.181	7.53
Health Indicators						
Stunting (%)	Morowali	1.372	0.974	1.569	0.140	6.351
	Banggai	2.431	1.912	1.210	0.615	4.663
Pneumonia (%)	Morowali	1.662	1.174	1.141	0.677	4.032
	Banggai	4.355	4.366	0.631	3.026	5.228
Infant death (%)	Morowali	1.098	1.071	0.566	0.318	2.339
	Banggai	0.893	0.929	0.396	0.215	1.560
Low birth weight (%)	Morowali	2.177	0.865	2.391	0.382	7.379
	Banggai	1.277	1.266	0.713	0.286	2.746
Mortality	Morowali	276.67	257.21	66.91	216.24	418.67
	Banggai	971.05	911.29	255.92	701.97	1488.20
Control Variables						
Mean years of schooling (MYS)	Morowali	9.86	8.46	2.99	6.73	14.24
	Banggai	10.05	9.37	1.83	8.14	12.93
Healthcare facilities	Morowali	10.43	11.0	1.60	8.0	13.0
	Banggai	26.71	28	2.97	21	30

3.5. Econometric Model

The Difference-in-Differences (did) model for this study is represented by the following equation:

$$Y_{it} = \alpha + (\beta_1 \text{ x } Treatment_i) + (\beta_2 \text{ x } Time_t) + (\gamma \text{ x } Treatment_i \text{ X } Time_t) + \delta X_{it} + \varepsilon_{it}$$

The coefficients and variables in the context of this research are as follows:

- Y_{it} : The dependent variable, representing the health or socioeconomic outcome of interest for certain region and time.
- α : The intercept, representing the average value of Y_{it} When all independent variables are equal to zero. This means α captures the baseline level of the dependent variable before industrialization,
- β_1 : The coefficient for the $Treatment_i$ Variable, a binary indicator that signifies whether a region is a treatment or control area. In this study, Morowali as a treated area is assigned a value of 1, while Banggai as a control area is assigned a value of 0.
- β_2 : The coefficient for the $Time_i$ Variable, which is a time dummy variable where 1 for observations in the post-industrialization period (2015 – 2023) and 0 for the pre-industrialization period (2010 – 2014)
- γ : The coefficient for the interaction term $Treatment_i \text{ X } Time_t$. This captures the treatment effect by measuring the difference in the outcome trends between the industrialized (Morowali) and non-industrialized (Banggai) regions over time.
- δX_{it} : Other covariates. A vector of control variables for each region-year observation. These control variables account for other factors that may influence the health and socioeconomic outcomes. Control variables include: healthcare access (e.g. Number of hospitals) and educational level
- ε_{it} : The error term representing unobserved factors that may affect Y_{it}

3.6. Hypotheses

To empirically assess the socioeconomic and health effects of nickel industrialization in Morowali, the following hypotheses are formulated:

Socioeconomic Impact Hypotheses

Nickel industrialization is expected to bring economic growth but may also have distributional effects on poverty, household income, and labor markets. The hypotheses are:

- Null Hypothesis (H_{01}): Nickel industrialization does not significantly affect socioeconomic outcomes in Morowali.
- Alternative Hypothesis (H_{11}): Nickel industrialization significantly affects socioeconomic outcomes in Morowali.

Health Impact Hypotheses

The establishment of nickel industrialization may influenced key health indicators due to prolonged air pollution exposure. The hypotheses are as follows:

- Null Hypothesis (H_{02}): Nickel industrialization does not significantly affect health outcomes in Morowali.
- Alternative Hypothesis (H_{12}): Nickel industrialization significantly affects health outcomes in Morowali.

4. Results

4.1. Estimation the Impact of Nickel Industrialization: DiD Regression Result

The primary model mentioned in Section 3.5 is used to analyse data and estimated the change in key socioeconomic (Table 5) and health indicators (Table 6) over time. Variable *"treatment#time"* represents the condition of Morowali after the establishment of the industrial park (2015 – 2023) compared to Banggai. Control variables are used to account for factors that might influence the dependent variables. Result of the DiD regression for both socioeconomic and health aspect are presented in the following subsections.

Socioeconomic Impact

Result shows that nickel industrialization has influences on the key socioeconomic indicators on this study (Table 5). There is a significant increase of GRDP per capita in Morowali compared to Banggai after the operation of the nickel industrial park. Household expenditure has also increased, suggesting that nickel industrialization has improved living standards for some households. Although poverty rate declined, the less substantial effect indicates that economic gains were not equitable distributed. All the coefficients for the interaction terms in the socioeconomic model are statistically significant at a high and moderate confidence level ($p < 0,05$), except for unemployment rate ($p > 0.1$). This shows that nickel industrialization did not significantly affect unemployment rates.

The inclusion of control variable mean year of schooling (MYS) accounts for the potential influence of education levels on the socioeconomic variables. The results indicates that higher MYS contributes to economic growth as it has positive and significant effect on GRDP per capita. Additionally, MYS plays a key role in poverty reduction and has a small but significant positive effect on household expenditure, implying that education may improve earning potential. However, result shows that MYS does not significantly influence unemployment rates.

Table 5. Difference-in-Differences (DiD) Regression Result for Socioeconomic Aspect

Variables	GRDP per capita	Household expenditure	Poverty rate	Unemployment rate
Treatment#time	330.429*** (91.902)	6.843** (2.474)	-3.988** (1.440)	0.578 (0.902)
Control (MYS)	59.615* (30.789)	1.743* (0.872)	-1.154*** (0.255)	-0.445 (0.383)
Constant	-711.427* (378.609)	-17.389 (10.905)	24.776*** (3.133)	10.632** (4.910)
R-squared	0.714	0.864	0.913	0.421

Note: Standard errors are in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01

Health Impact

Nickel industrialization has some influence on key health indicators, as shown in Table 6. There is a significant increase in stunting prevalence in Morowali compared to Banggai after the establishment of nickel industrial park. The prevalence of pneumonia also increased although with a weaker statistical significance. This implies a potential link between industrialization and respiratory health issues. While the effect of industrialization on low birth weight was not statistically significant, infant death significantly increased in Morowali relative to Banggai, reinforcing concerns that industrial activities may pose serious health risks to infants. In contrast, total mortality is found declining, which may be attributed to improvements in healthcare services or changes in population dynamics.

Control variable in the model accounts for the potential influence of healthcare infrastructure availability on health outcomes. The results indicate that better healthcare access significantly increases recorded mortality, potentially due to improved reporting and medical interventions rather than an actual rise in deaths. However, for all other health indicators—stunting, pneumonia, low birth weight, and infant death—the coefficients for healthcare are small and statistically insignificant. This suggests that while healthcare availability may influence the accuracy of mortality data, it does not appear to substantially change other observed health outcomes in the industrialized area.

Table 6. Difference-in-Differences (DiD) Regression Result for Health Aspect

Variables	Stunting Prevalence	Pneumonia prevalence	Low birth weight	Infant death	Mortality
Treatment#time	2.567*** (0.621)	1.272* (0.682)	2.217 (1.370)	1.592*** (0.301)	-118.99* (68.849)
Control (healthcare Facilities)	-0.256 (0.178)	0.062 (0.144)	0.502 (0.249)	0.071 (0.057)	57.518*** (17.637)
Constant	9.833** (4.161)	2.743 (3.461)	-11.149 (5.824)	-0.397 (1.320)	583.627 (418.025)
R-squared	0.503	0.781	0.372	0.585	0.924

Note: Standard errors are in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01

4.2. Hypothesis Testing

After establishing the coefficients for the variables in this study, the next step involves subjecting these findings to hypothesis testing to answer the research questions. In general, the hypothesis is that industrialization impacts the socioeconomic and health related condition of the local community. The following are the specific hypotheses:

Null hypotheses (H_0)

Following the establishment of nickel industrial park in Morowali in 2015, there is no significant difference in the change of socioeconomic and health outcomes between treated (Morowali) and control region (Banggai). Specifically, the study proposes that the observed variation in GRDP per capita, poverty rate, household expenditure, unemployment, stunting, pneumonia, infant mortality, and overall mortality does not differ significantly from pre-treatment period. Any changes detected after 2015 are assumed to be due to external unrelated factors than the effects of industrialization.

Alternative hypotheses (H_1)

Following the establishment of the nickel industrial park in Morowali in 2015, there is a significant difference in the change of socioeconomic and health outcomes between the treated region (Morowali) and the control region (Banggai). In particular, the study expects that the majority of the observed socioeconomic and health indicators will show statistically significant changes in the post-treatment period. This provides sufficient evidence to conclude that nickel industrialization has had a measurable impact on the treated population.

As previously outlined in Section 3.6, this study formulated separate hypotheses for socioeconomic (H_{01} and H_{11}) and health aspect (H_{02} and H_{12}). In this section, the findings are assessed against the stated hypotheses. If the majority of the respective indicators in each group are found to be statistically significant, the corresponding null hypotheses (H_{01} and H_{02}) are rejected, supporting the alternative hypotheses (H_{11} and H_{12}). Table 7 shows the result of the assessment.

Table 7. Hypotheses testing summary table

Variables	Effect direction	Significance (p-value)	Interpretation
Socioeconomic			
GRDP per capita	Positive	0.002	Reject H_{01}
Household expenditure	Positive	0.011	
Poverty rate	Negative	0.011	
Unemployment rate	No significant change	0.528	
Health			
Stunting prevalence	Positive	0.000	Reject H_{02}
Pneumonia prevalence	Positive	0.075	
Low birth weight	Positive	0.119	
Infant death	Positive	0.000	
Mortality	Negative	0.100	

Among the socioeconomic aspect, three out of four indicators: GRDP per capita, household expenditure, and poverty rate exhibit statistically significant changes post-treatment. Only the unemployment rate does not show a significant change. Similarly, four out of five health indicators: stunting prevalence, pneumonia prevalence, infant death, and overall mortality also show statistically significant results. The only health variable without significant effect is low birth weight.

Since the majority of indicators in both categories display statistically significant changes, both null hypotheses (H_{01} and H_{02}) are rejected. This suggests that the changes in socioeconomic and health condition reflect the impacts of nickel industrial activity in Morowali. Lastly, to ensure that these findings are reliable, the next section presents a series of robustness checks to validate the consistency and credibility of the estimated effects.

4.3. Robustness Check

Robustness check in empirical research involves systematically modifying the statistical model, typically by adding or removing regressors, to assess whether the core relationships identified remain consistent under these alterations (Lu & White, 2014). This is crucial to ensure the reliability of findings. In this section, three robustness check are conducted and compared with the main model. The first robustness check (Model 2) is adjusting the sample by excluding observations. The second robustness check (Model 3) implements a placebo test by assigning a false intervention year, prior to the actual industrialization, to test the validity of the parallel trend assumption. The last robustness check (Model 4) runs the did regression without control variables, allowing an assessment of whether the main treatment effects persist even in a simplified model. Table 8 presents the results from these models, and the following subsections will discuss the findings.

Table 8. Result of robustness check

Variables	Main Model	Model 2	Model 3	Model 4
Socioeconomic				
GRDP per capita	330.429*** (91.902)	330.118*** (94.251)	12.499** (4.699)	188.704*** (48.917)
Household expenditure	6.843** (2.474)	6.760** (2.502)	0.096 (2.549)	2.698 (1.754)
Poverty rate	-3.988** (1.440)	-3.920** (1.446)	-1.625 (1.157)	-1.244 (1.175)
Unemployment rate	0.578 (0.902)	0.526 (0.841)	-0.957 (1.249)	1.615* (0.855)
Health				
Stunting prevalence	2.567*** (0.621)	2.704*** (0.678)	0.864 (0.480)	3.238*** (0.722)
Pneumonia prevalence	1.272* (0.682)	1.212* (0.682)	-0.033 (0.412)	1.108** (0.511)
Low birth weight	2.217 (1.370)	2.211 (1.465)	-0.441 (0.736)	0.901 (1.012)
Infant death	1.592***	1.615***	0.037	1.406***

	(0.301)	(0.314)	(0.412)	(0.246)
Mortality	-118.99* (68.849)	-114.80* (60.636)	-77.758** (21.201)	-237.46*** (97.488)

Note: Standard errors are in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01

Robustness Check 1 – Excluding Observation

As with countries worldwide, Indonesia faced economic decline and significant health and human costs during the COVID-19 pandemic. To test the potential distortion caused by the COVID-19 pandemic, a robustness test was conducted by excluding the year 2020 from the regression sample. Table 9 show the result of the first robustness check (Model 2).

Table 9. Robustness check 1 result

Variables	Effect direction	P-value	Interpretation	Hypothesis test
Socioeconomic				
GRDP per capita	Positive	0.002	Consistent with main model	Reject H_{01}
Household expenditure	Positive	0.013	Consistent with main model	
Poverty rate	Negative	0.013	Consistent with main model	
Unemployment rate	No significant change	0.539	Not significant, consistent as main model	
Health				
Stunting prevalence	Positive	0.001	Consistent with main model	Reject H_{02}
Pneumonia prevalence	Positive	0.079	Consistent with main model	
Low birth weight	Positive	0.146	Not significant	
Infant death	Positive	0.000	Consistent with main model	
Mortality	Negative	0.075	Consistent with main model	

The results shows that Model 2 is consistent with the main model. After removing the year 2020 from the sample, the estimated impact of nickel industrialization on GRDP per capita, household expenditure, and poverty rate remains statistically significant and directionally consistent. This suggests that these socioeconomic outcomes are not driven solely by potential anomalies due to the pandemic. Result also shows that unemployment rate continues to show no statistically significant change, reinforcing previous estimation that nickel industrialization did not lead to a clear improvement in employment outcomes. Overall, these findings confirm the robustness of the socioeconomic effects under Model 2.

For health indicators, stunting prevalence, pneumonia prevalence and infant death remain significant and in the same direction, confirming the negative health impacts identified in the main model. Low birth weight also remains statistically insignificant, suggesting this variable may be more sensitive to the inclusion of 2020 data. Mortality, while only marginally significant, retains its negative direction, consistent with the main model. These results provide further evidence that the key health impacts of industrialization are not anomaly of the pandemic period.

In terms of hypothesis testing, three out of four socioeconomic indicators (GRDP, expenditure, and poverty rate) are statistically significant, providing strong support to reject H_{01}. Likewise, four out of five health indicators are significant, supporting the rejection of H_{02}. Overall, Model 2 reinforces the validity and robustness of the main findings.

Robustness Check 2 – Placebo Test

A placebo test was conducted by assigning a false intervention year (2013) to verify the parallel trend assumption. In this model, nickel industrialization starts in 2013 to check whether any treatment effect was already present before the actual operation of the industrial park. Table 10 shows the result of the second robustness check (Model 3).

Table 10. Robustness check 2 result

Variables	Effect direction	P-value	Interpretation	Hypothesis test
Socioeconomic				
GRDP per capita	Positive	0.037	Significant effect – weakens parallel trend	Fail to reject H_{01}
Household expenditure	Positive	0.971	No effect – supports parallel trend assumption	
Poverty rate	Negative	0.210	No effect – supports parallel trend assumption	
Unemployment rate	Negative	0.473	No effect – supports parallel trend assumption	
Health				
Stunting prevalence	Positive	0.122	No effect – supports parallel trend assumption	Fail to reject H_{02}
Pneumonia prevalence	Negative	0.938	No effect – supports parallel trend assumption	

Low birth weight	Negative	0.571	No effect – supports parallel trend assumption
Infant death	Positive	0.930	No effect – supports parallel trend assumption
Mortality	Negative	0.010	Significant effect – weakens parallel trend

It is important to note that the placebo test used a more limited sample of pre-treatment years, which reduces the number of observations. This smaller sample size can lead to smaller coefficient estimates than the main model, even in the presence of true underlying effects. As such, the generally smaller magnitude of coefficients in Model 3 compared to the main model (Table 8) may reflect reduced statistical power rather than the absence of association. The lack of statistically significant effects for the outcomes is more critical as it supports the parallel trend assumption.

As shown in Table 10, almost all variables are not statistically significant, including all socioeconomic outcomes except GRDP per capita, and all health outcomes except mortality. In this specification, the absence of statistically significant treatment effects would support the assumption that Morowali and Banggai were following similar trajectories before the actual industrialization happened. In other words, statistical insignificance in the placebo model suggests no pre-treatment differences in trends, thereby reinforcing the credibility of the Difference-in-Differences approach.

The significance of GRDP per capita and mortality suggests some caution is needed when interpreting those specific effects in the main model, as they may have been influenced by pre-existing trends or unobserved factors. With only one out of four socioeconomic variables and one out of five health variables showing significance, there is insufficient evidence to reject H_{01} and H_{02} in the placebo scenario. This result supports the credibility of the main model and strengthens confidence in the estimated treatment effects as being driven by the actual intervention rather than pre-existing differences.

Robustness Check 3 – Excluding Control Variables

Lastly, the DiD model was estimated without control variables to test the consistency of the treatment effect. The control variables mean years of schooling and healthcare access are removed from the model to assess whether the estimated treatment effects remain detectable in a simplified model.

Table 11. Robustness check 3 result

Variables	Effect direction	P-value	Interpretation	Hypothesis test
Socioeconomic				
GRDP per capita	Positive	0.001	Significant – robust to model simplification	Partially reject H_{01}
Household expenditure	Positive	0.137	Not significant – less robust without control	
Poverty rate	Negative	0.300	Not significant – less robust without control	
Unemployment rate	Positive	0.072	Marginally significant – robust to model simplification	
Health				
Stunting prevalence	Positive	0.000	Highly significant – robust to model simplification	Reject H_{02}
Pneumonia prevalence	Positive	0.040	Significant – robust to model simplification	
Low birth weight	Positive	0.382	Not significant – possibly control-dependent	
Infant death	Positive	0.000	Highly significant – robust to model simplification	
Mortality	Negative	0.011	Significant – robust to model simplification	

The results show that GRDP per capita, unemployment rate, stunting prevalence, infant death, and mortality all remain significant at the 1% level and maintain consistent directions with the main model. Pneumonia prevalence also remains significant at the 5% level, supporting the consistency of this result. However, several other outcomes show weaker significance under Model 4; household expenditure, poverty rate, and low birth weight deviate from their previous 5% or 10% significance levels in the base model. Unemployment rate becomes marginally significant at the 10% level, which differs from its earlier non-significance in the main model.

In terms of hypothesis testing for the socioeconomic aspect, there is moderate evidence to reject H_{01}, since only two out of four indicators are statistically significant — reflecting a notably less robust pattern than in the main model. For the health aspect, four out of five indicators are statistically significant, providing strong support to reject H_{02}.

5. Discussion and Recommendation

This section concludes the findings and answers the research questions posed, followed by a discussion of the results. Notable limitations and recommendation for future research are also discussed.

5.1. Discussion

The general research question is as follows: *"*What are the impacts of nickel industrialization on local communities in Morowali*"*. Two specific research questions are then formulated:

1. Sub-question 1: What is the impact of nickel industrialization on key socioeconomic outcomes?

The first sub-question investigates the relationship between nickel industrialization and socioeconomic conditions. The analysis focuses on four key indicators: GRDP per capita, household expenditure, poverty rate, and unemployment rate to reflect changes in regional economic output, welfare, and labor absorption.

The main model shows that nickel industrialization significantly increases GRDP per capita at the 1% level, suggesting substantial growth in regional income following the industrial park operations. This aligns with previous literature arguing that industrial expansion can serve as regional economic booster, especially in resource-rich developing countries (Lavopa & Szirmai, 2012; An et al., 2022). However, in Model 3 (placebo test), GRDP per capita shows a statistically significant effect even before the actual intervention. This indicates a weak parallel trend for this variable, suggesting a pre-existing differences between Morowali and Banggai. As a result, while the main model shows a strong positive association between industrialization and strong and active economy, the presence of a pre-treatment effect implies that the causal interpretation of GRDP per capita should be approached with caution. Some portion of the observed effect may not be only attributable to the post-2015 industrialization.

Household expenditure also increased significantly at 5% level, suggesting improved income among some households. However, the results from Model 4 indicate that this effect becomes statistically insignificant when control variables of mean years of schooling was removed. This signals that the observed improvements in welfare may be partially due to educational attainment rather than industrialization alone.

The poverty rate saw a moderate but significant decline (5% level), consistent with theories suggesting that industrial growth can reduce poverty through labor absorption and higher wages. However, this effect was not replicated in the robustness tests (Model 3 and Model 4), implying a weaker, possibly more volatile relationship. It may also indicates a growing disparities with specific groups experiencing greater benefits than the broader population. This aligns with concerns raised in the theoretical discussion about unequal distribution of industrial gains (Wau, 2022; Rahman et al., 2021).

Notably, unemployment rate did not significantly change in the main model but became marginally significant (10%) in the simplified model (Model 4), suggesting potential sensitivity to model specification. This finding may stem from the employment structure at IMIP, where a large proportion of skilled roles are occupied by foreign workers while local labor is concentrated in low-wage, informal jobs (ABC News, 2023).

Taken together, the findings support partial rejection of H_{01}, the null hypothesis for socioeconomic outcomes. Nickel industrialization in Morowali has had a positive but uneven impact on the observed key socioeconomic outcomes. While the evidence indicates that nickel industrialization has driven measurable economic growth in Morowali (through increased GRDP per capita and household spending) it is important to question the inclusiveness of this growth. The absence of significant effects on unemployment and the weaker, less consistent results for poverty reduction raise concerns about whether the economic gains are equitably distributed across the population. Although this study shows that growth has occurred, the uneven effects across socioeconomic indicators suggest that not all segments of the population may be benefiting equally.

2. Sub-question 2: What is the impact of nickel industrialization on air pollution-related health outcomes?

The second sub-question investigates the relationship between nickel industrialization and public health conditions, specifically on morbidity and mortality associated with PM2.5 pollution exposure. The analysis focuses on five key health indicators: stunting prevalence, pneumonia prevalence, low birth weight, infant death, and overall mortality. Based on these indicators, the findings reveals evidence that nickel industrialization in Morowali has contributed to worsening public health conditions among children/infant as the vulnerable population.

The main model shows statistically significant increases in stunting prevalence, pneumonia prevalence, and infant death, indicating deteriorating health outcomes post-industrialization. These findings are consistent with the body of literature linking PM2.5 exposure to respiratory diseases, developmental issues, and mortality (Pope et al., 2002; Liu et al., 2019; Syuhada et al., 2020).

The effect on low birth weight, however, is positive but statistically insignificant, suggesting that while there may be an adverse association, the evidence is inconclusive within the limits of this model. Its consistent direction across robustness checks suggests the need for further investigation. In contrast, mortality rate among adults, found decreased in Morowali relative to Banggai. While this could be attributed to improvements in healthcare access or demographic changes, the robustness of this result (observed consistently across all models) suggests it is a reliable pattern.

Additionally, robustness checks further validate the core findings. In Model 2 (excluding 2020), four out of five indicators remain statistically significant, confirming that the observed health effects are not driven by irregularities related to the COVID-19 pandemic. In Model 4 (no control variables), stunting, pneumonia, infant death, and mortality remain significant, indicating that these health impacts persist even without accounting for covariates. The placebo test (Model 3) supports the parallel trend assumption for all health indicators except mortality, thereby reinforcing the causal interpretation of the main effects.

Taken together, the four out of five health indicators are statistically significant, therefore the study rejects the null hypothesis for health outcomes (H_{02}). The nickel industrialization in Morowali has had a significant and detrimental impact on air pollution-related health outcomes.

5.2. Limitations and recommendations for future research

While this study offers insights on the impacts of nickel industrialization in Morowali, several limitations should be acknowledged. First, the analysis relies on regency-level data which may not show intra-regional dynamics and limit the ability to explore the impacts on different subgroups (e.g. age, gender, income level). Additionally, due to unavailability of air quality monitoring infrastructure at regional/industrial park level, the study does not directly incorporate PM2.5 concentration data as an explanatory variable. Future research should incorporate geospatial data or pollution modelling to analyze proximity-based exposure to the industrial facilities and captive coal power plants.

Second, while it allows for a clear treatment-control comparison, the small sample size limits the statistical power on the analysis. It also restricts the inclusion of multiple control variables without risking model overfitting. Moreover, the analysis of mortality in this study uses a broad definition that includes deaths from chronic conditions based on the Global Burden of Disease report. The observed post-industrialization decline in mortality may reflect improvements in healthcare access or demographic shifts. It may also be influenced by the time lag between pollution exposure and the diagnosis of chronic disease, meaning some adverse health effects may not yet be fully visible. This highlights the need for disaggregated mortality data and longer-term health monitoring. Incorporating higher-frequency (e.g. quarterly instead of annually) or individual-level panel data can refine the estimation in future studies.

In conclusion, this study sheds light on the complex outcomes of large-scale nickel industrialization in Morowali. While the evidence highlights economic gains it also reveals significant health burdens, pointing to a deeper trade-off between economic growth and public health. Furthermore, the partial rejection of hypotheses in this study reflects the inherent complexity of social science research where effects are often context-dependent.

5.3. Policy recommendations

Observed rise in regional income following the establishment of Indonesia Morowali Industrial Park suggests that Indonesia's downstreaming policy can indeed generate economic benefits as the government claimed. However, this has come alongside rising public health concerns. At the same time, the country has been facing growing domestic and international pressure to establish a cleaner industrial development plan. Thus, the following are the policy recommendations for future nickel industrial park development:

1. Address the national air pollution crisis linked to coal use

Indonesia remains heavily reliant on coal-fired power that has not only contributes to local air pollution and adverse health outcomes but also undermines Indonesia's credibility in global climate efforts. A gradual shift toward cleaner energy sources instead of developing another CFPPs, accompanied by mandatory PM2.5 monitoring is essential to reduce pollution and improve public health.

2. Upskilling workers for an inclusive economic gain

Despite growth in GRDP, indicators such as unemployment and poverty show less consistent improvement. This raises questions about the equitability of industrialization benefit for local community. One key issue is the limited absorption of local labor, often attributed to skill mismatches. Local workers in Morowali are low-skilled, leading companies to import high-skilled foreign labor to meet technical demands. To address this imbalance, policies must prioritize workforce upskilling such as strengthening vocational training and linking local education to industry needs.

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