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The Influence of Tin Prices and Production Costs on the Net Profit Margin of PT Timah Tbk with Exchange Rate as a Moderating Variable (2018–2025)

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ABSTRACT

Purpose: This study examines the associations of tin prices and a Cost of Goods Sold (COGS)-based cost proxy with PT Timah Tbk's Net Profit Margin (NPM) and evaluates the moderating role of the rupiah–US dollar exchange rate during 2018–2025.

Research Method: The study uses a quantitative time-series design comprising 32 quarterly observations obtained from PT Timah Tbk, the London Metal Exchange, and Bank Indonesia. Daily tin prices and exchange rates were aggregated into quarterly arithmetic averages. Data were analyzed using descriptive statistics, diagnostic tests, multiple linear regression, and Moderated Regression Analysis in EViews 13.

Results and Discussion: Tin prices are positively associated with NPM, whereas the COGS-based cost proxy has no statistically supported association with NPM. The interaction results provide insufficient evidence that the exchange rate moderates either relationship. Thus, insignificant interaction directions are not interpreted as strengthening or weakening effects.

Implications: Management and investors should evaluate commodity-price movements alongside production volume, sales, cost composition, and foreign-currency exposure. The findings represent associations and do not establish causal or dominant determinants of profitability.

Originality: This study integrates tin prices, reported costs, and exchange-rate interactions using recent quarterly data from an Indonesian tin-mining company.

Keywords: COGS; exchange rate; Net Profit Margin; PT Timah Tbk; tin price.

1. Introduction

The tin mining industry is a strategic sector contributing to Indonesia's economy through exports and state revenue. As one of the world's largest tin producers, PT Timah Tbk plays a vital role in the national tin industry. However, a mining company's performance is determined not only by production volume but also by global commodity price movements, operational costs, and macroeconomic conditions. During 2018–2025, movements in global tin prices, PT Timah Tbk's reported Cost of Goods Sold (COGS), and the rupiah–US dollar exchange rate coincided with substantial variation in the company's Net Profit Margin (NPM). These variations raise a practical question about whether changes in profitability are associated with tin market conditions and company costs, and whether the exchange rate alters these relationships.

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Net Profit Margin reflects a company's ability to generate net profit from sales after accounting for expenses. For mining companies, an increase in commodity prices may raise revenue but does not necessarily translate into a comparable increase in net profit when operational costs rise. The rupiah–US dollar exchange rate may likewise operate through different channels: rupiah depreciation may increase the domestic-currency value of export revenue while also increasing foreign-currency-denominated expenditures. Therefore, the relationships among tin prices, company costs, exchange rates, and NPM cannot be inferred from changes in any single variable. They require empirical examination that accounts for their potentially overlapping movements.

Previous studies provide evidence that commodity-market conditions are associated with the financial performance of mining companies. Jang *et al.,* (2023) stated that changes in commodity prices affect mining companies' revenue and profitability because international market conditions drive a substantial proportion of revenue. Christiani *et al.,* (2021) explained that the decline in tin prices during the COVID-19 pandemic was accompanied by reduced global demand and weaker performance among mining companies. Nugroho *et al.,* (2023) further noted that the post-pandemic increase in global tin demand drove tin prices upward and contributed to higher corporate revenue. Collectively, these findings suggest that tin-price movements may be associated with mining-company profitability, although they do not establish that tin prices are necessarily the dominant determinant of profitability.

Company costs constitute another relevant consideration. Technical and operational factors, corporate efficiency strategies, and changes in production capacity influence production-cost dynamics. Febrianti and Rahmadani (2022) explain that NPM is affected by selling prices and the costs incurred in producing goods. However, the present study uses reported COGS as a proxy for production-related costs. COGS may also reflect inventory adjustments, depreciation, royalties, processing expenses, and other accounting components. Accordingly, the variable is referred to in this study as a "COGS-based cost proxy," unless a detailed reconciliation demonstrating its equivalence to production cost can be provided.

Research concerning exchange rates has yielded mixed findings. Barasyid & Setiawati (2023) state that exchange rates are relevant to international trade because they affect the revenues and costs of companies conducting export and import transactions. Wahyuni (2022) reported that the exchange rate moderated the relationship between financial ratios and stock returns. Conversely, Istiqomah and Mardiana (2020) found that exchange rates did not consistently moderate relationships among financial variables. These divergent findings indicate that the moderating role of the exchange rate may depend on the variables, industrial setting, period examined, and the company's exposure to foreign-currency transactions. Although previous studies have examined commodity prices, company costs, exchange rates, and financial performance, three limitations remain. First, much of the evidence examines the direct relationships separately rather than placing tin prices and a COGS-based cost proxy within the same profitability model. Second, evidence on the moderating role of exchange rates remains inconsistent and often derives from outcomes other than NPM. Third, limited evidence specifically addresses PT Timah Tbk over the 2018–2025 period. Moreover, the relationships must be interpreted cautiously because sales, production volume, costs, financing expenses, taxes, inventory changes, hedging, and impairment losses may jointly affect profitability. Consequently, the estimated coefficients represent conditional statistical relationships and should not be interpreted automatically as causal effects.

Based on these gaps, this study addresses two research questions: (1) how are global tin prices and the COGS-based cost proxy related to the NPM of PT Timah Tbk during 2018–2025, and (2) does

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the rupiah–US dollar exchange rate significantly moderate these relationships? Accordingly, this study aims to examine the relationships between global tin prices and the COGS-based cost proxy and NPM, and to test the moderating role of the exchange rate. The study's novelty lies in integrating commodity-market conditions, a company-level cost proxy, and exchange-rate interactions within a single-company time-series analysis covering the most recent 2018–2025 period. Its contribution is to provide context-specific evidence for evaluating the profitability of an Indonesian tin producer, while acknowledging the limitations of the cost proxy and potentially omitted operational factors.

The remainder of this paper is organized as follows. Section 2 provides a literature review and hypothesis development. Section 3 presents the research method and design. Section 4 provides the results and discussion. Section 5 presents Concluding Remarks and Recommendations.

2. Literature Review and Hypothesis Development

2.1 Literature Review

***2.1** Profitability Theory and Net Profit Margin*

Profitability reflects a company's ability to generate earnings by managing revenue, assets, capital, and expenses efficiently during a given period. From a profitability perspective, financial performance results from the interaction between revenue generation and resource consumption rather than from sales growth alone. Financial ratios provide measurable information about corporate strengths and weaknesses, although each ratio captures a different dimension of performance. Kaya *et al.,* (2024) position profitability ratios as important components of financial performance evaluation alongside liquidity, leverage, efficiency, and market indicators. (C.-C. Lee, 2023) similarly demonstrates that operating performance is associated with cost management, solvency, operating capacity, and business scale. Moreover, Mengstie *et al.,* (2024) show that profitability is related to working-capital management and firm-specific financial characteristics, although the significance of individual determinants varies. These findings indicate that profitability is multidimensional and should not be attributed to a single operational or financial factor.

Net Profit Margin (NPM) measures the proportion of net income retained from sales after deducting operating expenses, financing costs, taxes, and other recognized expenses. Darendeli *et al.,* (2022) employ the DuPont framework to distinguish NPM, calculated as net income divided by sales, from asset turnover as a separate component of corporate profitability. A higher NPM generally indicates that a company retains more earnings per unit of sales; however, it does not, by itself, identify whether the improvement stems from higher prices, increased sales volume, cost efficiency, financing arrangements, or taxation. Al-Khazaleh *et al.,* (2024) also use NPM as a sales-based profitability indicator in evaluating corporate financial performance. Accordingly, NPM is relevant for assessing PT Timah Tbk's capacity to convert tin sales into net earnings. Nevertheless, variations in NPM must be interpreted as the combined outcome of commodity prices, company costs, production and sales volumes, financing expenses, taxes, inventory adjustments, hedging, impairment losses, and other operating conditions, rather than the result of a single determinant.

***2.2** Tin Prices*

Tin prices represent the market value of tin determined through interactions among global supply, industrial demand, inventories, trading activity, and macroeconomic conditions. Tin is economically

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important for its applications in electronics, soldering, chemicals, and emerging technologies, while its limited substitution options and exposure to supply disruptions increase its market criticality. Bradley *et al.,* (2024) demonstrate that growing demand, supply concentration, recycling limitations, and difficult substitution contribute to the vulnerability of the global tin market. In Indonesia, tin price formation is closely linked to national production, export supply, available reserves, world demand, and production policy decisions. Firmanto *et al.,* (2025) show that these factors form a dynamic system in which production decisions affect global supply, prices, corporate revenue, resource depletion, and future exploration. Consequently, tin prices should not be treated as an isolated market indicator because their movements reflect simultaneous changes in physical availability, industrial consumption, national policies, and global economic activity.

Tin prices also exhibit substantial volatility, meaning that shocks may continue influencing market movements beyond the period in which they initially occur. Gil-Alana & Poza (2024) identify persistent volatility across metal prices and emphasize the relevance of supply disruptions and economic uncertainty in explaining price behavior. Gong *et al.,* (2022) further demonstrate that volatility is dynamically transmitted across industrial metal markets, although its intensity varies across commodities and periods. Schischke *et al.,* (2024) explain that industrial-metal prices are shaped by commodity-specific supply and demand, co-production, co-consumption, trading activity, global output, interest rates, and exchange-rate movements. Their findings also indicate that tin is less connected to other metal markets due to its smaller trading volume. However, its price remains responsive to its own fundamentals and global shocks. Therefore, changes in tin prices may be associated with PT Timah Tbk's sales-based profitability. However, higher prices do not automatically translate into higher Net Profit Margin, as the financial consequences also depend on sales volume, production output, cost recognition, inventory changes, and other corporate expenses.

2.3 *Production Cost*

Production costs comprise the economic resources consumed in extracting, processing, and preparing products for sale. In mining, these costs extend beyond raw materials and direct labor to include exploration, extraction, energy, equipment operation and maintenance, mineral processing, royalties, and environmental management. Bang & Trellevik (2023) explain that declining ore grades and deposit accessibility reduce output per unit of capital and increase unit extraction costs. Radebe & Chipangamate (2024) similarly show that greater mining depth, difficult operating conditions, energy requirements, supply chain disruptions, and processing complexity can exert upward pressure on mining costs. Moreover, mining activities generate environmental consequences that may impose rehabilitation, pollution-control, and social costs. Badakhshan *et al.,* (2023) demonstrate that environmental costs vary according to extraction methods and production scale but are not always fully incorporated into conventional financial accounts. Thus, mining production costs are multidimensional and may change with production capacity, resource quality, operational efficiency, regulatory obligations, and external disruptions.

This study, however, obtains the cost variable from PT Timah Tbk's reported Cost of Goods Sold (COGS). COGS should not be treated automatically as equivalent to production cost, as it may include inventory adjustments, depreciation, royalties, processing expenses, and other accounting components. García Osma *et al.,* (2023) operationalize production costs as COGS plus inventory changes, showing that inventory movements are necessary when constructing an accounting-based production-cost

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measure. He (2023) employs a similar measurement. He demonstrates that overproduction can distribute fixed overhead across more units, reduce reported unit costs, and increase inventory even when underlying economic efficiency does not improve. Accordingly, this study treats COGS as a proxy for production-related costs rather than a complete measure of production cost. An increase in this proxy may be associated with a lower Net Profit Margin when sales and other income components do not rise proportionately. Nevertheless, its coefficient must be interpreted cautiously because COGS, production volume, sales, and inventory changes may be jointly determined. At the same time, financing costs, taxes, hedging, impairment losses, and other expenses also influence net profitability.

2.4 *Exchange Rate*

The exchange rate represents the value of one currency relative to another and constitutes an important macroeconomic exposure for export-oriented mining companies. For PT Timah Tbk, movements in the rupiah against the US dollar generate two potentially opposing effects. Rupiah depreciation may increase export revenue when US-dollar-denominated sales are converted into rupiah. However, it may simultaneously raise the rupiah value of imported machinery, fuel, spare parts, foreign-currency liabilities, and other internationally sourced inputs. Lee & Naknoi (2024) demonstrate that the effects of exchange-rate movements on export margins depend on the invoicing currency and on firms' adjustments to export prices and quantities. Similarly, Huang & Zhang (2024) find that exchange-rate movements affect firms differently through upstream suppliers and downstream customers within global value chains. Evidence from Indonesian exports to the United States further indicates that the exchange rate does not necessarily produce a significant short-run change in export value across commodity groups, because export adjustment also depends on industrial production and commodity-specific characteristics (Asyifa, 2026). Depreciation against suppliers' currencies can increase imported input costs, whereas currency movements against customers' currencies can affect foreign sales, operating performance, and investment capacity. Therefore, depreciation cannot automatically be interpreted as beneficial to an exporter, as its net effect depends on the relative magnitudes of foreign-currency revenues and costs.

Exchange-rate volatility also introduces uncertainty into trade, cash flows, and corporate financial planning. Lal *et al.,* (2023) show that its relationship with international trade varies across countries, periods, and economic conditions, indicating that a uniform effect should not be assumed. In Indonesia, Heriqbaldi *et al.,* (2022) identify asymmetric responses of trade flows to exchange-rate volatility, suggesting that appreciation and depreciation may have different magnitudes. At the broader financial level, exchange-rate volatility can also affect refinancing conditions and debt management strategies, underscoring its relevance to financial planning amid macroeconomic uncertainty (Aparatunisa *et al.,* 2026). Companies may reduce this exposure through foreign-currency cash-flow hedging, although the effectiveness and adoption of hedging depend on corporate incentives and reporting transparency (Jin & Marshall, 2024). Accordingly, this study conceptualizes the rupiah–US dollar exchange rate as a moderating variable rather than an inherently favorable or unfavorable determinant. It may alter the association between tin prices and Net Profit Margin by changing the rupiah value of export proceeds, and modify the association between production costs and Net Profit Margin through foreign-currency input costs. The direction and significance of these moderating effects must therefore be determined empirically.

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2.2 Hypothesis Development

2.5.1 *Tin Prices and Net Profit Margin*

Under the supply-and-demand mechanism, an increase in international commodity prices can raise a mining company's revenue when sales volume and other conditions remain relatively stable. Nevertheless, higher commodity prices do not automatically translate into higher profitability, as the financial consequences also depend on production volume, operating costs, and other expenses. Jang *et al.,* (2023) indicate that changes in tin prices affect the revenue and profitability of mining companies. Christiani *et al.,* (2021) similarly found that declining tin prices during the pandemic were accompanied by deteriorating mining-company performance. Nugroho *et al.,* (2023) further noted that the post-pandemic increase in global demand drove tin prices upward and contributed to higher corporate revenue. Although these studies do not establish tin prices as the dominant determinant of profitability, their findings support the expectation that higher tin prices are associated with higher margins when cost increases do not fully offset the resulting revenue gains. Based on these findings, this study proposes the following hypothesis:

H1: *Global tin prices are positively associated with the Net Profit Margin of PT Timah Tbk.*

2.5.2 *COGS-Based Cost Proxy and Net Profit Margin*

The cost–profit relationship suggests that an increase in company costs can reduce the margin between revenue and net profit when revenue does not increase proportionally. Siregar and Utama (2023) state that changes in production costs are associated with production capacity and corporate efficiency strategies. Febrianti and Rahmadani (2022) explain that Net Profit Margin is influenced by product selling prices and the company's total costs. However, this study measures the cost variable using reported Cost of Goods Sold (COGS), which may include inventory adjustments, depreciation, royalties, processing expenses, and other accounting components. Therefore, COGS is treated as a proxy for production-related costs rather than as an exact equivalent of production cost. Building on the findings of Siregar and Utama (2023) and Febrianti and Rahmadani (2022), an increase in the COGS-based cost proxy is expected to be associated with a lower NPM when revenue and other profitability components do not increase proportionately. Accordingly, this study proposes:

H2: *The COGS-based cost proxy is negatively associated with the Net Profit Margin of PT Timah Tbk.*

2.5.3 *Moderating Role of the Exchange Rate in the Tin Price–NPM Relationship*

For an export-oriented mining company, the exchange rate may alter how international commodity prices are translated into domestic-currency revenue. Rupiah depreciation may increase the rupiah value of US-dollar-denominated export revenue, but higher foreign-currency-denominated operating expenses may offset this potential benefit. Barasyid and Setiawati (2023) state that exchange-rate movements affect the revenues and costs of companies involved in international trade. Wahyuni (2022) indicates that the exchange rate can moderate relationships between financial variables and corporate outcomes. Conversely, Istiqomah and Mardiana (2020) found that the exchange rate does not consistently exert a significant moderating effect. Because these findings are inconsistent and the exchange rate may operate through opposing revenue and cost channels, the direction of moderation cannot be predetermined. Based on this evidence, this study tests whether the exchange rate affects

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the relationship between global tin prices and NPM, without assuming that it necessarily strengthens or weakens it. Therefore, the proposed hypothesis is:

H3: *The rupiah–US dollar exchange rate significantly moderates the relationship between global tin prices and the Net Profit Margin of PT Timah Tbk.*

2.5.4 *Moderating Role of the Exchange Rate in the COGS–NPM Relationship*

Exchange-rate movements may also condition the relationship between the COGS-based cost proxy and profitability. Rupiah depreciation can increase the domestic-currency value of imported equipment, fuel, spare parts, and other foreign-currency-denominated inputs. However, the effect depends on the currency composition of COGS, inventory recognition, payment timing, and corporate hedging arrangements. Barasyid and Setiawati (2023) demonstrate the relevance of exchange rates to corporate costs, while the contrasting results reported by Wahyuni (2022) and Istiqomah and Mardiana (2020) indicate that moderation is context-dependent. Accordingly, the exchange rate may alter the magnitude of the relationship between the COGS-based cost proxy and NPM. However, the available evidence does not support a predetermined direction of strengthening or weakening. Based on these findings, this study proposes:

H4: *The rupiah–US dollar exchange rate significantly moderates the relationship between the COGS-based cost proxy and the Net Profit Margin of PT Timah Tbk.*

3. Research Method

This study employed a quantitative explanatory design using quarterly time-series data to examine the associations of tin prices and a COGS-based cost measure with the Net Profit Margin (NPM) of PT Timah Tbk, as well as the moderating role of the rupiah–US dollar exchange rate. The term "association" is used instead of "causal effect" because the observational design does not independently eliminate reverse causality, simultaneity, or omitted-variable bias. The unit of analysis was the quarter, covering the first quarter of 2018 through the fourth quarter of 2025, yielding 32 observations. This quarterly frequency was selected because eight annual observations would be insufficient for estimating the main effects, moderator, interaction terms, and control variables. The study used a census of all quarterly observations for which the variables could be consistently matched; therefore, purposive sampling and population-based sample-size calculations were not applied.

Financial data were obtained from PT Timah Tbk's audited annual reports and quarterly financial statements published through the company's official reporting channels and the Indonesia Stock Exchange. Daily tin-price observations were obtained from the London Metal Exchange (LME), while daily rupiah–US dollar exchange rates were obtained from Bank Indonesia. Daily LME tin prices, denominated in USD per metric tonne, were aggregated into quarterly observations using the arithmetic mean of all available trading-day prices within each quarter. Non-trading days and dates without published prices were excluded rather than interpolated. Daily rupiah–US dollar observations, expressed as rupiah per USD, were similarly converted into quarterly arithmetic means using all available Bank Indonesia trading-day observations. These aggregation procedures aligned the market variables with the quarterly accounting period and prevented the arbitrary selection of a single daily or month-end value.

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Tin price () represents the quarterly average international tin price. The second explanatory variable () was measured using the Cost of Goods Sold (COGS) reported by PT Timah Tbk. COGS was not treated as conceptually identical to pure production cost. Instead, it was explicitly defined as a COGS-based cost proxy because the reported amount may include inventory adjustments, depreciation, royalties, processing expenditures, purchased materials, and other cost components in accordance with the company's accounting policies. The corresponding financial-statement notes were reviewed for changes in classification and accounting policy. This operationalization captures the costs recognized against revenue but does not isolate engineering-level extraction or processing costs. Consequently, its coefficients are interpreted as associations involving reported COGS, not the marginal or technical cost of producing tin.

NPM () was calculated by dividing quarterly net income after tax by quarterly revenue and multiplying the result by 100. The moderating variable () was the quarterly average rupiah–US dollar exchange rate. A higher value denotes rupiah depreciation. Thus, the interaction terms indicate whether the association of tin prices or reported COGS with NPM varies with the rupiah's value; an insignificant interaction is interpreted as insufficient evidence of moderation and is not described as strengthening or weakening the relationship.

To reduce scaling disparities and improve the interpretation of the interaction model, tin prices, COGS, and exchange rates were transformed into natural logarithms when their values were strictly positive, then standardized as z-scores before constructing the interaction terms. The interaction variables were calculated as and . Standardization does not eliminate multicollinearity or endogeneity, but it makes the coefficients comparable and reduces nonessential collinearity between constituent variables and their products. Production volume and sales volume were incorporated as operational controls because output, sales activity, costs, and profitability may be jointly determined. Financing costs and tax expenses were included in supplementary specifications when they were separately and consistently disclosed. Inventory changes, hedging outcomes, impairment losses, and other nonrecurring items were documented in the financial statement notes and examined through sensitivity analyses because their inconsistent quarterly disclosure prevented their simultaneous inclusion in every specification.

Data were analyzed using EViews 13. The analysis began with descriptive statistics and time plots, followed by examination of missing values, extreme observations, and consistency across sources. Stationarity was evaluated using the Augmented Dickey–Fuller test to reduce the risk of spurious regression in time series. The residual diagnostics included the Jarque–Bera test for normality, variance inflation factors and a correlation matrix for multicollinearity, the Breusch–Pagan–Godfrey test for heteroscedasticity, and the Breusch–Godfrey LM test for serial correlation. When heteroscedasticity or autocorrelation was detected, heteroscedasticity-and-autocorrelation-consistent standard errors were reported.

Moderation was tested hierarchically. Model 1 included the standardized tin price and COGS variables, along with the relevant controls. Model 2 added the standardized exchange rate. Model 3 added both interaction terms. Evidence of moderation was assessed using interaction coefficients, 95% confidence intervals, changes in adjusted R-squared, model-comparison tests, and full-model VIF values. Statistically significant interactions were interpreted using conditional slopes at one standard deviation below the mean, at the mean, and one standard deviation above the mean of the exchange rate. The t-test assessed individual coefficients, while the F- or Wald test evaluated whether the regressors were jointly associated with NPM. The R-squared was interpreted exclusively as the

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proportion of variation in NPM explained by the model, not as the magnitude of causal influence. All statistical decisions were based on a two-tailed significance level of 5%.

Table 1. Variables and Measurement

Variable	Code	Operational measurement	Unit/source
Net Profit Margin		Net income after tax divided by revenue × 100	Percentage; PT Timah Tbk quarterly financial statements
Tin price		Arithmetic mean of all available daily LME tin prices within each quarter	USD per metric tonne; LME
COGS-based cost proxy		Cost of Goods Sold reported for the relevant quarter; treated as a financial-reporting proxy rather than pure production cost.	Rupiah; PT Timah Tbk quarterly financial statements and notes
Exchange rate		Arithmetic mean of available daily rupiah–US dollar rates within each quarter	IDR per USD; Bank Indonesia
Tin price × exchange rate		Product of standardized tin price and standardized exchange rate	Standardized interaction term
COGS × exchange rate		Product of standardized COGS and standardized exchange rate	Standardized interaction term
Production volume	Control	Tin output reported during the quarter	Metric tonnes; PT Timah Tbk operational reports
Sales volume	Control	Tin sales reported during the quarter	Metric tonnes; PT Timah Tbk operational reports

4. Results and Discussion

4.1 Analysis Results

4.1.1 *Descriptive Statistics*

Descriptive statistics provide an overview of the central tendency, dispersion, and distribution of the variables. The analysis covers 32 quarterly observations from 2018 to 2025.

Table 2. Descriptive Statistics

Statistic	NPM (Y)	Tin price (X_1)	COGS-based cost proxy (X_2)	Exchange rate (Z)
Mean	0.056188	26.040.06	6.658.701	15.068.06
Median	0.048500	25.301.00	5.756.405	14.923.50
Maximum	0.145000	43.719.00	18.167,065	16.720.00
Minimum	0.004000	15.756.00	1.715.460	13.756.00
Standard deviation	0.039942	7.560.687	3.991.851	895.9251
Skewness	0.565961	0.452822	0.917462	0.502458
Kurtosis	2.304086	2.270517	3.555596	1.985945
Jarque–Bera probability	0.308193	0.405937	0.086257	0.256975
Observations	32	32	32	32

Source: *Authors' calculations using EViews 13 (2026).*

Table 2 shows that NPM averaged 0.056188 (5.62%) and ranged from 0.40% to 14.50%. Tin prices averaged USD 26,040.06 per metric tonne, with values ranging from USD 15,756.00 to USD 43,719.00, indicating substantial price fluctuations. The COGS-based cost proxy averaged IDR 6,658,701 million and exhibited the greatest dispersion, with a standard deviation of IDR 3,991,851 million. This variable represents reported COGS rather than pure production cost. Meanwhile, the exchange rate

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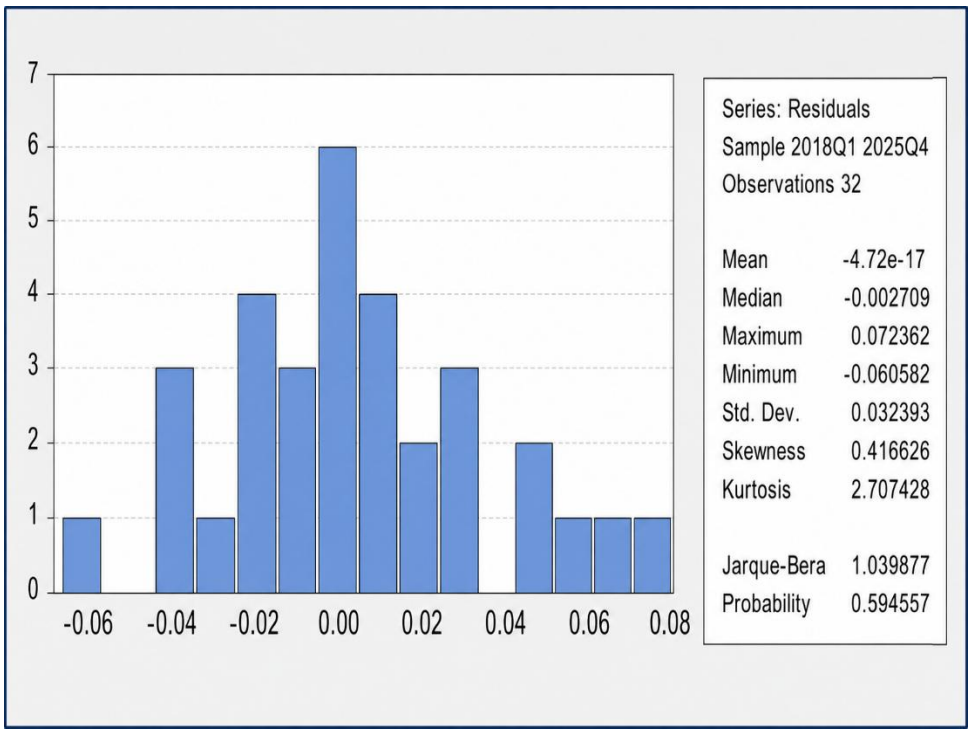
averaged IDR 15,068.06 per USD and showed comparatively lower dispersion. All variables were positively skewed. Their Jarque–Bera probabilities exceeded 0.05; however, regression normality must subsequently be evaluated using model residuals rather than these individual variables.

4.1.2 *Normality Test*

The normality test evaluates whether the regression residuals are approximately normally distributed. This assumption supports the validity of statistical inference in a small sample but does not determine whether the OLS estimators are unbiased. Residual normality was examined using the Jarque–Bera test at a 5% significance level. Residuals are considered consistent with normality when the probability value exceeds 0.05.

Figure 1. Distribution of Regression Residuals



Source: *Authors' calculations using EViews 13 (2026).*

Figure 1 shows a Jarque–Bera statistic of 1.039877 with a probability of 0.594557. Because the probability exceeds 0.05, the null hypothesis of normally distributed residuals is not rejected. Thus, the baseline regression residuals do not show statistically significant departures from normality. This conclusion is based on the probability value, not on comparing the Jarque–Bera statistic with 0.05.

4.1.3 *Multicollinearity Test*

Multicollinearity testing examines whether strong linear relationships exist among the explanatory variables. High multicollinearity may increase coefficient standard errors and make individual estimates unstable. The assessment uses the centered Variance Inflation Factor (VIF), with a value below 10 indicating no serious multicollinearity.

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Table 3. Variance Inflation Factor Results

Variable	Coefficient variance	Uncentered VIF	Centered VIF
Constant	0.012774	351.8679	N/A
Tin price (X_1)	8.08E−13	16.31468	1.231785
COGS-based cost proxy (X_2)	2.79E−18	4.590501	1.185494
Exchange rate (Z)	5.70E−11	357.5120	1.220242

Source: *Authors' calculations using EViews 13 (2026).*

Table 3 shows that the centered VIF values for tin price, the COGS-based cost proxy, and the exchange rate range from 1.185494 to 1.231785. As all values are below 10, no serious multicollinearity is detected in the baseline model. The uncentered VIF values are not used for this conclusion because the model includes a constant. Multicollinearity in the interaction model is assessed separately after the standardized interaction terms are introduced.

4.1.4 *Heteroscedasticity Test*

The White test was applied to determine whether the residual variance remains constant across observations. The null hypothesis is homoscedasticity. A probability value for Obs*R-squared greater than 0.05 indicates insufficient evidence to reject constant residual variance.

Table 4. White Heteroscedasticity Test

Test statistic	Value	Probability
F-statistic	1.004616	0.4653
Obs*R-squared	9.320715	0.4082
Scaled explained SS	6.092251	0.7307

Source: *Authors' calculations using EViews 13 (2026).*

Table 4 reports an Obs*R-squared probability of 0.4082, which exceeds 0.05. Therefore, the null hypothesis of homoscedasticity is not rejected, and the test provides no evidence of heteroscedasticity in the baseline regression residuals. This finding addresses the constancy of residual variance but does not, by itself, establish the overall adequacy of the regression model.

4.1.5 *Autocorrelation Test*

The Breusch–Godfrey Serial Correlation LM test was used to examine residual autocorrelation up to two lags. The null hypothesis states that no serial correlation exists. A probability value exceeding 0.05 indicates insufficient evidence to reject this hypothesis.

Table 5. Breusch–Godfrey Serial Correlation LM Test

Test statistic	Value	Probability
F-statistic	2.552060	0.0973
Obs*R-squared	5.251132	0.0724

Source: *Authors' calculations using EViews 13 (2026).*

Table 5 shows that the Obs*R-squared probability is 0.0724 and the F-statistic probability is 0.0973. Both values exceed 0.05; therefore, the null hypothesis of no serial correlation up to two lags is not rejected. The baseline model consequently shows no statistically significant evidence of residual autocorrelation at the 5% level, although the result is close to the significance threshold and should be interpreted with caution.

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4.1.6 Multiple Linear Regression

Multiple linear regression was employed to estimate the associations of tin price, the COGS-based cost proxy, and the exchange rate with PT Timah Tbk's Net Profit Margin (NPM). The model was estimated using Ordinary Least Squares with 32 quarterly observations.

Table 6. Multiple Linear Regression Coefficients

Variable	Code	Coefficient	Direction
Constant	C	−0.185570	—
Tin price	X_1	2.67E−06	Positive
COGS-based cost proxy	X_2	1.96E−09	Positive
Exchange rate	Z	1.06E−05	Positive

Dependent variable: Net Profit Margin (NPM).
Source: *Authors' calculations using EViews 13 (2026).*

Based on Table 6, the estimated regression equation is:

The tin-price coefficient is positive, indicating that a 1 USD increase in the quarterly average tin price is associated with a 0.00000267 increase in NPM, holding other variables constant. The COGS-based cost coefficient is also positive, but this should not be interpreted as evidence that higher production costs improve profitability. COGS may increase with production scale, sales activity, inventory adjustments, depreciation, royalties, and processing expenses, while these operational factors may be jointly determined with NPM. The exchange-rate coefficient indicates that an increase of IDR 1 per USD—representing rupiah depreciation—is associated with a 0.0000106 increase in NPM, ceteris paribus. The constant is not assigned a substantive economic interpretation because zero tin prices, COGS, and exchange rates fall outside the observed data range. These coefficients represent conditional associations rather than causal effects.

4.1.7 Moderated Regression Analysis

Moderated Regression Analysis was conducted to evaluate whether the rupiah–US dollar exchange rate moderates the associations between tin prices and the COGS-based cost proxy and NPM. The model includes the main effects and two interaction terms. Because the variables have substantially different measurement scales, the extremely small interaction coefficients should be interpreted relative to their original units rather than as evidence of weak economic effects.

Table 7. Moderated Regression Analysis Coefficients

Variable	Code	Coefficient	Direction
Constant	C	−0.691132	—
Tin price	X_1	2.05E−05	Positive
COGS-based cost proxy	X_2	1.59E−09	Positive
Exchange rate	Z	4.46E−05	Positive
Tin price × exchange rate	$X_1 \times Z$	−1.19E−09	Negative
COGS × exchange rate	$X_2 \times Z$	6.60E−19	Positive

Dependent variable: Net Profit Margin (NPM).
Source: *Authors' calculations using EViews 13 (2026).*

The estimated moderation equation is:

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The negative coefficient for the interaction between tin price and the exchange rate indicates that the estimated slope linking tin price with NPM decreases as the IDR-per-USD exchange rate rises. Conversely, the positive coefficient for the interaction between COGS and the exchange rate indicates that the estimated COGS–NPM slope increases as the exchange rate rises. However, the coefficient's direction alone does not demonstrate whether the exchange rate weakens or strengthens either relationship. Such a conclusion requires statistically significant interaction terms, confidence intervals that exclude zero, acceptable VIF values for the full interaction model, and a meaningful improvement over the main-effects model. Therefore, insignificant interaction coefficients must be reported as insufficient evidence of moderation, regardless of whether their estimated signs are negative or positive. The MRA coefficients also remain associational because profitability, COGS, output, sales, and exchange-rate exposure may be jointly related to unobserved operational conditions.

4.1.8 *Partial t-Test*

The partial t-test evaluates whether each regression coefficient differs significantly from zero. H1 and H2 were assessed using the main-effects regression model, whereas H3 and H4 were assessed using the interaction terms in the MRA model. Decisions were based on two-tailed probability values at the 5% significance level.

Table 8. Summary of Partial Tests and Hypothesis Decisions

Hypothesis and relationship	Coefficient	Std. error	t-statistic	p-value	Approximate 95% CI	Decision
H1: Tin price → NPM	2.67E−06	8.99E−07	2.968864	0.0061	[8.29E−07, 4.51E−06]	Supported
H2: COGS-based cost → NPM	1.96E−09	1.67E−09	1.173145	0.2506	[−1.46E−09, 5.38E−09]	Not supported
H3: Tin price × exchange rate → NPM	−1.19E−09	9.23E−10	−1.293925	0.2071	[−3.09E−09, 7.08E−10]	Not supported
H4: COGS × exchange rate → NPM	6.60E−19	1.22E−18	0.540557	0.5934	[−1.85E−18, 3.17E−18]	Not supported

Source: *Authors' calculations using EViews 13 (2026).*

Tin price has a positive and statistically significant coefficient (,); therefore, H1 is supported. The COGS-based cost coefficient is positive but not statistically significant (,). Because its direction is inconsistent with the hypothesized negative association and its confidence interval includes zero, H2 is not supported.

The tin price–exchange rate interaction is negative but not statistically significant (,), while the COGS–exchange rate interaction is positive but not statistically significant (,). Both confidence intervals include zero. Consequently, H3 and H4 are not supported, and there is insufficient evidence that the exchange rate moderates either relationship. The signs of these insignificant interaction coefficients must not be interpreted as weakening or strengthening effects.

4.1.9 *Simultaneous F-Test*

The F-test evaluates whether tin price, the COGS-based cost proxy, and the exchange rate are jointly associated with NPM in the main-effects model. Unlike individual coefficient tests, the F-test does not indicate a "positive" joint effect or identify which variable drives the overall significance.

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Table 9. Overall Model Test and Coefficient of Determination

Model statistic	Value
F-statistic	4.857523
Prob. F-statistic	0.007622
R-squared	0.342299
Adjusted R-squared	0.271832
Standard error of regression	0.034084
Durbin–Watson statistic	1.222439
Observations	32

Source: *Authors' calculations using EViews 13 (2026).*

Table 9 shows an F-statistic of 4.857523 with a probability of 0.007622. Because the probability is below 0.05, the null hypothesis that all slope coefficients are jointly equal to zero is rejected. Thus, tin price, the COGS-based cost proxy, and the exchange rate are jointly associated with NPM. This result does not demonstrate that all three variables are individually significant or that their combined relationship is positive.

4.1.10 *Coefficient of Determination*

The model has an of 0.342299, indicating that 34.23% of the observed quarterly variation in NPM is explained by tin price, the COGS-based cost proxy, and the exchange rate. After adjusting for the number of predictors and observations, the adjusted R-squared is 0.271832, indicating that the model explains approximately 27.18% of the variation in NPM. The remaining variation is unexplained by this specification and may relate to production and sales volume, financing costs, taxes, inventory movements, hedging, impairment losses, and other operational or macroeconomic factors. Accordingly, the model has modest explanatory power, and neither statistical significance nor supports describing tin price as the dominant or causal determinant of profitability.

4.2 Discussion

4.2.1 *Tin Price and Net Profit Margin*

The results support H1, indicating a positive association between international tin prices and PT Timah Tbk's Net Profit Margin. This finding is consistent with supply-and-demand theory, which provides the principal theoretical explanation for the relationship between commodity prices and mining-company profitability. When global demand rises relative to available supply, higher tin prices can increase the sales value received by an export-oriented producer. Provided that sales volume and operating costs do not change proportionately, the resulting revenue improvement can be reflected in a higher margin. Tin-price movements are especially relevant because metal markets exhibit persistent volatility and interconnected responses to global demand, supply disruptions, and trading conditions (Gong *et al.,* 2022; Gil-Alana & Poza, 2024). Tin circularity, supply constraints, and production planning may also influence market availability and price formation (Bradley *et al.,* 2024; Firmanto *et al.,* 2025).

The finding is consistent with Aprillia and Putri (2021), who identify tin price movements as a factor associated with the profitability of tin-mining companies. Nevertheless, the result does not establish tin price as the dominant or causal determinant of profitability. Commodity-price increases may not generate proportional improvements in NPM when they coincide with lower sales volume, higher extraction and processing costs, inventory adjustments, or unfavorable contractual and hedging

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positions. Commodity markets are also shaped jointly by production, consumption, and trading relationships rather than by an isolated price mechanism (Schischke *et al.,* 2024). Accordingly, the positive association should be understood as conditional on PT Timah Tbk's operating and market circumstances during the observation period.

4.2.2 *COGS-Based Cost Proxy and Net Profit Margin*

The results do not support H2 because the cost variable is not significantly associated with NPM and its estimated direction is inconsistent with the hypothesized negative relationship. Cost theory suggests that rising production costs should reduce profit when revenue and output remain unchanged. However, the variable used in this study is reported COGS rather than a direct measure of technical production cost. COGS may include processing expenses, depreciation, royalties, inventory adjustments, purchased materials, and other accounting components. Consequently, changes in COGS can reflect variations in production scale, sales activity, accounting recognition, and the composition of goods sold rather than cost inefficiency alone. The positive estimated direction must not be interpreted as evidence that higher costs improve profitability. COGS, production volume, sales, and profitability may be jointly determined because increased operating activity can simultaneously raise recognized costs, output, and revenue. Inventory accumulation and overproduction may also alter the timing of production expenditure recognition in earnings (He, 2023). Moreover, mining profitability is affected by capital efficiency, environmental obligations, operational risks, and supply-chain resilience (Badakhshan *et al.,* 2023; Bang & Trellevik, 2023; Radebe & Chipangamate, 2024).

The result differs from Zainuddin *et al.,* (2023), who report an association between production costs and net profit at PT Aneka Tambang Tbk. This difference may arise because net profit and NPM represent different outcomes and because company-level cost classifications are not necessarily comparable. Consistent with Savolainen *et al.,* (2022), the finding indicates that mining profitability must be evaluated alongside commodity prices, production planning, output, and operational efficiency. However, the exclusion of financing costs, taxes, inventory changes, hedging outcomes, and impairment losses means that the estimated coefficient may partly capture operational factors omitted from the model.

4.2.3 *Moderating Role of the Exchange Rate in the Tin Price–NPM Relationship*

The results do not support H3, meaning that the study provides insufficient evidence that the rupiah–US dollar exchange rate moderates the association between tin prices and NPM. The insignificant interaction must not be interpreted as evidence that the exchange rate weakens the relationship, given its negative direction. Instead, the result indicates that changes in the estimated tin price–NPM relationship across exchange-rate conditions cannot be distinguished reliably from sampling variation. This finding can be explained by the dual channels through which exchange rates affect an export-oriented mining company. Rupiah depreciation may increase the rupiah value of US-dollar export receipts. However, it may simultaneously raise the costs of imported equipment, fuel, spare parts, foreign-currency liabilities, and internationally priced services. Exchange-rate movements may therefore create offsetting revenue and cost effects. Their consequences also depend on the invoicing currency and firms' adjustments in export prices and quantities (Lee & Naknoi, 2024). Huang and Zhang (2024) similarly show that exchange-rate exposure differs between upstream suppliers and downstream customers within global value chains. These competing operational channels provide a more

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appropriate theoretical explanation than signaling theory, which does not directly explain the interaction tested in this study.

The finding is consistent with Ady (2021), who reports that the rupiah exchange rate does not moderate the relationship between commodity-related variables and mining-company performance. Sani and Purbadharmaja (2022) also indicate that the denomination of international commodity prices can affect the transmission of exchange-rate movements to domestic outcomes. Although Bielak *et al.,* (2021) identify metal prices and exchange rates as important mining-industry risks, their effects on profitability may offset each other when foreign-currency revenues coexist with foreign-currency costs. Furthermore, Indonesian trade responds asymmetrically to exchange-rate volatility, meaning that appreciation and depreciation need not produce equivalent consequences (Heriqbaldi *et al.,* 2023). Thus, the absence of moderation does not imply that exchange rates are economically irrelevant; it indicates only that the interaction specified in this model is not empirically supported.

4.2.4 *Moderating Role of the Exchange Rate in the COGS–NPM Relationship*

The results do not support H4 because the exchange rate does not significantly moderate the association between the COGS-based cost proxy and NPM. The positive sign of the interaction term cannot be interpreted as strengthening the relationship, as an insignificant coefficient does not indicate a systematic change in the COGS–NPM association. This interpretation is particularly important because COGS combines cost components with different levels of foreign-currency exposure. Domestic labor and locally sourced services may respond differently to exchange-rate movements than imported machinery, fuel, spare parts, and foreign-currency obligations. The absence of moderation may reflect the aggregation of heterogeneous cost components within COGS. Exchange-rate-sensitive and domestically determined costs can offset one another when combined into a single accounting figure. The timing of inventory recognition, depreciation, royalties, impairment charges, and hedging outcomes may further weaken the correspondence between current exchange-rate movements and reported quarterly COGS. Companies can also use foreign-currency cash-flow hedges to reduce exposure, although hedging decisions depend on managerial incentives and reporting transparency (Jin & Marshall, 2024). Consequently, exchange-rate movements do not necessarily generate uniform changes in reported costs or profitability.

This result is broadly consistent with Ady (2021), who finds no significant moderating role of the exchange rate in the relationship between mining company performance and exchange rates. It is also compatible with Lal *et al.,* (2023), who show that the consequences of exchange-rate volatility vary across countries, periods, and economic conditions. The finding should not be interpreted as proof that exchange rates have no role in PT Timah Tbk's cost structure. Rather, the available COGS proxy may be too aggregated to isolate the foreign-currency cost component through which moderation is theoretically expected. Future research should separate cash production costs, imported-input expenditures, royalties, depreciation, inventory movements, and hedging gains or losses to provide a more valid test of the proposed moderating mechanism.

5. Concluding Remarks and Recommendation

This study examined whether tin prices and reported costs are associated with PT Timah Tbk's Net Profit Margin (NPM) and whether the rupiah–US dollar exchange rate moderates these relationships during

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2018–2025. The analysis employed 32 quarterly observations, with daily tin prices and exchange rates aggregated using the arithmetic mean of all available trading-day values within each quarter. Reported Cost of Goods Sold (COGS) was treated as an accounting-based cost proxy rather than as equivalent to technical production cost. The results indicate that tin prices are positively associated with NPM, whereas the COGS-based cost proxy is not statistically associated with NPM. The interaction results also provide insufficient evidence that the exchange rate moderates either the tin price–NPM or COGS–NPM relationship. Accordingly, the signs of the insignificant interaction coefficients should not be interpreted as strengthening or weakening effects, and the findings reflect statistical associations rather than causal relationships.

Theoretically, this study integrates supply-and-demand reasoning, cost theory, and exchange-rate exposure to explain profitability in an export-oriented mining company. Its originality lies in its examination of commodity prices, reported costs, and exchange-rate interactions within a quarterly, company-level model. From a practical perspective, management should monitor global tin-price movements when planning production, sales, cash flows, and risk management. However, tin price should not be described as the dominant determinant of profitability merely because its coefficient is statistically significant. The model's modest explanatory power indicates that profitability is also associated with operational and financial conditions not included in the analysis. Management should therefore combine commodity-price monitoring with cost disaggregation, production planning, inventory control, and foreign-currency risk management. Investors should similarly assess tin prices alongside company-specific operating and financial information rather than treating commodity prices as a stand-alone indicator of future profitability.

This study is limited to one company, a relatively short observation period, and a modest number of quarterly observations, restricting its generalizability and statistical power. The use of COGS may weaken construct validity because it can include inventory adjustments, depreciation, royalties, processing expenses, and other accounting components. Potential simultaneity between costs, output, sales, and profitability also remains, while the exclusion of sales volume, production output, financing costs, taxes, inventory changes, hedging outcomes, and impairment losses may produce omitted-variable bias. Future studies should involve multiple mining companies, use longer quarterly or monthly series, distinguish cash production costs from reported COGS, and incorporate relevant operational and financial controls. They should also employ standardized interaction terms, report complete interaction-model VIF values, confidence intervals, changes in, and formal model comparisons, while considering panel-data, lagged-variable, instrumental-variable, or other identification strategies to address endogeneity more effectively.

Statement of Use of Generative AI

During the preparation of this work, the author used generative artificial intelligence tools to support the scientific writing process. Grammarly was used to check grammar, refine writing style, and improve clarity in scientific writing. All interpretations, analyses, and conclusions presented in this study are the sole responsibility of the author.

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