Pak. J. Statist.
2015 Vol. 31(5), 575-586

A MULTIVARIATE TODA-YAMAMOTO ANALYSIS: THE LONG-RUN NEXUS BETWEEN INDUSTRIAL EFFICIENCY AND DISAGGREGATED ENERGY CONSUMPTION

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ABSTRACT

This paper examines the long-run nexus between industrial efficiency and disaggregated energy consumption in Malaysia. Disaggregated data from 1971 to 2011 facilitated by World Bank and Toda-Yamamoto (TY) estimation techniques are employed in the investigation process. The findings of this study indicate that energy consumption at disaggregated levels maintains a long-run relationship with industrial efficiency. Findings further indicate that higher levels of industrial efficiency cause environmental pollution through the spread of carbon emissions. This study proposes significant policy recommendations for efficient use of energy that would improve industrial efficiency and reduce environmental pollution.

KEYWORDS

Energy usage; fossil; carbon emission; Malaysia; environmental pollution; Multivariate.

1. INTRODUCTION

Malaysia is a fast growing economy and is one of the most industrialized countries in Asia. Malaysia was a key producer of rubber and tin raw materials during the colonial period. However, in later period industrial sectors such as electricity and machinery products emerged as vigorous contributors to the economy playing dynamic roles. The circumstances and environment in which the country manoeuvres have improved considerably over the period. Malaysia is an open trade economy operating in a tremendously competitive and accelerating global marketplace. Financial expansion highly depends on industrial development as this sector has generated intensifying demands for energy. Industrial sectors consume nearly 40% of primary energy and nearly 55% of the electricity inputs of total energy consumption.

According to IEA (2013)[1], Malaysia is the third leading energy consumer among the ASEAN[2] countries with an average GDP growth of 4% per year. It is expected that energy consumption can make further contributions to economic growth. Therefore, the Malaysian government is attempting to upgrade renewable energy such as natural gas, oil, minerals, coal, waste and other sources in order to determine ways in which renewable energy can lessen undesirable influences on the environment. Hence, it is crucial to inaugurate studies on the significance of energy use upon the production industry of Malaysia by estimating the long-run relationship between energy consumption and industrial efficiency.

Many studies have been carried out on energy consumption (e.g. Bekhet and Harun, 2012; Erbaykal, 2008; Ewing *et al.*, 2007; Jumbe, 2004; Kraft and Kraft, 1978; Yang, 2000; Ziramba, 2009). Following the pioneer work of Kraft and Kraft (1978), numerous and other similar studies have been conducted in developing and developed countries to find out the nexus between income or output, and energy. Studies after Kraft and Kraft (1978) were conducted in different regions for various phases using diverse approaches. However, the results of these studies varied substantially. A majority of previous researchers employed GDP as the measurement of output. However, official GDP is not an accurate measurement because of the magnitude of the unrecorded economy (Karanfil, 2008). Contrastingly, Jumbe (2004) distinguishes total GDP from agricultural and non-agricultural GDP in order to investigate the energy-income relationship in Malawi.

Other studies use industrial output instead of GDP (e.g. Ewing *et al.*, 2007; Ziramba, 2009). Most of the studies utilized aggregate data, with the remarkable exception of Erbaykal (2008), Ewing *et al.* (2007), Yang (2000), and Ziramba (2009). Subsequent studies using aggregate data for different regions and different countries produced contradictory outcomes for which there may be numerous explanations. The diverse financial structures of different countries could be one explanation for contradictory outcomes since every country is at a particular phase of expansion whereby one country's dependence on energy consuming technology could also be different from another country (Ewing *et al.*, 2007). Differences in the data could be another explanation. In fact, a majority of preceding studies use aggregate data for energy. The limitation of using aggregate data of energy is that countries could rely on various energy properties(Yang, 2000). Thus it is quite difficult to justify the effects of a particular type of energy with aggregate data. The energy–industrial efficiency relationship permits us to recognize the influence of various energy sources on industrial output in Malaysia using disaggregate energy consumption. Additionally, past researchers used bivariate models rather than a multivariate model to analyse the energy-output relationship. A multivariate model can provide the substitution effect of energy with additional inputs to be evaluated (Stern, 1993).

Previous numerical studies on the nexus between energy consumption and income or output can be summarized into four groups. However, the results are mixed. The first group of studies (e.g. Abosedra and Baghestani, 1991; Cheng and Lai, 1997; Erol and

[1] International Energy Agency (IEA)
[2] Association of South-East Asian Nations (ASEAN)

Yu, 1987; Lee, 2006; Yu and Choi, 1985) found a unidirectional causality (Granger, 1988) relationship running from income to energy consumption that supports the conservative hypothesis. However, the second group of studies (e.g. Stern, 1993; Yu and Choi, 1985; Bouoiyour and Selmi, 2013; Lee, 2005; Stern, 2000; Zachariadis, 2007) supports a causality relationship running from energy consumption to income that confirms the growth hypothesis.

Subsequently, the third group of studies (e.g. Ziramba, 2009; Arouri *et al.*, 2012; Belke *et al.*, 2011; Chontanawat *et al.*, 2008; Ghali and El-Sakka, 2004; Hwang and Gum, 1992) instigated the indication of bidirectional Granger-causality between aggregated or disaggregated energy consumption and income or output, favouring the feedback hypothesis. The fourth group of studies (e.g. Akarca and Long, 1980; Altinay and Karagol, 2004; Asafu-Adjaye, 2000; Yu and Hwang, 1984) do not find any evidence of Granger-causality between energy consumption and real income or output thereby confirming the neutrality of energy hypothesis.

The earlier studies indicate the relationship of real GDP, income and output growth with energy consumption. Industrial efficiency that contributes to economic development is not considered in the preceding study to justify productivity. To the best of our knowledge, none of the earlier studies show whether or not industrial production causes carbon emissions in the Malaysian economy. Furthermore, a specific country such as Malaysia is taken into consideration compared to studies of cross-sectional countries that do not capture the depth of profound histories for each individual country. Therefore, the objective of this paper is to explore the long-run nexus between industrial efficiency and energy consumption at disaggregated levels in order to consider policy implications for a single country, in this case Malaysia.

This paper is organised as follows: Section 2 designates the data and methodology following the analysis of findings in Section 3, while Section 4 delivers concluding remarks along with a discussion of policy implications.

2. METHODS

2.1 Data and Variables

First, the long-run causal relationship between industrial efficiency and disaggregated energy consumption is examined where the consumption of total energy, electricity, fossil fuel, natural gas, coal and minerals represent disaggregated energy. Secondly, the long-run causal relationship is investigated between industrial efficiency and carbon emissions and waste in order to examine to what extent the industrial sector causes negative externalities to overall productivity and social life. All of the data are collected from the World Bank spanning the period of 1971 to 2011 on an annual basis and transformed into log form. It is likely that industrial efficiency maintains a long-run relationship with disaggregated energy consumption, carbon emission and waste.

2.2 Toda and Yamamoto (TY)

The Toda and Yamamoto (1995) technique considers additional lag order $\left(k + d_{\max}\right)$ with that of optimal lag, (Caporale and Pittis, 1997). The maximum lag length (k) is determined using either the Schwarz Information Criterio (SIC) or Akaike Information

Criteria (AIC) according to (Lütkepohl, 1991, p. 306). This technique has comparative advantages in respect to the pre-testing of cointegration estimation and overcomes any form of biasness that emerges from unit root and cointegration tests. The TY technique reduces the cumbersomeness of implementation and minimizes the risk of identifying correct order as it is performed regardless of cointegration orders (Caragata and Giles, 2000).

The specified model is as follows:

$$\begin{aligned} Industrial\ \text{efficiency}_t = \ & \delta_{i,0} + \sum_{i=1}^{k} \Omega_{1,i} industrial_{t-1} + \sum_{j=k+1}^{d_{\max}} \Omega_{2,j} industrial_{t-i} \\ & + \sum_{i=1}^{k} \gamma_{1,i} energy_{t-1} + \sum_{j=k+1}^{d_{\max}} \gamma_{2,j} energy_{t-i} + \sum_{i=1}^{k} \psi_{1,i} electricity_{t-1} \\ & + \sum_{j=k+1}^{d_{\max}} \psi_{2,j} electricity_{t-i} + \sum_{i=1}^{k} \xi_{1,i} fossil_{t-1} + \sum_{j=k+1}^{d_{\max}} \xi_{2,j} fossil_{t-i} \\ & + \sum_{i=1}^{k} \omega_{1,i} \min eral_{t-1} + \sum_{j=k+1}^{d_{\max}} \omega_{2,j} \min eral_{t-i} + \sum_{i=1}^{k} \tau_{1,i} ngas_{t-1} \\ & + \sum_{j=k+1}^{d_{\max}} \tau_{2,j} ngas_{t-i} + \sum_{i=1}^{k} \vartheta_{1,i} coal_{t-1} + \sum_{i=1}^{d\max} \vartheta_{2,i} coa_{t-1} \\ & + \sum_{i=1}^{k} \varphi_{1,i} cemission_{t-1} + \sum_{j=k+1}^{d_{\max}} \varphi_{2,j} cemission_{t-i} \\ & + \sum_{i=1}^{k} \eta_{1,i} waste_{t-1} + \sum_{j=k+1}^{d_{\max}} \eta_{2,j} waste_{t-i} + \varepsilon_{i,t} \end{aligned} \tag{1}$$

$$\begin{aligned} y_{i,t} = \ & \delta_{i,0} + \sum_{i=1}^{k} \phi_{1,i} industrial\ \text{efficiency}_{t-1} \\ & + \sum_{j=k+1}^{d_{\max}} \phi_{2,j} industrial\ \text{efficiency}_{t-i} + \varepsilon_{i.,t} \end{aligned} \tag{2}$$

Here, $\Omega_i, \gamma_i, \psi_i, \xi_i, \omega_i, \tau_i, \vartheta_i, \varphi_i,\ and\ \eta_i$ are the parameters of lagged industrial efficiency, total energy, electricity, fossil fuels, minerals, natural gas, coal, emissions and waste respectively. The significant coefficients of explanatory variables indicate Granger causality from disaggregated energy consumption to industrial efficiency in equation (1). $y_{i,t}$ is the set of energy consumption variables influenced by industrial efficiency in equation (2). The unidirectional Granger cause from energy consumptions to industrial efficiency supports the growth hypothesis, if $\gamma_i \neq 0 \forall_i$ in equation (1). The conservation hypothesis is supported by the unidirectional long-run causality in equation (2) if $\phi_i \neq 0 \forall_i$. The feedback hypothesis is supported by bidirectional Granger causality between energy consumption and industrial efficiency, if, $\gamma_i \neq 0 \forall_i$ and $\phi_i \neq 0 \forall_i$ in equation (2). Finally, the neutrality hypothesis is supported if no Granger causality exists between them, when $\gamma_i = 0 \forall_i$ and $\phi_i = 0 \forall_i$ in both equations (1) and (2). Furthermore, this technique removes the problem of power and size property in estimating unit root test for long-run relationship (Zapata and Rambaldi, 1997). The maximum order of integration is found based on unit root test given in Table A1.

The findings of ADF and PP tests in Table A1 indicate that the null hypothesis of unit root problem for all of the series are not rejected at the level form, but are rejected at the first difference at 1% level of significance. This indicates that all of the series are integrated at order one or I (1), which means the maximum order of integration is one. Furthermore, the optimal lag length based on Akike Information Criterion (AIC) is two in the VAR model, which means that the total number of lag $\left(k+d_{\max}\right)$ is three. All of the findings of this study are tested for diagnostic checking in order to see whether or not the models used in the study are correctly specified. The null hypothesis of no autocorrelation and heteroskedasticity are not rejected which means the findings are free from autocorrelation and heteroskedasticity problems.

3. RESULTS AND DISCUSSION

Table A2 shows the results of long-run causal relationship between disaggregate energy consumption and industrial efficiency in total and by sector. The findings indicate that disaggregated energy consumption contributes to elevating industrial efficiency.

In panel A (Table A2), the null hypothesis of industrial efficiency does not indicate Granger-causality. Total energy is rejected at 1% level of significance that supports the conservative hypothesis. The positive coefficient suggests that industrial efficiency has a great impact on the use of total energy. The result conflicts with that of Bouoiyour and Selmi (2013) who find a cogent nexus between total energy consumption and output supporting the growth hypothesis along with Arouri *et al.* (2012) and Belke *et al.* (2011) who find evidence of the feedback hypothesis. However, the findings do coincide with the findings of Erol and Yu (1987) and Lee (2006) supporting the conservative hypothesis. The results can be explained by the fact that energy is the basic factor for industrial production and is indispensable for all economic activities. Thus, industrial efficiency has a positive nexus with energy consumption in an emerging industrialized country such as Malaysia.

The rejection of both-way null hypothesis in panel B and D (Table A2) supports the feedback hypothesis and indicates a bidirectional linkage between electricity and industrial efficiency. The findings are unexpected since industrial energy consumption uses up to 55% of total electricity consumption. These results are consistent with the previous findings of Ghali and El-Sakka (2004) and Lee (2006) that also support the feedback hypothesis, and that are partially consistent with the findings of Fatai *et al.* (2004) and Thoma (2004) who find unidirectional causality between output and electricity consumption in favour of the conservative hypothesis. Moreover, Malaysian industries heavily depend on oil particularly fossil fuel as the greatest amount and most significant source of electricity that directly contributes to industrial efficiency (Ewing *et al.*, 2007; Choong, 2012).

The null hypothesis in panel E and F (Table A2) are rejected which supports the feedback hypothesis. The findings indicate a bidirectional relationship between minerals and industrial efficiency as well as natural gas and industrial efficiency. Minerals and natural gas are the traditional sources of energy inputs in industrial production. Malaysian industries heavily rely on minerals and natural gas via the world famous petroleum company, PETRONAS that supplies energy components at low cost to the local economy. Furthermore, panel G (Table A2) provides evidence of the conservative hypothesis where the null hypothesis of industrial efficiency does not indicate Granger-causality whereby coal is rejected at 10% level of significance. The findings are parallel with the earlier results of Qazi *et al.* (2012) and Ziramba (2009) who find a unidirectional causality nexus between industrial production and coal confirming the conservative hypothesis. This could be explained by the circumstance that coal is not directly utilized for production procedures but rather to generate the electricity that is utilized in industrial production (see Ziramba, 2009, p. 5). The summary of the findings is provided in the following Table A3.

Moreover, panel C (Table A2) indicates the long-run relationship between carbon emissions and industrial efficiency and supports the feedback hypothesis. The existence of a positive linkage between carbon emissions and industrial efficiency are complementary to each other and indicates that higher uses of energy consumption increase the level of carbon emissions. Our findings are in line with Dinda and Coondoo (2006) and Halicioglu (2009) that find a bidirectional causality between carbon emissions and income or output or energy consumption for North America and Turkey respectively. Hence, there is a dynamic link between carbon emissions and industrial efficiency as well as economic growth from a production point of view (Soytas and Sari, 2009). Finally, panel H (Table A2) supports the neutral hypothesis that implies there is no significant relationship between waste and industrial efficiency. The findings refute that of Sari *et al.* (2008), a study that indicates a significant relationship between industrial production and waste. Though the results for waste and industrial production are comparable with the neutrality hypothesis, the findings may be attributed to the following: (a) There is no sequential dependence between the waste measures and industrial production or; (b) The limited sample size (though larger than several preceding studies used in this study) might have biased the results towards failing to find a causal relationship.

4. CONCLUSIONS AND POLICY

This study investigates the long-run relationship between industrial efficiency and Malaysian energy consumption at disaggregated levels employing the multivariate TY econometric technique with World Bank data from 1971 to 2011. The findings of this study present several outcomes: First, industrial efficiency in Malaysia responds in a bi-directional relationship with electricity, fossil fuel, minerals and natural gas supporting the feedback hypothesis. Secondly, industrial efficiency via Granger-causality between total energy and coal supports the conservation hypothesis. Thirdly, the neutral relationship between industrial efficiency and waste indicates that waste has no effect on industrial efficiency and vice versa. Finally, higher levels of industrial efficiency increase carbon emissions. Industrial sectors contribute 27.5% of total GDP in the Malaysian economy (Lindsay, 2012). If energy consumption is minimized within a certain level of production, industrial sectors can play a better role in economic development. Furthermore, energy consumption causes negative effects on industrial sectors, the economic environment and social life and can only be reduced by minimizing energy inputs.

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APPENDIX-A

Table A1
Unit Root Test Result

Variables	ADF		PP	
	Level	1st diff	Level	1st diff
Industry	-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*
Emission	-1.802	-7.544*	-1.797	-7.503*
Fossil	-1.998	-5.288*	-1.998	-8.215*
Coal	0.796	-7.834*	-1.549	-7.962*
Mineral	-1.775	-7.520*	-1.939	-7.425*
Natural gas	-1.901	-6.440*	-1.651	-6.440*
Waste	-2.049	-7.225*	-2.033	-7.489*

*Lags length has been selected based on AIC and *, **,*** represent 1%, 5% and 10% significance level respectively*

Table A2
Toda-Yamamoto Causality Test over 1971 to 2011

Null hypothesis		Modified Wald Statistics	Sum of Lagged Coefficient
Panel A	Total energy does not Granger cause Industrial Efficiency	2.346 [0.504]	1.315
	Industrial Efficiency does not Granger cause total energy	13.689 [0.003]*	0.030
Panel B	Electricity does not Granger cause Industrial Efficiency	29.479 [0.000]*	0.367
	Industrial Efficiency does not Granger cause electricity	7.281 [0.064]***	0.089
Panel C	Carbon emission does not Granger cause Industrial Efficiency	31.951 [0.000]*	0.645
	Industrial Efficiency does not Granger cause carbon emission	16.674 [0.001]*	0.387
Panel D	Fossil does not Granger cause Industrial Efficiency	18.562 [0.000]*	1.204
	Industrial Efficiency does not Granger cause fossil	7.037 [0.071]***	-0.002
Panel E	Mineral does not Granger cause Industrial Efficiency	57.959 [0.000]*	0.319
	Industrial Efficiency does not Granger cause mineral	76.729 [0.000]*	-5.396
Panel F	Natural gas does not Granger cause Industrial Efficiency	20.605 [0.000]*	0.064
	Industrial Efficiency does not Granger cause natural gas	17.248 [0.001]*	0.397
Panel G	Coal does not Granger cause Industrial Efficiency	3.128 [0.372]	-0.017
	Industrial Efficiency does not Granger cause coal	7.290 [0.063]***	11.692
Panel H	Waste does not Granger cause Industrial Efficiency	2.349 [0.503]	0.162
	Industrial Efficiency does not Granger cause waste	5.603 [0.133]	-52.782

Asterisks *, ** and *** represent 1%, 5% and 10% significance level. The p-values at different significant level are in the parenthesis.

Table A3
Granger Causality Direction

Bidirectional Granger Causality	**Unidirectional Granger Causality**	**No Granger Causality**
Industrial ↔ Fossil Fuel Industrial ↔ Emission Industrial ↔ Electricity Industrial ↔ Mineral Industrial ↔ Natural Gas	Industrial → Coal Industrial → Total Energy	Industrial ▬ Waste

Note: ▬, →, ↔ indicate no Granger causality, unidirectional Granger causality and bidirectional Granger causality respectively