The Relationship between Value Addition and Profitability in Zambia's Copper Mining Sector

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ABSTRACT

Zambia remains a major copper producer, yet domestic participation is concentrated in extraction, concentration and cathode production rather than downstream beneficiation. This study examined the relationship between value addition and profitability in Zambia's copper mining sector. A positivist, longitudinal quantitative design was applied to ten annual observations for 2015-2024. Descriptive statistics, Pearson correlation and bivariate ordinary least squares regression were used. Estimated value addition increased from 18% to 27%, while estimated profit margin rose from 14.2% to 18.1%. Value addition was positively correlated with profit margin ($r = 0.710$, $p = 0.021$), and the regression explained 50.4% of margin variation. A one-percentage-point increase in value addition was associated with a 0.293-percentage-point increase in profit margin. The findings support selective downstream processing, provided Zambia strengthens electricity reliability, infrastructure, policy stability, industrial finance and market linkages.

Keywords: copper mining; value addition; profitability; mineral beneficiation; industrial policy; Zambia

INTRODUCTION

Background and context

Copper remains central to Zambia's export base, fiscal position and industrial development prospects. However, the commercial structure of the sector is still dominated by mining, concentration, smelting and refining, with comparatively limited participation in beneficiation activities such as rods, wires, cables, tubes and engineered components. This matters because value capture is not determined by production volume alone. Firms and economies positioned further downstream can combine material transformation, product differentiation, customer access and technical capability to secure wider margins and more stable revenue streams (Gereffi, 2018; World Bank, 2025).

The policy case for mineral beneficiation is embedded in Zambia's current development agenda. The Eighth National Development Plan (2022-2026) anchors economic transformation in industrialisation and value addition across mining and manufacturing, while the national energy-transition-minerals roadmap identifies reliable electricity, infrastructure, finance, skills and policy coordination as prerequisites for deeper downstream participation (Government of the Republic of Zambia, 2022; World Bank, 2025). Despite that policy intent, the gap between refined copper production and domestic beneficiation remains material. Zambia therefore captures substantial export earnings from copper but retains a smaller portion of the value embedded in finished products and associated services.

The profitability proposition is credible but not automatic. Smelting, refining and manufacturing require capital, dependable electricity, specialised technology, quality control, logistics and access to product markets. Additional processing may increase unit value, but it also adds fixed costs, working-capital requirements and market risk. Profitability is further affected by global copper prices, exchange-rate movements, ore grades, energy tariffs and production disruptions (Bank of Zambia, 2026; International Monetary Fund, 2026). A sound assessment must therefore distinguish a positive statistical association from proof of causality.

Critical literature synthesis

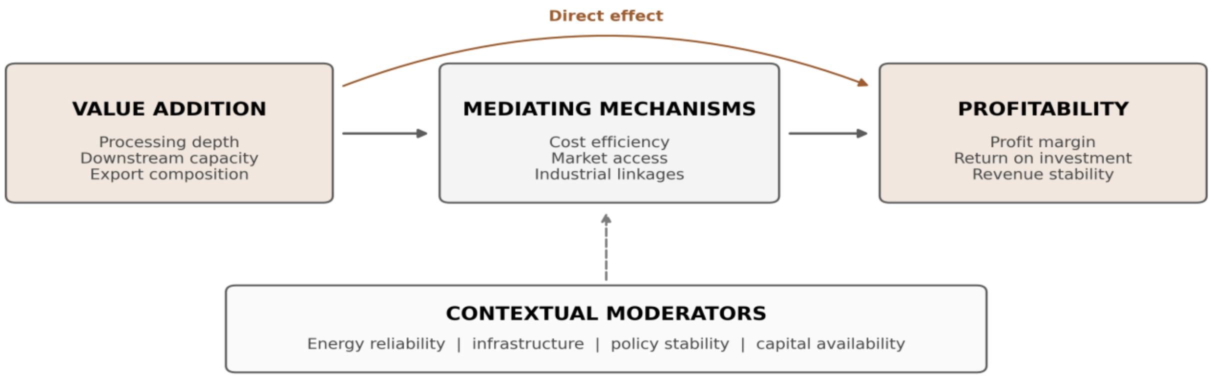
Contemporary strategy analysis treats competitive advantage as the outcome of linked activities rather than the simple possession of a natural resource (Grant, 2024). Applied to copper, extraction creates the initial mineral value, while further value may be created through concentration, smelting, refining, alloying, fabrication, engineering, distribution and customer-specific product development. Downstream movement can therefore improve profitability through higher unit prices, a broader customer base, product differentiation and reduced dependence on a single commodity quotation.

The resource-based view adds an important qualification. Copper deposits are valuable, but mineral ownership alone does not generate sustained competitive advantage when producers sell broadly standardised material into the same global market. Superior returns depend on capabilities that are scarce and difficult to replicate, including process technology, engineering skills, low-cost energy arrangements, reliable operations, product certification and market relationships (Barney & Mackey, 2016). Value addition should therefore be understood as a capability-building strategy rather than merely the installation of additional processing equipment.

Global value-chain theory further explains why participation and value capture are not equivalent. A country may be deeply integrated into a global chain while remaining concentrated in functions with limited pricing power (Gereffi, 2018). Transaction cost economics explains why firms may rationally remain upstream: internalising fabrication is commercially defensible only when expected gains exceed the costs of capital, coordination, market development and policy uncertainty (Ketokivi & Mahoney, 2020). Recent commodity-dependence and Zambia-specific research similarly shows that mineral-rich economies can remain concentrated in lower-value functions when local firms, finance, technology and enabling infrastructure are weak (United Nations Conference on Trade and Development, 2025; Cervantes Barron, Clube, Chabala, Matokwani, & Chikwamo, 2024).

Recent evidence specific to Zambia is dominated by macroeconomic, policy and value-chain analysis. Institutional sources document copper's importance to the external sector, the economy's exposure to commodity cycles and the need for stronger mining-manufacturing linkages (International Copper Study Group, 2025; Bank of Zambia, 2026; World Bank, 2025). Current peer-reviewed evidence also highlights limited local-company participation and weaknesses in the enabling environment for downstream ventures (Cervantes Barron, Clube, Chabala, Matokwani, & Chikwamo, 2024). However, these sources discuss output, exports, investment conditions and diversification more often than they quantify the relationship between downstream participation and profitability.

Figure 1. Analytical framework linking value addition and profitability



Note: Adapted from the conceptual framework in the underlying study.

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Research gap, rationale and study focus

The literature supports a strong strategic case for value addition but leaves a clear empirical gap. Few Zambian studies connect a measurable value-addition indicator to a financial-performance indicator over time, and audited firm-level data are difficult to obtain. Addressing this gap is important because policy incentives and private capital should be directed toward downstream activities that can generate durable, risk-adjusted returns rather than toward beneficiation as an end in itself.

The research gap was analysed using the following research questions:

- What pattern is visible in copper production, estimated value addition and estimated profit margin from 2015 to 2024?
- Is estimated value addition significantly associated with estimated profit margin in Zambia's copper mining sector?
- Which operating and policy conditions determine whether downstream investment can translate into sustainable profitability?

Null hypothesis (H0): Estimated value addition has no statistically significant relationship with estimated profit margin.

Alternative hypothesis (H1): Estimated value addition has a positive and statistically significant relationship with estimated profit margin.

The study is delimited to Zambia's copper mining sector and ten annual observations covering 2015-2024. The analysis is sector-level rather than firm-level and evaluates association rather than causation. The remainder of the article describes the methodology, reports the results, interprets the findings against the literature, and closes with implications, limitations, future research priorities and a conclusion.

METHODOLOGY

Research design

The study adopted a positivist, deductive and mono-method quantitative design. A longitudinal correlational strategy was appropriate because the objective was to test whether annual changes in estimated value addition were associated with changes in estimated profitability over time. The design used secondary sector data and did not manipulate operating conditions; it therefore supports statistical inference about association but does not establish a causal effect.

Population, sample and data sources

The target analytical population comprised annual performance outcomes for Zambia's copper mining sector. The sample consisted of ten sector-year observations from 2015 to 2024. The period was selected using a criterion-based approach: all years in the supplied study with complete values for copper production, estimated value addition and estimated profit margin were included. The sample size therefore reflects complete coverage of the available study period rather than a power calculation or sampling of human participants.

Variables, materials and analytical model

Three annual series formed the analytical material. Copper production, measured in thousands of tonnes, provided sector context. Estimated value addition, expressed as a percentage, was the independent variable and represented the reported progression in domestic processing and downstream participation. Estimated sector profit margin, also expressed as a percentage, was the dependent variable and served as the profitability proxy. No questionnaire, interview protocol or laboratory apparatus was used.

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The underlying study proposed copper prices, exchange rates, energy costs and production volume as possible controls. Because a complete multivariable series was not supplied, the estimable specification was deliberately restricted to a bivariate ordinary least squares model: PMt = b0 + b1VAt + et. In this equation, PMt is the estimated profit margin in year t, VAt is estimated value addition, b0 is the intercept, b1 is the slope and et is the error term. The slope measures the percentage-point change in estimated profit margin associated with a one-percentage-point change in estimated value addition.

Procedure and data analysis

First, the reported annual values were ordered chronologically and checked for consistent units and completeness. Second, means, sample standard deviations, minima and maxima were calculated for each series. Third, Pearson's product-moment correlation was used to estimate the strength and direction of the association between value addition and profit margin. Fourth, the bivariate ordinary least squares model was fitted and the coefficient, standard error, t statistic, 95% confidence interval, R-squared and F statistic were reported. Finally, model adequacy was assessed using the Shapiro-Wilk test of residual normality, Breusch-Pagan test of heteroscedasticity and Durbin-Watson statistic for first-order serial dependence. Multicollinearity testing was not applicable because the model contained one explanatory variable.

All hypothesis tests were two-sided and evaluated at the 5% significance level. The dataset was organised in Microsoft Excel, and the descriptive statistics, regression estimates and diagnostic values were independently verified in Python using NumPy and SciPy. The analysis remains exploratory because ten observations provide limited statistical and diagnostic power.

Ethical considerations

The study used secondary, sector-level information and did not involve human participants, personal data or an experimental intervention. Informed consent and institutional review approval were therefore not applicable. The article reports the full analytical series to support transparency, identifies estimated measures clearly, and avoids presenting association as proof of causality. No external research funding or conflict of interest was reported.

RESULTS

Descriptive results

Copper production averaged 790.5 thousand tonnes per year (SD = 58.1) and ranged from 698 thousand tonnes in 2023 to 882 thousand tonnes in 2020. Production ended the period at 821 thousand tonnes, compared with 711 thousand tonnes in 2015, which is equivalent to an approximate compound annual growth rate of 1.6%. The pattern was volatile rather than linear, with strong years followed by contractions.

Estimated value addition averaged 22.1% (SD = 2.8) and increased from 18% in 2015 to 27% in 2024. Estimated profit margin averaged 16.2% (SD = 1.1), with a minimum of 14.2% and a maximum of 18.1%. Margins weakened in 2019, 2022 and 2023 despite the continuing rise in the value-addition estimate. This divergence shows that production and processing depth do not fully account for year-to-year profitability.

Table 1. Annual copper production, value addition and profit margin, 2015-2024

Year	Copper production ('000 tonnes)	Estimated value addition (%)	Estimated profit margin (%)
2015	711	18	14.2
2016	774	19	15.1
2017	801	20	16.3

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2018	861	21	17.0
2019	792	22	15.4
2020	882	22	16.8
2021	801	23	17.2
2022	764	24	16.5
2023	698	25	15.8
2024	821	27	18.1

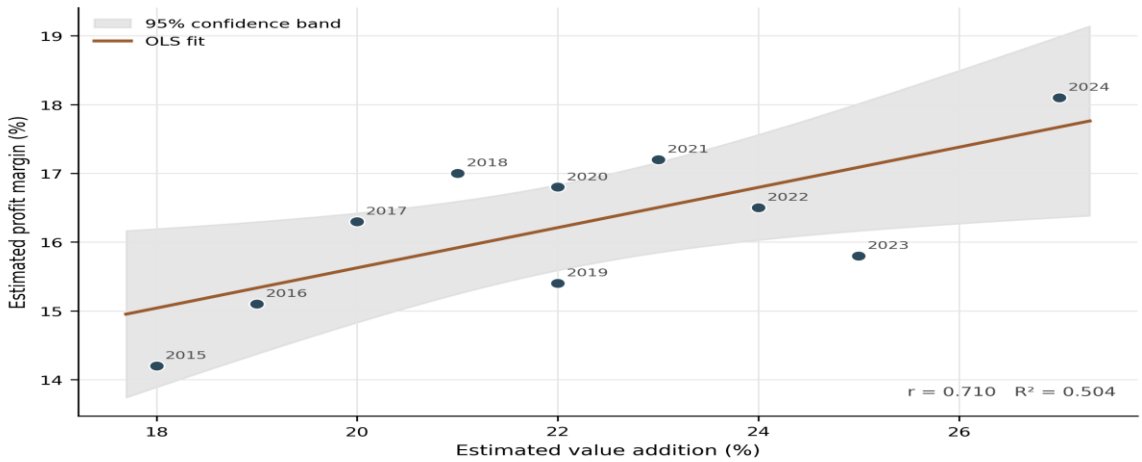
Source: Author's calculations from the annual secondary series reported in the underlying study.

Association and hypothesis testing

Estimated value addition and profit margin were positively correlated ($r = 0.710$, $p = 0.021$). The relationship was statistically significant at the 5% level. Figure 2 presents the annual observations, fitted ordinary least squares line and 95% confidence band. The pattern is positive but dispersed; years with similar value-addition estimates recorded different margins, indicating the influence of unobserved market and operating conditions.

The ordinary least squares slope was 0.293 (SE = 0.103, $t = 2.851$, $p = 0.021$). Within the reported series, a one-percentage-point increase in estimated value addition was associated with an average 0.293-percentage-point increase in estimated profit margin. The 95% confidence interval ranged from 0.056 to 0.529. The model explained 50.4% of observed margin variation (adjusted R-squared = 0.442) and was statistically significant, $F(1, 8) = 8.129$, $p = 0.021$.

Figure 2. Relationship between estimated value addition and estimated profit margin, 2015-2024



Note: Labels identify observation years; the shaded area is the 95% confidence band for the fitted mean response.

Table 2. Ordinary least squares estimates for estimated profit margin

Term	**B**	**SE**	**t**	**p**	**95% CI**
Constant	9.774	2.284	4.279	0.003	[4.507, 15.040]
Value addition (%)	0.293	0.103	2.851	0.021	[0.056, 0.529]

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Note: Dependent variable = estimated profit margin (%); n = 10; R-squared = 0.504; adjusted R-squared = 0.442; F(1, 8) = 8.129, p = 0.021.

Regression diagnostics

The diagnostic statistics did not identify a material violation of the basic bivariate ordinary least squares assumptions. Residuals were consistent with normality, their variance showed no systematic change across fitted values, and the Durbin-Watson statistic was close to two. These findings support interpretation of the model within the sample, although the small number of observations limits the power of all diagnostic tests.

Table 3. Diagnostic tests for the bivariate regression model

Assumption	Test	Statistic	p	Interpretation
Residual normality	Shapiro-Wilk	W = 0.926	0.413	No departure detected
Homoscedasticity	Breusch-Pagan	LM = 0.051	0.821	No heteroscedasticity detected
Serial dependence	Durbin-Watson	DW = 2.037	-	No first-order autocorrelation indicated
Multicollinearity	Not applicable	One predictor	-	VIF is not meaningful

Note: Non-significant p values for the Shapiro-Wilk and Breusch-Pagan tests are consistent with the respective assumptions. Diagnostic power is limited by n = 10.

DISCUSSION

Summary of findings and hypothesis decision

The study found that estimated value addition and estimated profit margin moved together positively across the 2015-2024 series. The correlation and regression slope were statistically significant at the 5% level, and the bivariate model explained approximately half of the observed annual variation. The null hypothesis was therefore rejected and the alternative hypothesis was supported within the reported sample. This decision concerns statistical association only; it does not demonstrate that a specific downstream investment caused the observed margin changes.

Interpretation and comparison with the literature

The positive direction is consistent with value-chain theory. Downstream transformation can raise unit value, diversify the product mix and provide access to customers who purchase technical specifications rather than undifferentiated metal (Grant, 2024). The result is also consistent with the resource-based view because profitable downstream participation depends on accumulated processing, engineering and market capabilities, not copper reserves alone (Barney & Mackey, 2016). From a global value-chain perspective, the result supports movement toward functions with greater scope for product differentiation and customer-specific value (Gereffi, 2018).

The findings also reinforce the caution in transaction cost economics. The fitted model left 49.6% of annual margin variation unexplained. Margin declines in 2019, 2022 and 2023 occurred while the value-addition estimate continued to rise. This pattern is consistent with a conditional relationship in which copper prices, energy costs, operational efficiency, exchange-rate movements and production disruptions can strengthen or offset the commercial benefits of processing (Ketokivi & Mahoney, 2020; Bank of Zambia, 2026; International Monetary Fund, 2026). Recent official data also show that refined-copper export earnings and volumes can shift materially from month to month (Zambia Statistics Agency, 2026). The correct managerial question is therefore not whether value addition is desirable in the abstract, but which products, technologies and market channels can generate risk-adjusted returns under Zambia's operating conditions.

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The production series supports the same interpretation. Output fluctuated between 698 and 882 thousand tonnes, but production and value addition did not move together in a simple pattern. Higher extraction can increase revenue when prices are favourable, yet it does not by itself change Zambia's functional position in the global copper chain. A value-capture strategy must connect mining output to competitive downstream facilities and customers; otherwise, additional tonnes mainly scale the existing upstream model.

Theoretical and practical implications

Theoretically, the study links value-chain positioning to profitability in a resource-dependent economy and shows that capability and context should be treated as part of the explanatory mechanism. Value addition may affect profitability directly through higher-value products and indirectly through cost efficiency, market access and industrial linkages. Energy reliability, infrastructure, policy stability and capital availability moderate the strength of that relationship. The findings therefore extend a simple processing-profit argument into a conditional value-capture framework.

For government, a stable mining and industrial policy framework should be paired with dependable electricity, lower logistics friction and clear investment-approval processes. Fiscal incentives should be transparent, time-bound and conditional on verifiable downstream output, employment, exports and technology transfer. Public procurement and regional trade opportunities can support demand, but product standards and competitive pricing must remain non-negotiable (Government of the Republic of Zambia, 2022; World Bank, 2025; Cervantes Barron, Clube, Chabala, Matokwani, & Chikwamo, 2024).

For mining companies, downstream expansion should be staged. Firms can begin with product lines that use existing cathode output, have proven regional demand and require manageable technology transitions. Joint ventures with cable, conductor and component manufacturers can provide technical knowledge and customer access. Investors and lenders should test power security, feedstock arrangements, logistics, product certification, market contracts and policy durability before committing long-term capital. Value addition is commercially credible only when those fundamentals are secured (World Bank, 2025).

For research and reporting institutions, the immediate requirement is better data architecture. Zambia would benefit from an annual mineral value-chain dataset that distinguishes concentrates, anodes, cathodes, semi-fabricated products and finished copper goods and, where possible, links those products to costs, employment, investment and financial performance. Such reporting would allow public policy and private investment to move from broad aspiration to evidence-based portfolio management (World Bank, 2025).

Future research

Future studies should use audited firm-level or product-level panel data and distinguish value capture at the concentrate, anode, cathode, rod, wire, cable and component stages. Multivariable models should include copper prices, exchange rates, power cost and reliability, ore grade, capacity utilisation, financing cost and production volume. Quasi-experimental designs could examine major policy or electricity-supply changes, while project-level studies should compare the life-cycle economics of specific downstream products. Qualitative interviews with mines, manufacturers, lenders and regulators could also explain the contracting, technology and market-access mechanisms that annual sector data cannot capture.

CONCLUSION

This study examined whether value addition was associated with profitability in Zambia's copper mining sector. Across the 2015-2024 estimates, higher value addition was associated with higher profit margins, and the bivariate model explained approximately half of the observed annual variation. The evidence supports the alternative hypothesis within the sample and is directionally consistent with value-chain, resource-based and global value-chain theories.

The central implication is practical: Zambia is unlikely to maximise copper value capture through production growth alone. Selective downstream processing and manufacturing can improve commercial outcomes, but only when supported by reliable electricity, efficient infrastructure, stable regulation, suitable finance, technical capability and access to credible markets. The strategic objective should therefore be profitable and competitive value addition, not processing depth for its own sake.

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