Assessing the Key Determinants of Energy Consumption in Malaysia over Four Decades (1980–2022): A Multivariate Regression Analysis

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ABSTRACT

This study empirically investigates the effects of selected macroeconomic factors—GDP per capita, energy prices, industrial value-added share, transport services for commercial trade (exports and imports), and urbanization—on energy consumption in Malaysia from 1980 to 2022. The key aim is to quantify the extent to which these macroeconomic factors explain variations in national energy usage across four decades.

The regression results, supported by diagnostic tests, indicate that only GDP per capita and industrial sector share exert a positive and statistically significant effect on energy consumption in Malaysia. This outcome lends support to the Kaya identity framework, emphasizing the integral role of energy utilization in driving economic growth and industrial expansion.

Therefore, Malaysia policy efforts should focus on improving industrial energy efficiency, promoting renewable energy adoption, and facilitating structural transformation toward less energy-intensive sectors. Such measures are essential to ensure that economic growth remains sustainable while mitigating excessive increases in national energy demand.

Keywords: Energy consumption, GDP per capita, Energy prices, Industrial share, Transport services for commercial trade, Urbanization, Regression analysis

INTRODUCTION

Malaysia, a middle-income economy aspiring to achieve high-income status, continues to experience steady economic growth accompanied by rising energy consumption, rapid industrialization, and urban expansion. While technological advancements and the adoption of sustainable energy sources are essential to support continued growth, increasing urbanization has intensified energy demand.

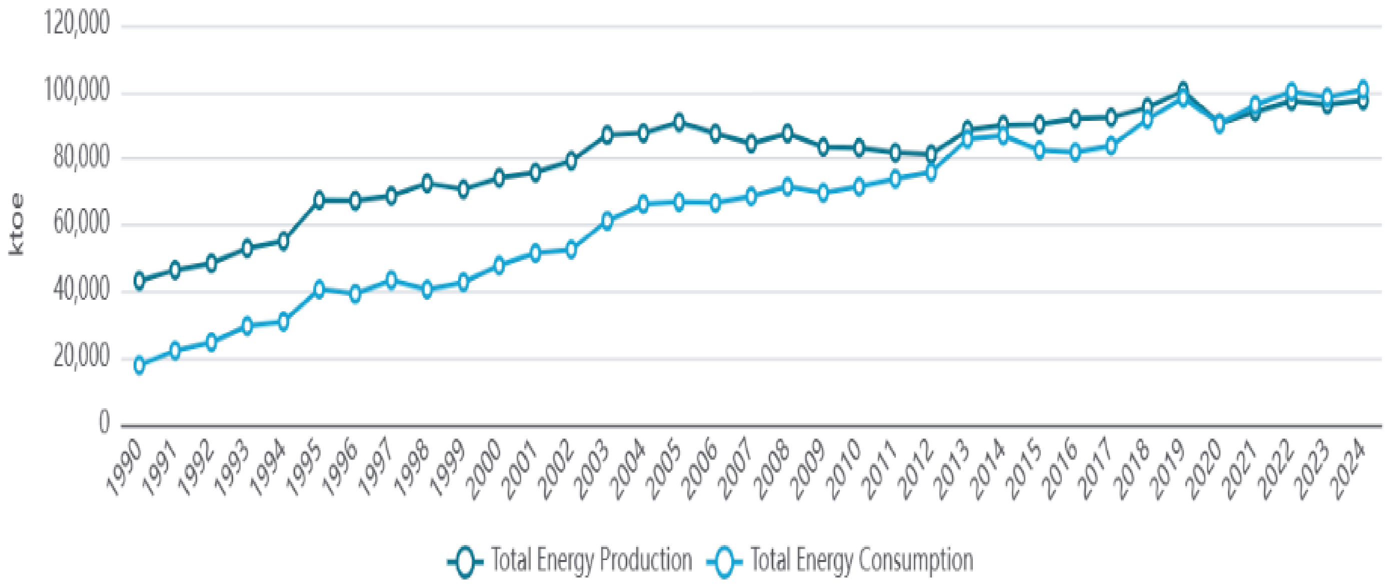
Urban households, particularly, consume higher levels of energy for transportation, cooling, lighting, and household appliances, thereby reinforcing the link between structural transformation and environmental pressures. Figure 1 portrays Malaysia significant stable growth in both total energy consumption and production throughout the years from 1990 to 2024. It reflects its transformation into a developed nation driven by industrialization and urbanization.

Malaysia's energy demand is projected to soar 20% in next decade, with fossil fuels still dominating until 2033 (International Renewable Energy Agency, 2023). Despite these challenges, Malaysia has made notable progress toward a cleaner energy transition. Renewable energy capacity—including solar, hydropower, and biomass—has expanded in recent years, although its share in total energy consumption remains relatively modest.

Additionally, efforts to promote biofuels (including biodiesel blends), sustainable aviation fuels, and broader energy sector modernization reflect Malaysia's commitment to sustainable development and long-term netzero aspirations. Government policy initiatives, such as the National Energy Transition Roadmap (NETR), aim not only to reduce carbon emissions but is also essential to improve energy efficiency across economic sectors.

Figure 1. Malaysia's Total Energy Production and Consumption

Source: Malaysia energy report



Though the NETR envisions a greater role for renewables energy post-2040, fossil fuels will still account for more than 55% of installed capacity from 2025 to 2035 (The Sun Malaysia, 11 Oct 2024). On one hand, the energy production saw Malaysia being a major oil and gas producer in the Asia-Pacific region.Despite its own production, Malaysia has increasingly relied on imported coal over the past decade for electricity, which accounted for roughly 43% of electricity generation in 2023–2024.

According to Asia Natural Gas and Energy Association, hydropower has a long-standing supporting role in Malaysia's energy system, however its vast solar potential is largely untapped. Less than 2% of Malaysia's electricity in 2023 came from solar and the NETR points to a variety of policy initiatives that could see photovoltaic installed capacity grow to 58% by 2050.

Possible measures include the removal of regulatory barriers hindering development of floating solar and agrivoltaics, and government collaboration to establish designated parks for utility-scale solar.

LITERATURE REVIEW

Energy Consumption per Capita

As a crucial input in economic production, energy is extensively utilized across all sectors of social production and consumption, exerting a substantial influence on global economic activities(Gong et al., 2022a).

Kraft and Kraft (1978) were the pioneer researchers to examinethe energy consumption and economic growth, before more studies were then conducted further by other researchers applying variety of techniques on both variables.Theoretically, literature classifies the relationship between energy consumption and economic growth into four categories: growth hypothesis, conservation hypothesis, neutrality hypothesis, and feedback hypothesis (Lu et al., 2024).

For example, evidence to support the growth hypothesis is demonstrated through increased energy consumption, economic growth, and higher GDP. In other words, it suggests there is a positive relationship between energy consumption and economic development.

Gross Domestic Product per Capita

Gross Domestic Product (GDP) per capita refers to the total value of goods and services produced within a country divided by its total population. In the context of Malaysia, GDP per capita measures the average economic output or income per person and is commonly used as an indicator of the country's standard of living and level of economic development.Malaysia's economic growth is basically driven by manufacturing, services, and increasingly, high-value-added sectors.

Being an upper middle-income country, its GDPper capita has steadily increased, supported by industrialization, export-oriented policies, foreign direct investment, and urbanization. The OECD Economic Outlook 2026 has projected Malaysia's economic growth to expand by 3.8% to 4.1% in 2026.

Energy Price

Energy price is commonly proxied by the international benchmark price of Brent Crude, which represents the global reference price for crude oil traded in international markets. It reflects global oil marketconditions and price volatility.

However, in Malaysia energy prices are influenced by both global market conditions and government regulation.Recent empirical studies on Malaysia indicate that energy demand is generally price inelastic in both the short and long run (Tang & Tan, 2015).Tang et al., 2022 found that energy consumption across Malaysian sectors responds asymmetrically to income and price changes, with economic growth exerting a stronger and consistently positive effect, while energy price changes have weaker and sector-specific impacts, indicating relatively inelastic demand.

In contrast, GDP per capita exerts a stronger and statistically significant positive influence on energy consumption. Structural factors such as industrialization and urbanization further intensify energy demand, reflecting Malaysia's transformation into a more urban and manufacturing-based economy (Bekhet& Othman, 2017).

Industry Share

The role of the industrial sector in the economy is measured by industry share. The processing, manufacturing and construction are very energy consuming industries. With the growing proportion of industry in the GDP, the amount of energy consumed will also experience growth because of the increase in the demand of electricity, fuel, and machinery.

The variable is particularly applicable to Malaysia that has experienced a quick industrialization process in recent decades.International Renewable Energy Agency (IRENA) reported thatthe industry sector's share of national energy consumption in Malaysia accounted for nearly 30% of final energy consumption, with key sub-sectors including iron and steel, cement, and chemicals.It also projects energy consumption trends in the industry through to 2050, highlighting Malaysia's growth in energy use and the need to adopt clean technology for decarbonization strategies.

Transport Commercial Services

Logistics, shipping services, air freight services, and similar services are the commercial export services in transport. A growth in export-related transport services is usually associated with more freight and logistics activities that can increase the energy-demand of the transport sector due to the need to move and handle more goods, necessitating energy inputs such as fuel and electricity (Alkhateeb et al., 2019).

They further discussed thathigh levels of trade openness and increase in exports is related to growth in energy consumption since trade enlargement increases production and transport activities that consume energy.

The port operations, warehousing, cargo handling, and transport logistics are included in the import activities. Increased levels of imports cause an increase in the consumption of energy, particularly in the transportation, trucking, and logistic sectors (Shahbaz et al., 2015).

Thus, the import transport services are an applicable predictor of energy demand (Dinh et al., 2021).Shahbaz et al. (2015) observe that Malaysian energy consumption is enhanced by trade openness whileDinh et al. (2021) illustrated that trade flows caused by transportation contribute greatly to the consumption of renewable and non-renewable energy.

Urbanization

Urbanization is widely associated with rising energy demand because it expands the need for electricity, transportation, infrastructure, commercial activities, and residential services. Poumanyvong& Kaneko (2010) argue that urbanization is a major factor contributing to higher energy consumption across countries. Similarly, Ghosh (2002) found that population concentration in urban areas significantly increases electricity demand, as urban lifestyles tend to be more energy-intensive than rural ones. As urban populations grow, average per capita energy consumption generally rises due to greater reliance on modern appliances, transport systems, and commercial services. Therefore, urbanization is expected to have a positive relationship with energy consumption.

A more recent study by Shamshuddin et al. (2025) examines the long-run relationship between energy consumption, demographic growth, and economic activity from 2000 to 2021, focusing on sectoral drivers, efficiency performance, and projections up to 2030. The findings reveal a strong positive relationship between GDP and Final Energy Consumption, indicating that economic growth in Malaysia continues to be closely linked to increased energy use.

RESEARCH METHODOLOGY

This analysis has utilized a multiple regression analysis selecting Malaysia as the scope of study for fortythree-year period (1980-2022). Based on the theories and past empirical studies, there are five independent variables identified to have a relationship with energy consumptionnamely, gross domestic product (GDP), energy price, industry share, transport commercial services (export and import), and urbanization.

A diagnostic check would be carried out to validate that the estimation meets the requirements of the Classical Linear Regression Model (CLRM) assumptions.

These assumptions are: (i) regression model must be linear, correctly specified, and include an error term; (ii) error term has a zero population mean; (iii) all explanatory variables are uncorrelated with the error term; (iv) the error term itself is uncorrelated with each other meaning no serial correlation; (v) the error term has a constant variance or simply means no heteroskedasticity; (vi) no perfect multicollinearity among each explanatory variable; and (vii) the error term is normally distributed drawn independently from a distribution with a mean of zero and a constant variance (Gujarati & Porter, 2009).

Econometric Modelling

The economic model starts with a simple function of energy consumption shown as:

ECN = f (GDP, EPR, TCSX, TCSM, IND, URB) (1)

Where:

ECN = Energy consumption

GDP = Gross Domestic Product per capita

EPR = Energy prices

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TCSX = Transport commercial services export

TCSM = Transport commercial services import

IND = Industry share

URB = Urbanization

From (1) the multiple regression model analysis is as follows:

$lnECN_t = \alpha + \beta_1 lnGDP_t + \beta_2 lnEPR + \beta_3 lnTCSX_t + \beta_4 lnTCFM_t + \beta_5 lnIND_t + \beta_6 lnURB_t + \varepsilon_t$(2)

which $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6 > 0$

t = year 1980 to 2022; α = constant; ε_t = error term

Equation 1 meets the first assumption of which the multiple regression model is linear, correctly specified since the variables understudy are chosen based on the theories and past researches conducted on carbon emission.

The error term is additive, independently and identically distributed. The second assumption can be shown in terms of notation:

$E(\varepsilon_i) = 0$

The third assumption regarding explanatory variables are uncorrelated with the error term means:

$Cov(Xi, \varepsilon i) = 0$

In contrast, the fourth assumption of no serial correlation or autocorrelation can be notated as:

$Cov(\varepsilon i, \varepsilon j) = 0$

The fifth assumption of no heteroskedasticity again refers to the error term has a constant variance is written as: $Var(\varepsilon j) = \sigma^2$

Assumption 6 of no perfect multicollinearity means none of the independent variables should have a perfect linear relationship with any other variables. However, even if these variables are not, there can still be a problem.

The final assumption 7 states that the error term should be normally distributed is referring by a notation of:

$\varepsilon j \sim N(0, \sigma^2)$.

As stated earlier, a series of analysis from checking the goodness fit statistics and conducting diagnostics tests referring to the seven assumptions would be performed to ensure the estimated model is robust and unbiased (Shresta&Bhatta, 2018).

Sources of Data

The source of data was mainly collected from the World Bankgathered by World Development Indicator (WDI).The scope of data must be available forall chosen variables andeach year from 1980 until 2022 (43 years) to conduct the time series analysis.

RESULTS AND DISCUSSIOn

This section starts with a discussion of the preliminary results, followed by the description, analysis, and

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interpretation of the multiple regression findings. It concludes with diagnostic tests to identify potential issues such as autocorrelation, heteroskedasticity, and multicollinearity. All analyses are performed using STATA software. Several statistical tests are employed, including the F-statistic, t-statistic, adjusted R^2, Durbin–Watson statistic, Breusch–Pagan–Godfrey test, and White test.

Preliminary Analysis

The preliminary report consists of descriptive statistics and correlation analysis for each variable. Table I presents the mean and standard deviation, while the Kurtosis test is used to assess the normality of the data.

Table2.Descriptive analysis

Variable	Statistics		
	Mean	Standard Deviation	Kurtosis
Energy consumption (ECN)	2,010.600	692.258	1.574
Gross Domestic Product per capita (GDP)	6,682.601	2,484.335	1.833
Energy prices (EPR)	49.280	25.992	2.157
Transport commercial services export (TCSX)	35.858	6.766	2.308
Transport commercial services import (TCSM)	24.142	11.451	2.083
Industry share (IND)	41.429	3.286	2.255
Urbanization (URB)	3.844	1.062	1.702

The results indicate that GDP per capita records the highest mean value (6,682.6), followed by ECN (2,010.6) and EPR (49.28), while the lowest mean value is observed for URB (3.84). The standard deviation reflects the dispersion of each variable around its mean, where a larger value indicates greater variability.

URB has the lowest standard deviation (1.06), suggesting highly consistent variation, whereas GDP shows the highest standard deviation (2,484.3), indicating greater fluctuation. These findings imply that URB exhibits less variability compared to GDP.

The analysis incorporates kurtosis values to assess the tail weight and peakedness of the distributions. A kurtosis value of three serves as the benchmark for a normal distribution; values below three indicate a platykurtic distribution, characterized by a flatter peak and lighter tails. The kurtosis results suggest that the variables are approximately normally distributed, with only minor deviations in symmetry and tail behavior. These findings are consistent with the descriptive statistics and support the normality assumption required for parametric testing.

Correlation Matrix

Table 3 presents the correlation analysis, which examines the strength of the relationships among the variables. The results reveal four pairs of variables exhibiting strong correlations with ECN. The strongest positive association is only between ECN and GDP (0.977).In contrast, the strong negative correlations are observed between ECN and TCSM (-0.924), ECN and URB (-0.853), and ECN and TCSX (-0.766). The remainder two

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variables showed a positive weak association between ECN and EPR (0.496), and the lowest stated between ECN and IND (0.135).

Table3.Correlation Matrix

Variable	Variable						
	lnECN	lnGDP	lnEPR	lnTCSX	lnTCSM	lnIND	lnURB
lnECN	1.000	0.977	0.496	-0.766	-0.924	0.135	-0.853
lnGDP	0.977	1.000	0.526	-0.810	-0.919	-0.024	-0.910
lnEPR	0.496	0.526	1.000	-0.343	-0.406	-0.139	-0.703
lnTCSX	-0.766	-0.810	-0.343	1.000	0.819	0.224	0.707
lnTCSM	-0.924	-0.919	-0.406	0.819	1.000	-0.120	0.743
lnIND	0.135	-0.024	-0.139	0.224	-0.120	1.000	0.249
lnURB	-0.853	-0.910	-0.703	0.707	0.743	0.249	1.000

Multiple Regression Analysis

The multiple linear regression is employed to test if the six explanatory variables significantly predicted the energy consumption in Malaysia. From Table 4, the fitted regression model can be presented as below: $lnECN_t = -1.317 + 0.929lnGDP_t + 0.002lnEPR - 0.001lnTCSX_t - 0.001lnTCFM_t + 0.020lnIND_t - 0.006lnURB_t + \varepsilon_t$

Table4.Regression analysis

ariable	Beta Coefficient	t-ratio
Constant	-1.317	-0.986
lnGDP	0.929***	7.020
lnEPR	0.002	0.83
lnTCSX	-0.001	-0.366
lnTCSM	-0.001	-0.210
lnIND	0.020***	4.740
lnURB	-0.006	-0.146

Note: ***1% level of significance

Adjusted $R^2 = 0.977$

F-statistics = 302.149; p-value = 0.000

A commonly used measure of goodness of fit in multivariate analysis is the adjusted R^2. As reported in Table 4, the adjusted R^2 value of 0.977 indicates a strong model fit, suggesting that approximately 97.7% of the variation in the dependent variable is explained by the set of explanatory variables included in the model. Furthermore, the F-statistic is statistically significant at the 5% level, confirming that the regression model is jointly significant and appropriate for inference.

The empirical results show that only two explanatory variables, namely GDP and IND, exhibit a statistically significant relationship with ECN at the 1% significance level (p-value < 0.001). Both variables are positively associated with ECN, implying that economic growth and industrial activity contribute to higher energy consumption. Specifically, a 1% increase in GDP is associated with a 0.929 percentage-point increase in energy consumption, while a 1% increase in IND leads to a 0.020 percentage-point increase in energy consumption. The remaining four explanatory variables do not demonstrate statistically significant effects.

Nevertheless, caution is warranted when interpreting an adjusted R^2 value that is extremely close to unity, such as 0.977, as this may signal the presence of spurious regression, particularly in time-series data. To address this potential issue, it is essential to conduct appropriate diagnostic tests to ensure the robustness and validity of the estimated model.

Diagnostic Checks

Autocorrelation test

As stated in the fourth assumption of no serial correlation, two common autocorrelation tests are the Durbin Watson statistic and Breusch-Godfrey test. The Durbin Watson d-statistic for the analysis is equal to 0.992 meaning less than 2 showing strong evidence of positive first-order autocorrelation. The rule of thumb is that if the statistic value in the range of 1.5 to 2.5 is considered normal for time series analysis whereas a value of 2 means there is no autocorrelation. Table 5 shows the result of Breusch-Godfrey test where the Chi-square value is significant meaning strong evidence of autocorrelation in the residuals.

Table5.Autocorrelation results of Breusch-Godrey Test

F-statistic	2.541	Probability F	0.059
Observed R-squared	10.367	Probability Chi-Square	0.035

Heteroskedasticity test

This test is conducted to confirm that the error terms do not have constant variance referring to assumption five. The common statistical test known as Breusch-Pagan-Godrey test as shown in Table 6 has failed to reject the null hypothesis (H_0) implying there is no heteroscedasticity issue.

Table6.Heteroskedasticityresultsof Breusch-Pagan-GodreyTest

F-statistic	0.417	Probability F	0.863
Observed R-squared	2.795	Probability Chi-Square	0.834

Variance Inflationary test

The Variance Inflation Factor (VIF) test was performed to verify Assumption 6 of the classical linear regression model, namely the absence of perfect multicollinearity among the explanatory variables. A centered VIF value exceeding 10 indicates a high degree of collinearity between a particular independent variable and the remaining regressors in the model. As a rule of thumb, VIF values should be below 10 to avoid serious multicollinearity concerns.

As reported in Table 7, three variables exhibit VIF values above the recommended threshold, suggesting the presence of multicollinearity. Nevertheless, this does not render the regression model invalid. Multicollinearity does not bias the estimated coefficients, although it may inflate standard errors and make the coefficients sensitive to model specification. In particular, the estimated coefficients may change substantially when variables are added or removed from the model.

In this study, six explanatory variables were included based on strong theoretical justifications. Therefore, despite the presence of multicollinearity among certain variables, they were retained in the model to preserve theoretical consistency and ensure comprehensive analysis.

Table7.Variance Inflationary Test

Variable	Uncentered VIF	Centered VIF
Constant	21,828.24	NA
lnGDP	16,366.31	32.832
lnEPR	124.634	2.679
lnTCSX	139.853	4.700
lnTCSM	65.269	11.758
lnIND	359.249	2.195
lnURB	287.137	19.935

CONCLUSION

The empirical findings suggest that energy consumption in Malaysia is significantly driven by economic growth and structural changes in the economy. GDP per capita and the share of industry exhibit positive and statistically significant relationships with energy consumption, supporting the Energy–Economy Nexus hypothesis. This indicates that higher income levels and increasing industrial activities remain key determinants of energy demand in Malaysia.

Conversely, variables such as energy prices, transport export services, transport import services, and urbanization growth were found to be statistically insignificant and displayed negative coefficients, which diverge from theoretical expectations. These results may be attributed to several econometric issues, including multicollinearity among explanatory variables, common trending behaviour in time-series data, and the presence of autocorrelation. As a result, although the regression model exhibits a relatively high explanatory power, the goodness-of-fit may be overstated and the reliability of statistical inference for some variables may be limited.

Despite these limitations, the findings highlight that Malaysia's energy consumption pattern is closely associated with its economic expansion and industrial structure. The effects of energy prices, transport activities, and urbanization should therefore be interpreted cautiously under the current model specification. Future studies should employ more appropriate time-series econometric techniques to address issues of autocorrelation, multicollinearity, and potential non-stationarity to obtain more robust and policy-relevant estimates.

From a policy perspective, the results suggest that energy planning must remain closely aligned with Malaysia's long-term economic and industrial development strategies. As economic growth continues, energy demand is expected to increase correspondingly. Policymakers should therefore prioritize improvements in industrial energy efficiency, promote technological innovation, and encourage structural transformation toward less energy-intensive sectors. At the same time, various policy initiatives implemented by the Malaysian government—such as the National Energy Efficiency Action Plan, the National Transport Policy 2019–2030, and the Low Carbon Cities Framework—may have contributed to moderating the impact of urbanization and transportation activities on overall energy consumption.

Finally, it should be noted that the use of a simple regression framework in this study is primarily intended as an introductory application of econometric analysis. The analysis serves as a foundational exercise for undergraduate students in the BBA (Business Economics) program, whose exposure to econometric techniques is relatively limited. While the approach provides useful preliminary insights, future research should extend the analysis using more advanced econometric methods to better capture the dynamic relationships between economic development, structural transformation, and energy consumption in Malaysia.

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