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E-B Environment - Behaviour Proceedings Journal

KICSS2024
Kedah International Conference on Social Sciences:
https://kicss2024.wixsite.com/kicss2024

e-IPH e-International Publishing House Ltd., United Kingdom

BizFame 2024: 3rd International Conference on Business Finance Management & Economics
Suan Sunandha Rajabath University, Bangkok, Thailand, 24 & 25 October 2024
Organised by: Universiti Teknologi MARA, Kedah, Malaysia

Energy Intensity, Financial Development, Emissions and Growth In Malaysia

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Abstract
This paper investigates the dynamic relationship between energy intensity, financial development, emissions, and economic growth in Malaysia using the econometric time series method to test the long-term relationship between selected variables. Based on samples from 1980 to 2019, our empirical findings suggest that all the variables' interests are cointegrated in the long run. Moreover, energy intensity and economic growth have the expected outcome where a higher growth rate in Malaysia promotes more efficient energy use. Meanwhile, emissions and financial development provide evidence that energy intensity will increase as emissions and financial development increase.

Keywords: Dynamic ARDL; energy intensity; economic growth; Malaysia

DOI: https://doi.org/10.21834/e-bpj.v10iSI28.6947

1.0 Introduction

Discussions about the impact of economic development and energy use often find a place among researchers and policymakers. Malaysia is committed to balancing its economic growth while at the same time preserving environmental sustainability. To achieve high-income status, Malaysia must tread this path carefully. The Green Technology Master Plan 2017-2030 reflects Malaysia's response to global warming and the concern of maintaining a sustainable environmental management process. One of the important targets outlined in the program is to reduce carbon intensity by 40 percent by 2030 compared to 2005. The National Energy Transition Roadmap (NETR) was introduced to accelerate the program to zero carbon emissions. The goal can be achieved when using energy-efficient technology for all economic activities. However, a country's ability to use energy-efficient technology is varied. It can economically alter a country's progress or ideal of infinitely prioritising a certain instrument. Financing green technology is not generally available in many regions, which becomes an obstruction. The awareness of the stakeholders and the trust in implementing this environmental package still need to be completed to achieve the desired sustainable development.

Sustainable development is meeting the needs of the present without compromising on future generations' ability to meet their own needs. One is energy intensity, which indicates how well an economy uses energy to generate economic output. Here, economic performance and energy intensity are inextricably connected, and this relationship is central to Malaysia's development story. Malaysia's energy intensity and economic growth dynamics provide essential insights into the country's sustainable development, technological progress, and policy frameworks. As there is a strong relationship between these indicators, lower energy intensity translates to better

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DOI: https://doi.org/10.21834/e-bpj.v10iSI28.6947

use of its resources and contributes to sustainable development by reducing environmental impacts with efficient consumption. Knowing the importance of energy intensity and growth, the objective of this study is to examine the dynamic impact of economic growth on energy efficiency in Malaysia. The findings of this study are important in providing information from the perspective of economic analysis. Our study contributes to the literature on the dynamic long-run analysis of energy intensity and other variables, including economic growth, emissions and financial liberalisation in Malaysia. We focus on energy intensity instead of energy demand to complement the importance of energy efficiency to the economy and in line with the current aims of the government in achieving energy-efficient technology transitions.

2.0 Literature review

Several studies suggest a negative relationship between economic growth and energy intensity. Such findings are reported by Wang et al. (2019), Díaz et al. (2019), Zhang et al. (2022), and Janahi et al. (2024). Chen et al. (2022) found a significant negative correlation, showing that as an economy grows, it becomes more energy-efficient by gradually reducing energy consumption. This aligns with Matahir et al. (2023), who examined Malaysia's dynamic link between energy efficiency and growth, and Emir and Bekun (2019) in Romania.

However, other studies present mixed results, often using panel data. For instance, Shang (2014) showed that the effect of economic growth on energy intensity varies by region in China. Deichmann et al. (2019), using data from 137 economies, identified threshold effects and non-linear relationships. Such variations are attributed to differing national policy contexts. In response to these inconsistencies, this study focuses specifically on Malaysia and employs a dynamic ARDL approach to capture both long- and short-run effects more accurately. This method allows for a deeper understanding of how economic growth, financial development, and carbon emissions relate to energy efficiency in a developing country.

In addition, several studies affirm the positive role of financial development in reducing energy intensity, such as Canh et al. (2020), Chen et al. (2019), and Mukhtarov et al. (2020). Jin and Yu (2020) found a negative correlation in developing nations, suggesting that stronger financial systems enhance energy efficiency. Similarly, Sadorsky (2010) observed that countries with advanced financial markets achieve higher energy productivity. By contrast, Shahbaz et al. (2013) reported that financial development raised energy use in Pakistan due to increased economic activity and consumer credit access.

Evidence on the impact of carbon emissions on energy intensity remains limited. Shahbaz et al. (2013) found a bidirectional relationship in Malaysia, while Bekhet et al. (2017) found unidirectional causality in some Gulf states but bidirectional in others. Sbia et al. (2014) showed that emissions reduce energy intensity over time in the UAE. Abdullah et al. (2023) added that emissions may influence digital technology use and energy-efficient behaviour.

3.0 Methodology and Data

3.1 Model specification

Equation (1) below is the specification model used in this study. This model derives from the Solow growth model (See Matahir et al., 2023):

$$EI_t = f\left(GDP_t, CO2_t, FD_t\right) \tag{1}$$

where energy intensity (EI), is a function of economic development (GDP), emissions (CO2) and financial development (FD). Economic development can promote using more sophisticated technologies characterized by energy efficiency. It can be seen that high-income countries tend to encourage greater environmental awareness and investment in energy-saving technologies. In addition, financial development can enable businesses and industries to gain access to capital to invest in modern energy-efficient technologies, thus becoming a long-term investment strategy in energy-efficient infrastructure. Regarding CO2, several studies, such as Saidi and Hammami (2015), and Tong et al. (2020), have found a strong connection that environmental degradation leads to energy consumption, a bi-directional causality between the two. Higher emissions indicate the use of inefficient sources of energy production that led to a positive relationship with energy intensity. Lowering energy intensity can be facilitated by putting emission reduction plans into action. This entails switching to renewable energy sources, enhancing energy management procedures, and implementing energy-efficient technology. We expect the variables to have a positive connection. Lower energy intensity results from less energy being wasted due to reduced emissions.

3.2 Unit root test

In conducting the analysis, the first step is to check for the presence of a unit root for the individual variables. Most empirical studies show that time series data might contain a nonstationary property that leads to spurious regression. Thus, we conduct two types of conventional unit root tests, namely Augmented Dickey-Fuller (ADF) and Kwiatkowski, Phillips, Schmidt, and Shin (1992) or KPSS, to examine the order of integration of each variable. Although the two methods are often complementary to test the unit root, a significant weakness of this conventional method is that it needs to be more robust in detecting the presence of a unit root if a time series contains a structural break. On top of that, failure to consider structural breaks will result in a tendency to reject the results regarding the presence of unit roots in the series. Thus, this study also applies the unit root testing method that contains structure breaks by Perron (1989) (Perron hereafter) to overcome the possible weaknesses of the ADF and KPSS tests.

3.3 ARDL approach to cointegration and dynamic ARDL

Our next strategy is to examine the presence of cointegration among the variables using the ARDL approach to the cointegration technique proposed by Pesaran, Shin, and Smith (2001), as shown by Equation (2).

$$\Delta EI_t = \alpha + b_1 EI_{t-1} + b_2 GDP_{t-1} + b_3 CO2_{t-1} + b_4 FD_{t-1} + \sum_{j=1}^{q} \beta_{1j} \Delta EI_{t-j} + \sum_{j=0}^{q} \beta_{2j} \Delta GDP_{t-j} + \sum_{j=0}^{q} \beta_{3j} \Delta CO2_{t-j} + \sum_{j=0}^{q} \beta_{4j} \Delta FD_{t-j} + \varepsilon_t \quad (2)$$

Here, Δ is the first-different operator, α is the intercept, b_i are the long-term coefficient variables, β_i are coefficients that measure the short-run impact of independent variables towards the dependent variable. ε_t is the error term that fulfils the normality condition, and q denotes the lag(s) for the first-differenced variables. We will test the null hypothesis of no cointegration against the alternative hypothesis of the presence of cointegration. This method has two critical values, namely the upper bound and lower bound of the critical value. The decision to reject the null hypothesis depends on the *f*-statistic value obtained from the test, which will be compared with the critical value provided by Kripfganz and Schneider (2020) critical values and approximate p-values. Suppose the value of the *f*-statistic exceeds the upper bound critical value. In that case, the null hypothesis will be rejected, and the result will conclude that there is a long-term relationship in the selected variable.

Additionally, a set of ARDL models could have more complex dynamic specifications, including lag differences among variables in the model, first-differences, or lagged first-differences (Jordan & Philips, 2018). Hence, we employ the dynamic ARDL method proposed by Jordan and Philips (2018) to mitigate the dynamic complexity of an ARDL model. To implement the method, we need to ensure the presence of cointegration among the variables in the model. The cointegration results from the conventional ARDL thus can help carry out the dynamic ARDL.

3.4 Data

With regards to data, we employ the ratio of energy demand to GDP as the proxy energy intensity (EI), and carbon dioxide (CO2) emission is employed to measure the environmental impact on the economy. Financial development (FD) and real gross domestic product (GDP) were extracted from the World Bank database. The range of data used in this paper is from 1980 to 2019 due to the availability of reported statistics. We transformed all the series into natural log form except for EI.

4.0 Findings

4.1 Unit root

As mentioned previously, we conduct the unit root tests as a preliminary step to examine the stationarity of the individual variables. Based on the ADF and KPSS tests, all series are not stationary at the level form but at the first difference form. Interestingly, EI had an inconclusive outcome as the ADF test failed to reject the null hypothesis of non-stationary at level or first differenced, indicating the possibility of a higher order of integration than *I*(1). Conversely, the KPSS results depict that the EI is stationary at the level while all other variables are stationary at the first difference. We conducted Perron tests to determine the order of integration of the variable. The test includes both IO and AO models. According to the IO model, all variables are stationary in their first differenced form. The AO model revealed that CO2 and FD variables are stationary in their original form, while the others are stationary in their first-difference form. In conclusion, we found a mix of stationary characteristics among the variables[1].

4.2 ARDL cointegration results

Next, we estimate the long-run cointegration among the variables using the ARDL approach to cointegration, and the results are summarised in Table 1. The calculated F-statistic and the t-statistic for the ARDL (1, 2, 0, 0) are 7.568 and -4.801, respectively. We follow Kripfganz and Schneider's (2020) response surface critical values and approximate p-value to check the presence of cointegration among the variables. Accordingly, given the p-value of F- statistics are 0.001 for I(0) and 0.006 for I(1), while the p-values for the t-statistics are 0.001 and 0.008 for I(0) and I(1), respectively, we able to decide that there is cointegration among the variable in the ARDL model as the null hypothesis of no level relationship is rejected. Moreover, the ARDL model also passed all the diagnostic test procedures.

Table 1: ARDL output and diagnostic tests

ARDL model	Test statistic	Value	Null hypothesis (H_0)
ARDL (1, 2, 0, 0)	*F*-statistic	7.568	No level relationship
	t-statistic	-4.801	

[1] The ADF, KPSS and Perron unit root results are not reported here to save space but are available upon request.

Level of significance	*F*-statistic		*t*-statistic		Decision on H_0
	I(0)	I(1)	I(0)	I(1)	
10%	2.906	4.130	-2.539	-3.436	Reject
5%	3.564	4.960	-2.896	-3.842	Reject
1%	5.146	6.938	-3.628	-4.667	Reject
p-value	0.001	0.006	0.001	0.008	
Diagnostic tests					
1. LM test for autocorrelation (*F*-statistic)		4.070 [1]	2.504 [2]	1.731 [3]	1.351 [4]
2. Cameron and Trivedi's decomposition of the IM test					
Source	Chi-square		*p*-value		
Heteroskedasticity	37.00		0.4226		
Skewness	6.98		0.5384		
Kurtosis	2.49		0.1148		
Total	46.47		0.4116		
3. Skewness and kurtosis tests for normality for residual					
Variable	Observation	Pr(skewness)	Pr(kurtosis)	Joint adj chi-square (2)	P > chi-square
Residual	37	0.7088	0.1294	2.62	0.2994

Notes: # Kripfganz and Schneider (2020) critical values and approximate p-values. Diagnostic checks in (1) confirm the model has no issue of autocorrelation up until lag 4. Moreover, test (2) provides evidence that the model does not present a heteroskedasticity problem. Test (3) shows no sign of non-normality distribution.

4.3 Dynamic ARDL results

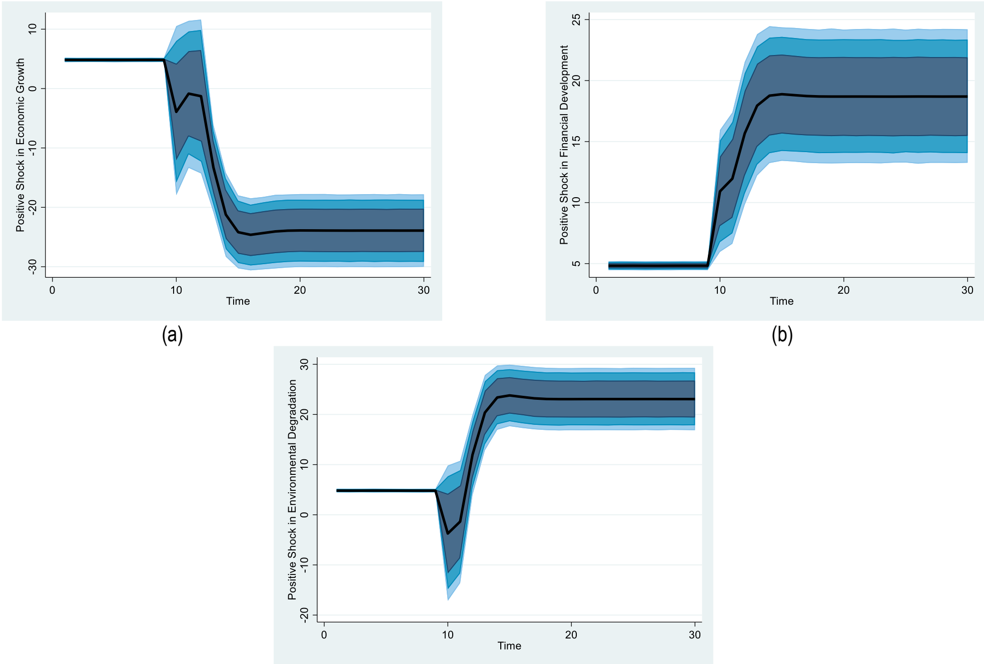
We proceed with our analysis to estimate the estimation model using the dynamic ARDL technique with 5000 simulations (Table 2). In the short run, financial development significantly impacts energy intensity, while output growth has a lag effect on energy intensity. Nevertheless, its impact is positive. In the long run, our empirical output demonstrates that all variables show significance at 1 and 5 percent levels in influencing energy intensity. We find that economic growth negatively impacts energy intensity. That is, given that all other factors remain constant, and a 1 percent increase in economic growth decreases by about 1.5 percent in energy intensity. Meanwhile, a 1 percent increase in financial development and emissions increases energy intensity by 0.73 percent and 0.96 percent, respectively. These elasticities show the varying magnitude of macroeconomic effects on energy use.

Table 2: Dynamic ARDL simulations

Variables	Coefficient	*t*-statistic
$lnEI_{t-1}$	-0.526	-4.88***
$lnGDP_{t-1}$	-1.516	-3.58***
$lnFD_{t-1}$	0.732	2.19**
$lnCO2_{t-1}$	0.958	2.62**
$\Delta lnEI_{t-1}$	0.193	1.230
$\Delta lnGDP_{t}$	-0.886	-1.24
$\Delta lnGDP_{t-1}$	1.527	2.45**
$\Delta lnGDP_{t-2}$	1.113	1.84
$\Delta lnFD_{t}$	0.614	2.39**
$\Delta lnFD_{t-1}$	-0.423	-1.49
$\Delta lnCO2_{t}$	-0.865	-1.26
$\Delta lnCO2_{t-1}$	-1.019	-1.53
Constant	31.840	3.81***
R-squared = 0.732, Simulations = 5000, F-statistics = 5.46***		

*Notes: asterisks *** and ** indicate significant at 1 and 5 per cent level, respectively. The R-squared and F-statistics are the coefficient values.*

Finally, the parameter plot of the results from dynamic ARDL is shown in Fig. 1, in which the dynamic interaction of energy intensity towards any shock in economic growth, financial development, and environmental degradation. The solid line indicates the predicted value of the dependent variable, while the shaded area from darker to lightest shows the 75, 90, and 95 percent confidence intervals. Fig. 1(a) shows an initial negative response in the energy intensity towards a positive shock in economic growth at time 10. In the long run, the response is maintained, with the expected value reaching about less than -20 positive shocks occur. Fig.1 (b) shows the response of energy intensity towards changes in financial development. A 10 percent positive shock of financial development would initially give a sharp response to energy intensity at time 10. The long-run predicted value could be expanded to about less than 20. Concerning environmental degradation, Fig.1 (c) shows the impact of emissions on energy intensity. Accordingly, a 10 percent positive shock in the variable initially decreases the energy intensity, at least in the short run. However, in the long run, energy intensity increases to reach a stable value of 20.



(a) (b) (c)

Fig. 1. (a) Positive shock in economic growth; (b) Positive shock in financial development; (c) Positive shock in environmental degradation.
(Source: Stata output)

5.0 Discussion

Our findings regarding the impact of economic growth on energy intensity are in line with Díaz et al. (2019), Chen et al. (2022), Zhang et al. (2022), and Matahir et al. (2023). It shows that economic growth can promote energy conservation and support sustainable growth in the long run. However, the current study finds that financial development does not positively impact energy saving as the relationship between financial development and energy intensity is positive. The finding contradicts Canh et al. (2020), Chen et al. (2019), and Mukhtarov et al. (2020). Moreover, the long-run coefficient shows a significant positive impact on energy intensity. This could be related to access to financing for more profitable projects in energy-intensive sectors, while insufficient green finance initiatives limit investments in energy-efficient projects. Meanwhile, our research shows a positive long-term relationship between emissions and energy intensity. That suggests an increase in emissions will reduce efficient energy use. Reliance on inefficient energy use, such as fossil and carbon sources, makes reducing energy intensity difficult. We also provide the dynamic interaction of the dependent variables toward the energy intensity in Fig.1. Generally, the impact of the three variables on the energy intensity is different over time. In the short term, the energy intensity response is relatively fast to any shock of individual variables. Any 10 percent positive shock to the variables sparks a sharp response of energy intensity. Both economic growth and emissions posit a contrasting trend towards the long-run level.

6.0 Conclusions and Recommendations

Malaysia's energy intensity and economic growth patterns provide important insights into sustainable development, technological advancements, and policy structures. The relationship between these factors indicates that lower energy intensity results in more efficient resource utilisation, leading to sustainable development through reduced environmental impact and more efficient consumption. This study analyses the dynamic relationship between energy intensity, emissions, financial development, and economic growth in Malaysia using data from 1980 to 2019. The results show that the selected variables are cointegrated. Additionally, all variables significantly impact energy intensity in the long run. However, higher financial development and emissions lead to increased energy intensity. The impact of the variables on energy intensity can be observed through dynamic ARDL simulations. One limitation of this study is its single-country focus, which may restrict the generalisability of the findings to broader regional contexts. Moreover, the model does not account for potential nonlinear effects or structural policy shifts, which may also influence energy intensity trends.

Addressing energy efficiency is an essential step towards achieving sustainable development in Malaysia. Therefore, its development framework must prioritise policies such as stricter standards and regulations for emissions, introducing carbon pricing, promoting renewable energy sources, and offering incentives for improvements in energy intensity practices. In addition, financial institutions in Malaysia still need to play a role in contributing to energy-saving goals. Recommendations should be made to the financial institutions to promote green financing, provide incentives for energy-efficient investments, and encourage banks to finance renewable energy projects. Creating green bonds, low-interest loans for clean technologies, and fostering public-private partnerships can drive sustainable development and reduce energy consumption per economic output.

Acknowledgements

The authors thank the Kedah International Conference on Social Sciences, UiTM Teknologi MARA, Kedah, Malaysia, for supporting participation in the 3rd International Conference on Business, Finance, Management and Economics (BIZFAME).

Paper Contribution to Related Field of Study

This paper contributes to the economic growth and energy studies focusing on the Malaysian context

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