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Disaggregated Energy Consumption and Sectoral Outputs in Thailand: ARDL Bound Testing Approach

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Abstract: *From an economic perspective, energy-output relationship studies have become increasingly popular in recent times, partly fuelled by a need to understand the effect of energy on production outputs rather than overall GDP. This study dealt with disaggregated energy consumption and output of some major economic sectors in Thailand. ARDL Bound Testing approach was employed to examine the co-integration relationship. The Granger causality test of the aforementioned ARDL framework was done to investigate the corresponding causality effect. Results showed that, from year 1980 to 2010, productivity of most scrutinized industries was highly reliant on crude oil and natural gas. However, coal usage in transportation and agricultural industries can be reduced without affecting productivity. Few recommendations are given thereafter for Thailand to better manage their imported and local energy sources.*

Keywords: Sectoral outputs, disaggregated energy consumption, ARDL Bound testing, Thailand, economic growth.

Introduction

Presently, the interest and attention on energy studies have been increased among researchers in order to address the problems caused by repetitive occurrence of energy crises since the first oil shock in the early 1970s (particularly in 1973 and 1979) until the recent massive drop in oil prices. Such crises have substantially heightened many countries' energy bill and affected the nations' productivity growth, causing energy sources to become one of the major growth constraints in term of output growth. This setback, in particular, has motivated numerous researchers to focus on energy-outputs relationship studies rather than the common energy-GDP study, such as Liew, Nathan, and Wong (2012); Costantini and Martini (2010); Ghali and El-Sakka (2004); Collard, Fève, and Portier (2005). Liew et al. (2012) specified that the advantage in investigating the energy-output relationship is to specifically pinpoint the dependency of other sectors on the energy sector in a particular country. In relation to this and taking a step further, this study is contributing to the existing literature through the introduction of a new approach in disaggregating the overall energy sector into sub-energy sectors to provide a more precise picture on the dependency of economy sectors according to specific type of energy.

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This study has chosen Thailand as the target since the nation's GDP growth has been increasing after the stock market recovered from the 1997-1998 Asian financial crisis. At the same time, according to the *Department of Alternative Energy Development and Efficiency* (2004) the energy consumption in many economic sectors in Thailand is also increasing. This means that the country will benefit from having good energy policies in place to strengthen the country's GDP growth before the economy is hampered by another economic crisis. This is also in view of the fact that energy accessibility and consumption play vital roles in production and output growth, and thus considerable attention has been placed on identifying energy-outputs relationship in Thailand.

This study has also contributed in terms of the application of the Autoregressive Distributive Lag (ARDL) bound testing approach developed by Pesaran and Shin (1998); Pesaran, Shin, and Smith (2001) in identifying the pertaining co-integration relationship. ARDL test has two advantages over the commonly used Johansen co-integration test; (1) it can overcome the problems often encountered with small sample sizes (Pesaran & Shin, 1998; Raza, 2015) and (2) it omits the necessity to examine the non-stationarity property and order of integration (variables integrated at I(1), I(0) or a mixture of both are acceptable). This study also utilized the WALD test of ARDL framework to identify the causality effect between the disaggregated energy consumption and selected sectoral outputs.

The results of the study showed that different sectors are reliant on different types of energy. The causality results indicated that sectors such as industrial and services are highly reliant on the energy sector in Thailand. The outcome of this study shall be presented in the following order: the second section briefly discuss the four types of testable hypothesis in energy-output relationship analysis; Section 3 discusses the methodology and data adopted; Section 4 presents the results, while section 5 concludes the study. The appendix offers the stability test for the regression.

Literature Review

Generally, the findings of energy-output studies can be illustrated in four situations in the causality term. Nevertheless, in general, the identification of the direction of causality relationship between energy and outputs is the most important to allow policy restructuring. The relationship was initially introduced by Kraft and Kraft (1978) and later on, Apergis and Payne (2010) categorized it into four testable hypotheses, i.e. growth, conservation, feedback, and neutrality hypothesis. The growth hypothesis implies that energy consumption is crucial to the outputs' growth, and can be identified using the unidirectional causality relationship that runs from energy consumption towards the relevant outputs (Apergis & Payne, 2010; Costantini & Martini, 2010; Ho & Siu, 2007). If otherwise, it means that energy protection policies can be implemented without harming the performance of the sector (conservation hypothesis) (Al-Iriani, 2006; Hatemi, Irandoust, et al., 2005). Meanwhile, the feedback hypothesis indicates that energy consumption and outputs are interdependent of each other and this is identified as the bidirectional causality (Esso, 2010; Tang, 2008; Altinay & Karagol, 2005; Raza, 2015). So, this interdependent indicates that any changes in energy consumption or sectoral outputs going to affect each other's. Finally, the neutrality hypothesis holds if there is no causality relationship between energy consumption and outputs (Ghorbani, Mansoori, & Hamraz, 2009; Chiou-Wei, Chen, & Zhu, 2008). This hypothesis implies that any changes in energy consumption and sectoral outputs do not affect each other's performance in economy. These are the hypotheses that have often been used in published works and also taken as the fundamental of this study.

Methodology

Data Description

This study used annual data recorded from 1980 to 2010 for the oil, coal and gas consumption of Thailand contributed by the *U.S. Energy Information Administration* (2011). Data on the sectoral outputs such as agricultural, industrial, services and transport outputs of Thailand were obtained from the *United Nation* (2011). Since the energy data were given in different unit for different energy, an energy converter had been used to standardize all values into Million British Thermal Unit (Mmbtu). Sectoral outputs were thus represented as the sum of outputs for all sub sectors by the values added up by respective sectors (Liew et al., 2012; Costantini & Martini, 2010). To overcome the problem of heteroskedasticity, all variables were subsequently changed into logarithmic forms (Gujarati, 2009; Alam, Raza, Shahbaz, & Abbas, 2015; Raza, Shahbaz, & Paramati, 2016). More details of the data can be found in Table 1.

Structural Break test (Zivot and Andrews model)

Waheed, Alam, and Ghauri (2006) argued that the common conventional unit root test such as ADF, DF-GLS and PP test cannot check for the possibility of structural break in the data set. Identifying the structural breaks in the data is important since it could lead to biasness in the estimation (Allaro, Kassa, & Hundie, 2011). Accordingly, model without trend and with intercept is chosen for the estimation[1].

$$\Delta lnY_t = c + \alpha lnY_{t-1} + \beta t + \gamma DU_t + \sum_{j=1}^{k} d_j \Delta lnY_{t-j} + \epsilon \tag{1}$$

Where DU_t is an indicator, dummy variable for a mean shift occurring at each possible break-data (BD). In formal terms,

$$DU_t = \begin{cases} 1.........if \quad t > \text{BD} \\ 0.........otherwise \end{cases} \tag{2}$$

The null hypothesis is $\alpha=0$, which implies that the series lnY_t contains a unit root without structural break. The alternative hypothesis $\alpha < 0$ implies that the series has a stationary process with one-time break occurring at an unknown point in time (Waheed et al., 2006).

Co-integration test

An ARDL model uses the lags of the dependent variable and the lags of independent variables to identify the short-run effect and long-run equilibrium relationship. In this study, the ARDL model has been estimated using the following unrestricted error correction model:

$$\Delta lnY_t = \alpha + \sum_{i=0}^{k_1} \beta_0 \Delta lnX_{t-1} + \sum_{i=1}^{k_2} \beta_1 \Delta lnY_{t-1} + \delta_o lnX_{t-1} + \delta_1 lnY_{t-1} + \epsilon_t \tag{3}$$

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[1]Zivot and Andrews model divided into 3 types i.e. with intercept only (Model 1), with trend only (Model 2) and with intercept and trend (Model 3). The model is chosen based on the nature of the data set.

$$\Delta lnX_t = \varphi + \sum_{i=0}^{k_1} \mu_0 \Delta lnY_{t-1} + \sum_{i=1}^{k_2} \mu_1 \Delta lnX_{t-1} + \delta_o lnX_{t-1} + \delta_1 lnY_{t-1} + \mu_t \qquad (4)$$

where Y and X stand for type of energy consumption and sectoral output, respectively; k_1 and k_2 represent the lag lengths; and ϵ_t and μ_t are white noise error terms. The co-integration relationships are sequentially examined using the Wald test (F-test). The null hypothesis of no co-integration among variables for Eq. (3) and (4) are H_o: $\delta_0 = \delta_1 = 0$ and H_o: $\sigma_0 = \sigma_1 = 0$ respectively, which are against H_1: $\delta_0 \neq \delta_1 \neq 0$ and H_1: $\sigma_0 \neq \sigma_1 \neq 0$. Decision to accept and reject the null hypothesis is based on the critical value provided by Pesaran et al. (2001). Finally, if a long-run relationship has been identified, then an error correction model within the ARDL model will be estimated using simple linear transformation.

Table 1
Data Descriptions in Detail

Variables	Unit	Descriptions
Data on energy consumption		
Oil consumption	Thousand barrels per-day	Total oil consumption includes internal consumption; refinery fuel and loss; and bunkering. Direct combustion of crude oil is included if available.
Gas consumption	Billion cubic Feet	Dry natural gas
Coal consumption	Million short tons	Coal consumption includes anthracite, sub-anthracite, bituminous, sub-bituminous, lignite, brown coal, and for Estonia, oil shale. It also includes net imports of metallurgical coke.
Data on sectoral outputs		
Agricultural outputs		Include agriculture, hunting, forestry, and fishing activities.
Industrial outputs	Billions	Industry activities
Services outputs	(U.S constant 2005 price)	Include wholesale, retail trade, restaurants, and hotels.
Transportation outputs		Include transport, storage and communication activities.

Source: U.S. Energy Information Administration (EIA) (2011)

Causality test

The causality relationships among all variables are examined using the Granger Causality Test. The following illustrates the model used to investigate the Granger causality between co-integrated variables, transformed from Eq. (3) and (4):

$$\Delta lnY_t = \alpha + \sum_{i=1}^{k_1} \beta_0 \Delta lnY_{t-i} + \sum_{i=1}^{k_2} \beta_1 \Delta lnX_{t-i} + \vartheta_0 ECT_{t-1} + \epsilon_t \qquad (5)$$

$$\Delta lnX_t = \varphi + \sum_{i=1}^{k_1} \mu_0 \Delta lnX_{t-i} + \sum_{i=1}^{k_2} \mu_1 \Delta lnY_{t-i} + \omega_0 ECT_{t-1} + \mu_t \qquad (6)$$

The causality effect is measured using the WALD test (F-statistics) ARDL framework where $H_0 = \beta_1$ and $H_0 = \mu_1$ for all i in Eq. (5) and (6), respectively (Shahbaz, Awan, & Nasir, 2009;

Ozturk & Acaravci, 2010; Keong, Yusop, & Liew, 2005)[2]

Empirical Results and Discussions

Table 2 shows the results of Zivot and Andrews structural break test. The results suggest that the null hypothesis which states that the structural break has occurred in the data series can be reject at 10% significant level for coal consumption and services outputs, 5% significant level for all other sectoral outputs, and 1% significant level for oil and gas consumption. To summarize, the most significant structural break in every series examined has been listed in Table 2, with all having important implications in term of policy reforming[3].

Table 2
Zivot and Andrews Structural Breaks Test Results

Variables	Optimum Lag (k)	t-statistics	Break Year
Oil consumption	1	-3.2623*	1989
Gas consumption	3	-5.1356*	2005
Coal consumption	5	-4.1956***	1998
Agricultural outputs	1	-3.2034**	1996
Services outputs	1	-4.9604***	1995
Industrial outputs	1	-2.4601**	1988
Transportation outputs	0	-2.4044**	1989

Note: (*) (**) and (***) denotes statistical significance at 10%, 5% and 1% level, respectively.
Source: Authors' Estimation

Table 3
Bound Testing Results

Dependent Variable	Independent Variable	Optimum Lag	F-statistics [Prob]	Dependent Variable	Independent Variable	Optimum Lag	F-statistics [Prob]
LNOIL	LNAGR	8	3.068 [0.246]	LNGAS	LNIND	7	19.20 [0.005]*
LNARG	LNOIL	7	0.724 [0.530]	LNIND	LNGAS	5	2.417 [0.135]
LNOIL	LNSER	6	3.939 [0.018]	LNGAS	LNTRA	7	56.16 [0.000]*
LNSER	LNOIL	6	2.704 [0.127]	LNTRA	LNGAS	7	0.718 [0.532]
LNOIL	LNIND	3	1.338 [0.289]				
LNIND	LNOIL	7	1.887 [0.245]	LNCOAL	LNAGR	6	1.879 [0.214]
LNOIL	LNTRA	5	9.940 [0.003]*	LNAGR	LNCOAL	7	0.183 [0.838]
LNTRA	LNOIL	5	2.526 [0.125]	LNCOAL	LNSER	5	2.348 [0.142]
				LNSER	LNCOAL	6	0.913 [0.439]
LNGAS	LNAGR	4	4.028 [0.023]	LNCOAL	LNIND	5	5.977 [0.017]**
LNAGR	LNGAS	6	2.656 [0.130]	LNIND	LNCOAL	5	4.315 [0.041]
LNGAS	LNSER	5	1.869 [0.200]	LNCOAL	LNTRA	7	3.945 [0.094]
LNSER	LNGAS	6	10.38 [0.006]*	LNTRA	LNCOAL	7	0.418 [0.680]

Notes: (*) (**) indicate that the variables were co-integrated at 1% and 5% significance level. The optimum lag was selected using SBC. The maximum lag was fixed at 9. The critical values were obtained from Table CI (iii) Case III: Unrestricted intercept zand no trend reported in Pesaran et al. (2001) pp. 300-301.

The Bound Testing results for various variable combinations are presented in Table 3. The

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[2]Microft 4.0 and Eviews statistical software were used for the results estimation.
[3]For further details, refer to study of (Waheed et al., 2006)

optimum lag was chosen using the minimum value of the Schwarz-Bayesian Criterion (SBC).[4] To make sure that the model was well-fitted, the selected optimum lag had been tested using diagnostic test for serial correlation, functional form, normality and heteroscedasticity.

Table 4
Long-run Coefficients, and Short-run Error-Correction Model

Dependent variable	Regressor	Coefficient	Standard Error	t-ratio [Prob]
Panel A: Estimated long-run coefficients				
LNOIL (1,1)	LNTRA	1.206	0.046	26.214 [0.000]
	INPT	12.513	0.105	118.815 [0.000]
LNSER (6,6)	LNGAS	0.484	0.029	16.977 [0.000]
	INPT	-6.790	0.623	-10.900 [0.000]
LNGAS (3,7)	LNIND	1.098	0.144	7.611 [0.000]
	INPT	16.849	0.724	23.279 [0.000]
LNGAS (4,0)	LNTRA	1.368	1.353	1.011 [0.326]
	INPT	18.415	4.235	4.349 [0.000]
LNCOAL (1,0)	LNIND	1.043	0.060	17.438 [0.000]
	INPT	16.595	0.239	69.444 [0.000]
Panel B: Error-correction representation for the selected ARDL model				
ΔLNOIL (1,1)	ΔLNTRA	0.474	0.074	6.398 [0.012]
	ΔINPT	4.913	0.708	6.943 [0.000]
	EC_t	-0.393	0.057	-6.862 [0.000]
ΔLNSER (6,6)	ΔLNGAS$_t$	0.245	0.421	0.582 [0.572]
	ΔLNGAS$_{t-1}$	0.546	0.361	1.512 [0.159]
	ΔLNGAS$_{t-2}$	0.587	0.236	2.483 [0.030]
	ΔLNGAS$_{t-3}$	0.675	0.266	2.537 [0.028]
	ΔLNGAS$_{t-4}$	-0.41	0.226	-1.816 [0.097]
	ΔLNGAS$_{t-5}$	-0.027	0.014	-1.997 [0.071]
	ΔINPT	-9.463	3.189	-2.967 [0.013]
	EC_t	-1.394	0.452	-3.082 [0.010]
ΔLNGAS (3,7)	ΔLNIND$_t$	-0.147	0.266	-0.553 [0.590]
	ΔLNIND$_{t-1}$	-0.565	0.264	-2.143 [0.053]
	ΔLNIND$_{t-2}$	-0.086	0.245	-0.353 [0.730]
	ΔLNIND$_{t-3}$	-0.633	0.248	-2.552 [0.025]
	ΔLNIND$_{t-4}$	-0.549	0.282	-1.950 [0.075]
	ΔLNIND$_{t-5}$	-0.539	0.270	-1.998 [0.065]
	ΔLNIND$_{t-6}$	-0.384	0.269	-1.428 [0.179]
	ΔINPT	7.333	1.637	4.479 [0.001]
	EC_t	-0.435	0.112	-3.894 [0.002]
ΔLNGAS (4,0)	ΔLNTRA$_t$	0.094	0.143	0.659 [0.519]
	ΔINPT	1.270	0.707	1.795 [0.090]
	EC_t	-0.069	0.048	-1.450 [0.165]
ΔLNCOAL (1,0)	ΔLNIND$_t$	0.722	0.129	5.604 [0.000]
	ΔINPT	11.492	1.454	7.905 [0.000]
	EC_t	-0.693	0.094	-7.353 [0.000]

Source: Authors' Estimation

We use the f-statistics value to find the co-integration of all combinations of variables. The following table lists the combinations which have long-run relationship. This include oil consumption and transport outputs; services outputs and gas consumption; gas consumption and industrial outputs; gas consumption and transport outputs; and coal consumption and industrial outputs.

After this, the long-run coefficients (Panel A) and short-run error correction model (ECM)

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[4]SBC value is better than other model specification criteria since it fits small sample data (Ozturk & Acaravci, 2010; Verma, 2007)

(Panel B) of the ARDL model were estimated (Table 4). In this table, all the independent variables have a significant impact on dependent variables except LNTRA. The long-run coefficient of transport outputs was 1.206 at a significance level of 1%. It means that 1 percent of increase in transport output will increase the oil consumption by about 1.206 percent. Based on Panel B of Table 4, the estimated coefficient of EC_t for oil consumption and transport outputs was -0.393. This suggests that any deviation occurred will be corrected by 39% over the following year. Also, probability value of the t-ratio is less than 0.01, implying that the selected co-integration is significant at 1% level. The long-run relationship for all other co-integrated variables can be interpreted similarly.

Table 5
ARDL Diagnostic Tests Result

Dependent Variable	Independent Variable	Serial Correlation[a]	Functional Form[b]	Normality[c]	Heteroscedasticity[d]
LNOIL	LNTRA	1.047 [0.306]	0.025 [0.875]	0.740 [0.691]	0.210 [0.647]
LNSER	LNGAS	3.829 [0.050]	1.174 [0.279]	3.863 [0.145]	1.269 [0.260]
LNGAS	LNIND	0.186 [0.666]	1.394 [0.238]	0.117 [0.943]	2.734 [0.098]
LNGAS	LNTRA	0.036 [0.850]	2.304 [0.129]	1.120 [0.571]	0.391 [0.532]
LNCOAL	LNIND	1.009 [0.315]	2.770 [0.096]	0.255 [0.880]	5.921 [0.015]

Notes: **a** Lagrange multiplier test of residual serial correlation. **b** Ramsey's RESET test using the square of the fitted values. **c** Based on a test of skewness and kurtosis of residuals. **d** Based on the regression of squared residuals on squared fitted values.
Source: Authors' Estimation

At the final stage, diagnostic tests (Table 5), cumulative sum tests (CUSUM) and cumulative sum of squares (CUSUMSQ) tests were conducted to identify the model's stability. Results demonstrated that the models are well-fixed and the CUSUM and CUSUMSQ results indicated that the parameters are stable throughout the sample period of 1980-2010 (refer to appendix, Table A1).

The WALD test done during the final stage identifies the short-run causality among all variables (see Table 6 for results). The null hypothesis is rejected if the probability value is less than the 5% significance level. The probability of oil consumption, not Granger-causing transport outputs was, 0.000. Also, the probability of transport outputs, not Granger-causing oil consumption, was 0.871.

Therefore, it can be concluded that there is a unidirectional causality relationship running from oil consumption towards transport outputs in the short-run. With reference to the study done by (Altinay & Karagol, 2005), an increase in oil consumption can be viewed as the prominent indicator of transport outputs growth. Such unidirectional causality relationship has also been found between gas consumption and agricultural outputs; services outputs and oil, gas, and coal; and finally coal consumption and industrial outputs.

Besides that, bidirectional causality exists between gas consumption and industrial outputs. Bidirectional causality relationship implies that both variables are resolute and affected at the same time (Masih & Masih, 1998). On the other hand, there is no causality effect for oil and coal consumption towards agricultural outputs.

Table 6
Granger Causality Test Results (Wald Test F-statistic)

Null Hypothesis	Wald Test		Direction
	Chi-square	Prob	
LNOIL does not Granger-cause LNAGR	0.498	0.480	-
LNAGR does not Granger-cause LNOIL	0.008	0.930	-
LNOIL does not Granger-cause LNSER	0.003	0.954	
LNSER does not Granger-cause LNOIL	4.469**	0.035	OIL ← SER
LNOIL does not Granger-cause LNIND	15.048*	0.000	OIL → IND
LNIND does not Granger-cause LNOIL	4.462**	0.035	OIL ← IND
LNOIL does not Granger-cause LNTRA	40.935*	0.000	OIL → TRA
LNTRA does not Granger-cause LNOIL	0.026	0.871	-
LNGAS does not Granger-cause LNAGR	5.000**	0.025	GAS → AGR
LNAGR does not Granger-cause LNGAS	1.469	0.226	-
LNGAS does not Granger-cause LNSER	0.386	0.534	-
LNSER does not Granger-cause LNGAS	4.368**	0.037	GAS ← SER
LNGAS does not Granger-cause LNIND	16.226*	0.000	GAS → IND
LNIND does not Granger-cause LNGAS	12.785*	0.000	GAS ← IND
LNGAS does not Granger-cause LNTRA	0.435	0.510	-
LNTRA does not Granger-cause LNGAS	0.498	0.481	-
LNCOAL does not Granger-cause LNAGR	2.069	0.150	-
LNAGR does not Granger-cause LNCOAL	0.042	0.837	-
LNCOAL does not Granger-cause LNSER	5.507	0.019	-
LNSER does not Granger-cause LNCOAL	3.928**	0.047	COAL ← SER
LNCOAL does not Granger-cause LNIND	31.407*	0.000	COAL → IND
LNIND does not Granger-cause LNCOAL	2.660	0.103	
LNCOAL does not Granger-cause LNTRA	0.327	0.568	-
LNTRA does not Granger-cause LNCOAL	0.692	0.405	-

Notes: (*) and (**) denote the rejection of the null hypothesis at 1% and 5% level of significance. Prob represents the probability value.
Srouce: Authors' Estimation

Conclusion and Recommendation

The main contribution of this study is in the disaggregation of energy consumption in accordance to sectoral outputs. The rapid growth in Thailand in term of productivity and energy has been the main motivation for this study. The data had been tested for structural break before the analysis was carried out. ARDL test was done to check for the co-integration among variables. WALD test was adopted for the causality test. For Thailand, the industrial and transportation sectors are driven by energy consumption. This indicates that the growth hypothesis holds and that the industrial and transportation sectors' growth in term of outputs is heavily reliant on the amount of energy consumed. Any energy shortfalls and crisis may have huge impact on the output of those sectors. According to the *U.S. Energy Information Administration* (2011) the highest energy consumed by Thailand was natural gas (34%), followed by coal (33%) in 2009. Moreover, the industrial sector was the major contributor to Thailand's GDP growth (43% of overall GDP), followed by the services sector (19% of overall GDP) (*United Nation*, 2011). Consistent supply that satisfies the demand of natural gas is crucial to increase the productivity of industrial and agricultural sectors while for the industrial sector, oil supply proves to be the main productivity driver. Simply to say, to encourage growth within the nation, the government needs to supply or explore more energy sources, particularly natural gas and oil.

According to the *Department of Alternative Energy Development and Efficiency* (2004) Thailand is a coal producer, but it also imports energy from other countries such as Indonesia (65% of

overall import), Vietnam, Myanmar, Australia, China, and Laos. Within the country, coal is used in two major productions-power sector (electricity production) and industrial sector. Statistically, Thailand can reduce the usage of coal in the agricultural and transport sectors without harming the respective production rates. This is because neutrality hypothesis holds for the agricultural and transportation sectors towards the coal consumption. This conserved energy resource can then be channeled to other sectors, primarily the industrial sector, to boost production growth.
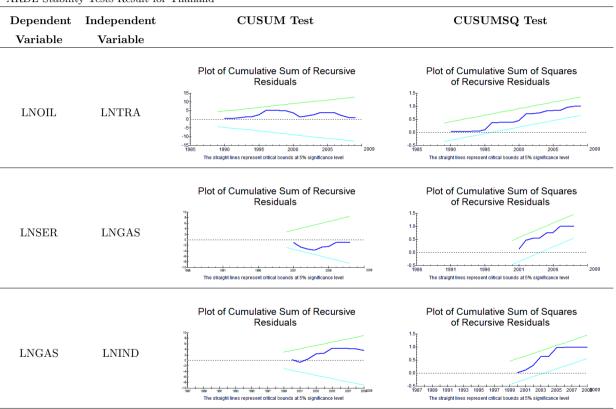
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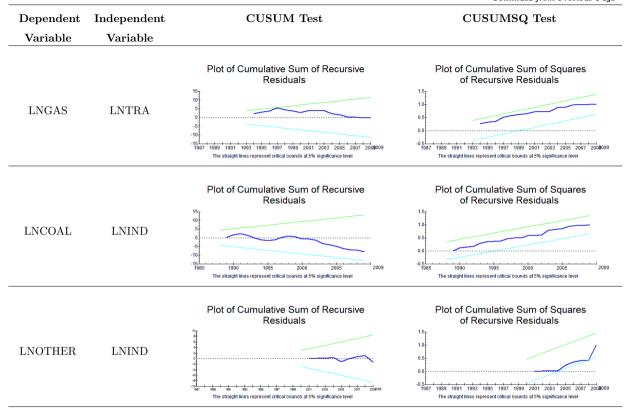
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Appendix:

Table 7
ARDL Stability Tests Result for Thailand

Dependent Variable	Independent Variable	CUSUM Test	CUSUMSQ Test
LNOIL	LNTRA	Plot of Cumulative Sum of Recursive Residuals *The straight lines represent critical bounds at 5% significance level*	Plot of Cumulative Sum of Squares of Recursive Residuals *The straight lines represent critical bounds at 5% significance level*
LNSER	LNGAS	Plot of Cumulative Sum of Recursive Residuals *The straight lines represent critical bounds at 5% significance level*	Plot of Cumulative Sum of Squares of Recursive Residuals *The straight lines represent critical bounds at 5% significance level*
LNGAS	LNIND	Plot of Cumulative Sum of Recursive Residuals *The straight lines represent critical bounds at 5% significance level*	Plot of Cumulative Sum of Squares of Recursive Residuals *The straight lines represent critical bounds at 5% significance level*

Continued on Next Page

Dependent Variable	Independent Variable	CUSUM Test	CUSUMSQ Test
LNGAS	LNTRA	Plot of Cumulative Sum of Recursive Residuals The straight lines represent critical bounds at 5% significance level	Plot of Cumulative Sum of Squares of Recursive Residuals The straight lines represent critical bounds at 5% significance level
LNCOAL	LNIND	Plot of Cumulative Sum of Recursive Residuals The straight lines represent critical bounds at 5% significance level	Plot of Cumulative Sum of Squares of Recursive Residuals The straight lines represent critical bounds at 5% significance level
LNOTHER	LNIND	Plot of Cumulative Sum of Recursive Residuals The straight lines represent critical bounds at 5% significance level	Plot of Cumulative Sum of Squares of Recursive Residuals The straight lines represent critical bounds at 5% significance level

Notes: The illustration of CUSUM test and CUSUMSQ test has been generated from Microfit 4.1 and attached into the table.