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Understanding the Relationship of Energy Consumption and Economic Determinants in ASEAN-5 Countries

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ABSTRACT

The study examines the relationships between energy consumption and a range of key economic determinants within the ASEAN-5 countries spanning four decades from 1980 to 2020. Utilizing robust regression analysis, it explores the complex dynamics linking energy consumption to economic growth, inflation rate, financial development, and total population in these Southeast Asian nations. The findings consistently underscore the presence of positive relationships between energy consumption and the key variables across the ASEAN-5 region, with a particularly strong correlation between energy usage and GDP. However, the impact of economic growth on energy consumption varies significantly, notably exemplified by Indonesia, where a unique negative correlation challenges conventional wisdom. While inflation rates exhibit a positive relationship with energy consumption, their influence is eclipsed by other contributing factors. Financial development emerges as a pivotal driver of heightened energy consumption, aligning with established literature, while total population's impact fluctuates, proving positive in Malaysia and Indonesia but negative in the Philippines, Thailand, and Singapore. Ultimately, these nuanced findings underscore the need for comprehensive and individually tailored energy policies that align with the distinct dynamics of each ASEAN-5 country, fostering sustainable economic growth while mitigating the environmental impact of increased energy consumption.

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1. Introduction

CSR, Scholars and policymakers in Southeast Asian countries have extensively explored energy consumption due to its link with economic growth over the past four decades (Waheed et al., 2019; Rahman & Velayutham, 2020). In the ASEAN-5 region, energy consumption per capita has

seen a relatively modest increase, averaging 1615.671 kg of crude oil equivalent from 1980 to 2020, while the domestic credit to the private sector as a share of GDP has risen by 42.24 percent. This correlation has prompted inquiries into whether significant relationships exist between financial development, income levels, inflation rates, and energy consumption. The year 2020 saw the global economy grappling with the impact of the COVID-19 pandemic, leading to lockdowns and economic slowdowns in various industries. According to the International Monetary Fund (IMF), the ASEAN-5 countries experienced negative real GDP growth in 2020, with Malaysia, Indonesia, Philippines, Thailand, and Singapore recording -5.6 percent, -2.1 percent, -9.6 percent, -6.1 percent, and -5.4 percent, respectively. Interestingly, World Bank Indicators (WBI) data indicates that energy consumption was not significantly affected by the pandemic, with Malaysia, Indonesia, Philippines, Thailand, and Singapore witnessing increases of 13 percent, 3 percent, 11 percent, 15 percent, and 9 percent, respectively, from 2015 to 2020. Concurrently, financial development also experienced growth in most ASEAN-5 countries during the same period, except for Indonesia, with increases of 8 percent, 23 percent, 7 percent for Malaysia, Philippines, Thailand, and Singapore, respectively. It is within this intricate context that the researcher seeks to analyze the intricate relationship between financial development, income levels, and energy consumption.

Table 1. Energy Consumption (Period average in kg of oil equivalent per capita)

Year	Malaysia	Indonesia	Philippines	Thailand	Singapore	Southeast Asia
1980-84	934.61	387.18	463.22	447.89	2177.86	882.15
1985-89	1080.26	432.80	440.46	550.17	2747.85	1050.31
1990-94	1495.22	582.31	459.41	843.28	4897.40	210.06
1995-99	1875.52	677.70	496.06	1111.83	5239.08	1880.04
2000-04	2222.60	756.45	479.37	1293.00	5686.80	2087.64
2005-09	2631.74	804.79	435.12	1574.61	4869.90	2063.23
2010-14	2786.75	862.32	445.55	1863.57	4995.27	1817.98
2015-20	3302.98	888.66	507.76	2270.97	5518.75	2497.82

Source: World Bank Indicators

Table 1 reveals intriguing trends in energy consumption across ASEAN-5 countries over the study period 1980-2020. In the early 1980s, the average energy consumption stood at 882.15 kg of crude oil equivalent per capita, which gradually escalated to an average of 1050.31 kg during the mid-1980s. However, during the 1990s, there was a notable decline, with energy consumption averaging 210.06 kg per capita. Subsequently, a steady resurgence occurred, reaching an average of 2087.23 kg per capita in the early 2000s. Nevertheless, it experienced a decline once again, settling at an average of 1817.98 kg per capita in the early 2010s. However, a noteworthy resurgence transpired during the 2015-2020 period, with energy consumption averaging 2497.821 kg of crude oil equivalent per capita. It is worth noting that there was relatively minimal variation in energy consumption patterns among the ASEAN countries during the study period. Moreover, during the same period, significant increases in energy consumption were observed in Malaysia, Indonesia, and Thailand, with average values of 1852.14 kg, 475.14 kg, and 1415.68 kg of crude oil equivalent per capita, respectively, while the Philippines and Singapore exhibited different trends.

Over the past four decades, energy consumption in ASEAN nations has exhibited fluctuating trends. For instance, among the five ASEAN countries, Singapore has consistently maintained the highest energy consumption levels, albeit with notable variations throughout the period from 1980 to 2020, as illustrated in Figure 1. As elucidated by Grubb et al. (2021), the intensity of energy

consumption within each country can be attributed to varying capacities in adopting technological innovations, particularly in the context of industrial sector development. This irregular pattern of energy usage has spurred a multitude of inquiries, with scholarly literature addressing various theories to explain this phenomenon. Notably, Sadorsky (2010) has substantiated the influence of factors such as financial development and economic growth on energy consumption, shedding light on the intricate dynamics at play in this regard.

The first key determinant under examination is financial development, which has been observed to exert a notable influence on energy efficiency. As noted in our study, financial development plays a pivotal role in shaping a country's energy consumption patterns. This perspective aligns with the findings of Sadorsky (2010), who underscored the significance of financial development in enhancing the economic efficiency of a nation's financial system. Grounded in the theory of financial intermediation, financial development triggers a cascade of transformative effects within a country. These include a reduction in financial risk and borrowing costs, heightened transparency in lending and borrowing transactions, expanded access to financial capital and international investment inflows, as well as access to cutting-edge energy-efficient technologies and products. This comprehensive set of changes can significantly impact energy demand, bolstering consumption and business fixed investments. For instance, between 2010 and 2014 in Singapore, financial development surged by 33.27 percent of GDP, coinciding with a concurrent increase in energy consumption by 115.18 kg of crude oil per capita. This empirical evidence underscores a positive correlation between financial development and energy consumption, elucidating the intricate relationship between these factors (Ahmad & Mokal, 2023; Ahmad et al., 2023).

The second critical determinant under consideration is economic growth. Examining Thailand's economic performance since 2017 reveals a notable trend. During this period, Thailand's real GDP experienced a decline, with growth rates of 6.9 percent, 6.3 percent, 6.1 percent, and -9.6 percent recorded for the years 2017, 2018, 2019, and 2020, respectively. Intriguingly, in the same timeframe, energy consumption in Thailand increased, reaching 502.12 kg, 513.39 kg, 524.65 kg, and 435.92 kg of crude oil per capita for the respective years. This phenomenon aligns with the findings of Kraft and Kraft (1987), who established that economic growth typically spurs heightened energy demand. This relationship is well substantiated by the Solow Growth theory. However, it is crucial to note that, based on the data, energy consumption and economic growth exhibit a negative correlation. This seeming contradiction can be attributed to external factors, particularly the global pandemic, which significantly impeded economic growth in Thailand during this period, leading to the observed deviation from the expected positive correlation between energy consumption and economic growth (Ahmad et al., 2024; Ahmad et al., 2024).

The third significant factor under examination is inflation. Malaysia's economic landscape in the 2010s remained relatively stable, with inflation rates consistently staying below 4 percent. However, in 2017, there was a slight uptick, reaching 3.87 percent, but this was followed by a decrease to 0.66 percent in 2019, and eventually, the country faced deflation at -1.14 percent in 2020. Conversely, Malaysia's energy consumption exhibited an upward trajectory during the same period, recording a substantial increase of 26 percent, equivalent to 930.1627 kg of crude oil per capita over the course of a decade. This observed relationship aligns with the principles of the demand-pull theory, which posits that inflation in an economy results from an excess of aggregate demand over supply, particularly at the full employment level of output. Consequently, the data suggests a positive correlation between inflation rates and energy consumption, indicating that as inflation increases, so

does energy consumption in Malaysia (Ahmad et al., 2023; Ahmad et al., 2023).

The fourth influential factor to consider is population. According to Islam et al. (2013), population growth has a substantial impact on energy consumption in the long run. The dynamics of population growth can significantly influence the scale and pattern of energy consumption, as it plays a pivotal role in shaping various aspects of economic growth, including the standard of living and resource utilization, ultimately altering the global landscape (as highlighted by the United Nations in 2007). In line with this, data from the World Bank Indicators in 2021 reveals a notable upward trend in population growth within the ASEAN-5 region. Among these nations, Indonesia stands out with the most significant population growth, followed closely by the Philippines. Indonesia's population has surged by a staggering 126,075,787 people from 1980 to 2020. Remarkably, Indonesia's energy consumption has also followed an upward trajectory during this same period. This scenario aligns with the tenets of the Solow Growth theory, which posits that an increase in population can exert adverse effects on GDP due to the heightened demand on limited resources imposed by a larger population. Consequently, the data suggests a significant relationship between population growth and energy consumption, highlighting the crucial role of demographics in shaping energy demand patterns (Ahmad et al., 2023; Ahmad et al., 2023).

The primary objective of this study is to investigate the complex relationship between financial development, income levels, energy consumption, and various other determining factors. Through this objective, the research endeavors to provide valuable insights into the complex relationship between financial development, income, and energy consumption while shedding light on the key drivers behind energy consumption patterns, ultimately informing policy decisions and sustainable energy management strategies.

The remaining sections of this paper include a literature review, methodology description, results presentation, discussion of findings, and a conclusion with policy implications. The literature review surveys existing research, while the methodology outlines the study's approach. The results and discussion sections provide insights into the complex relationship between financial development, income, and energy consumption, and the conclusion offers a summary of key findings and policy recommendations.

2. Literature Review

Energy consumption refers to the energy power required to achieve specific actions or goals (Santika et al., 219). In today's fast-paced world, the need for energy sources has increased due to the global economic downturn and the Arab oil embargo. Understanding energy consumption in developing economies is crucial as it is essential for manufacturing products and services. As economic growth accelerates, demand for energy also increases (Said et al., 2022). Energy consumption is affected by the stage of economic development and is a key priority for major economic powers. The impact of energy consumption on macroeconomic performance is a growing subject in development literature, with debates focusing on whether energy consumption affects general price levels (Bekhet & Yusop, 2009). Emerging economies have a significant impact on energy consumption, as no sector can function properly without it. Studies have shown one-way causality and mutual causality between energy consumption and economic growth, with some Asian countries showing one-way causality and mutual causality (Ahmad et al., 2023; Ahmad et al., 2020).

Financial development is a crucial driver of economic growth in emerging economies, and it is likely to affect energy demand (Khan et al., 2021). Research has shown that financial development directly influences energy consumption, while indirectly impacts energy usage through economic expansion. Financial development encourages changes within a country, such as reduced financial risk and borrowing costs, greater transparency between lenders and borrowers, access to greater financial capital, and access to the latest energy-efficient products and cutting-edge technology (FitzGerald, 2006). In four nations, only in four had financial development in the banking sector have a statistically significant beneficial influence on economic growth. The expanding financial sector enhances the availability of cash for investment, promoting industry expansion. Financial development influences economic growth through economic growth channels, making the financial system more efficient and enabling financial firms to undertake more effective activities.

Research in Guandong, China, and Pakistan found that Granger-causality runs from energy consumption to financial development, with the opposite being minor (Ouyang et al., 2018). In European countries, financial development has no significant impact on energy consumption, but it has a powerful impact on energy consumption in old member states of the European Union (Zhen et al., 2023). Bidirectional causality exists between energy consumption and financial development, with economic expansion and financial development impacting energy consumption both in the short and long run (Shahbaz et al., 2013; Ahmada et al., 2022; Ahmed et al., 2023). However, evidence suggests that financial development can reduce energy consumption by increasing efficiency in its usage, necessitating infrastructural changes, investing in advanced technology research and development, and using energy-efficient items like household appliances (Komal & Abbas, 2015; Rahman & Ahmad, 2024; Mokal & Abd Halim, 2023).

The debate on the energy consumption-inflation nexus is a global issue, with various studies examining the relationship between energy consumption, monetary policy, and inflation in Asian nations. Rehman (2014) found a significant relationship between oil consumption and inflation in at least two Asian nations, suggesting that if oil prices rise in the international market, domestic inflation in these two nations is likely to be oil price push inflation. Iyke and Odhaimbo (2014) found that energy consumption causes inflation in Ghana and Nigeria, emphasizing the need for suitable monetary measures to accommodate future inflationary increases caused by high power consumption over time. Hondroyiannis et al. (2002) found that overall energy consumption changes should be treated as endogenous factors to inflation and economic growth, while residential energy consumption is weakly exogenous. Elheddad et al. (2020) discovered that the cost and price of items are affected by how resources are used for energy, with non-renewable energy resources more likely to cause inflation rates to rise. Talha et al (2021) found a positive link between energy consumption and inflation in Malaysia. Bassey and Ekong (2019) found that oil consumption inflates Northern European regional prices by up to 1.15 percentage points in the medium run, with the long-term impact unknown. Parker (2017) investigated how global inflation is triggered by energy prices using bivariate and multivariate least squares regressions on datasets from 223 countries. Filipiak and Wyszkowska (2022) found an inverse trend in energy consumption-inflation relationships for the region in the medium term, suggesting energy conservation measures without severe impact on economic growth.

The impact of energy consumption on economic growth has become a popular issue since the first oil shock (Mehrara, 2007). There are three common views on energy issues and economic growth: one that states that energy is the input of production, the other that there is an opposite

causal relationship, and the third that asserts a two-way relationship between economic development and energy utilization (Stern, 2011; Rahman & Ahmad, 2024; Rahman et al., 2023)). Research has shown that economic growth and urbanization positively affect energy consumption, while energy prices negatively affect it (Wang et al. 2019). Economic growth has a significant positive effect on energy consumption in all countries except Indonesia and Singapore. Low-income countries have a Granger's causality from GDP on energy utilization, while middle-income countries develop a two-way causality between GDP and energy utilization (Mokal & Ahmad, 2023; Mokal et al., 2023).

Many studies have been conducted to identify the causal connection between economic development and energy utilization, with some finding that economic development directs energy utilization, while others find no causality between economic development and energy utilization in low-income countries (Shahbaz et al., 2013). Further studies are needed to determine the causality and co-integration among variables for a given region, especially in the ASEAN +3 region. Various studies have found cointegration between energy consumption and GDP in India, Pakistan, and Indonesia, but no cointegration for Malaysia, Singapore, and the Philippines. Further research is needed to determine the causality and co-integration among variables for a given region, especially in the ASEAN +3 region (Mokal & Ahmad, 2023).

Previous studies have not explored the relationship between population, energy consumption, and economic growth. Energy is primarily used in densely populated areas, leading to economic activities like transportation and business. However, higher population density can cause environmental issues like pollution and public health problems. Limited energy resources limit economic activities and hinder economic development. Studies show that population and economic growth are major drivers of increased energy consumption and CO^2 emissions. As living standards rise and population continues to grow, so does energy consumption and CO^2 emissions in city areas.

3. Methodology

This study uses regression analysis or Ordinary Least Square Method (OLS) to fit a relationship between explanatory variables and outcome variables (Leng et al., 2007). OLS models, such as linear regression, are based on assumptions like independence, homoscedasticity, and normality of residuals (Das & Das, 2019). If these assumptions are met, OLS regression produces unbiased estimates with the smallest variance among linear estimators (Puntanen & Styan, 1989). This study uses a multiple regression model based on consumer behavior theory to calculate energy consumption function. It assumes rational consumers maximize usefulness under budget constraints and presents an empirical model for log-linear estimation.

$$ENERGY_t = \alpha_o + \alpha_1 GDP_t + \alpha_2 INF_t + \alpha_3 FD_t + \alpha 4 POPt + \mu_t + D_i \quad (1)$$

$$LENERGY_t = \alpha_o + \alpha_1 LGDP_t + \alpha_2 INF_t + \alpha_3 LFD_t + \alpha 4\ LPOPt + \mu_t + D_i \quad (2)$$

Where:

FD = Financial Development (Domestic credit to the private sector as share of GDP is used to measure financial development)
GDP = Economic Growth (Growth in Real GDP)
Energy = Total Energy consumption
INF = Inflation Rate

POP = Total Population
μ_t = Error that obtained from the data collected
α_0 = Intercept
$\alpha_1\ \alpha_2, \alpha_3\ and\ \alpha_4$= Partial Coefficient ENERGY to FD, GDP, INF and POP
D_i = 0 for economic crisis
= 1 for non-economic crisis

The study uses secondary data to analyze economic conditions in Malaysia, Indonesia, Philippines, Thailand, and Singapore, focusing on existing data rather than human perspectives. This method helps evaluate the relationship between economic growth, financial development, inflation, and energy consumption in ASEAN-5. Furthermore, the study uses data from the World Bank and IMF databases to analyze energy consumption, domestic credit, real GDP growth, inflation, and total population from 1980 to 2020, using a forecast technique.

4. Result and Discussion

An auxiliary regression, also known as a variance inflation factor (VIF) analysis, is used to check for multicollinearity among independent variables in a regression model. If the R-squared (R2) in this auxiliary regression exceeds 0.94, it indicates a significant degree of multicollinearity, suggesting that the independent variables are closely related and may cause instability in the model. Conversely, an R-squared value below 0.94 suggests that multicollinearity is not a substantial issue, indicating that the model may not suffer from the adverse effects associated with multicollinearity. In summary, an R-squared above 0.94 prompts further investigation and potential corrective measures to mitigate multicollinearity's impact on the regression model's stability and interpretability.

TABLE 2. AUXILIARY REGRESSION OF ASEAN

Regression*	R^2									
	Malaysia	Multi**	Indonesia	Multi**	Philippines	Multi**	Thailand	Multi**	Singapore	Multi**
1.	0.9946	Suffer	0.9870	Suffer	0.9204	No	0.9866	Suffer	0.9948	Suffer
2.	0.4128	No	0.1587	No	0.3731	No	0.4640	No	0.3475	No
3.	0.5579	No	0.1925	No	0.3523	No	0.5912	No	0.8638	No
4.	0.9946	Suffer	0.9865	Suffer	0.9214	No	0.9872	Suffer	0.9957	Suffer

*Regression: 1. regress lgdp inf lfd lpop
2. regress inf lfd lpop lgdp
3. regress lfd lpop lgdp inf
4. regress lpop lgdp inf lfd
**Multi = Multicollinearity

The Variance Inflation Factor is a statistic that indicates the degree of collinearity between predictor variables in a multiple regression. It is determined by dividing the variance of all the betas in a given model by the variance of a single beta fit alone.

TABLE 3. VARIANCE INFLATION FACTOR FOR ASEAN

Variables	Malaysia	Indonesia	Philippines	Thailand	Singapore
viflgdp	185.1852	76.92308	12.56281	74.62687	192.3077
vifinf	1.702997	1.188637	1.595151	1.865672	1.532567
viflfd	2.261932	1.23839	1.543925	2.446184	7.342144
viflpop	185.1852	74.07407	12.72265	78.125	232.5581

The general rule of thumb is that a Variance Inflation Factor (VIF) value less than 10 is considered an indication of no significant multicollinearity in a regression model. Upon reviewing Table 3, it becomes evident that Malaysia's VIF values for viflgdp and viflpop surpass this threshold, registering values of 185.19 for both variables. This outcome suggests that both viflgdp and viflpop in Malaysia's model are indeed affected by severe multicollinearity. Conversely, the VIF values for vifinf and viflfd in Malaysia, which are 1.70 and 2.26, respectively, indicate that these variables are not suffering from multicollinearity. Similarly, in the case of Indonesia, both viflgdp and viflpop exhibit VIF values exceeding 10, implying the presence of multicollinearity. On the other hand, the VIF values for vifinf and viflfd in Indonesia, measuring 1.19 and 1.24, respectively, suggest that these variables have a moderate level of correlation but do not suffer from severe multicollinearity. These findings underscore the importance of addressing multicollinearity issues, particularly for viflgdp and viflpop in both Malaysia and Indonesia, to enhance the stability and interpretability of the regression models.

Table 3 provides insights into the multicollinearity issues within the ASEAN-5 countries. In the Philippines, concerning VIF values of 12.56 and 12.72 for viflgdp and viflpop respectively suggest the presence of multicollinearity, while vifinf and viflfd exhibit VIF values of 1.60 and 1.54, indicating no multicollinearity concerns. In Thailand, viflgdp's high VIF of 74.63 implies multicollinearity, whereas vifinf's VIF of 1.87 signifies its independence from multicollinearity. Although viflfd is highly correlated with a VIF of 2.45, it does not suffer from multicollinearity. Conversely, viflpop's VIF of 78.13 indicates multicollinearity. Singapore's VIF values reveal severe multicollinearity for viflgdp at 192.31, moderate correlation for vifinf at 1.53 without multicollinearity, and high correlation for viflfd at 7.34 without multicollinearity. Viflpop's VIF of 232.56 signals multicollinearity. The Durbin-Watson test is a common method used to assess autocorrelation in regression analysis. It is readily available in statistical software packages like STATA. This test yields a test statistic that falls within the range of 0 to 4. When the test statistic is close to 2, it indicates a lower level of autocorrelation, suggesting that the residuals are relatively independent. On the other hand, values close to 0 or 4 suggest a more significant positive or negative autocorrelation, respectively, indicating that the residuals exhibit a stronger correlation pattern, potentially violating the assumption of independence in the regression model. The Durbin-Watson test is a valuable tool for identifying and addressing autocorrelation issues, ensuring the reliability of regression results.

TABLE 4. DURBIN WATSON STATISTICS FOR ASEAN

Countries	**d-Statistic**	**Zone**	**Autocorrelation**
Malaysia	1.065479	$0 \leq d \leq dL$	Positive
Indonesia	0.518618	$0 \leq d \leq dL$	Positive
Philippines	0.468057	$0 \leq d \leq dL$	Positive
Thailand	0.7013042	$0 \leq d \leq dL$	Positive
Singapore	0.6572346	$0 \leq d \leq dL$	Positive

The critical values for the Durbin-Watson test, based on the sample size (k = 41) and the number of explanatory variables (n - 1 = 4), are dL (lower critical value) of 1.287 and dU (upper critical value) of 1.776. In the Durbin-Watson test, the result falls within the range of 0 to 4, and these critical values help determine whether there is autocorrelation present in the data. In the analysis, the Durbin-Watson statistic (denoted as "d") likely falls outside this critical range. Specifically, it seems that your calculated Durbin-Watson statistic is less than 1.287, indicating positive autocorrelation in the ASEAN data. This suggests that there is a significant correlation between the residuals of your regression model, violating the assumption of independence. Addressing autocorrelation is crucial for accurate regression analysis and interpretation of results.

TABLE 5. LOG-LINEAR REGRESSION OF MALAYSIA

LEC	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LGDP	.3738199	.1477412	2.53	0.016	.0741868	.6734531
INF	.0072124	.0048213	1.50	0.143	-.0025657	.0169905
LFD	.1080894	.0426449	2.53	0.016	.0216016	.1945772
LPOP	.6621849	.3783519	1.75	0.089	-.1051482	1.429518
cons	-14.26845	2.487777	-5.74	0.000	-19.31389	-9.223

$$\mathbf{LENERGY_t = -14.2684 + 0.3738LGDP_t + 0.0072INF_t + 0.1081LFD_t + 0.6622LPOPt}$$

Based on Table 5, several significant findings emerge from the analysis. The elasticity of energy consumption concerning economic growth is calculated at 0.3738. This means that when economic growth increases by 1 percent, energy consumption, on average, rises by approximately 0.37 percent. This observation aligns with Keynesian Consumption Theory, indicating that as income increases, consumption tends to increase as well. Furthermore, the partial slope coefficient of 0.0072 represents the elasticity of energy consumption concerning the inflation rate. Holding other independent variables constant, if the inflation rate increases by 1 percent, energy consumption increases by about 0.007 percent. This result corresponds to the Demand-Pull Theory, which suggests that sustained growth in energy consumption can contribute to the economy's aggregate demand component, potentially triggering inflation. Similarly, when financial development increases by 1 percent while other factors remain constant, energy consumption, on average, increases by approximately 0.11 percent. This establishes a positive relationship between financial development and energy consumption, which is supported by Chang's (2015) earlier study, indicating that improved financial intermediation efficiency can drive energy consumption. Lastly, the estimated elasticity coefficient for total population is approximately 0.6622, signifying that a 1 percent increase in the total population corresponds to a 0.66 percent rise in average energy consumption. In the case of Malaysia, the sum of the four elasticity coefficients equals 1.1513, suggesting increasing returns to scale. These findings provide valuable insights into the complex interplay between various factors and their impact on energy consumption within the Malaysian context.

$$\mathbf{R^2 = 0.9901; 0.9901 \times 100\% = 99.01\%}$$

99.01 per cent variation in the dependent variable which is energy consumption can be explain by their independent variables which including GDP, inflation rate, financial development and total population. A variation of 0.99 per cent from regression can be explained by the error term.

TABLE 6. LOG-LINEAR REGRESSION OF INDONESIA

LEC	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LGDP	-.3488357	.1704848	-2.05	0.048	-.6945948	-.0030765
INF	.0008929	.0013565	0.66	0.515	-.0018581	.003644
LFD	.0524224	.027269	1.92	0.062	-.0028818	.1077265
LPOP	2.665264	.5213235	5.11	0.000	1.607971	3.722557
cons	-32.1906	3.987054	-8.07	0.000	-40.27673	-24.10448

$$\mathbf{LENERGY_t = -32.1906 - 0.3488LGDP_t + 0.0089INF_t + 0.0524LFD_t + 2.6653LPOPt}$$

Based on the findings presented in Table 6, several significant insights can be gleaned. The economic growth elasticity for Indonesia is calculated at -0.3488, indicating that when economic growth increases by 1 percent, energy consumption, on average, decreases by approximately 0.35 percent. This negative relationship suggests that as the economy grows, there is a tendency for energy consumption to decrease, which can have implications for energy efficiency and conservation efforts. The partial slope coefficient of 0.0089 represents the elasticity of energy consumption concerning the inflation rate. Holding other independent variables constant, if the inflation rate increases by 1 percent, energy consumption increases by about 0.009 percent. This observation aligns with the demand-pull inflation theory, suggesting that policies aimed at reducing each component of total aggregate demand can help mitigate inflationary pressures. Furthermore, when financial development increases by 1 percent while other factors remain constant, energy consumption, on average, increases by approximately 0.05 percent. This result is supported by Fung's (2009) study, which suggests that an efficient financial system can stimulate the creation of more products, thereby increasing the demand for energy. Lastly, the estimated total population elasticity for Indonesia is approximately 2.6653, indicating that a 1 percent increase in the total population corresponds to a 2.67 percent rise in average energy consumption. The sum of the four elasticity coefficients, totaling 2.3777, suggests increasing returns to scale for Indonesia. These findings provide valuable insights into the complex relationships between economic factors and energy consumption within the Indonesian context, offering valuable information for policymakers and energy management strategies.

$$\mathbf{R^2 = 0.9524;\ 0.9524\ x\ 100\% = 95.24\%}$$

95.24 per cent variation in the dependent variable which is energy consumption can be explain by their independent variables which including GDP, inflation rate, financial development and total population. A variation of 4.76 per cent from regression can be explained by the error term.

TABLE 7. LOG-LINEAR REGRESSION OF PHILIPPINES

LEC	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LGDP	.0156942	.0518236	0.30	0.764	-.089409	.1207973
INF	-.0011152	.0010367	-1.08	0.289	-.0032178	.0009874
LFD	.1500576	.0253335	5.92	0.000	.0986788	.2014364
LPOP	-.0925438	.0981396	-0.94	0.352	-.2915801	.1064925
-cons	6.852646	.6769379	10.12	0.000	5.479753	8.22554

$$\mathbf{LENERGY_t = 6.8526 + 0.1569LGDP_t - 0.0112INF_t + 0.1501LFD_t - 0.0925LPOPt}$$

Based on the findings presented in Table 7, several key insights emerge regarding the Philippines' energy consumption and its relationship with various factors. The economic growth elasticity for the Philippines is calculated at 0.0157, signifying that when economic growth increases by 1 percent, energy consumption in the Philippines, on average, rises by approximately 0.02 percent. This positive relationship suggests that GDP and energy consumption are positively correlated, meaning that as the economy grows, energy consumption tends to increase as well. Conversely, the partial slope coefficient of -0.0011 represents the elasticity of energy consumption concerning the inflation rate. Holding other independent variables constant, if the inflation rate increases by 1 percent, energy consumption decreases by about 0.001 percent. This finding indicates that inflation has a minimal negative impact on energy consumption in the Philippines. Moreover, when financial development increases by 1 percent while other factors remain constant, energy consumption, on average, increases by approximately 0.15 percent. This suggests a positive relationship between financial development and energy consumption in the Philippines, aligning with the idea that a more developed financial system can stimulate demand for energy. However, the estimated total population elasticity for the Philippines is about -0.0925, implying that a 1 percent increase in the total population corresponds to a 0.09 percent decrease in average energy consumption. This suggests that population growth may have a dampening effect on energy consumption in the Philippines. The sum of the four elasticity coefficients, totaling -0.6192, suggests decreasing returns to scale for the Philippines. These findings provide valuable insights into the intricate relationships between economic factors, population, and energy consumption within the Philippines, which can inform energy policies and strategies.

$$\mathbf{R^2 = 0.5687;\ 0.5687 \times 100\% = 56.87\%}$$

56.87 per cent variation in the dependent variable which is energy consumption can be explain by their independent variables which including GDP, inflation rate, financial development and total population. A variation of 43.13 per cent from regression can be explained by the error term.

TABLE 8. LOG-LINEAR REGRESSION OF THAILAND

LEC	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LGDP	1.037356	.1183978	8.76	0.000	.7972339	1.277478
INF	.0084536	.0029795	2.84	0.007	.002411	.0144962
LFD	-.097937	.0361345	-2.71	0.010	-.1712212	-.0246528
LPOP	-.1133023	.6169949	-0.18	0.855	-1.364626	1.138021
-cons	-20.88581	7.702614	-2.71	0.010	-36.50744	-5.264189

$$\mathbf{LENERGY_t = -20.8858 + 1.0374LGDP_t + 0.0085INF_t - 0.9794LFD_t - 0.1133LPOPt}$$

Based on the information presented in Table 8, we can discern important insights regarding Thailand's energy consumption and its relationship with various factors. The economic growth elasticity for Thailand is calculated at 1.0374, indicating that when economic growth increases by 1 percent, energy consumption in Thailand, on average, rises by approximately 1.04 percent. This positive relationship aligns with the concept articulated by Keynes, where the current level of income is a determining factor for individual and societal consumption patterns. The partial slope coefficient of 0.0084 measures the elasticity of energy consumption concerning Thailand's inflation rate. Holding other independent variables constant, if the inflation rate increases by 1 percent, energy

consumption increases by about 0.008 percent. This suggests that inflation has a limited positive effect on energy consumption in Thailand. Interestingly, when financial development increases by 1 percent while other factors remain constant, energy consumption, on average, decreases by approximately 0.10 percent. This finding may indicate that in Thailand, a more developed financial system could lead to increased efficiency and potentially reduced energy consumption. However, the estimated total population elasticity for Thailand is about -0.1133, implying that a 1 percent increase in the total population corresponds to a 0.11 percent decrease in average energy consumption. This suggests that population growth in Thailand may be associated with a slight reduction in energy consumption. The sum of the four elasticity coefficients, totaling 0.8347, indicates decreasing returns to scale for Thailand. These findings provide valuable insights into the intricate relationships between economic factors, population, and energy consumption within Thailand, which can be valuable for shaping energy policies and strategies in the country.

$$\mathbf{R^2 = 0.9925; 0.9925 \times 100\% = 99.25\%}$$

99.25 per cent variation in the dependent variable which is energy consumption can be explain by their independent variables which including GDP, inflation rate, financial development and total population. A variation of 0.75 per cent from regression can be explained by the error term.

TABLE 9. LOG-LINEAR REGRESSION OF SINGAPORE

LEC	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LGDP	2.889253	.4743924	6.09	0.000	1.92714	3.851365
INF	.003634	.0139203	0.26	0.796	-.0245977	.0318658
LFD	.6462859	.3908143	1.65	0.107	-.1463223	1.438894
LPOP	-6.978075	1.376921	-5.07	0.000	-9.7706	-4.18555
-cons	36.52688	7.553424	4.84	0.000	21.20783	51.84593

$$\mathbf{LENERGY_t = 36.5269 + 2.8893LGDP_t + 0.0036INF_t + 0.6463LFD_t - 6.9781LPOPt}$$

The findings from Table 9 provide valuable insights into Singapore's energy consumption and its relationship with various factors. The economic growth elasticity for Singapore is calculated at an impressive 2.8893, indicating that when economic growth increases by 1 percent, energy consumption in Singapore, on average, rises by approximately 2.90 percent. This strong positive relationship suggests that economic growth significantly drives energy consumption in the country. The partial slope coefficient of 0.0036 measures the elasticity of energy consumption concerning Singapore's inflation rate. Holding other independent variables constant, if the inflation rate increases by 1 percent, energy consumption increases by about 0.004 percent. This implies that inflation has a relatively small positive effect on energy consumption in Singapore. Notably, when Singapore's financial development increases by 1 percent while keeping other factors constant, energy consumption, on average, rises by approximately 0.65 percent. This suggests that a more developed financial system in Singapore may lead to increased demand for energy, aligning with the findings in the analysis. However, the estimated total population elasticity for Singapore is notably negative at -6.9780, indicating that a 1 percent increase in the total population corresponds to a substantial 6.98 percent decrease in average energy consumption. This suggests that population growth in Singapore is associated with a significant reduction in energy consumption per capita. The sum of the four elasticity coefficients, totaling -3.4388, suggests decreasing returns to scale for Singapore. These findings provide valuable insights into the complex relationships between

economic factors, population, and energy consumption within Singapore, which can inform energy policies and strategies in the country.

$$R^2 = 0.8195; 0.8195 \times 100\% = 81.95\%$$

81.95 per cent variation in the dependent variable which is energy consumption can be explain by their independent variables which including GDP, inflation rate, financial development and total population. A variation of 18.95 per cent from regression can be explained by the error term.

In the comprehensive analysis of the ASEAN countries, several crucial findings have emerged. Firstly, Malaysia, Indonesia, and Thailand have been identified as countries suffering from multicollinearity due to their high R-squared values, confirmed through auxiliary regression and Variance Inflation Factor (VIF) tests, particularly in the context of GDP and total population. Secondly, the partial correlation analysis reveals that among the ASEAN nations, the strongest correlation exists between economic growth and total population, underscoring a significant relationship between these variables. Thirdly, autocorrelation findings exhibit variations, with the Durbin-Watson test suggesting positive autocorrelation in all five ASEAN countries, while two-way scatter graphs reveal positive autocorrelation specifically in the Philippines, Thailand, and Singapore. Lastly, the log-linear regression results indicate that different factors impact each ASEAN country uniquely, with Singapore influenced primarily by economic growth, Thailand by inflation rate, the Philippines by financial development, and Indonesia by total population. These findings collectively provide valuable insights into the complex dynamics of multicollinearity, autocorrelation, and the specific determinants of energy consumption across the ASEAN region, informing potential policy directions and energy management strategies for each nation.

5. Conclusion and Policy Implications

This comprehensive study examined the intricate connections between energy consumption and various economic factors across five ASEAN countries from 1980 to 2020, relying on regression analysis. The findings consistently revealed positive associations between energy consumption and key variables, including economic growth, inflation rate, financial development, and total population, across the ASEAN-5 nations, with energy consumption closely linked to GDP. However, the impact of economic growth varied, with Indonesia showing a unique negative correlation, diverging from prior research. Inflation rates demonstrated a positive relationship with energy consumption, although their influence was overshadowed by other factors. Financial development was found to significantly drive-up energy consumption, aligning with existing literature, while total population had varying effects, being positive in Malaysia and Indonesia but negative in the Philippines, Thailand, and Singapore. These nuanced findings shed light on the complex dynamics of energy consumption and offer valuable insights for tailored policy decisions and energy management strategies in each country. One crucial policy implication arising from these findings is the importance of a balanced and tailored approach to energy policy within the ASEAN-5 countries. Recognizing the positive correlation between energy consumption and economic growth, policymakers should prioritize strategies that foster sustainable economic development while also promoting energy efficiency and resource conservation. For countries like Indonesia, where economic growth was negatively correlated with energy consumption, there is an opportunity to explore alternative energy sources and improve energy efficiency measures. Moreover, given the influence of financial development on energy consumption, policymakers should consider initiatives that encourage efficient financial

systems to support economic growth without excessive energy consumption. In countries where total population was positively correlated with energy consumption, such as Malaysia and Indonesia, strategies to optimize human capital and increase productivity should be at the forefront of policy agendas. Conversely, for countries like the Philippines and Thailand where population had a negative impact on energy consumption, policies that balance economic growth with population management and energy conservation are essential. In essence, these nuanced findings underscore the need for comprehensive and customized energy policies that align with the unique dynamics of each ASEAN-5 country, fostering sustainable economic growth while mitigating the environmental impact of increased energy consumption.

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