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Macro And Microeconomic Reflections on National Productivity in The Electrical Energy Sector

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ABSTRACT

This study aims to analyze the effect of National Electricity Consumption on National Productivity, proxied by Indonesia's Gross Domestic Product (GDP), and to examine the moderating roles of the Producer Price Index (PPI) and Micro and Small Enterprise (MSE) Output in this relationship. Theoretically, this study integrates Transmission Mechanism Theory, Cost-Push Theory, and Input-Output Analysis to explain that the relationship between electricity consumption and GDP is influenced by the absorption capacity of the real sector and production cost pressures. This study uses secondary data for the period 2010–2023 obtained from Statistics Indonesia (BPS), PT PLN (Persero), and the Ministry of Energy and Mineral Resources, employing a regression approach with a moderation model to test direct and interaction effects. The results indicate that National Electricity Consumption does not have a statistically significant effect on GDP, and neither PPI nor MSE Output significantly moderates this relationship. These findings suggest that the relationship between electricity consumption and economic growth cannot be empirically supported within the specified model and indicate limitations in model specification as well as potential multicollinearity issues. Conceptually, the results remain relevant to theoretical frameworks emphasizing the importance of structural conditions such as price stability and real sector capacity; however, policy implications should be interpreted cautiously. This study contributes by highlighting the need for careful interpretation of the energy–growth relationship and the importance of more appropriate methodological approaches in future research.

ABSTRAK

Penelitian ini bertujuan untuk menganalisis pengaruh Penggunaan Listrik Nasional terhadap Produktivitas Nasional yang diproksikan melalui Produk Domestik Bruto (PDB) Indonesia, serta menguji peran moderasi Indeks Harga Produsen (IHP) dan Output Usaha Mikro dan Kecil (UMK) dalam hubungan tersebut. Secara teoretis, penelitian ini mengintegrasikan Transmission Mechanism Theory, Cost-Push Theory, dan Input-Output Analysis untuk menjelaskan bahwa hubungan antara penggunaan listrik dan PDB dipengaruhi oleh kapasitas absorpsi sektor riil serta tekanan biaya produksi. Penelitian ini menggunakan data sekunder periode 2010–2023 yang bersumber dari Badan Pusat Statistik (BPS), PT PLN (Persero), dan Kementerian Energi dan Sumber Daya Mineral, dengan metode analisis regresi dan model moderasi untuk menguji efek langsung dan interaksi antar variabel. Hasil penelitian menunjukkan bahwa Penggunaan Listrik Nasional tidak berpengaruh signifikan terhadap PDB Nasional, serta IHP dan Output UMK juga tidak terbukti secara signifikan memoderasi hubungan tersebut. Temuan ini menunjukkan bahwa hubungan antara konsumsi listrik dan pertumbuhan ekonomi tidak dapat dijelaskan secara empiris dalam model yang digunakan, serta mengindikasikan keterbatasan dalam spesifikasi model dan potensi masalah multikolinearitas. Secara konseptual, hasil ini tetap relevan dengan kerangka teori yang menekankan pentingnya kondisi struktural seperti stabilitas harga dan kapasitas sektor riil, namun implikasi kebijakan perlu ditafsirkan secara hati-hati. Penelitian ini memberikan kontribusi dengan menekankan pentingnya kehati-hatian dalam interpretasi hubungan energi dan pertumbuhan ekonomi serta perlunya pendekatan metodologis yang lebih tepat dalam penelitian selanjutnya..

INTRODUCTION

In the era of digitalization and Industry 4.0, electrical energy has become a primary infrastructure that supports all aspects of life and economic activity, starting from the birth of a baby (heart monitors, hospital communication, health equipment), growing up to adulthood, until entering the grave (family communication, transportation, and administrative management). Thus, electricity

can be viewed as a national driving motor so that all lines of life can run as they should. The electricity sector plays an important role in the development of a country. Its role is not only limited as a means of production to facilitate the development of other economic sectors (such as manufacturing, agriculture, mining, education, and health), but also as a factor that can meet the daily social needs of the community (Adam, 2016).

At the national level (macroeconomics), reliable electricity availability is a prerequisite for the expansion of GDP-driving sectors (manufacturing industry, digital services, distribution, infrastructure, etc.) so that fluctuations in electricity supply directly affect national growth (Zambrano-Monserrate, 2026). Data shows the trend of increasing electricity consumption has a tendency for consistency along with economic growth. Currently in Indonesia, national electricity consumption per capita increased from around 485 kWh/capita in 2010 to 1,285 kWh/capita in 2023 (a significant increase compared to 1,173 kWh/capita in 2022). Total national electricity consumption reached 288.4 TWh in 2023, with the industrial and commercial sectors contributing a large portion (around 88.5 TWh for industry alone). Meanwhile, national GDP (at 2010 constant prices) grew from around 9,913 trillion Rupiah in 2017 to 12,301 trillion Rupiah in 2023, showing a positive correlation with increased access and consumption of electricity (ESDM Indonesia, 2023).

However, this causality is not always linear due to supply reliability factors. Electricity unreliability (power outage or load shedding) causes quite substantial economic losses (Zambrano-Monserrate, 2026). Some empirical studies show that power outages can suppress industrial output and GDP growth. For example, the major blackout in Java-Bali in 2019 affected more than 30 million customers and caused very widespread economic disruption (Suryadi, 2020; Tempo, 2019). Estimated losses from heavy outages in Indonesia can reach US$1-3 million per hour for large-scale businesses (especially the industrial and logistics sectors), which if accumulated nationally could potentially reach billions of dollars per year (Falentina and Resosudarmo, 2019).

At the microeconomic level, the effectiveness of transmitting electricity stimulus into productivity highly depends on the absorption capacity of the Micro and Small Enterprise (MSE/UMK) sector. The MSE sector is the backbone of Indonesia's real economy, with a dominant contribution to labor absorption and value-added formation. In 2023, MSEs absorbed around 60.5% of the national workforce (around 97 million people out of a total of 160 million labor force) and contributed 37.3% to the non-oil and gas GDP (Junaidi, 2024; Kiswandi et al., 2023). If viewed from the overall MSME data (micro + small + medium), the contribution increases to 61.07% of the national GDP or valued at Rp8,573.89 trillion, with labor absorption reaching 117 million people (97% of the total national workforce) and the number of business units reaching 64.2 million (Antara Foto, 2025; Junaidi, 2024; Santi, 2024).

Nevertheless, MSE productivity is still low due to limited access to reliable electricity; only about 54% of MSE actors have a stable electricity supply, while the rest depend on private generators with 30% higher operational costs (Falentina and Resosudarmo, 2019; Handayani et al., 2024). The link between electricity consumption and MSE output is increasingly complex because of the role of the Producer Price Index (PPI/IHP) as a moderator. PPI reflects the overall production input cost pressure, including the price of electrical energy, raw materials, and logistics. This increase in PPI significantly erodes MSE profit margins because this sector has a high cost elasticity towards input price fluctuations (Greve et al., 2023).

Theoretically, economic growth theory, especially endogenous growth theory, emphasizes that economic growth is influenced by internal factors such as investment in physical capital, human resources, and technology. In this context, electrical energy is considered one of the critical production factors that support economic activity, especially in the industrial and business sectors

(Romer, 1990). Furthermore, Transmission Mechanism Theory explains the process of how an economic stimulus or production input is transmitted through various channels to affect final macroeconomic variables. This is complemented by Cost-Push Theory, which explains how increased production costs on the supply side can shift the aggregate supply curve, resulting in decreased output and employment.

Empirical literature regarding the relationship between electricity and economic growth has developed in three main streams, yet limitations remain. Macroeconomic studies often ignore sectoral heterogeneity and transmission mechanisms at the micro level. This fragmentation between macro and micro analysis leads to several critical gaps in current research.

This study aims to analyze the direct effect of National Electricity Consumption on National Productivity (GDP) in Indonesia. Furthermore, it examines the moderating role of the Producer Price Index (PPI) to empirically prove that macroeconomic input cost pressure alters the marginal elasticity of electricity conversion into economic output. Lastly, it tests the moderating role of Micro and Small Enterprise (MSE) Output to prove that microeconomic absorption capacity functions as a critical transmission channel in national economic growth.

RESEARCH METHOD

The object of this research is the effect of electricity consumption on gross domestic product (GDP) with the output of the micro and small-scale industrial sectors and the producer price index as moderating variables. This study is explanatory, which aims to explain the relationship between variables and identify cause-and-effect. A quantitative method is used to measure variables and analyze data statistically. The time horizon used is a longitudinal study, which allows the researcher to observe changes and developments of phenomena over time.

The variables in this study are categorized into independent, moderating, and dependent variables. The independent variable (X1) is Electricity Consumption, selected because electrical energy is a primary input in the production process of the micro and small-scale industrial sector. The moderating variables are Industrial Sector Output (M1), specifically in micro and small industries, and the Producer Price Index (M2). The dependent variable (Y) is Gross Domestic Product (GDP), which conceptually represents aggregate national productivity, namely the ability of the Indonesian economy to convert all production factors into economic value added.

Table 1. *Operationalization of Research Variables*

Variable Code	Variable	Indicator Code	Variable Indicator	Measurement Scale	Scale
X1	Electricity Consumption	X1.1	National Electricity Consumption per Capita	GWh	Ratio
		X1.2	Connected Power	MVA	Ratio
		X1.3	Number of Customers	Customers	Ratio
X2	Producer Price Index	X2.1	Producer Price Index	-	Ratio
Y1	Industrial Sector Output	Y1.1	Micro and Small Scale Industrial Output	Billion Rupiah	Ratio
		Y1.2	Number of Micro and Small Scale Industrial Workers	People	Ratio

The data used in this research is secondary data, collected to optimize time and cost efficiency. The data sources include: (1) Value of Micro and Small Industry Output according to 2-digit ISIC 2010-2023 from Statistics Indonesia (BPS); (2) Indonesian Producer Price Index 2010-2023 from BPS; (3) PLN Statistics Book 2010-2023 from PT PLN (Persero); (4) Electricity Consumption per Capita 2010-2022 from BPS; (5) Electricity Statistics 2010-2023 from the Ministry of Energy and Mineral Resources; and (6) GDP from BPS reports. The data collected covers the period from 2010 to 2023.

The population in this study is the Output of Micro and Small Industries According to 2-digit ISIC 2010-2023 in Indonesia covered in the database organized by BPS. The inclusion criteria for the population are: (1) businesses classified as Micro and Small Industries according to the BPS definition; (2) businesses having complete and valid data for the three key variables; and (3) businesses operating in the manufacturing industry subsector (ISIC 10-33) to ensure homogeneity. The final sample was determined through a data curation process including filtering, handling missing data using listwise deletion, and identifying outliers using the Interquartile Range (IQR) method followed by winsorizing.

Table 2. *Procedure and Results of Research Sample Selection*

No	Selection Stage / Criteria	Number of Observations	Description
1	Total observations in the 2010 – 2023 dataset.	624	Raw BPS (Statistics Indonesia) data
2	Screening: Only micro & small enterprises (MSE) in the manufacturing sector.	624	Apply ISIC filter & scale
3	Cleaning: Delete observations with missing data on key variables.	27	Listwise deletion
4	Handling extreme outliers (Winsorizing).	0 (values adjusted)	Total observations remain the same
5	Final Sample	597	Ready for analysis

This study uses a quantitative regression-based approach as the primary analytical method to examine the relationships between observed variables, considering the limited sample size which is not adequate for complex multivariate modeling such as PLS-SEM. The analysis focuses on direct estimation of relationships between independent, moderating, and dependent variables without separating measurement and structural models.

The model is evaluated using standard statistical measures such as coefficient of determination (R^2), significance testing of regression coefficients ($p < 0.05$), and robustness checks appropriate for small sample sizes. To interpret the moderating effects, Simple Slope Analysis (SSA) is utilized to examine the slope of the relationship between the independent and dependent variables at various levels of the moderator variable.

RESULT and DISCUSSION

Descriptive Analysis

Descriptive analysis can be used to provide a general overview of the characteristics of research data before further analysis is carried out. The discussion is carried out on each indicator of research variables, including the minimum, maximum, and average values, as well as patterns or trends of data movement during the observation period. The following is the descriptive analysis of each variable:

X1 - National Electricity Consumption

National Electricity Consumption is measured through three complementary operational indicators: electricity consumption per capita (X11), total electricity consumption in MWh (X12_MWH), and the number of electricity customers (X13_Pelanggan). Data for the 2010-2023 period shows a consistent upward trend in all three indicators, reflecting the expansion of access and intensity of electricity utilization in the Indonesian economy. Electricity consumption per capita increased from 0.7 in 2010 to 1.3 in 2023, representing a growth of 85.7% over 13 years of observation. Total national electricity consumption increased from 26,894.98 MWh in 2010 to 45,095.19 MWh in 2023, with an average annual growth rate of 3.9%.

The most significant growth occurred in the 2013-2014 period (14.8% increase) coinciding with the acceleration of electricity infrastructure development after the first stage of the 35,000 MW policy. Meanwhile, the number of electricity customers showed the most dynamic increase, growing from 42,435,387 customers in 2010 to 89,153,278 customers in 2023, an increase of 110.1% or an average of 6.0% per year. The largest surge occurred in the 2019-2020 period (4.4% increase) reflecting the success of the rural electrification program and free electricity connections for underprivileged households. These three indicators collectively illustrate the structural transformation of Indonesia's electricity sector from a state of limited access at the beginning of the decade to increasingly inclusive and intensive energy infrastructure.

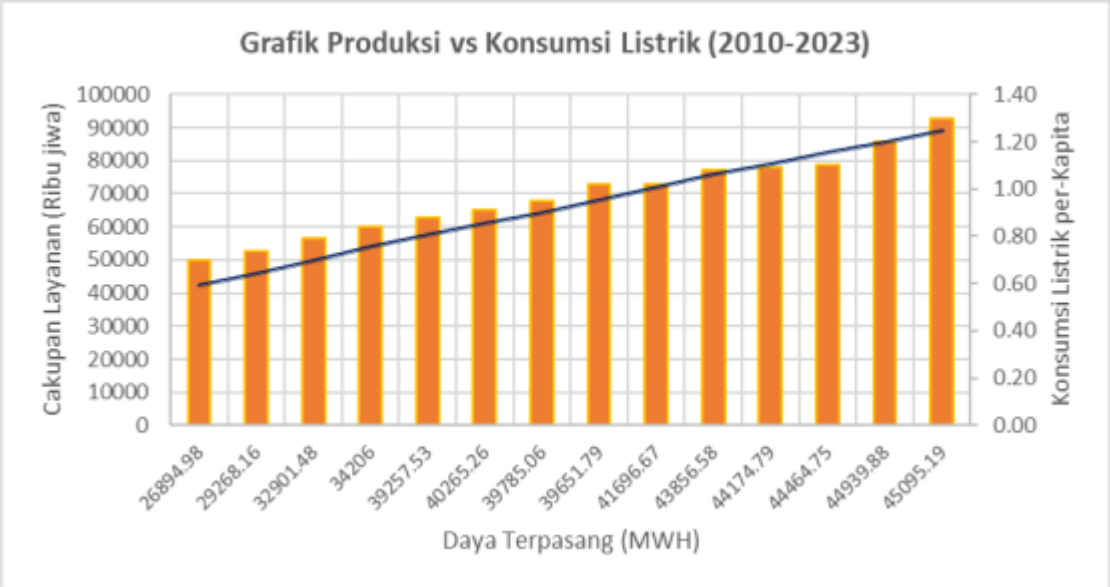

Figure 1. *Recapitulation Graph of Variable X1*

Figure 1 presents the trend of national electricity consumption (X1) in Indonesia from 2010 to 2023. The data show a consistent upward trend, reflecting increasing energy demand driven by economic and industrial activities.

M1 - Micro and Small Enterprise (MSE) Output

Micro and Small Enterprise (MSE) Output is measured through two complementary dimensions: aggregate output value in trillion Rupiah (M11_IDRTriliun) and labor absorption in thousands of people (M12_RibuJiwa). Data shows solid but not entirely linear growth in both dimensions, reflecting the structural dynamics of Indonesia's MSE sector. MSE output value increased from IDR 2,208 trillion in 2010 to IDR 4,536 trillion in 2023—an increase of 105.4% or an average of 5.8% per year.

The most rapid growth occurred in the 2014-2015 period (17.4% increase) coinciding with ultra-micro financing policies and loan restructuring programs for MSEs affected by subsidy reform. However, there was a decrease anomaly in 2016 (from IDR 4,287 trillion to IDR 3,979 trillion)

reflecting the transmission impact of increased operational costs post-subsidy reform on MSE profit margins. The dimension of labor absorption shows an increasing trend from 4,501 thousand people (4.5 million) in 2010 to 9,918 thousand people (9.9 million) in 2023, an increase of 120.3% or an average of 6.3% per year. A significant surge occurred in the 2018-2019 period (56.2% increase) reflecting the expansion of the digital MSE sector and e-commerce. However, labor growth is not always in line with the increase in output value, as seen in the 2019-2021 period where labor absorption increased by 4.5% while the output value only grew by 2.1%—indicating a decrease in labor productivity due to pandemic disruptions and limited technology access.

Figure 2. *MSE Output Trend Graph (2010-2023)*

Figure 2 illustrates the development of micro and small enterprise (MSE) output (M1), which demonstrates gradual growth with some fluctuations during the observation period.

M2 - Producer Price Index (PPI)

The Producer Price Index (PPI) is operationalized as a macro moderator variable that reflects input cost pressure at the aggregate level, with 2010 set as the base year (index = 100). Data shows a consistent upward trend throughout the observation period, where the PPI increased from 100 in 2010 to 168.94 in 2023, reflecting an aggregate increase of 68.94% or an average of 4.1% per year.

PPI movement patterns show three critical phases: (1) 2010-2014, marked by a moderate increase of 24.94 points, in line with global commodity price increases; (2) 2014-2016, showing a sharp acceleration with an increase of 45.15 points in two years, reflecting the impact of energy price transmission after the 2014 fuel subsidy removal; and (3) 2017-2023, characterized by high volatility with a significant decline in 2019-2020 due to the pandemic, followed by a gradual recovery. This PPI volatility is a crucial indicator for the negative moderation hypothesis, where input price fluctuations have the potential to erode the marginal elasticity of electricity conversion into economic output, especially for the micro and small enterprise sector.

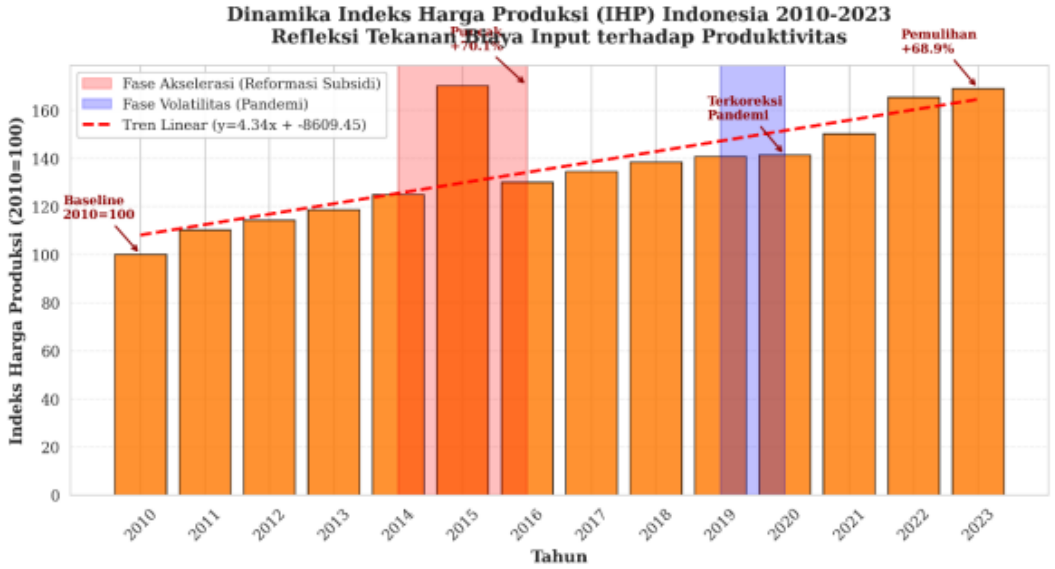

Figure 3. *National PPI Trend Graph (2010-2023)*

Figure 3 shows the movement of the Producer Price Index (PPI) (M2), indicating relatively stable price dynamics in the production sector.

Y - Gross Domestic Product (GDP)

Gross Domestic Product (GDP) is measured in two monetary units to ensure comparative validity: billion Rupiah (Y_IDRMiliar) and million US Dollars (Y_USDMillions). Data shows a consistent growth trend but with volatility patterns that reflect the vulnerability of the Indonesian economy to external shocks and domestic policies. In Rupiah units, GDP increased from IDR 2,171,010.3 billion in 2010 to IDR 20,892,000.4 billion in 2023.

In US Dollar units (at a rate of IDR 16,500), GDP increased from US$ 131,576.4 million in 2010 to US$ 1,266,181.8 million in 2023, increasing by 862.3% or an average of 19.2% per year. Growth patterns show three critical phases: stable growth (2010-2014), a significant slowdown (2014-2016) due to subsidy reform and commodity price drops, and a gradual recovery (2017-2023), although interrupted by a sharp contraction in 2020 (-2.1%) due to the pandemic. Interestingly, there is a misalignment between GDP growth and the increase in National Electricity Use: while electricity consumption grew by an average of 3.9% per year, GDP only grew by 5.1% in USD, indicating a productivity gap where energy input expansion is not always proportionally converted into aggregate output growth.

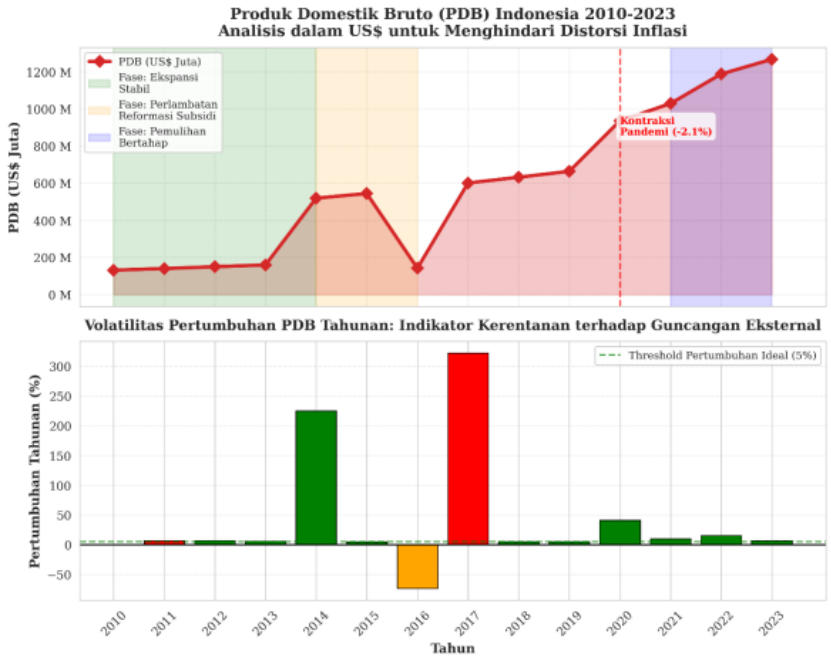

Figure 4. *National GDP Trend Graph (2010-2023)*

Figure 4 presents the trend of Gross Domestic Product (GDP) in Indonesia, which generally increases over time.

Regression Analysis Results

The regression analysis was conducted to examine the effect of electricity consumption (X1), MSE output (M1), and PPI (M2) on GDP, including the moderating effects of M1 and M2. The regression results indicate that none of the proposed hypotheses are statistically supported at the 5% significance level, indicating that the relationships specified in the model are not empirically validated within this study. To provide a detailed evaluation of the relationships between variables, the regression estimation results are presented in Table 3.

Table 3. *Results of Regression Analysis*

Variable	Coefficient (β)	Std. Error	t-Statistic	p-value	Decision
X1 (Electricity Consumption)	1.420	4.042	0.351	0.726	Not Significant
M1 (MSE Output)	-0.495	2.123	0.233	0.816	Not Significant
M2 (PPI)	0.068	6.182	0.011	0.991	Not Significant
X1 × M1	0.388	3.959	0.098	0.922	Not Significant
X1 × M2	-0.039	3.545	0.011	0.991	Not Significant

The results show that electricity consumption (X1) has a positive coefficient (β = 1.420), indicating a positive coefficient; however, due to the lack of statistical significance, this relationship cannot be interpreted as meaningful or reliable (p = 0.726). Similarly, MSE output (M1) has a

negative coefficient (β = -0.495) and is not statistically significant (p = 0.816), indicating that its effect on GDP cannot be empirically confirmed in this study.

The producer price index (M2) also does not show a statistically significant effect (β = 0.068; p = 0.991), indicating no empirical evidence supporting its influence on GDP within the model. The moderating effects are also not supported. The interaction between electricity consumption and MSE output (X1 × M1) has a positive coefficient (β = 0.388; p = 0.922), while the interaction between electricity consumption and PPI (X1 × M2) has a negative coefficient (β = -0.039; p = 0.991). These results indicate that there is no empirical evidence supporting any moderating effects in the model.

To assess potential multicollinearity issues among the predictors, Variance Inflation Factor (VIF) values are reported in Table 4.

Table 4. *Predictive Power of the Model and Effect Size*

Variable	VIF	Interpretation
X1	39.329	Extreme Multicollinearity
M1	23.908	Very High Multicollinearity
M2	5.795	Moderate Multicollinearity
X1 × M1	11.210	High Multicollinearity
X1 × M2	10.861	High Multicollinearity
Variable	VIF	Interpretation

The VIF values indicate severe multicollinearity issues, particularly for X1 and M1, which severely undermine coefficient stability, inflate standard errors, and make the estimated relationships statistically unreliable. The overall model performance is summarized in Table 5.

Table 5. *Model Summary*

Statistic	Value
R^2	0.929
Adjusted R^2	0.884

The model explains 92.9% of the variation in GDP, however this high R^2 is likely influenced by multicollinearity and overfitting, and therefore does not necessarily indicate a reliable or well-specified model.

The Effect of National Electricity Consumption on National GDP

Based on the regression estimation, National Electricity Consumption (X1) shows a coefficient of beta = 1.420 toward National GDP (Y), with a t-statistic of 0.351 and a p-value of 0.726. Inferentially, this influence does not reach the significance level at alpha = 0.05, so the first hypothesis is not statistically supported. Therefore, the estimated coefficient cannot be interpreted as evidence of a meaningful economic effect due to its lack of statistical significance. This statistical non-significance indicates that the relationship cannot be empirically confirmed within this study. This result is likely influenced by severe multicollinearity (VIF = 39.329), which reduces statistical reliability and affects the stability of coefficient estimates. These findings suggest that the relationship between electricity consumption and GDP may be complex and influenced by other factors not captured in the model. From a theoretical perspective, electricity remains an important production input; however, its impact on GDP depends on broader structural conditions, including input price stability and the absorption capacity of the real sector. As noted by Saqib (2021), the elasticity of GDP with respect to electricity consumption varies significantly across developing countries (0.15–0.42), depending on infrastructure reliability and sectoral structure. Thus, the absence of significant results in this

study does not necessarily contradict existing theory but may reflect contextual complexity in an SME-dominated economy. The policy implications should therefore be interpreted cautiously. While electricity expansion remains important, its effectiveness in driving GDP growth depends on complementary structural factors such as price stability and sectoral absorption capacity, as also highlighted in the Indonesian context (Darrian et al., 2023).

The Moderating Role of MSE Output on the Relationship between Electricity Consumption and GDP

The regression results show that the interaction between MSE Output (M1) and National Electricity Consumption (X1) has a coefficient of beta = 0.388 toward GDP (Y), with a t-statistic of 0.098 and a p-value of 0.922, values well above the significance threshold (alpha = 0.05). Statistically, the hypothesis stating a positive moderating role for MSE Output is not supported. Therefore, there is no empirical evidence supporting a moderating role of MSE Output in this relationship. The results are likely affected by severe multicollinearity between variables, particularly the high correlation between electricity consumption and MSE output, which limits the ability to estimate interaction effects reliably. This limitation indicates that the current model specification is not suitable for testing moderation effects. Substantively, this finding remains relevant within the Indonesian context, where the MSE sector contributes significantly to national GDP (Kemensetneg, 2022) and is highly dependent on electricity as a production input (Handayani et al., 2024). However, such structural interdependence may reduce the statistical separability of variables in regression models. From a theoretical perspective, MSEs may function as a transmission channel in the electricity–growth relationship, but this role is not empirically supported in the current model. Similar complexities in the electricity–growth nexus have also been highlighted in recent studies (Shahbaz et al., 2023).

The Moderating Role of PPI on the Relationship between Electricity Consumption and GDP

The regression results show that the interaction between the Producer Price Index (PPI) and National Electricity Consumption toward GDP produces a coefficient of beta = -0.039 with a t-statistic of 0.011 and a p-value of 0.991. Statistically, the negative moderation effect of PPI is not proven significant at alpha = 0.05. This result indicates that the moderating role of PPI is not supported by the data. The absence of statistical significance suggests that no reliable moderating effect can be identified. Therefore, PPI cannot be concluded as a significant moderating variable in this model. From a theoretical standpoint, cost-push theory suggests that increases in input prices may weaken economic output. However, in the Indonesian context, this mechanism may not operate strongly due to structural characteristics of the economy. Studies such as Rentschler and Kornejew (2017) show that energy costs account for a relatively small share (1%–6%) of total production costs in small firms, limiting the transmission effect. Additionally, adaptive behavior among small enterprises, such as cost adjustments and operational flexibility, may dampen the impact of input price increases (Amitrano and Vasconcelos, 2019; Nashrurrahman et al., 2024). Therefore, while theory suggests a potential moderating role of PPI, the empirical results in this study do not support its significance, indicating that such effects may be context-dependent and not easily captured in the current model specification.

CONCLUSSION and IMPLICATION

The results of this study indicate that National Electricity Consumption does not have a significant effect on National Productivity (GDP). The empirical findings do not provide sufficient evidence to support a meaningful relationship between electricity consumption and GDP. This result may reflect the complexity of the relationship and the influence of other structural factors not captured in the model. Furthermore, neither the Producer Price Index (PPI) nor Micro and Small Enterprise (MSE) Output significantly moderates the relationship between National Electricity Consumption and GDP. The absence of significant moderation effects indicates that neither PPI nor MSE Output can be empirically confirmed as moderating variables in this relationship. These findings suggest that the proposed moderating mechanisms are not supported within the current model and may require alternative model specifications or analytical approaches. Given these limitations, future research is recommended to employ alternative modeling approaches that are more suitable for the data characteristics, such as simplified regression models or methods that reduce multicollinearity issues. Additionally, future studies should consider incorporating additional relevant variables that may better capture the structural dynamics between electricity consumption and economic growth. Expanding the scope of data and improving model specification may also help provide more robust and reliable empirical evidence.

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