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Long-run relationship between sectoral productivity and energy consumption in Malaysia: An aggregated and disaggregated viewpoint

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ABSTRACT

This paper investigates the causal relationship between energy consumption and economic productivity in Malaysia at both aggregated and disaggregated levels. The investigation utilises total and sectoral (industrial and manufacturing) productivity growth during the 1971–2012 period using the modified Granger causality test proposed by Toda and Yamamoto [1] within a multivariate framework. The economy of Malaysia was found to be energy dependent at aggregated and disaggregated levels of national and sectoral economic growth. However, at disaggregate level, inefficient energy use is particularly identified with electricity and coal consumption patterns and their Granger caused negative effects upon GDP (Gross Domestic Product) and manufacturing growth. These findings suggest that policies should focus more on improving energy efficiency and energy saving. Furthermore, since emissions are found to have a close relationship to economic output at national and sectoral levels green technologies are of a highest necessity.

1. Introduction

Over three decades, since the pioneering study of Kraft and Kraft [2], researchers have attempted to capture the relationship between energy consumption and economic growth. Examples of the early studies are shown in Table 1. The study of Akarca and Long [3] documented no causal relationship between GEC (Gross Energy Consumption) and GNP (Gross National Product) in the US economy which was confirmed by the study of Yu and Hwang [4]. Yu and Choi [5] identified mixed results on the causal relationship between GNP and energy using the data of in five countries. Similarly, the finding of Erol and Yu [6] found different results for six industrial countries. Nachane, Nadkarni [7] revealed bidirectional causal relationship between energy and GDP (Gross Domestic Product) in 16 countries except Colombia and Venezuela by adopting Engle-Granger cointegration and Sim's techniques. These studies focused solely on developed countries, while later studies included emerging markets. There are many reasons for this research phenomenon. One reason is the lack of available and reliable data [8]. Another and more important reason is that the economies of developed countries are usually more energy-dependent while emerging markets do not rely as much on energy consumption until later stages of development. Studies conducted on early stages of the energy-growth nexus in emerging markets may not reveal meaningful information. However, in recent decades, many emerging markets with rapid economic growth have become more energy dependent. Information on the real causal relationship between energy consumption and economic growth has become a must for emerging market governments in order to design policies that can sustain economic growth with limited energy resources. Moreover, with the increasing awareness of environmental issues and accompanying pressures at domestic and international levels, studies on the nexus between energy and growth that provide reliable findings are urgently needed.

Malaysia is an emerging market with remarkable economic growth. From 1967 to 1997, Malaysia managed to maintain an annual average growth rate of more than 7 percent [9]. After the

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Table 1
Existing studies and their findings on the relationship between growth, energy and emission.

Author	Period	Model	Sample	Nexus
Kraft and Kraft [2]	1947–1974	Granger causality	USA	GNP→EC
Akarca and Long [3]	1950–1970	Sims' technique	USA	GNP—EC
Yu and Hwang [4]	1947–1979	Sims' technique	USA	GNP—EC
Yu and Choi [5]	1950–1979	Sims' and Granger causality	5 countries	GDP—EC (UK, Poland, USA) GDP→ EC(Korea) EC→GDP (Philippines)
Erol and Yu [6]	1950–1982	Sims' and Granger causality	6 countries	EC↔GNP (Japan) GDP→EC (Germany, Italy) EC→GDP (canada) EC—GDP (France, UK)
Nachane, Nadkarni [7]	1950–1985	Engle-Granger cointegration Sims' and Granger Causality	16 countries	GDP↔EC (except Colombia and Venezuela)
Tang and Shahbaz [17]	1972–2010	Johansen Cointegration and Toda–Yamamoto Test	Pakistan	Electricity→GDP Electricity↔Manufacturing Growth
Masih and Masih [19]	1955–1990 (India, Pakistan and Malaysia); 1960–1990 (Indonesia and Singapore); 1955–1991 (Philippines)	Johansen Cointegration and Granger causality	6 countries	Energy→GDP (India) GDP→Energy (Indonesia) GDP↔Energy (Pakistan)
Chandran, Sharma [15]	1971–2003	ARDL and Granger causality	Malaysia	Electricity→GDP
Soytas and Sari [20]	1950–1992	Johansen cointegration and Granger causality	G-7 countries	EC↔GDP (Argentina) GDP→EC (Italy, Korea) EC→GDP (Turkey, France, Japan, Germany)
Yoo and Jung [21]	1977–2002	Johansen cointegration and Granger causality	Korea	Energy→GDP
Masih and Masih [24]	1955–1991	Johansen cointegration and Granger causality	Thailand and Sri Lanka	GDP—Energy (Thailand) Energy→GDP (Sri Lanka)
Masih and Masih [25]	1955–1991(Korea); 1952–1992(Taiwan)	Johansen cointegration and Granger causality	Korea and Taiwan	EC↔GDP
Rafiq [26]	1965–2006	Johansen cointegration and VECM	6 countries	Energy→GDP(China) GDP→Energy (India) GDP↔Energy (Thailand) Energy—GDP (Malaysia, Indonesia, Philippines)
Wang, Wang [30]	1972–2006	ARDL and Granger causality	China	Energy→GDP
Tang and Tan [27]	1972–2009	Johansen cointegration, ARDL and Granger causality	Malaysia	EC↔GDP
Ghali and El-Sakka [28]	1961–1997	Johansen cointegration and VEC	Canada	EC↔GDP
Soytas and Sari [29]	1968–2002	Johansen cointegration and VEC	Turkey	Electricity↔value added
Chang [32]	1981–2006	Johansen cointegration and VEC	China	GDP↔emission GDP↔Energy (coal, crude oil and electricity)
Ozturk and Acaravci [33]	1968–2005	ARDL and Granger causality	Turkey	Energy—GDP Emission—GDP
Shahbaz, Khan [31]	1971–2011	ARDL and Granger causality	China	Energy→GDP
Yoo [44]	1971–2002	Engle–Granger cointegration and Hsiao's Granger causality test	Indonesia, Malaysia, Singapore, and Thailand	GDP↔Electricity (Malaysia, Singapore); Electricity→GDP (Indonesia, Thailand)
Tang [45]	1970 to 2005	ARDL and Granger causality	Malaysia	GDP↔Electricity
Ang [46]	1971–1999	Johansen cointegration and ECM	Malaysia	Energy→GDP
Shaari, Hussain [47]	1980 to 2010	Johansen cointegration and Granger causality	Malaysia	Energy—GDP (oil,coal) GDP→ Electricity Gas→GDP
Park and Yoo [48]	1965–2011	Johansen cointegration and ECM	Malaysia	GDP↔Oil
Gross [16]	1970–2007	ARDL and Granger causality	USA	Commercial Growth→energy Transport Growth↔energy

Note: "→" stands for "unidirectional Granger cause", "—" stands for "does not Granger cause" and "↔" stands for "bidirectional Granger cause", "ARDL" stands for Autoregessive Distributed Lags, "ECM" stands for error-correction model.

Asian financial crisis, economic growth began to slow down until 2013 [10]. However, with the aim to achieve the status of high-income nation by 2020 (the 2020 Vision), Malaysia must at the very least maintain its economic growth rate and plan well in order to regain its historical high growth momentum. Therefore, there is no room for mistakes in designing and implementing economic policies. Consequently, the government has continuously revised its energy policies in order to sustain the supply of energy resources [11]. Additionally, more initiatives and programs have been implemented to achieve the 2020 Vision Plan. The ETP (Economic Transformation Program) launched in 2010 is considered the most comprehensive plan to stimulate the economy. Under this program, numerous government-driven high impact projects have been initiated.

Along with the implementation of ETP, energy demand has been growing steadily. As a country that initially relied solely on crude, Malaysia has gradually managed to achieve a good mix of energy resources. Due to the energy crisis of the 1970s, Malaysia adopted a four fuel diversification policy in 1981 that helped the country to better manage its energy sources by utilising alternatives such as hydropower, natural gas, and coal [11,12]. This diversification policy mitigates the negative impact of any energy crisis related to dependence on crude oil and has been maintained and further expanded. A five fuel diversification policy that incorporated renewable energy was introduced in 1999 [13] and implemented in 2001 [12]. However, as Ong, Mahlia [13] have pointed out, in the near future Malaysia will not be able to fully utilise renewable energy in order to replace non-renewable energy that is gradually being exhausted and that causes greenhouse gas emissions. From the perspective of environmental preservation and energy security, identifying the relationships between economic growth, energy consumption, and emissions is particularly significant for Malaysia's sustainable development.

This research contributes to the existing literature in several ways. First, most of the studies in Malaysia adopted a bivariate framework. Lütkepohl [14] pointed out that the bivariate model for the Granger causality test suffers from the drawback of providing biased results due to the omission of other important variables. Therefore, this investigation adopts the modified Granger causality introduced by Toda and Yamamoto [1] within a multivariate framework that includes both aggregate and disaggregate energy consumption of electricity, fossil, mineral, waste, and coal. Chandran, Sharma [15] suggested that future studies in Malaysia should incorporate different types of energy consumption so that policy implications on sectors can be derived. Additionally, the studies of Gross [16], Tang and Shahbaz [17] show that the findings using sectoral data of economic growth are necessary to enable the government to formulate a more comprehensive energy policy at both aggregate and sectoral levels. Hence, data on manufacturing and industrial growth are utilised in this paper. Furthermore, since environmental issues are largely related to energy consumption, economic growth emissions are also included in this research. The multivariate framework incorporating disaggregate energy consumption along with sectoral economic growth and environmental indicators will provide more comprehensive and reliable findings to aid policy design and implementation in Malaysia.

The earlier studies focused on the nexus between energy and growth following the pioneering study of Kraft and Kraft [2] as shown in Table 1. However, the findings are rather mixed due to the estimation techniques and hence, it is difficult to derive conclusive evidence for policy making [8,18]. Two major reasons contribute to this phenomenon. First is the selection of the model. Some studies followed the early trend of adopting a bivariate model (Kraft and Kraft [2] for USA; Masih and Masih [19] for six Asian countries; Soytas and Sari [20] for G-7 countries; Yoo and Jung [21] for Korea). However, the bivariate model has been criticised for being biased due to the omission of other relevant variables [8,22,23]. Two groups of studies used the multivariate model, 1) the studies that applied economic theoretical models and focused on the demand side that incorporates prices, such as Masih and Masih [24] for Thailand and Sri Lanka, Masih and Masih [25] for Korea and Taiwan, Rafiq [26] for six countries and Tang and Tan [27] for Malaysia. 2) the studies that applied a production function that incorporates labour and capital, and utilised disaggregate energy consumption, sectoral economic growth or other variables, such as Ghali and El-Sakka [28] for Canada, Soytas and Sari [29] for Turkey, Wang, Wang [30], Shahbaz, Khan [31] and Chang [32] for China, Ozturk and Acaravci [33] for Turkey and Tang and Shahbaz [17] for Pakistan.

Secondly, the mixed findings are caused due to the limitations of the techniques. Existing studies use either Granger causality test for stationary data or cointegration tests proposed by Engle and Granger [35], Johansen [36] and Johansen and Juselius [37]. The former is criticised on the grounds that it may force the short-run dynamic into the residuals [38,39], while, the latter may fail when the assumption that all the variables should be integrated with the same order is violated. Toda and Yamamoto [1] proposed a test approach that does not require the test variables to be integrated at the same order and that has gained increasing popularity in recent studies (Wolde-Rufael [40], Bowden and Payne [41], and Soytas and Sari [42] and Banna, Rahman [43]).

The empirical studies on energy-growth are relatively few in the case of Malaysia as presented in Table 1. Masih and Masih [19] reported no causality while Yoo [44] and Tang [45] found a bidirectional causality. Ang [46] included pollutant emissions and found a unidirectional causal relationship running from GDP to energy while emissions is found to Granger cause GDP. Tang [45] took foreign direct investment and population into account and reported bidirectional causality between economic growth and electricity consumption. Chandran, Sharma [15] incorporated price and found that electricity consumption Granger causes economic growth indicating that Malaysia relies heavily on energy. Shaari, Hussain [47] included disaggregate energy consumption of oil, gas, coal, and electricity and found that economic growth is not caused by oil and coal consumption and vice versa. However, unidirectional causal relationships running from economic growth to electricity consumption and from gas consumption to economic growth are found. Tang and Shahbaz [17] used energy prices and technology and found a bidirectional causal relationship between electricity consumption and economic growth. Park and Yoo [48] investigated the causal relationship between economic growth and oil consumption and also reported bidirectional causality.

From the existing studies, we notice that the literature in Malaysia have inconsistent findings. More studies are necessary in order to reveal the true nature of the energy-growth nexus in Malaysia. Since most of the studies in Malaysia neglect the potential information that can be derived from examining the causal relationship at the sectoral and disaggregate level, this study is novel, as we have incorporated both aggregate and disaggregate energy consumption (electricity, coal fossil, waste, and minerals) and sectoral output growth (GDP growth, manufacturing growth, and industrial growth). In addition, carbon emission is included to investigate the interaction of energy consumption and economic growth with the environment. The objective is to provide more comprehensive and sufficient empirical evidence for policymakers to properly design policies that can better tackle the issues related to energy, the economy, and the environment simultaneously.

The remainder of this paper is organised as follows: Section 2 discusses the data and estimation techniques; Section 3 presents the empirical results, Section 4 focuses on the discussion; and Section 5 presents the concluding remarks.

2. Data and estimation technique

2.1. Data

This study examines the long-run causal relationship between sectoral productivity growth and energy consumption at both aggregated and disaggregated levels. The aggregate energy consumption refers to the usage of total energy consumed by all productive sectors, while disaggregated energy consumption refers to the energy usage from the specific energy sector, e.g. usage of electricity. The amount of aggregate energy is used in this study to identify the influences of overall energy usage on Malaysian output-growth. The disaggregate energy consumption identifies which energy sector has highest impact on the sectoral productivity. It further helps the policy makers to emphasise and improve the specific energy sector that shows the significant contribution on the productivity-growth. The components of disaggregate energy consumption used in this study are electricity, fossil fuel, coal, waste, and minerals. Both aggregate and disaggregate components are collected from the World Bank spanning the period from 1971 to 2012 on an annual basis and transformed into log form before they were used in the Toda and Yamamoto (T–Y) test. The trends of the data series are presented graphically in Fig. 1.

The data of total and disaggregated energy consumption is provided in Fig. 1 along with the sectoral productivity. The trend of both aggregate and disaggregate energy consumption is found statistically to maintains long-run relationship with the sectoral productivity. These findings are further empirically examined employing econometrics estimation technique.

2.2. Toda and Yamamoto (T–Y) causality test

The T-Y technique is used to present the long-run causal relationship between energy consumption and productivity growth. The long-run relationship is highlighted through the Granger causality between two variables as bivariate basis. Two variables are associated in long-run relationship when one is Granger caused by the other. For example, energy (y_i) is said to Granger-cause productivity-growth (m_i) if productivity-growth can be better predicted using the histories of both energy and productivity rather than using the history of productivity alone. We can estimate the Granger-cause using the following formula:

$$m_{i\,t} = \delta_{i,0} + \Omega_1 m_{t-1} + \ldots + \Omega_p m_{t-p} + \lambda_1 y_{t-1} + \ldots + \lambda_p y_{t-p} + u_{1t} \tag{1}$$

$$y_{i\,t} = \eta_{i,0} + \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \varsigma_1 m_{t-1} + \ldots + \varsigma_p m_{t-p} + v_{2t} \tag{2}$$

If the null hypothesis in Equation (1), H_0: $\lambda_1 = \lambda_2 = \ldots = \lambda_p = 0$ against the alternative hypothesis, H_a: Not H_0, is a test that energy does not Granger-cause productivity-growth. Therefore, the Granger causal relationship exist if the null hypothesis is rejected. Similarly, if the null hypothesis in Equation (2), H_0: $\varsigma_1 = \varsigma_2 = \ldots = \varsigma_p = 0$ against the alternative hypothesis, H_a: Not H_0, is a test that productivity-growth does not Granger-cause energy. If the null hypothesis is rejected, there would be Granger-causal relationship between two variables. If the null hypothesis of both Equations (1) and (2) is rejected, the Granger-causal relationship refers to bidirectional causal relationship but if the null hypothesis of either one is rejected, the relationship is called unidirectional causal relationship.

However, the Granger causality developed by Granger [49] is one of the earliest methods to estimate the causal effect by using time series data. It is normally conducted by estimating VAR (*Vector Autoregression*) models. It suffers if the dataset is non-stationary. Furthermore, in case of multivariable Granger causality, it is difficult to confirm the cointegrating relationship and cumbersome to estimate the VAR correctly when the system is integrated. To overcome these problem, Toda and Yamamoto [1] came up with the MWALD (Modified Wald) test or augmented VAR technique regardless of integrated or integrated series. It is easier to estimate the Granger causality test and does not require testing cointegration or transformation of VAR into VECM (Vector Error Correction Model). It has comparative advantages in respect to the pre-testing issue of cointegration estimation using unit root tests. This technique reduces the cumbersomeness of implementation and minimizes the risk of identifying correct order as it is performed regardless of orders of cointegration [50]. It is therefore an alternative approach and easier technique of cointegration for testing the (non) causality among time series variables.

This procedure restricts the parameters of VAR (p) model. Three stages of procedures are implemented in this technique. Firstly, testing each of series to determine the maximum order of integration (d_{max}). Normally, ADF (Augmented Dickey-Fuller) developed by Dickey and Fuller [51], PP (Phillips–Perron) developed by Phillips and Perron [52] tests and KPSS (kwiatkowski, Phillips, Schmidt and Shin test) test developed by Kwiatkowski, Phillips [53] are used to find the d_{max}. Secondly, the optimal lag length (p) is determined using different lag length criterion such as SC (Schwarz information criterion) developed by Schwarz [54], AIC (Aikaike's information criterion) developed by Akaike [55], HQ (Hannan Quinn) developed by Hannan and Quinn [56] and FPE (final prediction error) developed by Akaike [57]. Thirdly, the Modified Wald is used to test VAR (k) model for the causality, where the optimal lag length is equal to $k = (p + d_{max})$.

To undertake the T–Y based Granger causality test, we have specified the model as follows:

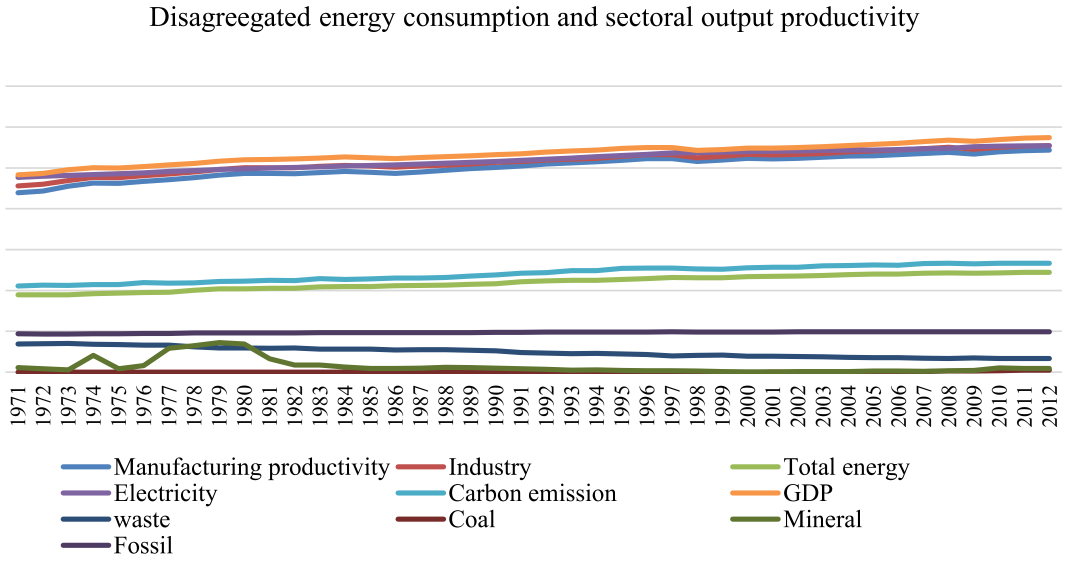

Fig. 1. Flow of sectoral productivity and disaggregated energy consumption.

$$\begin{aligned} m_{i,t} = {} & \delta_{i,0} + \sum_{i=1}^{k} \Omega_1 m_{t-i} + \sum_{j=k+1}^{d_{\max}} \Omega_2 m_{,\,t-j} + \sum_{i=1}^{k} \gamma_{1,i} energy_{t-i} + \sum_{j=k+1}^{d_{\max}} \gamma_{2,j} energy_{t-j} + \sum_{i=1}^{k} \psi_{1,i} electricity_{t-i} + \\ & \sum_{j=k+1}^{d_{\max}} \psi_{2,j} electricity_{t-j} + \sum_{i=1}^{k} \xi_{1,i} fossil_{t-i} + \sum_{j=k+1}^{d_{\max}} \xi_{2,j} fossil_{t-j} + \sum_{i=1}^{k} \omega_{1,i} \mathrm{mineral}_{t-i} + \sum_{j=k+1}^{d_{\max}} \omega_{2,j} \mathrm{mineral}_{t-j} + \\ & \sum_{i=1}^{k} \vartheta_{1,i} coal_{t-i} + \sum_{j=k+1}^{d_{\max}} \vartheta_{2,j} coal_{t-j} + \sum_{i=1}^{k} \phi_{1,i} emission_{t-i} + \sum_{j=k+1}^{d_{\max}} \phi_{2,j} emission_{t-j} + \sum_{i=1}^{k} \eta_{1,i} waste_{t-i} + \\ & \sum_{j=k+1}^{d_{\max}} \eta_{2,j} waste_{t-j} + \varepsilon_{i,t} \end{aligned} \tag{3}$$

where,

$\mathrm{m}_{i,t}$ → productivity, specifically GDP growth, industrial and manufacturing productivity.
Ω_i → Parameters of lagged productivity
γ_i → Parameters of total Energy
ψ_i → Parameters of electricity
ξ_i → Parameters of fossil fuel
ω_i → Parameters of mineral
ϑ_i→ Parameters of coal
ϕ_i→ Parameters of emission
η_i → Parameters of waste

We can test the causality from total energy consumption to productivity ($\mathrm{m}_{i,t}$) by checking the validity of the null hypothesis of $\gamma_{1,i} = 0\ \forall i$ in Equation (3). Similarly, we can test the causality from other variables to productivity in the same equation. Furthermore, the response of energy consumption (both of aggregate and disaggregate) to the change of productivity is estimated using the Equation (4) as follows:

$$y_{i,t} = \delta_{i,0} + \sum_{i=1}^{k} \phi_{1,i} m_{t-i} + \sum_{j=k+1}^{d_{\max}} \phi_{2,j} m_{t-j} + \varepsilon_{i,t} \tag{4}$$

where,

$y_{i,t}$ → The set of energy consumption variables: total energy, electricity, fossil fuel, mineral, coal and waste.
$\mathrm{m}_{i,t}$ → productivity, specifically GDP growth, industrial and manufacturing productivities
$\phi_{1,i}$→ Parameters of productivity

We can test the causality from productivity ($\mathrm{m}_{i,t}$) to energy consumption ($y_{i,t}$) by checking whether the null hypothesis of $\phi_{1,i} = 0\ \forall i$ is true or not. Similarly, we can test the causality from productivity ($\mathrm{m}_{i,t}$) to $x_{i,t}$ (emission) by checking the validity of null hypothesis of $\theta_{1,i} = 0\ \forall i$ in Equation (5).

$$x_{i,t} = \delta_{i,0} + \sum_{i=1}^{k} \theta_{1,i} m_{t-i} + \sum_{j=k+1}^{d_{\max}} \theta_{2,j} m_{t-j} + \varepsilon_{i,t} \tag{5}$$

where, $x_{i,t}$ → Emission

$\mathrm{m}_{i,t}$ → productivity, specifically GDP growth, industrial and manufacturing productivity

The above Equations (3)–(5) have four possible ways of showing the causal relationship. First, unidirectional relationship running from energy consumption (both of aggregate and disaggregate) to output productivity growth. Second, unidirectional relationship running from output productivity growth to energy consumption. Third, bidirectional relationship or the feedback relationship between both of energy consumption and productivity growth. Finally, lack of any form of causal relationship among the variables.

In addition, the results found in Equations (3)–(5) are tested for diagnostic checking in order to justify whether the models are correctly specified. Firstly, the test of autocorrelation is performed through Ljung–Box test where the null hypothesis of no autocorrelation in the squared errors is not rejected at all of the lag levels. Secondly, the presence of heteroskedasticity is tested through Ljung–Box test as well where the null hypothesis of no heteroskedasticity is not rejected at all levels. Thirdly, the normality of prediction errors is performed through Jarque–Bera test where the null hypothesis of normality is strongly rejected. The two Ljung–-Box tests indicate that the models used in this study are correctly specified where the error-prediction is non-normal due to the presence of GARCH effect. The previous literature of Rim and Setaputra [58] and Rahman et al. [59,60] indicates that models are considered as correctly specified, even in the presence of nonnormality in error-prediction.

3. Empirical results

3.1. Unit root results

Finding: In order to find the maximum order of lag for T-Y causality test, the ADF (Augmented Dickey-Fuller) and PP (Phillis-Perron) unit root tests were performed. Both tests have a null hypothesis that the variables are non-stationary. The findings of ADF

Table 2
Unit root test results.

Variables	ADF		PP	
	Level	1st diff	Level	1st diff
GDP	−2.034	−5.338*	−2.034	−4.939*
Manufacturing output	−3.479	−5.626*	−3.479	−4.869*
Industrial output	−2.531	−5.149*	−2.665	−5.523*
Total energy	−1.157	−6.576*	−1.106	−6.579*
Electricity	1.818	−4.389**	−0.988	−4.552*
Fossil fuel	−1.998	−5.288*	−1.998	−8.215*
Mineral	−1.775	−7.520*	−1.939	−7.425*
Coal	0.796	−7.834*	−1.549	−7.962*
Carbon emission	−1.802	−7.544*	−1.797	−7.503*
Waste	−2.049	−7.225*	−2.033	−7.489*

Note: *, **represent 1%, 5% significance level respectively based on MacKinnon [76] one-sided P-value. The lag length is selected based on AIC for ADF and based on Newey–West Bandwidth for PP. The unit root test is estimated using trend and intercept at the level form, while using intercept at the 1st difference.

and PP tests in Table 2 indicate that the null hypothesis of unit root problem at the level form were not rejected in any of the series, but all rejected at 1% level of significance at the first difference. Therefore, all series are integrated at order one or I(1) which means the maximum order of integration is one.

3.2. *Toda and Yamamoto (T–Y) causality test results*

Having confirmed the maximum order of integration of the series and the optimal lag length of the VAR, the results of the T-Y causality test are estimated which are presented in Tables 2 and 3 and in Fig. 2 graphically.

At the aggregate level, a positive (3.139) unidirectional causality relationship from total energy consumption to GDP was found at 10% significance level that supports the growth hypothesis indicated in Table 3. Additionally, bidirectional causal relationship was found between industrial growth and total energy consumption. These findings are consistent with Saboori and Sulaiman [61] for Indonesia, Malaysia and Philippine, Omri [62] for MENA countries, Zhang and Yang [63] for China, Bildirici and Bakirtas [64] for seven countries, Ghosh and Kanjilal [65] for India and Esseghir and Haouaoui Khouni [66] for Mediterranean countries. Manufacturing growth was found to Granger cause total energy consumption at 1% significance level. This finding is consistent with Salahuddin and Gow [67] for GCC region, Lin, Moubarak [68] for China and Bastola and Sapkota [69] for Nepal.

The findings of disaggregated energy consumption in Table 4 present a different causal relationship for different disaggregated energies. No causal relationship was found between fossil fuel and GDP, but there is a unidirectional causal relationship running from industrial growth and manufacturing growth to fossil at 5% and at 1% significance level. These findings are consistent with Lin, Moubarak [68] for China and Bastola and Sapkota [69] for Nepal but inconsistent with Behmiri and Manso [70] for Latin America. Bidirectional causal relationship was found between coal and economic growth. Electricity is found to negatively Granger cause GDP at 1% significance level. This finding is inconsistent with Shahbaz and Lean [71] who found that electricity consumption and economic growth positively Granger cause each other in Pakistan and Tang and Shahbaz [17] who found that electricity consumption positively Granger cause economic growth in Pakistan. In contrast, at the sectoral level, electricity is found to positively Granger cause industrial growth at 5% significance level and manufacturing growth at 1% significance level. In return, industrial growth is found to Granger cause electricity at 10% significance level. These findings are consistent with Soytas and Sari [29] for Turkey and Tang and Shahbaz [17] for Pakistan.

Finally, mineral is found to positively Granger cause GDP, industrial and manufacturing growth at 1% level of significance. In return, GDP and manufacturing growth are found to negatively Granger cause mineral at 1% significant level. Similar findings were found for waste. The findings of negative causal relationship between energy and economic growth are rare in the energy literature with the exception of Zhang and Yang [63], who documented negative bidirectional causal relationships running from total energy and coal to GDP, for example. The empirical results in Table 4 also reveal strong interactions between emissions and economic growth. Emission is found to Granger cause GDP at 10% significance level while GDP and industrial growth are found to Granger cause emission at 1% and 5% significance level. Manufacturing growth and emission are found to Granger cause each other at 1% significance level. These findings are consistent with Saboori and Sulaiman [61] for Malaysia, Indonesia and Philippines, Bastola and Sapkota [69] for Nepal, Kivyiro and Arminen [72] for Sub-Saharan Africa and Tang and Tan [73] for Vietnam but inconsistent with Lin, Moubarak [68] who found that a growth in manufacturing sector caused a decrease in carbon dioxide emission in China and Salahuddin and Gow [67] who found no Granger causality between emission and economic growth in the GCC region. The summary of recent studies and their relation to our findings are presented in Table 5.

Table 3
T–Y causality test results on aggregated level.

Granger causes from aggregated energy consumption to sectoral productivity			
GDP Growth	Industrial growth	Manufacturing growth	
3.139	2.169	0.541	Aggregated Energy
0.063	0.008	0.162	
Granger causes from sectoral productivity consumption to aggregated energy			
	GDP Growth	Industrial growth	Manufacturing growth
Aggregate energy	0.050	0.058	0.337
	0.139	0.074	0.001

* The maximum number of lag, $d_{max} = 1$ and the optimum number of lag, $p = 2$.

4. Discussion

The strong interaction between energy consumption and economic growth identified at both national level and sectoral level indicates that the Malaysian economy is energy-dependent. This is consistent with the current development stage of Malaysia. This finding is also consistent with Malaysia's national vision to achieve the status of a high-income industrialized country in 2020. The empirical results reveal that a national energy saving policy will harm economic growth as a whole and industrial growth in particular. However, it will not hamper manufacturing growth. Nevertheless, these policy implications should be considered together with the information obtained at the disaggregate level.

The empirical results on the causal relationship between disaggregate energy and economic growth have different implications. On one hand, the positive causal relationships identified are relatively easy to comprehend. The positive bidirectional causal relationships running from coal to GDP and electricity to industrial growth and the positive unidirectional causal relationship running from coal, waste and mineral to industrial growth, electricity and mineral to manufacturing growth, mineral and waste to GDP suggest that both GDP and sectoral growth in Malaysia are dependent on coal, minerals, waste, and electricity. Therefore, the decrease in coal, minerals, and waste consumption may cause a decrease in GDP and the decrease in electricity, coal, waste and mineral may hamper industrial growth. Similarly, a decrease in electricity and mineral consumption may also cause a decrease in manufacturing growth. In contrast, reductions of fossil fuel consumption will not hamper economic growth. On the other hand, the negative causal relationships identified are greatly different from the existing literature which documented positive causal relationship between disaggregate energy consumption and economic growth such as Shahbaz and Lean [71] and Tang and Shahbaz [17]. Such difference is attributed to the adoption of the new technique of Toda and Yamamoto [1] with the aid of multivariate analysis that helps mitigate the drawback of research techniques applied in the existing literature as suggested by Zhang and Yang [63].

The negative unidirectional Granger causality running from electricity to GDP and from coal to manufacturing growth suggest that increases in electricity and coal consumption actually lead to the decrease of economic growth. This appears to contradict the energy-led growth hypothesis. In addition, the negative unidirectional Granger causality running from industrial and manufacturing growth to waste and manufacturing growth and GDP to mineral suggest reveal that conservation hypothesis is not

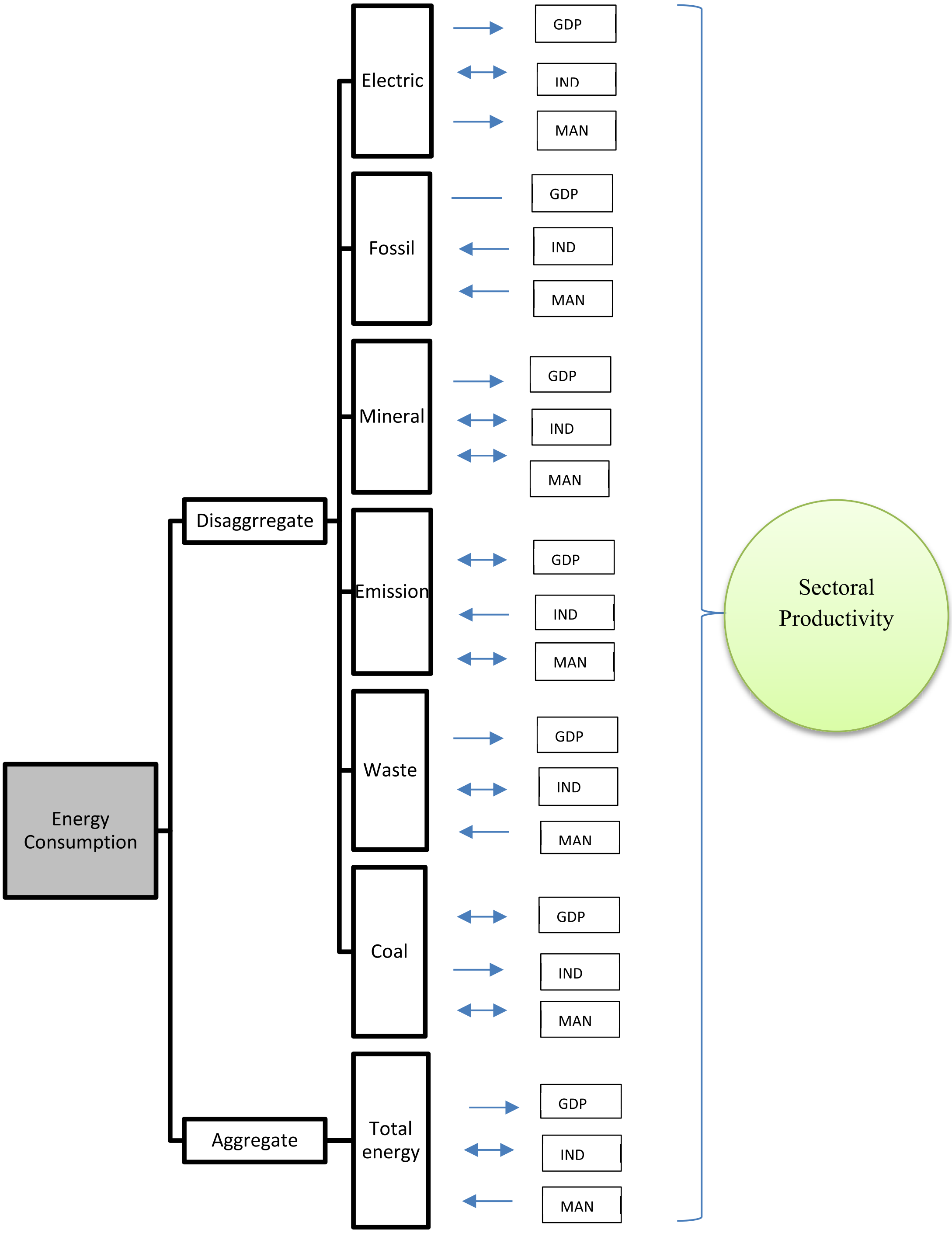

Fig. 2. Graphical presentation of causal relationship between energy consumption and sectoral productivity. Note: GDP, IND, MAN indicates GDP growth, industrial output growth and manufacturing output growth respectively. "→" stands for "unidirectional Granger cause", "—" stands for "does not Granger cause" and "↔" stands for "bidirectional Granger cause".

valid. However, following suggestions made by Squalli [74], these negative causal relationship can be explained. For the negative causal relationship running from electricity to GDP, there are two reasons. The first reason is that in a growing economy such as Malaysia, economic production gradually shifted towards industries that are less dependent on electricity consumption. The second reason is excessive electricity consumption in Malaysia due to inefficiency in electricity supply, unproductive economic sectors, or capacity constraints that lead to a decrease in economic output. Similar reasons may apply to the negative causal relationship from coal to manufacturing growth. The negative causal relationship from electricity to GDP implies that policies that aim to reduce electricity consumption will not hamper Malaysia's economic growth.

However, this implication should be taken cautiously in consideration of information found at the sectoral level. As mentioned above, at the sectoral level, the findings suggest any electricity shortages or reduction in electricity consumption may

Table 4
T-Y causality test results on disaggregated level.

Granger causes from disaggregated energy consumption to real GDP growth

	Electric	Fossil	Mineral	Emission	Waste	Coal
GDP growth	−6.405	−18.134	0.944	0.477	8.093	0.593
	0.004	0.154	0.000	0.052	0.003	0.003

Granger causes from Real GDP growth to disaggregated energy consumption

Electric	Fossil	Mineral	Emission	Waste	Coal	
−0.043	0.014	−0.521	0.133	−0.053	1.553	GDP growth
0.191	0.157	0.000	0.008	0.186	0.087	

Granger causes from disaggregated energy consumption to industrial output growth

	Electric	Fossil	Mineral	Coal	Emission	Waste
Industrial growth	0.319	1.764	0.116	7.023	0.123	2.403
	0.035	0.515	0.000	0.005	0.436	0.040

Granger causes from industrial output growth to disaggregated energy consumption

Electric	Fossil	Mineral	Coal	Emission	Waste	
0.032	0.027	−0.267	0.007	0.123	−0.061	Industry growth
0.060	0.023	0.209	0.849	0.032	0.090	

Granger causes from disaggregated energy consumption to manufacturing output growth

	Electric	Fossil	Mineral	Coal	Emission	Waste
Manufactur-ing growth	0.304	1.540	0.166	−0.040	0.311	0.034
	0.004	0.306	0.000	0.000	0.000	0.737

Granger causes from manufacturing output growth to disaggregated energy consumption

Electric	Fossil	Mineral	Coal	Emission	Waste	
0.115	0.076	−1.588	13.199	0.518	−0.312	Manufactur- ing growth
0.111	0.001	0.000	0.001	0.002	0.003	

* The maximum number of lag, $d_{max} = 1$ and the optimum number of lag, $p = 2$.

harm manufacturing growth and industrial growth. The decrease in industrial growth may in turn cause further reduction in electricity consumption. Therefore, the Malaysian government should be cautious in designing energy policies relating to electricity consumption when the overall information from the aggregate and sectoral levels is taken into consideration. A similar conclusion can be derived on coal consumption. For the negative causal relationship running from GDP to mineral and manufacturing growth to mineral and waste, several reasons may exist as suggested by Squalli [74]. For example, though the economic growth is increasing, factors such as constraints in infrastructure, managerial obstacles in certain sectors, and mismanagement or spending less than needed may cause inefficiencies and reduced consumption of goods and services such as energy.

The close interaction between emission and economic growth imply that policies that aim to reduce emissions should be made delicately for the reason that reductions may compromise Malaysia's economic growth and the 2020 Vision of its leaders to become a high-income country. At the same time however, although emissions can positively induce economic growth reducing emissions is urgently needed. The positive impact of economic growth is obtained at costs accrued through the destruction of the environment. Therefore, necessary actions should be taken to mitigate emissions problems in the long run while sustaining economic growth.

4.1. Energy policy

Based on our discussion of the findings, and since Malaysia is an energy-dependent economy where complicated causal relationships exist between disaggregate energy and economic growth, we recommend that the government design a prudent energy policy that can sustain economic growth while tackling environmental problems. If the government aims to tackle the emission problem by adopting a conservation policy, due to the negative causal relationship found on electricity and coal with growth, there are at least three actions that need to be done. First, the government should identify those sectors that are less dependent on electricity and coal consumption to ensure that no excessive electricity or coal inputs are provided to these sectors. Secondly, unproductive industries that cause excessive electricity and coal consumption should also be identified and urged to improve productivity. Third, more efforts should be made in improving energy efficiency and exploring energy saving technologies in conjunction with the second action. This can help increase economic productivity while at the same time minimise the possibility of energy shortages due to waste. Moreover, since reducing emissions would affect economic output negatively, green energy technologies should be sought to solve urgent environmental issues. Meanwhile, energy efficiency should be further improved to help the country achieve maximum economic growth with efficient energy consumption that can reduce emissions.

Overall, the findings of this study are significant in guiding policymakers to develop and implement prudent policies in order to achieve high economic growth while securing energy supplies and protecting the environment. If Malaysia's policymakers are unaware of these implications, negative externalities will produce long-term undesirable effects on economic productivity as well as negative impacts on the environment, human health, and society.

4.2. Future work

This study has considered aggregate and disaggregate indicators to show its impact on the sectoral output-growth. We have taken five elements of disaggregate energy consumption. The future study in Malaysia may consider other than these five indicators to ascertain the effect on each productive sector and its growth. Furthermore, the comprehensive approach of this study can be applied on other than Malaysian economy in order to see the long-run relationship between energy and output growth at both of aggregate and disaggregate level.

5. Conclusion

It is vital for policymakers in Malaysia to understand the causal relationship between energy consumption, economic growth, and environmental pollution so that proper policies can be designed to sustain the economy while preserving the environment. This study is different from a number of previous studies by examining such relationships at both aggregate and disaggregate levels with sectoral analysis for the 1971–2012 period by incorporating emissions as a variable. The findings of this study present several main outcomes. First, both the aggregate and disaggregated analysis using total and sectoral productivity data indicates that Malaysia is an energy dependent economy. Only fossil fuel consumption is found to have no causal effect on economic output. Secondly, negative causality running from electricity consumption to total economic growth and from coal consumption to manufacturing growth were found suggesting that reducing electricity and coal consumption can actually increase total and manufacturing output. However, a simplistic conclusion should not be made since this negative causality may actually indicate inefficient use of electricity and coal consumption in unproductive sectors. Therefore, energy efficiency

Table 5
Selected recent literature and their findings on the relationship between growth, energy and emission.

Esseghir and Haouaoui Khouni [66]	1980–2010	Westerlund's Panel cointegration test And panel ECM	Mediterranean	Energy↔ GDP
Salahuddin and Gow [67]	1980–2012	Panel cointegration and Granger causality test	GCC	GDP→Energy GDP—Emission
Lin, Moubarak [68]	1980–2012	ARDL and Johansen cointegration and Granger causality	China	Manufacturing Growth→ Energy Manufacturing Growth→Emission
Bastola and Sapkota [69]	1980–2011	Johansen and ARDL	Nepal	GDP→Energy GDP→ Emission
Shahbaz and Lean [71]	1972–2009	ARDL and Johansen cointegration and Granger causality	Pakistan	Electricity↔ GDP
Tang and Tan [73]	1976–2009	Johansen and Granger causality	Vietnam	Emission↔ GDP
Zhang and Yang [63]	1978–2009	Toda–Yamamoto Granger causality	China	Energy↔ GDP (negative) Coal↔ GDP (negative) Oil and Gas↔ GDP
Omri [62]	1990–2011	simultaneous equations models (GMM)	MENA	Energy↔ GDP Emission↔ GDP
Tang and Shahbaz [17]	1972–2010	Johansen Cointegration and Toda–Yamamoto Test	Pakistan	Electricity→GDP Electricity↔ Manufacturing Growth
Saboori and Sulaiman [61]	1971–2009	ARDL and Granger causality	ASEAN	Energy↔ GDP (Indonesia, Malaysia and Philippine); Emission↔ GDP (Malaysia, Philippine and Indonesia)
Kivyiro and Arminen [72]	1971–2009	ARDL and Granger causality	Sub-Saharan Africa	GDP→ Emission
Ghosh and Kanjilal [65]	1971–2008	ARDL, Johansen cointegration and Toda–Yamamoto Granger causality	India	Energy →GDP
Bildirici and Bakirtas [64]	1980–2011	ARDL and Granger causality	Brazil, Russian,India,China, Turkey and South Africa	Oil↔GDP (all) Coal↔GDP (China and Indian) Natural gas↔GDP (Brazil, Russia, Turkey)
Behmiri and Manso [70]	1980–2012	Panel Granger causality	Latin America: 3 panels: The Caribbean, central and South America	GDP—Oil (the Caribbean, South America) Oil→GDP (Central America)

Note: "→" stands for "unidirectional Granger cause", "—" stands for "does not Granger cause" and "↔" stands for "bidirectional Granger cause", "ARDL" stands for Autoregressive Distributed Lags, "ECM" stands for error-correction model.

and energy saving should be improved. Thirdly, at the sectoral level, manufacturing was found to be influenced by electricity consumption positively, and a bidirectional causal relationship was found between industrial growth and electricity consumption. Therefore, direct reduction of electricity consumption will almost certainly have a negative effect upon the growth of the manufacturing sector, a sector that contributes significantly to Malaysia's economy. In fact, the largest portion (27.5%) of Malaysian GDP is contributed to by manufacturing growth [75]. Therefore, direct reductions would eventually hamper total economic growth. Forth, to solve the emission problem, green technology should be promoted.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.energy.2015.04.049.

References

[1] Toda HY, Yamamoto T. Statistical inference in vector autoregressions with possibly integrated processes. J Econ 1995;66(1):225–50.
[2] Kraft J, Kraft A. Relationship between energy and GNP. J Energy Dev (United States) 1978;3(2).
[3] Akarca AT, Long TV. Relationship between energy and GNP: a reexamination. J Energy Dev (United States) 1980;5(2).
[4] Yu ES, Hwang B-K. The relationship between energy and GNP: further results. Energy Econ 1984;6(3):186–90.
[5] Yu ES, Choi J-Y. Causal relationship between energy and GNP: an international comparison. J Energy Dev (United States) 1985;10(2).
[6] Erol U, Yu ES. On the causal relationship between energy and income for industrialized countries. J Energy Dev 1987;13(1):113–22.
[7] Nachane DM, Nadkarni RM, Karnik AV. Co-integration and causality testing of the energy–GDP relationship: a cross-country study. Appl Econ 1988;20(11):1511–31.
[8] Payne JE. Survey of the international evidence on the causal relationship between energy consumption and growth. J Econ Stud 2010;37(1):53–95.
[9] World Bank. The growth report: strategies for sustained growth and inclusive development: world bank publications. 2008.
[10] Performance Management and Delivery Unit. Economic Transformation programme: a roadmap for Malaysia2013.
[11] Rahman Mohamed A, Lee KT. Energy for sustainable development in Malaysia: energy policy and alternative energy. Energy Policy 2006;34(15):2388–97.
[12] Zulkifli Z. Malaysia country report. Analysis on energy saving potential in East Asia region. 2012. p. 157.
[13] Ong H, Mahlia T, Masjuki H. A review on energy scenario and sustainable energy in Malaysia. Renew Sustain Energy Rev 2011;15(1):639–47.
[14] Lütkepohl H. Non-causality due to omitted variables. J Econ 1982;19(2):367–78.
[15] Chandran V, Sharma S, Madhavan K. Electricity consumption–growth nexus: the case of Malaysia. Energy Policy 2010;38(1):606–12.
[16] Gross C. Explaining the (non-) causality between energy and economic growth in the US—a multivariate sectoral analysis. Energy Econ 2012;34(2):489–99.
[17] Tang CF, Shahbaz M. Sectoral analysis of the causal relationship between electricity consumption and real output in Pakistan. Energy Policy 2013;60:885–91.
[18] Ozturk I. A literature survey on energy–growth nexus. Energy policy 2010;38(1):340–9.
[19] Masih AM, Masih R. Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques. Energy Econ 1996;18(3):165–83.
[20] Soytas U, Sari R. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. Energy Econ 2003;25(1):33–7.
[21] Yoo S-H, Jung K-O. Nuclear energy consumption and economic growth in Korea. Prog Nucl Energy 2005;46(2):101–9.
[22] Stern DI. A multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Econ 2000;22(2):267–83.
[23] Narayan PK, Smyth R. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. Energy Policy 2005;33(9):1109–16.

[24] Masih AM, Masih R. A multivariate cointegrated modelling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs. Appl Econ 1998;30(10):1287–98.
[25] Masih AM, Masih R. On the temporal causal relationship between energy consumption, real income, and prices: some new evidence from Asian-energy dependent NICs based on a multivariate cointegration/vector error-correction approach. J Policy Model 1997;19(4):417–40.
[26] Rafiq S. Energy consumption and income in six Asian developing countries: a multivariate cointegration analysis. Conference energy consumption and income in six Asian developing countries: a multivariate cointegration analysis. Curtin University of Technology, 29–53.
[27] Tang CF, Tan BW. The linkages among energy consumption, economic growth, relative price, foreign direct investment, and financial development in Malaysia. Qual Quant 2012:1–17.
[28] Ghali KH, El-Sakka MI. Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Econ 2004;26(2):225–38.
[29] Soytas U, Sari R. The relationship between energy and production: evidence from Turkish manufacturing industry. Energy Econ 2007;29(6):1151–65.
[30] Wang Y, Wang Y, Zhou J, Zhu X, Lu G. Energy consumption and economic growth in China: a multivariate causality test. Energy Policy 2011;39(7):4399–406.
[31] Shahbaz M, Khan S, Tahir MI. The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate framework analysis. Energy Econ 2013;40:8–21.
[32] Chang C-C. A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. Appl Energy 2010;87(11):3533–7.
[33] Ozturk I, Acaravci A. CO_2 emissions, energy consumption and economic growth in Turkey. Renew Sustain Energy Rev 2010;14(9):3220–5.
[35] Engle RF, Granger CW. Co-integration and error correction: representation, estimation, and testing. Econ J Econ Soc 1987:251–76.
[36] Johansen S. Statistical analysis of cointegration vectors. J Econ Dyn control 1988;12(2):231–54.
[37] Johansen S, Juselius K. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxf Bull Econ Statistics 1990;52(2):169–210.
[38] Banerjee A, Dolado J, Mestre R. Error-correction mechanism tests for cointegration in a single-equation framework. J Time Ser Anal 1998;19(3):267–83.
[39] Pattichis CA. Price and income elasticities of disaggregated import demand: results from UECMs and an application. Appl Econ 1999;31(9):1061–71.
[40] Wolde-Rufael Y. Disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952–1999. Energy Econ 2004;26(1):69–75.
[41] Bowden N, Payne JE. The causal relationship between US energy consumption and real output: a disaggregated analysis. J Policy Model 2009;31(2):180–8.
[42] Soytas U, Sari R. Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. Ecol Econ 2009;68(6):1667–75.
[43] Banna H, Rahman MS, Ahmad R, Koh EHY, Masud MM. The long-run nexus between industrial efficiency and disaggregated energy consumption: a Toda–Yamamoto analysis. Pak J Statistics September 2015;(Special issue).
[44] Yoo S-H. The causal relationship between electricity consumption and economic growth in the ASEAN countries. Energy policy 2006;34(18):3573–82.
[45] Tang CF. Electricity consumption, income, foreign direct investment, and population in Malaysia: new evidence from multivariate framework analysis. J Econ Stud 2009;36(4):371–82.
[46] Ang JB. Economic development, pollutant emissions and energy consumption in Malaysia. J Policy Model 2008;30(2):271–8.
[47] Shaari MS, Hussain NE, Ismail MS. Relationship between energy consumption and economic growth: empirical evidence for Malaysia. Bus Syst Rev 2012;2(1):17–28.
[48] Park S-Y, Yoo S-H. The dynamics of oil consumption and economic growth in Malaysia. Energy Policy 2014;66:218–23.
[49] Granger CWJ. Investigating causal relations by econometric models and cross-spectral methods. Econometrica 1969;37(3):424–38.
[50] Giles DE, Caragata PJ. The learning path of the hidden economy: tax and growth effects in New Zealand. Department of economics, University of victoria; 1998.
[51] Dickey DA, Fuller WA. Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 1979;74(366):427–31.
[52] Phillips PCB, Perron P. Testing for a unit root in time series regression. Biometrika 1988;75(2):335–46.
[53] Kwiatkowski D, Phillips PCB, Schmidt P, Shin Y. Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root? J Econ 1992;54(1–3):159–78.
[54] Schwarz G. Estimating the dimension of a model. Ann Statistics 1978;6:461–4.
[55] Akaike H. Information theory and an extension of the maximum likelihood principle. In: Parzen E, Tanabe K, Kitagawa G, editors. Selected papers of Hirotugu Akaike. New York: Springer; 1998. p. 199–213.
[56] Hannan EJ, Quinn BG. The determination of the order of an autoregression. J R Stat Soc 1979;41(2):190–5.
[57] Akaike H. Fitting autoregressive models for prediction. Ann Inst Stat Math 1969;21(1):243–7.
[58] Rim H, Setaputra R. Studies on the financial market integration and financial efficiency: evidence from Asian markets, vol. 10 (2). Cambridge: The business Review; 2008.
[59] Rahman MS, Aslam M, Lau W-y. The cross-linkage and comovement among ASEAN+3 exchange markets: an E-GARCH-in-mean approach. Asian Profile 2014;42(5):445–64.
[60] Rahman MS, Aslam M, Lau W-y, Shahari F. Does financial cooperation agreement influence the real economy? a GMM panel data approach on ASEAN+3 countries. DLSU Bus Econ Rev 2015;24(2):65–76.
[61] Saboori B, Sulaiman J. CO_2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: a cointegration approach. Energy 2013;55(0):813–22.
[62] Omri A. CO_2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. Energy Econ 2013;40(0):657–64.
[63] Zhang W, Yang S. The influence of energy consumption of China on its real GDP from aggregated and disaggregated viewpoints. Energy Policy 2013;57:76–81.
[64] Bildirici ME, Bakirtas T. The relationship among oil, natural gas and coal consumption and economic growth in BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries. Energy 2014;65:134–44.
[65] Ghosh S, Kanjilal K. Long-term equilibrium relationship between urbanization, energy consumption and economic activity: empirical evidence from India. Energy 2014;66:324–31.
[66] Esseghir A, Haouaoui Khouni L. Economic growth, energy consumption and sustainable development: the case of the Union for the Mediterranean countries. Energy 2014;71(0):218–25.
[67] Salahuddin M, Gow J. Economic growth, energy consumption and CO_2 emissions in Gulf Cooperation Council countries. Energy 2014;73(0):44–58.
[68] Lin B, Moubarak M, Ouyang X. Carbon dioxide emissions and growth of the manufacturing sector: evidence for China. Energy 2014;76(0):830–7.
[69] Bastola U, Sapkota P. Relationships among energy consumption, pollution emission, and economic growth in Nepal. Energy 2015;80(0):254–62.
[70] Behmiri NB, Manso JRP. The linkage between crude oil consumption and economic growth in Latin America: the panel framework investigations for multiple regions. Energy 2014;72:233–41.
[71] Shahbaz M, Lean HH. The dynamics of electricity consumption and economic growth: a revisit study of their causality in Pakistan. Energy 2012;39(1):146–53.
[72] Kivyiro P, Arminen H. Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: causality analysis for Sub-Saharan Africa. Energy 2014;74:595–606.
[73] Tang CF, Tan BW. The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy 2015;79(0):447–54.
[74] Squalli J. Electricity consumption and economic growth: bounds and causality analyses of OPEC members. Energy Econ 2007;29(6):1192–205.
[75] Lindsay E. Malaysia's GDP driven mainly by services, manufacturing sectors. 2012. www.theborneopost.com.
[76] MacKinnon JG. Numerical distribution functions for unit root and cointegration tests. J Appl Econ 1996;11:601–18.