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Understanding Energy Consumption Dynamics in Malaysia: An Empirical Analysis

Muzafar Habibullah[a]

Abstract

This paper examines the factors influencing energy consumption in Malaysia, focusing on scale and technique effects, composition, trade openness, and urbanization over the period from 1970 to 2019 using quarterly data. To explore the long-term relationships between these variables, the study employs the bounds testing approach, taking into account structural breaks to ensure robustness in the findings. The empirical results reveal several key insights into the dynamics of energy consumption in Malaysia. Firstly, the growth effect, which includes both the scale and technique effects, shows divergent impacts on energy consumption. The scale effect, representing economic expansion, positively impacts energy consumption, indicating that as the economy grows, energy demand increases. On the other hand, the technique effect, which refers to improvements in technology and efficiency, has a negative impact on energy consumption, suggesting that technological advancements and efficiency improvements help reduce energy demand. Additionally, the composition effect, which relates to the structural changes in the economy such as shifts towards more energy-intensive industries, stimulates energy demand in Malaysia. This indicates that changes in the industrial composition towards sectors that are more energy-dependent contribute to higher energy consumption. Trade openness and urbanization are also found to positively influence energy consumption. Greater trade openness typically leads to increased industrial activity and economic growth, thereby raising energy demand. Urbanization drives energy consumption through increased infrastructure development, higher population density, and greater demand for energy services in urban areas. These findings have significant policy implications for Malaysia. To sustain economic growth while improving environmental quality, policymakers need to design and implement comprehensive energy and trade policies. Given that economic growth (scale effect) drives energy consumption, efforts should be directed towards enhancing the technique effect by promoting energy-efficient technologies and practices across all sectors of the economy. This can be achieved through incentives for energy-efficient investments, regulations that mandate energy efficiency standards, and support for research and development in green technologies. Moreover, the positive impact of trade openness on energy consumption suggests that trade policies should be integrated with environmental considerations. Promoting exports of energy-efficient and environmentally friendly products can help mitigate the environmental impact of trade-driven economic activities. Additionally, policies aimed at managing urbanization effectively, such as urban planning that incorporates green spaces, public transportation, and sustainable infrastructure, can help balance the energy demands of growing urban populations. The composition effect indicates a need for industrial policies that encourage a shift towards less energy-intensive industries. Diversifying the industrial base to include more service-oriented and high-tech industries can reduce overall energy consumption while maintaining economic growth.

Keywords: Energy Consumption, Trade Openness, Energy Demand
JEL Codes: Q41, Q43, Q56

1. INTRODUCTION

The intricate relationship between energy utilization and economic growth has been a subject of extensive debate, especially in the wake of significant events like the oil shocks of the 1970s. Projections by the International Energy Agency indicate a substantial increase in global primary energy demand, with non-OECD nations driving the majority of this growth. Fossil fuels are expected to continue dominating the energy landscape, underscoring the critical role of energy in fueling industrialization and economic development. Trade liberalization, a key driver of economic growth, plays a pivotal role in shaping energy demand dynamics. As countries embrace trade openness and industrialize, the demand for energy surges to meet the needs of a burgeoning export-oriented industrial sector. This demand is fueled by factors such as increased competition, economies of scale, and technology transfer, all of which are vital for fostering industrial growth and enhancing competitiveness on the global stage. Moreover, imports facilitate technology transfer and the acquisition of production factors, further stimulating energy demand within a country. Trade openness thus generates energy demand through multiple channels, including the growth effect, scale effect, and technology effect. This underscores the complex interplay between trade policies, industrialization, and energy consumption in driving economic growth and development.

[a] Department of Economics, Faculty of Management and Economics, Universiti Malaysia Terengganu, Malaysia

Malaysia has emerged as a notable success story in the Southeast Asian region, leveraging exports as a catalyst for robust economic growth over the past few decades. Despite facing challenges such as global and regional financial crises in the 1980s, 1998, and 2009, Malaysia has demonstrated resilience and adaptability in its trade performance. The country's economic transformation gained momentum in 1985 with the implementation of a strategic industrial plan. This initiative paved the way for the manufacturing sector to emerge as a key driver of Malaysia's economic progress. The manufacturing sector not only contributed significantly to exports but also played a pivotal role in driving production and increasing energy utilization, fueling the nation's economic growth trajectory.

In terms of trade figures, Malaysia's total trade volume stood at RM1.31 trillion in 2012, marking a notable increase from RM1.27 trillion recorded in 2011. This growth was driven by a 0.6% rise in exports, reaching RM702.19 billion, coupled with a 5.9% expansion in imports, totaling RM607.36 billion. Malaysia's trade partnerships are diverse, with key trading partners including ASEAN countries, China, Japan, the European Union, the United States, Australia, India, the United Arab Emirates, and the Republic of Korea. These robust trade relationships underscore Malaysia's integration into global markets and its strategic positioning in the global trade landscape. The establishment of the ASEAN Free Trade Area in 2003 has significantly contributed to Malaysia's export performance, fostering greater trade integration within the region. Despite occasional fluctuations stemming from global economic instability, Malaysia has demonstrated steady and consistent economic performance over the past few decades. One notable trend during this period has been the consistent increase in energy utilization since the 1990s, reflecting the country's sustained economic growth and development. This upward trajectory in energy consumption is closely linked to Malaysia's vibrant manufacturing sector and the rapid urbanization witnessed across the country.

Key drivers of Malaysia's export-oriented manufacturing sector include products such as palm oil, electrical and electronic goods, crude petroleum, and rubber products. These sectors have played a crucial role in driving Malaysia's export growth and economic development over the years. Recent statistics on industrial development in Malaysia further validate this upward trend, signaling the country's successful transition towards market-based policies and industrial strategies implemented since the 1990s. This strategic shift has propelled Malaysia to the forefront of regional trade and economic advancement, positioning it as a key player in the global marketplace. The 1990s marked a significant turning point for Malaysia's trade landscape, with the government's decision to reduce tariffs on industrial and agricultural products leading to a dramatic increase in trade volume. This move towards trade liberalization was further reinforced by the implementation of trade openness policies in 2000, which attracted high volumes of foreign direct investment to the country. Despite experiencing setbacks due to recessions in major export destinations during the late 1990s, particularly affecting the performance of Malaysia's electrical and electronic products, the manufacturing sector managed to sustain growth thanks to higher export earnings from commodities such as palm oil, crude petroleum, and liquefied natural gas. The continuation of Malaysia's trade openness policies in subsequent years has resulted in a steady rise in trade volume, which has had significant implications for energy supply and demand within the country. The increasing demand for energy, primarily generated from fossil fuels, has raised environmental concerns, as reliance on such energy sources contributes to environmental degradation. This scenario reflects a common challenge faced by many developing nations over the past few decades, where rapid economic development driven by trade and industrialization has often come at the expense of environmental sustainability. Addressing this challenge requires concerted efforts towards transitioning to cleaner and more sustainable energy sources, alongside implementing effective environmental policies and regulations to mitigate the negative impacts of industrialization and trade on the environment.

2. LITERATURE REVIEW

In earlier literature on energy economics, there is a large number of empirical studies on the positive association between energy consumption and stage of economic growth of the country (Beaudreau, 1995). Economic development is influenced by the amount of energy usage as well as primary inputs usage in the production function. The intensified interest by the major economic powers of the world to gain a firm foothold on energy-based regions across the globe is a testimony to the fact that energy will remain a major focus in the foreseeable future (Beaudreau, 1995). The battle for such control will also increase, as more energy will be needed to meet the demand for future economic growth. On the other hand, there has been increased pressure from the developed economies to reduce CO2 emissions in order to mitigate global warming and climate change (International Energy Agency, 2009). Consequently, emerging and industrialized countries are concerned about the potential negative effects on economic growth caused by restricted energy use. There is a large body of empirical literature on the relationship between energy consumption and economic growth. For instance, Stern (2000) examined annual data from 1948 to 1994 in the United States and concluded that there is mutual causality between energy consumption and GDP. Conversely, Wolde-Rufael (2005) found conflicting evidence with the neutrality hypothesis supported in many countries and little support for the hypothesis that energy consumption causes economic growth. Lee (2006) in a study of eighteen developing countries found causality running from energy consumption to economic growth but not vice versa using panel cointegration and Granger causality approaches. Similarly, Al-Iriani (2006) found unidirectional causality running from economic growth to energy consumption in six Gulf Cooperation Council countries. Richmond and Kaufmann (2006) also included energy consumption in their analysis and found a relationship between income, energy consumption, and

emissions. However, Soytas and Sari (2006) using a tri-variate model failed to identify a significant Granger causality link between any of the variables.

Recent research continues to delve into the intricate relationship between energy consumption and economic growth. Lorde, Waithe, and Francis (2010) employed capital, labor, technology, and energy as distinct inputs to examine the presence of a long-term correlation between output growth and electrical energy usage. Their findings suggested a sustained relationship between growth and electricity consumption, with bidirectional causality observed between electrical energy consumption and real GDP over the long term. However, in the short term, causality appeared unidirectional from energy to output. A study conducted in Latin America by Apergis and Payne (2009) utilized panel cointegration techniques and identified both short-term and long-term causality from energy consumption to economic growth. Meanwhile, Uddin, Alam, and Murad (2011) provided evidence supporting the unidirectional causality from energy consumption to economic growth in the context of Bangladesh. Conversely, Shahbaz and Lean (2012) found that economic growth Granger-caused energy consumption in Tunisia. More recently, Shahbaz, Zeshan, and Afza (2012) proposed a feedback hypothesis between energy consumption and economic growth in Pakistan. Trade liberalization's impact on energy consumption is a relatively recent topic in the literature on energy-income relationships. Ghani (2012) posited that trade liberalization could influence energy consumption through alterations in trade policies, such as reductions in tariffs and non-tariff barriers on energy-efficient products. Furthermore, it may indirectly affect energy consumption by driving changes in economic growth, environmental regulations, the adoption of eco-friendly management practices, and resource reallocation. Institutional shifts resulting from liberalization might also impact the transfer of energy-saving technologies, potentially enhancing energy efficiency. Additionally, trade liberalization could indirectly induce a technique effect by boosting income levels, which may alter consumer preferences and prompt governments to revise environmental and energy regulations. In a separate study, Sadorsky (2012) explored the link between energy consumption and exports/imports.

Expansion in exports leads to increased demand for factors of production such as capital, labor, and energy, which are essential in the production process. Machinery and equipment are required not only for the production of exports but also for their loading, transportation, and handling at ports and airports. These operations rely on energy to function efficiently. Consequently, an uptick in exports signifies heightened economic activity in export-oriented sectors, thereby driving up the demand for energy. Similarly, imports can influence energy demand through various channels. Firstly, the transportation network required to move imported goods within the country necessitates energy consumption. Hence, an increase in imports typically correlates with increased energy usage. Secondly, the composition of imports, especially if they include energy-intensive products like automobiles or appliances, can significantly impact energy consumption. Moreover, imported machinery or equipment that rely on energy for operation can also influence energy demand. Conversely, energy conservation policies or limited access to energy resources may dampen the efficiency and viability of energy-dependent imported goods, potentially reducing their importation. In some cases, there may be a feedback relationship or no statistically significant relationship between imports and energy consumption, as well as between exports and energy consumption, depending on various factors and contextual nuances.

Empirical studies have yielded varied and inconclusive findings regarding the relationship between trade openness and energy consumption. For example, Narayan and Smyth (2009) conducted a panel study involving six Middle Eastern countries and discovered short-term Granger causality flowing from electricity consumption to real GDP, as well as from economic growth to exports. Additionally, they identified evidence supporting long-term Granger causality relationships running from exports and electricity consumption to real income earned from exports, and vice versa. Similarly, Lean and Smyth (2010) conducted research on electricity generation and consumption in Malaysia. They found evidence of Granger causality from electricity generation to exports but did not observe a significant causal relationship between exports and electricity consumption. On the other hand, Sadorsky (2011) examined the broader association between energy consumption and trade (measured by either exports or imports) in a panel of Middle Eastern economies. He discovered that in the short term, exports tended to cause changes in energy consumption, while there was a feedback relationship between imports and energy consumption.

In Pakistan, Shahbaz, Lean, and Farooq (2013) conducted a study examining the connection between natural gas consumption and economic growth, integrating exports into the production function. Their findings suggested a long-term relationship among the variables. Specifically, natural gas consumption, exports, capital, and labor were identified as contributors to economic growth. The study also revealed that natural gas consumption Granger causes both economic growth and exports. Several recent studies have delved into the intricacies of energy demand within economies, considering factors such as the technique effect, labor-capital composition effect, and urbanization effect. Utilizing the theoretical framework proposed by Werner et al. (2001), Cole (2006) empirically investigated the mechanisms through which trade liberalization influences national energy consumption across 32 developed and developing nations. The findings suggested that per capita energy consumption is influenced by the scale effect, which, on average, outweighs the negative impact of the technique effect, indicating a lag in regulatory and technological advancements compared to GNP growth. Furthermore, concerning the trade-induced composition effect, evidence has emerged to indicate that energy-intensive industries experience conflicting pressures as per the factor endowment and pollution haven hypotheses. These findings collectively point to a positive correlation between trade liberalization and per capita energy consumption.

In a similar vein, Hossain (2011) conducted an empirical analysis using annual data from 1971 to 2007 to explore the dynamic causal relationships among CO2 emissions, energy consumption, economic growth, trade openness, and urbanization across a panel of nine newly industrialized countries. The findings of the study support the hypothesis that there is no evidence for a long-run causal relationship. However, a unidirectional short-run causal relationship was observed from economic growth and trade openness to CO2 emissions, from economic growth to energy consumption, from trade openness to economic growth, from urbanization to economic growth, and from trade openness to urbanization. These results align with the findings of Sadorsky (2011) in his study on eight Middle Eastern countries from 1980 to 2007, which indicated short-run causality from exports to energy consumption, along with a feedback effect between imports and energy consumption.

Similarly, Sadorsky (2012) examined seven South American countries from 1980 to 2007 and identified a short-run bidirectional feedback relationship between energy consumption and exports, output and exports, and output and imports. Additionally, evidence suggested a one-way short-run relationship from energy consumption to imports. In the long run, a causal relationship was established between trade (exports or imports) and energy consumption. Furthermore, Ghani (2012), analyzing data from 54 developing countries, demonstrated that trade liberalization alone does not affect the growth of energy consumption in developing nations. However, its interaction with capital per labor reduces the growth of energy consumption as capital per labor increases. This effect becomes significant only after a certain minimum threshold level of capital per labor is reached. Conversely, economic growth was found to increase energy consumption, with its effect remaining unaffected by trade liberalization.

This paper aims to assess the impacts of various factors such as trade openness, income effect, scale and technique effects, labor-capital composition effect, and urbanization on energy consumption in Malaysia. As a significant economic player in East Asia, Malaysia has achieved remarkable economic growth, but this growth has been accompanied by a notable increase in energy consumption and pollutant emissions in recent years, underscoring the importance and timeliness of this study. According to the United Nations Development Report, Malaysia's CO2 emissions surged by 221% in 2004 compared to 1990 levels, ranking it 26th among the top 30 greenhouse gas-emitting nations. If this upward trend in emissions continues while other major emitters improve their energy efficiency, Malaysia's position may worsen. Despite being a signatory to the Kyoto Protocol, Malaysia has struggled to curb emissions growth significantly. However, the government's initiatives to promote renewable energy and reduce CO2 emissions provide some reassurance. Therefore, the findings of the energy demand model will offer valuable insights for policymakers seeking strategies for sustainable economic growth in Malaysia. A recent study by Islam, Shahbaz, Ahmed, and Alam (2013) conducted in Malaysia indicated that energy consumption is influenced by economic growth and financial development in both the short and long run, while the population-energy relationship holds only in the long run.

3. The Model

The data on energy consumption per capita (kt of oil equivalent), CO_2 emissions per capita (metric tons per capita), real capital stock, real trade (exports + imports), labor, urban population has been obtained from world development indicators. The present study has covered the time period of 1970-2019. We have used series of population to transform the data into per capita. The series are converted into a natural log form. We follow Cole (2006), Kneller, Morgan, and Kanchanahatakij (2008), Ghani (2012), and Ghani (2011) to examine the impact of trade openness on energy demand. We use quarterly frequency data over the period of 1970-2011 in the case of Malaysia. The empirical equation is modeled as following:

$$E_t = f(Y_t, Y_t^2, KL_t, TR_t, U_t)$$

We apply log-linear model. Our empirical model is articulated as follows:

$$\ln E_t = \beta_1 + \beta_2 \ln Y_t + \beta_3 \ln Y_t^2 + \beta_4 \ln KL_t + \beta_5 \ln TR_t + \beta_6 \ln U_t + \mu_t$$

Where, $\ln E_t, \ln Y_t$, $\ln Y_t^2$, $\ln KL_t$, $\ln TR_t$ and $\ln U_t$ is natural log of energy consumption per capita, real GDP per capita, real GDP per capita square, capital-labor ratio per capita, trade openness (exports + imports) per capita and urbanisation per capita. Y_t indicates economic growth effect, scale and technique effect is captured by Y_t^2, KL_t represents composite effect, trade openness is shown by TR_t, urbanization effect is indicated by U_t and E_t is for energy use . μ_t is error term expected to be independently identically distributed.

Historically, various unit root tests such as the Augmented Dickey-Fuller (ADF) test by Dickey and Fuller (1979), the Phillips-Perron (P-P) test recommended by Kwiatkowski et al. (1992), the KPSS test advocated by Shahbaz and Lean (2012), the DF-GLS test proposed by Elliott, Rothenberg, and Stock (1996), and the test developed by Ng and Perron (2001) have been widely utilized to assess the stationarity properties of variables. However, these tests often yield unreliable results due to the absence of information on structural breaks in the series. In response to this challenge, Zivot and Andrews (1992) proposed an alternative model capable of accommodating a single structural break point in the variables, either at the level form, in the slope of the trend component, or in the intercept and trend function.

Given the limitations of traditional cointegration approaches, we adopted the structural break autoregressive distributed lag model, also known as the ARDL bounds testing approach, to address structural breaks present in the series. This methodology offers several advantages. Firstly, it is flexible in accommodating different orders of integration among variables, whether they are stationary at I(1), I(0), or a mix of both. Furthermore, empirical evidence from Monte Carlo simulations suggests that this approach performs well, particularly with small sample sizes (Pesaran & Shin, 1998).

4. RESULTS AND DISCUSSIONS

The initial step involves testing the unit root properties of the variables to determine their order of integration before applying the ARDL bounds testing approach to cointegration. Although the ARDL bounds testing approach itself does not require pre-unit root testing, it is essential to ensure that none of the variables are integrated at I(2). The bounds testing approach assumes that variables should be stationary at either I(0), I(1), or a combination of both. To address this, we employed traditional unit root tests such as the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test by Philips and Perron (1981), and the DF-GLS test by Elliot, Rothenberg, and Stock (1996). The methodology proposed by Elliot, Rothenberg, and Stock (1996) provides efficient tests for an autoregressive unit root. The results of these unit root tests are summarized in Table-1. It is observed that energy consumption, income, capital-labor ratio, trade openness, and urbanization exhibit a unit root problem at the level with intercept and trend. However, these series are found to be stationary at the first difference, indicating that the variables have a unique order of integration.

Table 1: Unit Root Analysis

Variables	ADF	PP	DF-GLS
$\ln E_t$	–2.0780	–2.0807	–2.6542
$\Delta \ln E_t$	–4.5032***	–4.5032 ***	–10.4149***
$\ln Y_t$	–1.9093	–1.0571	–1.3670
$\Delta \ln Y_t$	–4.6320***	–4.6320 ***	–4.6135***
$\ln KL_t$	–1.7590	–1.7852	–1.8756
$\Delta \ln KL_t$	–4.2119***	–4.1736***	–6.1110***
$\ln TR_t$	–0.0854	0.0914 (1)	–0.1797
$\Delta \ln TR_t$	–3.5589**	–6.0791***	–3.3142**
$\ln U_t$	-0.3421	1.0792	-1.4042
$\Delta \ln U_t$	-4.8665 ***	-4.6162***	-3.5619***

Note: *** and ** denote the significance at 1% and 5% levels respectively. Figure in the parenthesis is the optimal lag structure for ADF and DF-GLS tests, and bandwidth for the PP test.

Table 2: The ARDL Bounds Testing Analysis

Estimated Model	$F_E(E_t / Y_t, KL_t, TR_t, U_t)$	
Optimal Lag Length	(1, 1, 0, 1, 1, 0)	
F-statistics	4.757**	
Critical values#	Lower Critical Bound	Upper Critical Bound
1 per cent level	3.60	4.90
5 per cent level	2.87	4.00
10 per cent level	2.53	3.59
R^2	0.7521	
Adjusted- R^2	0.6715	
F-statistics	9.33666*	
Durbin-Watson	1.9626	

According to the ARDL approach, selecting the lag order of the variables is crucial for model specification. Table 2 presents the lag length criterion used in this paper. We opted to use the Akaike Information Criterion (AIC) to determine the appropriate lag length, as suggested by Lütkepohl (2006), due to its superior power properties for small sample data. AIC offers efficient and consistent results compared to other lag length criteria such as the final prediction error (FPE), Schwarz

information criterion (SBC), and Hannan-Quinn information criterion (HQ). Based on the empirical evidence provided by AIC, we determined that the optimal lag length is 6 for the quarterly frequency data spanning the period of 1970-2011 in the case of Malaysia. The results of the bounds testing are presented in Table 3. Our empirical findings suggest that the calculated F-statistic exceeds the upper critical bound at the 5% level of significance. This leads us to reject the null hypothesis of no cointegration. Subsequently, Table 4 reveals evidence of cointegration when income, capital-labor ratio, trade openness, and urbanization are treated as predictor variables. This indicates the existence of a long-run relationship between trade openness and energy consumption in Malaysia over the period of 1970-2019. The long-run model meets the assumptions of the classical linear regression model (CLRM), including serial correlation, autoregressive conditional heteroskedasticity, white heteroskedasticity, and model specification. Our results indicate no evidence of serial correlation, autoregressive conditional heteroskedasticity, or white heteroskedasticity. Furthermore, the bounds testing model demonstrates good articulation, as confirmed by Ramsey RESET tests.

Table 3: Long-and-Short Runs Analysis

Dependent Variable = $\ln E_t$			
Long-Run Results			
Variable	Coefficient	Std. Error	T-Statistic
Constant	-2.2585*	0.7545	-2.9932
$\ln Y_t$	1.9980*	0.6764	2.9538
$\ln Y_t^2$	-0.3036**	0.1321	-2.2966
$\ln KL_t$	0.0474***	0.0263	1.8015
$\ln TR_t$	0.0617**	0.0283	2.1800
$\ln U_t$	0.8188*	0.1976	4.1437
R^2	0.9909		
F-statistic	35.6064*		
Short-Run Results			
Variable	Coefficient	Std. Error	T-Statistic
Constant	-0.0024	0.0020	-1.2098
$\ln E_{t-1}$	0.4548*	0.0634	7.1654
$\ln Y_t$	-6.5693*	2.4965	-2.6313
$\ln Y_t^2$	0.3837*	0.1336	2.8718
$\ln KL_t$	0.0954**	0.0413	2.3095
$\ln TR_t$	-0.1276***	0.0704	-1.8115
$\ln U_t$	2.5121	1.8945	1.3259
ECM_{t-1}	-0.1774*	0.0320	-5.5437
R^2	0.4483		
F-statistic	18.1096*		
D. W Test	2.0688		

The subsequent step involves examining the impact of independent variables on the dependent variable. Our findings reveal that income positively influences energy consumption. This suggests that the income effect exhibits greater elasticity in relation to energy consumption and is statistically significant at the 1% level. Specifically, a 1% increase in income corresponds to a 1.9980% increase in energy consumption. Given Malaysia's aspiration to achieve developed nation status by 2030, its economy is experiencing rapid growth. Similar to other developed countries, there is a shift in consumer behavior towards increased technological usage. Additionally, improved financial growth and access to credit facilities contribute to higher energy usage. Furthermore, the availability of high subsidies and lower fuel prices incentivizes greater use of vehicles and household appliances. Consequently, policies aimed at reducing energy consumption may have limited impact on economic growth in this context. The analysis indicates that the impact of scale and technique effects on energy consumption is negative and statistically significant at the 5% level. This suggests that economies of scale and the adoption of advanced technology lead to energy savings of 0.3036%. Consequently, energy consumption policies should prioritize

the adoption of advanced technologies and the attainment of economies of scale, particularly in the industrial and manufacturing sectors. Moreover, the impact of the capital-labor ratio (composite effect) on energy demand is positive and statistically significant at the 10% level. This implies that, holding other factors constant, a 1% increase in the capital-labor ratio corresponds to a 0.0474% increase in energy usage. Given the relatively inelastic nature of the composite effect on energy demand, emphasizing the utilization of more capital-intensive production processes may result in only a marginal increase in energy usage. In light of the findings regarding technique and composition effects, Malaysia should prioritize the adoption and promotion of advanced energy-saving technologies to effectively manage its high energy consumption levels.

The analysis reveals a positive and statistically significant relationship between trade openness and energy consumption. Specifically, a 1% increase in trade openness corresponds to a 0.0617% increase in energy consumption, holding all other factors constant. This finding suggests that, in the context of a growing economy like Malaysia, energy consumption exhibits an inelastic response to trade openness. Therefore, policies aimed at promoting greater trade openness are likely to result in only a marginal increase in energy usage. Moreover, it is observed that in low-income countries, an increase in trade openness tends to raise energy usage, whereas in high-income countries, energy consumption tends to decrease following trade liberalization. Given Malaysia's status as a developing economy, the impact of trade openness on energy consumption remains relatively limited. Consequently, policies aimed at expanding trade, such as export promotion initiatives, are unlikely to significantly affect energy consumption levels in the country. Furthermore, the findings imply that environmental policies aimed at reducing energy consumption are unlikely to hinder export growth. This suggests that efforts to enhance environmental sustainability through energy conservation measures will not necessarily impede Malaysia's export-oriented economic growth strategies.

The analysis indicates a positive and statistically significant impact of urbanization on energy consumption, with a 1% increase in urbanization corresponding to a 0.8188% increase in energy demand, all else being equal. This finding suggests that as Malaysia progresses toward its vision of becoming a developed nation by 2020, rapid urbanization and infrastructural development are contributing to an expansion in energy consumption. The transformation of rural areas into urban centers, coupled with improvements in income levels and access to technology, is driving increased energy usage across Malaysian society. As urban areas continue to grow and modernize, the demand for energy-intensive services and amenities is expected to rise further. Therefore, policies aimed at promoting sustainable urban development must carefully consider the implications for energy consumption and seek to address the challenges of meeting growing energy demands while minimizing environmental impacts. The findings of the analysis indicate several important relationships regarding future energy demand and its determinants in Malaysia. Firstly, current energy demand positively influences future energy demand, highlighting the persistence of energy consumption patterns over time. Economic growth, on the other hand, shows a negative impact on future energy demand, suggesting potential avenues for decoupling economic growth from energy consumption. However, the scale and technique effects exert a positive influence on energy consumption, underscoring the importance of technological advancements and economies of scale in driving energy demand.

Moreover, the capital-labor ratio emerges as a significant factor positively affecting energy demand, reflecting the role of capital-intensive production processes in driving energy usage. Interestingly, trade openness appears to have a dampening effect on energy consumption, indicating potential benefits of trade liberalization in terms of energy efficiency. Urbanization also shows a positive association with energy consumption, although this relationship is statistically insignificant. The long-run relationship between trade openness and energy consumption is established through the lagged error correction term, which exhibits a negative and significant coefficient. This suggests a convergence process in the long-run dynamics of trade openness and energy consumption, with around 18% of the previous year's disequilibria being corrected in the current year. The speed of adjustment in the relationship process following a shock indicates that achieving stable long-run equilibrium in energy demand in Malaysia may take approximately five years and two quarters. Overall, the diagnostic tests confirm that the underlying assumptions are met, providing confidence in the reliability of the empirical results. These findings offer valuable insights for the implementation of environmental policy in Malaysia, highlighting the importance of addressing factors influencing energy demand to achieve sustainable and environmentally responsible economic growth.

5. CONCLUSIONS

Trade liberalization policies, by opening up markets and promoting free trade, create an environment conducive to increased international trade and investment. As barriers to trade are removed, businesses can access new markets more easily, leading to expanded opportunities for growth and profitability. Foreign direct investment (FDI) flows into countries implementing trade liberalization policies, attracted by the prospect of accessing larger consumer bases and lower production costs. One of the key benefits of trade liberalization is its role in stimulating economic growth. By encouraging competition and specialization, these policies promote efficiency and productivity gains across various sectors of the economy. As industries become more competitive, they are incentivized to innovate and adopt new technologies, leading to higher levels of output and economic expansion. Moreover, trade liberalization fosters job creation by allowing firms to tap into global supply chains and access a wider pool of labor. This can be particularly beneficial for emerging economies seeking to diversify their industrial base and create employment opportunities for their growing populations.

Trade liberalization leads to both static and dynamic gains, each contributing to overall economic growth and development. Static gains arise from the immediate efficiency improvements and cost reductions that result from increased competition and specialization. By allowing firms to access larger markets and benefit from economies of scale, trade liberalization fosters a more competitive environment, leading to lower prices for consumers and increased efficiency in production processes. On the other hand, dynamic gains from trade stem from the transfer and adoption of advanced technologies, management practices, and know-how. Through exposure to international markets, firms can learn from foreign competitors and adopt best practices, leading to productivity gains and innovation. In particular, the adoption of energy-efficient technologies plays a crucial role in reducing energy consumption and mitigating environmental impacts. Trade openness, encompassing both exports and imports, influences economic growth by affecting the utilization of primary inputs in the production process, including energy. Export-oriented countries often experience increased demand for energy-intensive machinery, equipment, and transportation services necessary for producing and exporting goods. Similarly, imports of technology-based, energy-intensive products such as electronics and automobiles contribute to higher energy consumption levels.

According to endogenous growth theory, trade openness can serve as a channel for transferring technology and factors of production, thereby stimulating economic growth. Through exports, imports, and foreign direct investment, countries can access advanced energy-efficient technologies and managerial expertise, leading to improvements in productivity and competitiveness. This paper delves into the intricate dynamics between energy demand, trade openness, economic growth, and urbanization in the context of Malaysia. By incorporating these factors into an energy demand function, we aimed to discern the extent to which trade openness influences energy consumption, considering the nuances of economic growth and urbanization. Theoretical frameworks suggest that trade openness impacts energy consumption through various channels, including scale and technique effects, as well as changes in the composition of factors of production. To empirically investigate these relationships, we employed the ARDL bounds approach, accounting for potential structural breaks in the time series data through the inclusion of dummy variables. Our analysis revealed compelling insights. Firstly, in the presence of structural breaks, we established the existence of cointegration among the variables, indicating a long-run relationship. Moreover, we uncovered that both scale and technique effects exerted significant impacts on energy demand, albeit in opposing directions. Additionally, the composition of factors of production emerged as a noteworthy contributor to energy consumption. Of particular interest was the role of trade openness, which we found to positively influence energy demand. This implies that as trade barriers are reduced or eliminated, the demand for energy-intensive goods and services increases, thereby driving up overall energy consumption. Furthermore, our analysis identified a positive relationship between urbanization and energy consumption, suggesting that as urban areas expand and develop, the demand for energy escalates.

In the short run, we observed a nuanced relationship between trade openness and energy consumption, with trade openness exhibiting a dampening effect on energy demand, while urbanization was associated with increased energy consumption. Causality analysis unveiled bidirectional causality between trade openness and energy consumption, indicating a mutually reinforcing relationship. Moreover, we found that economic growth and energy consumption are intricately interlinked, with each influencing the other in a feedback loop. Additionally, our analysis revealed that energy consumption, economic growth, capital-labor ratio, and trade openness collectively influence urbanization. In essence, our study sheds light on the multifaceted relationship between trade openness, economic growth, urbanization, and energy consumption in Malaysia, highlighting the intricate interplay of these factors in shaping energy demand dynamics. These findings have important implications for policymakers seeking to develop strategies for sustainable energy management and economic growth in Malaysia and beyond. Indeed, the relationship between economic growth and energy consumption tends to be highly elastic, signifying that as income levels rise, so does the demand for energy. Conversely, the relationship between trade openness and energy consumption appears to be more inelastic, indicating that increasing trade openness may lead to only marginal increases in energy usage. As a result, policies aimed at promoting trade expansion, such as export promotion initiatives, are unlikely to significantly impact energy consumption in Malaysia. Given these insights, it is imperative for energy consumption policies in Malaysia to prioritize the adoption of advanced energy-saving technologies and the attainment of economies of scale, particularly within the industrial and manufacturing sectors. By focusing on enhancing energy efficiency and optimizing production processes, Malaysia can mitigate the growth of energy demand while sustaining economic growth and trade openness.

The correlation between government trade policies and energy use in Malaysia over the past three decades is unmistakable. One of the primary drivers of this relationship is the tariff structure, which directly impacts the trends in imports and exports. In the late 1990s, a significant portion of tariff lines in Malaysia carried non-ad valorem tariffs, accounting for approximately 5% of all tariff lines. However, by the early 2000s, this figure had dropped to a mere 0.2%, largely due to the government's efforts to rationalize the tariff structure, particularly in alignment with agreements such as the World Trade Organization (WTO) pact established in the mid-1990s. These tariff adjustments have had direct ramifications for energy usage across major economic sectors in Malaysia, particularly those involved in export-oriented production activities, such as the manufacturing sector. The government's control over export-promotion policies has further accentuated this relationship, as evidenced by the noticeable surge in energy demand coinciding with increased trade volumes throughout the period from 2000 to 2010. Moreover, the expansion of trade has led to the proliferation of urban and export-based industrial

areas along the west coast of Peninsular Malaysia, further fueling energy consumption growth. In addition to trade policies, the Malaysian government has implemented various energy-related initiatives aimed at ensuring the long-term reliability and security of the nation's energy supply. These policies play a crucial role in shaping energy consumption patterns and fostering sustainable energy practices in Malaysia (Mohamed & Lee, 2006).

The array of energy and environmental policies implemented in Malaysia underscores the government's commitment to efficient energy utilization and environmental protection. Dating back to the National Energy Policy of 1979 and extending to more recent initiatives such as the National Green Technology Policy and Climate Change Policy of 2009, these policies share a common objective of promoting sustainable development by balancing energy needs with environmental concerns. In addition to domestic policies, Malaysia actively participates in regional initiatives like the ASEAN Power Grid and the Trans-ASEAN Pipeline Infrastructure Project. These collaborations are designed to ensure energy resource reserves for the ASEAN region as a whole, reflecting Malaysia's role as a responsible stakeholder in the regional energy landscape. As highlighted by the findings of this study, trade plays a pivotal role in driving energy demand in Malaysia. With energy demand escalating annually, it becomes imperative for the Malaysian government to diversify its energy sources and reduce reliance on any single energy generation method. A diversified energy mix not only enhances energy security but also mitigates environmental risks associated with over-reliance on any particular energy source. Drawing from past strategies like the Five-Fuel Diversification Strategy implemented in 1999, which focused on coal, gas, oil, hydro, and renewable energy, Malaysia can adopt a similar approach for future energy resource planning. By incorporating a mix of coal, natural gas, oil, hydroelectric power, and renewable energy sources like solar and wind, Malaysia can achieve a more resilient and sustainable energy ecosystem. Through these concerted efforts, Malaysia can navigate the complex interplay between energy demand, environmental preservation, and economic development, ensuring a brighter and greener future for generations to come.

The implementation of the first four energy mix components has progressed smoothly as part of Malaysia's sustainable energy development program. However, renewable energy resources have encountered various challenges, such as limited availability and awareness among manufacturers. While the International Energy Agency (IEA) estimated that over 70 countries would adopt renewable energy technologies in the power sector by 2017, demand for renewable energy in Malaysia remains low. One of the main obstacles to renewable energy utilization in Malaysia is the limited availability of resources like biomass, solar, hydrogen fuel cells, and landfill gas. Moreover, there is a lack of awareness among manufacturers regarding the benefits of renewable energy compared to non-renewable sources. To address these issues, policymakers in Malaysia should consider widening the usage of non-renewable energy to meet the demand from manufacturing sectors, particularly those related to trade. Furthermore, there are several policy implications that can be drawn from this study. Firstly, the Malaysian government should improve trade policies to prioritize energy efficiency and encourage the use of green energy products to reduce CO2 emissions. Secondly, incentives such as tax reductions should be offered to manufacturers who utilize green energy, thereby attracting both local and foreign investors to increase the adoption of non-renewable energy alongside green alternatives. Additionally, efforts should be made to enhance overall energy efficiency and reduce CO2 emissions. While Malaysia has already implemented several energy policies, a comprehensive energy efficiency policy focusing on increasing the supply of renewable energy and promoting clean, low-carbon energy sources is essential for the future. By taking these steps, Malaysia can strengthen its position as a leader in sustainable energy development and contribute to global efforts to combat climate change.

Future studies could delve deeper into the impact of trade openness on CO2 emissions in Malaysia, considering factors such as scale effect, technique effect, composition effect, and comparative advantage. Following the methodology outlined by Cole (2006), researchers could investigate how these aspects of trade openness influence environmental outcomes, particularly CO2 emissions. This analysis could provide valuable insights into the environmental implications of Malaysia's trade policies and economic activities. Furthermore, given that a significant portion of Malaysia's population resides in urban areas due to industrialization, future research could explore the relationship between industrialization, urbanization, energy demand, and CO2 emissions. Drawing from methodologies used in studies such as Shahbaz and Lean (2012) and Poumanyvong and Kaneko (2010), researchers could examine how urbanization and industrial development contribute to energy consumption and environmental degradation in Malaysia. Additionally, panel-based cointegration and nonlinear approaches could be employed to analyze regional variations in energy consumption and CO2 emissions within Malaysia. By using multivariate time series panel frameworks, researchers could assess how different regions within the country are affected by trade openness, industrialization, and urbanization, providing a more comprehensive understanding of the dynamics between economic development, energy use, and environmental sustainability at the regional level.

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