The relationship between energy consumption and economic growth: evidence from Thailand based on NARDL and causality approaches

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Abstract

Energy plays a crucial role in the economic development of most economies. The causality nexus between energy consumption and economic growth is important in enacting energy consumption policy and environmental policy. This paper tries to investigate the relationship between energy consumption and economic growth for Thailand over the period from 1976 to 2014 applying NARDL approach. The main finding from the NARDL evidence cointegration among economic growth, energy consumption, capital formation and trade openness and found asymmetry is significant for both the long run and short run for economic growth, which implies that taking nonlinearity and asymmetry into account is important when studying the relationship between economic growth and energy consumption. This paper also found that most of the independent variables are found to be significant in the long run compared to the short run. In addition, this paper also discerned Granger-causal chain between the variables through the application of VECM, VDC and IRF analyses.

Keywords: Energy consumption, Economic growth, NARDL, VECM, VDC, Thailand

1. Introduction

Energy is one of the most vital form of energy and critical resource for modern life and is considered as a backbone to production worldwide. This demand is due to rising standard of living, industrialization and population growth. The causality between energy consumption and economic growth has attracted ample attention of economists and policy makers, in which countless studies have examined the relationship between these two. However, reports from such studies have been seemingly contradictory and different. Thus, implementation of policies for the conservation of energy needs to be tackled with extreme care to avoid economic policies that would link to the shrinks of economic development.

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For the case of Thailand, this study contributes to the understanding of the interchange between economic growth and energy consumption. Thai is the second largest economy in Southeast Asia with large industrial and manufacturing base. Manufacturing, which is the most energy-intensive sector, makes up 34% of the Thai economy, and contribute Thai as the world's 17th-largest manufacturer and 14th-largest car producer. Energy consumption growth rates in the manufacturing and commercial sectors have been much higher than the GDP growth rate, with increases of 3.0 and 3.7 times respectively compared with consumption in 1990 (EPPO, 2013).

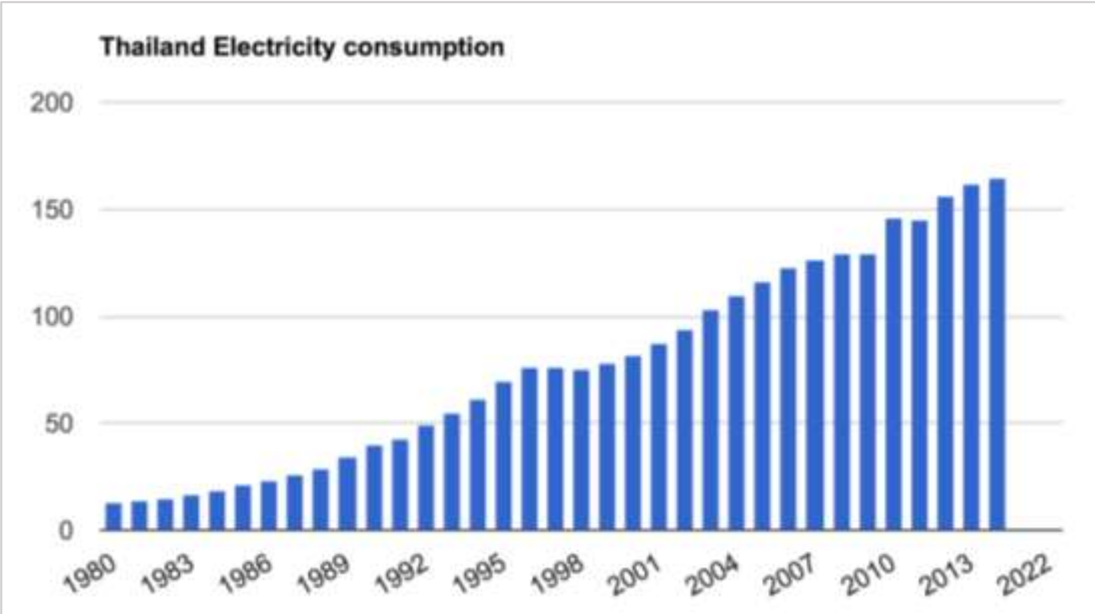
Thailand is a rapidly growing country with a large middle class, have undergone a structural transition via changing the nature and shape of energy demand in the upcoming years. Thai energy policy is driven by the three pillars, namely security, affordability and environmental sustainability. These three pillars are major drivers of Thailand's current long-term outlook of power sector development. Currently, the highest demand for energy is concentrated in the service area of the Metropolitan Electricity Authority (MEA), comprising Bangkok, Nonthaburi and Samut Prakarn which accounted for two-thirds of Thailand's energy demand.

The commercial energy production was at 1,026 thousand barrels of oil equivalent per day, down by 4.3% while the net primary energy imported stood at 1,251 thousand barrels of oil equivalent per day, increase by 6.8%. Production decreased due to the reduction of Mae Moh power plant while the energy imported increased because the starting of electric supply from Hongsa power plant in Lao PDR in February 2015. The final energy consumption was 1,420 thousand barrels of oil equivalent per day, or 4.0% up, according to Thailand's economy grew at 2.8%. It is a result of government stimulus policies that enhance the consumption and investment within the country.

In 2015, decreased energy production in Thai, resulting in more imports to meet domestic demand. The energy consumption increased due to hot weather occurred and the expansion of the business sector. The final energy consumption increased by 4.0% because the Thai economy started to recover, with GDP grew by 2.8%. Thai recovered from the negative impact that resulted increased to 3.1% in 2015 from growth rate of only 0.9% in 2014. The average annual growth rates expected of at least 3.6% between 2016 and 2020 (OECD, 2015).

Figure 1 is the overview of Thai electricity consumption from year 1980 and expectation of continuous consumption up till year 2018.

Figure 1. Thailand Electricity Consumption



Currently, Thai is heavily dependent on natural gas imports from Myanmar. To strengthening its gas supply infrastructure, Thailand is seeking to diversify its power sector over the next two decades. This diversification is expected to come mainly from two sources: an increase in coal generation and coal imports, and an increase in both domestic and imported renewables.

To the best of our knowledge, asymmetry has not been studied in this relationship. In this context, the results provided in this study can help policymakers better understand the causalities between these important economic variables and the ways in which an increase or a decrease in one variable can affect the others. The rest of the paper is organized as follows. Section 2 reviews the literature on energy consumption and economic growth where we present relevant literatures that will give us sound conception of the fact. Section 3 provides an avenue regarding research methodological approach and the relevant information on the time series data sets that are used for this study. Section 4 analyses the results, while Section 5 concludes the paper by paying particular attention to the policy implications of the results and the importance of taking the asymmetry into account.

2. Literature Review

2.1 Theoretical perspectives on energy consumption and economic growth

A number of studies has been conducted to investigate the relationship between energy consumption and economic growth (e.g., Squalli, 2007, Apergis and Payne 2011, Shahbaz et al. 2013, Wolde-Rufael 2014, Rafindadi and Ozturk 2016, Sarwar et al. 2017). Some researchers validate the growth hypothesis, which holds that energy consumption leads to economic growth (e.g., Apergis and Payne 2009, Ozturk et al. 2010, Ouedraogo 2013, Aslan et al. 2014b), while others validate the conservative hypothesis, which holds that economic growth influences energy consumption (e.g., Huang et al. 2008, Narayan et al. 2010, Kasman and Duman 2015).

There are some studies indicated mixed results regarding causal relationship between energy consumption and economic growth. Ghosh (2002) reported no long-term equilibrium between energy consumption and economic growth but found that economic growth Granger-causes energy consumption. Asghar (2008) found a neutral effect between energy consumption and GDP in India over the 1971–2003 period. Alam et al. (2011) showed no causal relationship between energy consumption and income. Dogan (2014) showed unidirectional causality running from energy use to economic growth in Kenya but no causality in Benin, Congo or Zimbabwe from 1971 to 2011. Acaravci et al. (2015) found unidirectional short-run and long-run causality running from energy consumption to economic growth, though not the reverse, in Turkey from 1974 to 2013.

For China, Furuoka (2016) found unidirectional causality running from natural gas consumption to economic development from 1980 to 2012. Ghosh and Kanjilal (2014) showed the unidirectional causality running from energy consumption to economic activity. Sehrawat et al. (2015) showed a neutral effect between energy consumption and economic growth in India over the 1971–2011 period. Nasreen and Anwar (2014) revealed bidirectional causality between energy consumption and economic growth in 15 Asian countries from 1980 and 2011. Shahbaz et al. (2016) showed that economic growth and energy consumption were complementary. Jafari et al. (2012) found no significant relationship between energy consumption and economic growth in Indonesia from 1971 to 2007 and Altinay and Karagol (2005) found strong evidence for unidirectional causality running from the energy consumption to income implies that an economy is energy dependent and shortage of energy may negatively affect economic growth or may cause poor economic performance in Turkey for the period 1950-2000.

Although economic theories do not explicitly state a relationship between these variables, overall findings are that there exists a relationship between energy consumption and economic growth. Yang and Zhao (2014) found that energy consumption causes economic growth. Gupta and Sahu (2009) reported that energy consumption Granger-caused economic growth over the 1960–2009 period. Cheng (1999) showed that economic growth Granger-causes energy consumption over the short term and the long term. Asafu Adjaya (2000) viewed that energy caused GDP and relationship exists between energy consumption and economic growth. Ahmad et al. (2016) found a feedback relationship between energy consumption and economic growth in India over the 1971–2014 period. Ouedraogo (2013) found causality running from GDP to energy consumption in the short run and the reverse in the long run for the Economic Community of West African States. Morimoto and Hope (2001) revealed that energy supply have significant impact on a change in real GDP in Sri Lanka. Aqueel and Butt (2001) investigate the relationship in Pakistan and results inferred that energy consumption leads to economic growth. Fang and Chang (2016) found that economic growth caused energy use in the Asia Pacific region (16 countries) from 1970 to 2011, but the relationship may have varied for individual countries.

In addition, Shahbaz and Lean (2012) investigate the causal links between energy consumption and economic growth in Pakistan. Their findings suggest in the long run that energy consumption has a positive effect on economic growth. However, when it comes to whether energy use is a result of or a prerequisite for, economic growth, there are no clear trends (Atle,2004).

However, most of these studies are conducting linear models. Few studies adapt non-linear modeling strategies to the relationship between energy consumption and economic growth. Since energy consumption and economic growth series are order one, I(1), nonlinear modeling in the context of co-integrating long-run relationships is important.

2.2 Empirical Review

Various non-stationary econometric methodologies have been deployed in numerous empirical studies to determine long-term and short-term links between energy consumption and economic growth (Chen et al. 2007, Narayan and Prasad 2008, Iyke 2015, Mutascu 2016, Streimikiene and Kasperowicz 2016, Tang et al. 2016, Shabhaz et al. 2016). The first generation of empirical studies investigate the energy-growth nexus in a stationary econometric framework by using both traditional causality measures, Granger and Sims causality tests based on the VAR methodology (Akara and Long 1980, Yu and Wang 1984, Yu and Choi 1985 among others).

Recently, the relationship between energy consumption and economic growth has been extensively investigated in a non-stationary setting by using a Vector Error Correction Model (VECM) to test for Granger causality (Cheng and Lai 1997, Stern 2000, Narayan and Singh 2007, Ghosh 2009). For example, Cheng and Lai (1997) confirm the presence of a unidirectional Granger causality running from economic growth to energy consumption for Taiwan in the period from 1955 to 1993. In a similar study, Dhungel (2008) found unidirectional causality running from per capita energy consumption using Granger causality test to determine the relationship between energy consumption and economic growth in Nepal during 1980-2004. The same causal relationship is obtained by Narayan and Singh (2007) when applying a production function, in which they incorporate the labor factor as an additional component of the relationship on Fiji for the period from 1971 to 2002. Thure Traber (2008) expressed relationship energy and economic growth using Granger Causality results asserted that energy demand is likely to increase as long as we experience economic growth.

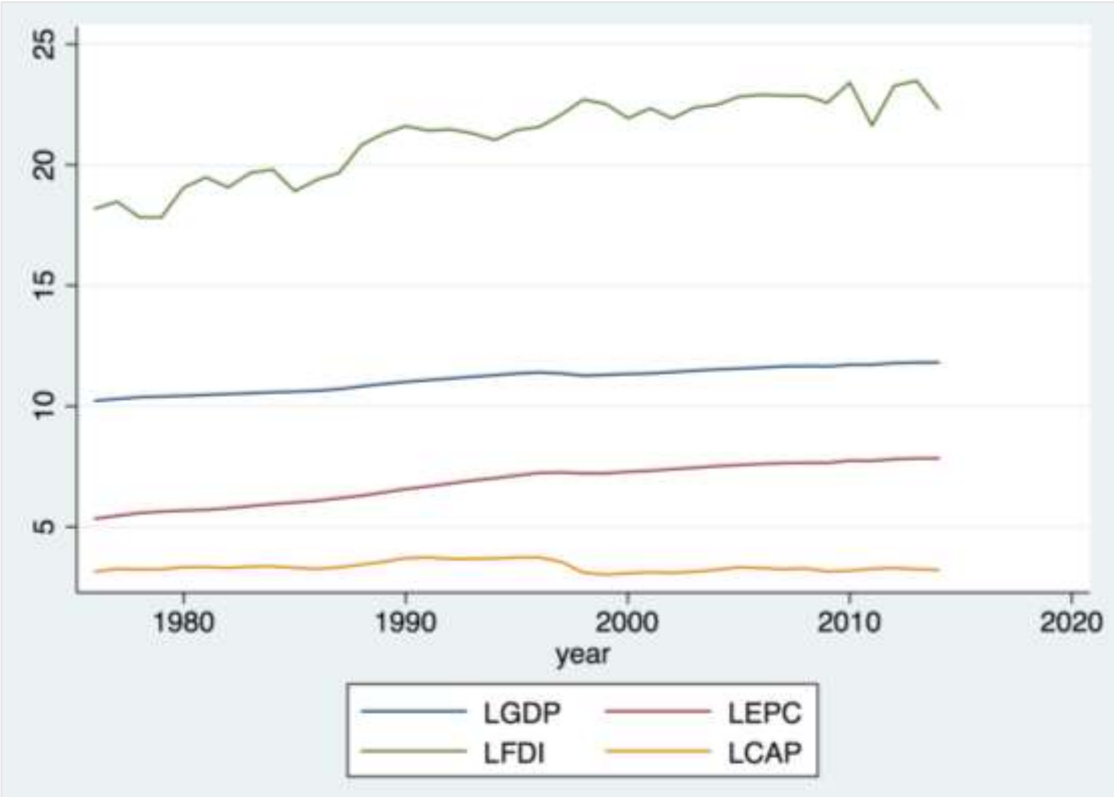
Economists are aware that the use of energy consumption may be an influential economic tool to sustain economic growth. Nevertheless, they face conflicting results from an academic viewpoint. The uncertainty in the empirical results may be due to the illiteracy of asymmetry or non-linearity arising in time series due to structural reforms, financial economic and energy reforms, and regional and global imbalances. This presence of asymmetry in time series may change the impact of energy consumption on economic growth and the direction of causality between both variables (Shahbaz et al. 2017). The presence of asymmetry in time series leads us to examine how positive or negative fluctuations in energy consumption impact economic growth. As such, certain studies prefer to use not only linear but also non-linear Granger causality models such as Chiou, Chen & Zhu (2008). This study uses nonlinear Granger causality models to examine the causality between energy consumption and output in eight Asian countries and United States. The findings indicate that a non-linear causal nexus between energy consumption and output is valid in the case of Taiwan, Hong Kong, Singapore, Indonesia and Philippines; whereas, in the pattern of United States, South Korea and Thailand there is no supportive evidence for causality. Other studies examine nonlinear Granger causality tests include Ajmi, Montasser & Nguyen (2013) and Dergiades, Martinopoulos & Tsoulfidis (2013). However, Ciarreta and Zarrage (2007) found no evidence of nonlinear Granger causality between the series in either direction when computed both linear and nonlinear causality between energy consumption and economic growth in Spain from 1971-2005. But, they found unidirectional linear causality running from GDP to energy consumption. Thus, this paper aims at narrowing the gap between the literature and practice by reconsidering the relationship between energy consumption and economic growth in the particularly interesting case of Thailand.

3. Data and Methodology

3.1 Data and Measures

This section will present the dataset and the methodological framework. All the data used are annual observations of the variables from year 1976 to 2014. The data for Economic growth, Energy consumption, Capital formation and Trade openness is retrieved from World Bank Datasets. Economic growth is proxy by GDP per capita at constant price and denominated in millions. Energy power consumption (EPC) is proxy by Electric Power Consumption (kWh per capita), Capital formation is proxy by Gross Fixed Capital Formation and Trade Openness is proxy by Foreign Direct Investment (FDI). Owing to the above specified models, the empirical analysis has been done through Eviews and Stata software since Microfit 4.1 cannot be used to estimate NARDL model. To examine the Granger causality between energy consumption and real GDP, the following methodology has been adopted. Figure 2 is the plot for Economic growth (GDP), Energy consumption (EPC), Capital formation (CAP) and Trade openness (FDI).

Figure 2. GDP, Energy consumption, Capital formation and FDI



3.3 Methodology

3.3.1 Unit Root / Stationarity Test

Stationarity are well known in the literature and can be test either using Augmented Dicker Fuller (ADF) test or Phillips-Perron test. Dickey and Fuller (1981) proposed the ADF test in order to handle the AR(p) process in the variables. Perron (1989) noted that the unit root problem in the series may cause biased empirical results. Likewise, Kim & Perron (2009) argued that traditional unit root tests provide ambiguous results due to their low explanatory power and poor size distribution, as structural breaks are treated asymmetrically not only in the null hypothesis but also in the alternative hypothesis.

Thus, we have applied the Augmented Dickey-Fuller (ADF, 1979) and Phillips-Perron (PP, 1988) unit root tests which is based on the same equation as the ADF test but without the lagged differences. While the ADF test corrects for higher order serial correlation by adding lagged difference terms, Phillips-Perron test is to makes a non-parametric correction to account for residual serial correlation without restricting the residuals to be white noise. These tests must be performed because the NARDL model of Shin et al. (2014) requires that the variables be integrated at orders 0 or 1 to examine the cointegration between the variables.

After checking for the unit root, we can then employ either the Johansen and Juselius (1990), or the Engle Granger cointegration test if the series of each variable is integrated of the same order. However, Johansen method for testing for cointegration requires the variables to be integrated of the same order. Otherwise the predictive power of the models tested would be affected. We however found that the variables used in our study are not all integrated of the same order and hence, thus suggestion is to employ ARDL or NARDL test. The explanation on NARDL and ARDL will be discuss in the next section.

3.3.2 NARDL Model to Test Cointegration

We choose to use the multivariate nonlinear ARDL (NARDL) bounds testing approach recently developed by Shin et al. (2014) because it can capture the nonlinear and asymmetric cointegration between variables, and thus, able to investigate the asymmetric and nonlinear long-term and short-term influence of energy consumption on economic growth. The NARDL model represents an extension of the linear ARDL of Pesaran et al. (2001) that allows the capture of asymmetries in the long-term and short-term linkages between variables. Furthermore, the NARDL approach represents a powerful instrument to test for cointegration among a set of time series variables in a single equation. Unlike other error correction models where the integration order of the considered time series should be the same, the NARDL model relaxes this restriction and allows for a combination of different integration orders. This flexibility is very important, as shown in Hoang et al. (2016). Finally, this method also helps solve the multicollinearity problem by choosing the appropriate lag order for the variables (Shin et al. 2014).

It is now well documented that financial and economic time series data are cointegrated and follow a common long-term equilibrium trend. However, linear cointegration tests such as the Johansen cointegration test and linear ARDL approach fail to properly detect these cointegrating relationships. The NARDL approach allows for the detection of these omitted cointegration relationships because it enables the testing of hidden cointegration (Granger and

Yoon, 2001). The NARDL model proposed by Shin et al. (2014) represents the asymmetric error correction model as follows:

NARDL Equation:

$$\Delta GDP_t = \beta_0 + \beta_1 GDP_{t-1} + \beta_2 EPC_{t-1}^{+} + \beta_3 EPC_{t-1}^{-} + \beta_2 FDI_{t-1}^{+} + \beta_3 FDI_{t-1}^{-} + \beta_2 CAP_{t-1}^{+} + \beta_3 CAP_{t-1}^{-} + \sum_{i=1}^{p} \varphi_i \Delta GDP_{t-i} + \sum_{i=0}^{q} (\theta_i^{+} \Delta EPC_{t-i}^{+} + \theta_i^{-} \Delta EPC_{t-i}^{-}) + \sum_{i=0}^{q} (\theta_i^{+} \Delta FDI_{t-i}^{+} + \theta_i^{-} \Delta FDI_{t-i}^{-}) + \sum_{i=0}^{q} (\theta_i^{+} \Delta CAP_{t-i}^{+} + \theta_i^{-} \Delta CAP_{t-i}^{-}) + u_t$$

Additionally, previous conventional cointegration tests require that all variables in the system be I(1). The NARDL relaxes the previous condition and permits testing cointegration between I(0), I(1) or a mix of I(0) and I(1) variables.

4.0 Results and Discussions

4.1 Unit root tests

In the level form the ADF and Phillips Perron test are found to be non-stationary except for LFDI via ADF. The estimated ADF values and Phillips Perron are greater than the critical values at the different form and are found to be stationary.

Table 1. Empirical results of a Unit Root Tests (ADF)

Variable	***Augmented Dickey Fuller (Level)***		***Augmented Dickey Fuller (First Difference)***	
	T-Stat	**Result**	**T-Stat**	**Result**
LGDP	-1.2442	Non-stationary	-4.3881***	Stationary
LEPC	1.6880	Non-stationary	-3.0024**	Stationary
LFDI	-2.9111*	Stationary	-0.6663	Stationary
LCAP	-2.3319	Non-stationary	-4.2045***	Stationary

Table 2. Empirical results of a Unit Root Tests (PP)

Variable	*Phillips-Perron (Level)*		*Phillips-Perron (First Difference)*	
	T-Stat	**Result**	**T-Stat**	**Result**
LGDP	-1.5195	Non-stationary	-3.4163**	Stationary
LEPC	-2.3739	Non-stationary	-2.9728**	Stationary
LFDI	-1.9038	Non-stationary	-8.4074***	Stationary
LCAP	-1.7567	Non-stationary	-3.8082***	Stationary

***** Show significance at the 1% level*
*** Show significance at the 5% level*
** Show significance at the 10% level*

4.2 Cointegration results

The NARDL results are shown in Table 3.

Table 3. Cointegration results

Dependent variable: Y_t			
Variable	**Coefficient**	**T-statistic**	**Prob.**
Y_{t-1}	-0.5680***	-3.27	0.005
$LEPC^{+}_{t-1}$	0.2250**	2.67	0.017
$LEPC^{-}_{t-1}$	3.8089***	2.98	0.009
$LFDI^{+}_{t-1}$	-0.0098	-1.03	0.320
$LFDI^{-}_{t-1}$	-0.0221**	-2.17	0.045
$LCAP^{+}_{t-1}$	0.2298**	2.14	0.048
$LCAP^{-}_{t-1}$	-0.1530**	-2.12	0.050
ΔY_{t-1}	0.7629***	3.52	0.003
ΔEPC^{+}	0.5513***	6.42	0.000
ΔEPC^{+}_{t-1}	-0.3212**	-2.40	0.029
ΔEPC^{-}	0.3149	0.36	0.725
ΔEPC^{-}_{t-1}	-3.9594***	-3.21	0.005
ΔFDI^{+}	0.0146	1.38	0.186
ΔFDI^{+}_{t-1}	-0.0052	-0.57	0.578
ΔFDI^{-}	0.0027	0.35	0.735

Δ FDI^{-}_{t-1}	0.0311***			3.07			0.007
Δ CAP^{+}	-0.1326			-1.08			0.298
Δ CAP^{+}_{t-1}	-0.0371			-0.48			0.638
Δ CAP^{-}	0.1471**			2.36			0.031
Δ CAP^{-}_{t-1}	0.0634			0.71			0.490
Asymmetry statistics:	Long-run effect [+]			Long-run effect [-]			
Exog. var.	coef.	F-stat	P>F	coef.	F-stat	P>F	
LEPC	0.396***	79.57	0.000	-6.706**	5.785	0.029	
LFDI	-0.017	1.453	0.246	0.039**	6.253	0.024	
LCAP	0.405***	19.42	0.000	0.270	2.533	0.131	
	Long-run asymmetry			Short-run asymmetry			
Wald Test	F-stat	P>F		F-stat	P>F		
LEPC	5.025**	0.040		4.565**	0.048		
LFDI	2.42	0.139		1.272	0.276		
LCAP	24.64***	0.000		3.474**	0.081		
	stat.	p-value					
Breusch/Pagan	.08477	0.7709		Cointegration test statistics			
Ramsey RESET test	.8996	0.4677		t_BDM	-3.2709		
Jarque-Bera test	5.512	0.0635		F_PSS	4.1150**		

Note: Long-run effect [-] refers to a permanent change in exog. var. by -1
The superscripts "+" and "−" denote positive and negative variations, respectively.
**** Show significance at the 1% level*
*** Show significance at the 5% level*
** Show significance at the 10% level*

F_PSS = 4.1150, which is larger than the upper bound critical value at 5% (i.e. 4.01). Accordingly, there is evidence for cointegration. Figure 3 is the Critical values from Pesaran et al. (2001).

Figure 3. Critical values from Pesaran et al. (2001):

Table CI(iii) Case III: Unrestricted intercept and no trend

	0.100		0.050		0.025		0.010		Mean		Variance	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	6.58	6.58	8.21	8.21	9.80	9.80	11.79	11.79	3.05	3.05	7.07	7.07
1	4.04	4.78	4.94	5.73	5.77	6.68	6.84	7.84	2.03	2.52	2.28	2.89
2	3.17	4.14	3.79	4.85	4.41	5.52	5.15	6.36	1.69	2.35	1.23	1.77
3	2.72	3.77	3.23	4.35	3.69	4.89	4.29	5.61	1.51	2.26	0.82	1.27
4	2.45	3.52	2.86	4.01	3.25	4.49	3.74	5.06	1.41	2.21	0.60	0.98
5	2.26	3.35	2.62	3.79	2.96	4.18	3.41	4.68	1.34	2.17	0.48	0.79
6	2.12	3.23	2.45	3.61	2.75	3.99	3.15	4.43	1.29	2.14	0.39	0.66
7	2.03	3.13	2.32	3.50	2.60	3.84	2.96	4.26	1.26	2.13	0.33	0.58
8	1.95	3.06	2.22	3.39	2.48	3.70	2.79	4.10	1.23	2.12	0.29	0.51
9	1.88	2.99	2.14	3.30	2.37	3.60	2.65	3.97	1.21	2.10	0.25	0.45
10	1.83	2.94	2.06	3.24	2.28	3.50	2.54	3.86	1.19	2.09	0.23	0.41

We also note the absence of heteroscedasticity via Breusch/Pagan test, in which we fail to reject the null hypothesis. Normality test via Jarque-Bera are found to be not significant at 5% level of significant. The functional form of the empirical model is well-designed and confirmed by the Ramsay Reset test. This finding indicates the reliability and consistency of the empirical results. More importantly, we find that the F-statistic exceeds the upper critical bound at the 5% level of significance, which confirms the presence of cointegration among economic growth, energy consumption, capital formation and trade openness for the period of 1976-2014. The Wald tests show the significance of asymmetry for both the long run and short run for economic growth, energy consumption and capital formation, which implies that taking nonlinearity and asymmetry into account is important when studying the relationship between economic growth and energy consumption. In addition, NARDL F-statistic from Shin et al. (2014) confirms the existence of asymmetric cointegration among the variables, which indicates that economic growth, energy consumption, capital formation and trade openness have long-run asymmetric association in the Thai economy.

<u>In the long term</u>

A positive shock in energy consumption (EPC) has a positive and significant effect on economic growth, which indicates that any positive shock to energy consumption will enhance economic growth in Thai. This indicate that any positive shock to energy consumption plays an enabling role in stimulating growth and development in the Thai economy. Thailand is a rapidly growing country with a large middle class, have undergo a structural transition via changing the nature and shape of energy demand in the upcoming years. This resulted Thailand's economy grew at 2.8%, merits to government stimulus policies that enhance the consumption and investment within the country. By contrast, a negative shock in energy consumption is positively linked with economic growth. This finding implies that any negative shock to energy consumption also plays a stimulating role in Thai's long-term economic growth. This could be due to transition of energy consumption from traditional consumption to renewable energy consumption which lead to the growing of Thai economy,

On the other hand, positive shock in trade openness (FDI) found to have negative impact towards economic growth. However, the result is found to be not significant. Meanwhile, negative shock in trade openness has negative and significant effect on economic growth, which indicates that any negative shock to trade openness will hamper the economic growth in Thai. This indicate that negative shock in FDI; investment made by a company or individual in one country in business interests in another country, will hinder the Thai economy. Thus, Thai policy maker need to ensure their policy could significantly attract foreign investor.

In the long term, positive shocks in capital formation (CAP) always have positive effects on economic growth. Positive shock to capital formation will result in greater long-term fiscal investments in infrastructure development and therefore increases economic growth in the long term. Thus, policy maker should always observe productive capital investments when designing sustainable policy that able to achieve long-term economic growth and development. By contrast, negative shocks in capital formation have a negative effect on economic growth. This could be explained via distinctive developmental feature of the Thai economy in which increasingly involved in manufacturer industry. Thus, any negative shock in capital formation, will hamper down the manufacturing industry in Thai and subsequently give negative impact to economic growth.

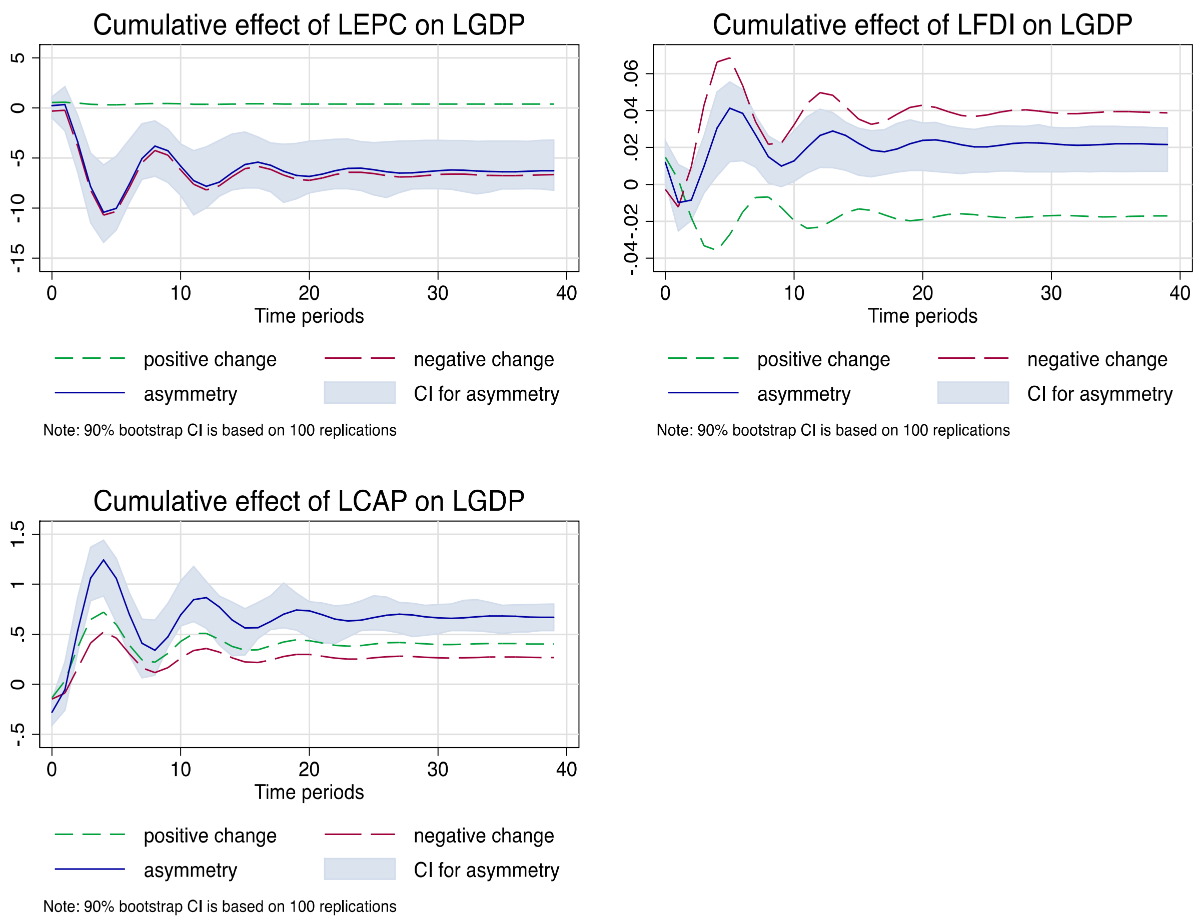
<u>In the short term</u>

Positive shock for energy consumption (EPC) is positively and significantly linked to economic growth in the short term. However, a positive shock and negative shock (at lag 1) has an inverse relationship with economic growth. This finding is possible in respecting any energy conservation act proposed by any government. If producers make any attempt to increase energy usage in production activities, economic growth will be enhanced for short term in Thai and vice versa.

For trade openness (FDI), negative shock (at lag 1) are found to be positively and significantly linked to economic growth in the short term. This in line with research by Xu (2000) that showed that in the case of some countries FDI has a negative impact on GDP growth.

For capital formation (CAP), negative shocks are found to have a positive impact on economic growth in the short term. This finding highlights the important role of capital use in short-term economic growth, as any negative shock to capital formation will have an adverse effect on economic growth in the following period. These findings further imply that, if the Thai government gives greater investment priority to infrastructure development in the previous period, the economic output in the present period will be greatly affected. The graphs in Figure 4 show the effect of shock on the variables.

Figure 4. Dynamic multiple adjustments of Economic Growth to a unitary variation of Energy Consumption, Capital formation and Trade Openness



4.3 Granger Causality Results based on VECM

In addition, this paper will test the granger causality test based on Error Correction Model. The ECM confirms the long-run relationship and helps to identify which variable is exogenous (strong) and which is endogenous (weak), whereby the coefficient of ecm(-1) is taken as the speed of adjustment or basically tell us how long it will take to get back to long term equilibrium if that variable is shocked. If the value is zero, then there exists no long-run relationship. If the speed of adjustment value is between -1 and 0, then there exists partial adjustment. A value which is smaller than -1 indicates that the model over adjusts in the current period.

The results of ECM are shown in Tables 4 and the causal channels are as per table 5. From the T-stat of error correction in table 4. We found that only CAP is significant and thus is endogenous. Meanwhile GDP, EPC and FDI are found to be exogenous (not statistically significant in ECM model).

Table 4. Error Correction Model

	Coefficient	Standard error	T-Stat	Significant	Result
ΔGDP	-0.0080	0.0801	1.0000	Not significant	Exogenous
ΔEPC	-0.1328	0.0780	-1.7027	Not significant	Exogenous
ΔFDI	0.1814	1.3485	0.1346	Not significant	Exogenous
ΔCAP	0.3893	0.1754	2.2192	Significant	Endogenous

This means when we shock capital formation which are shown to be the leader variables, the followers like GDP, FDI and EPC will be affected. Thus, it is imperative for policymakers to take better care of the said variables that will have a profound effect on the country's economy as a whole. Although the ECM model tends to show the absolute endogeneity and exogeniety of a variable, they do not give us the relative degree of endogeneity or exogeneity. For that, we need to proceed to the variance decomposition technique (VDC) to recognize the relativity of these variables.

Table 5. Granger Causality Results based on VECM

	Independent Variables			
Dependent Variable	χ^2 **-statistics of lagged 1st differenced term [p-value]**			
	ΔGDP	**ΔEPC**	**ΔFDI**	**ΔCAP**
ΔGDP	--	0.6095 [0.7373]	0.6459 [0.7240]	0.4549 [0.7965]
ΔEPC	5.0202* [0.0813]	--	3.9909 [0.1360]	0.5250 [0.7691]
ΔFDI	0.5629 [0.7547]	0.5623 [0.7549]	--	0.3149 [0.8543]
ΔCAP	4.0737 [0.1304]	0.3819 [0.8262]	0.9892 [0.6098]	--

***Note**: * denotes significant at 10% significance level.. The figure in the parenthesis (…) denote as t-statistic and the figure in the squared brackets […] represent as p-value.*

4.4 Variance Decompositions (VDCs)

ECM model in previous section only able to give us information about the absolute endogeneity or exogeneity, however, only VDCs could provide the relative of endogeneity or exogeneity. The VDCs decomposes the variance of the forecast error of each variable into proportions attributable to shocks from each variable including its own. In other word, VDCs finds out to what extent shocks to specified variables are explained by other variables in the system. If a variable explains most of its own shock, then it does not permit variances of other variables to assist to its explanation and is therefore said to relatively exogenous.

There are two types of VDCs namely orthogonalized VDCs and Generalized VDCs. Generalized VDCs are more informative due to absence of orthogonalized VDCs. Firstly, orthogonalized VDCs depends on the particular ordering of the variables in the VAR, whereas generalized VDCs are invariant to the ordering of the variables. Secondly, the orthogonalized VDCs assumes that when a particular variable is shocked, all other variables in the model are switched off, but the generalized VDCs do not make such a restriction. The results from the VDCs as per display in the table 6 below. The variable that is ranked higher is the leading variable, and therefore should be set as the intermediate target by policymakers.

Table 6. Variance Decomposition (VDCs)

Variance Decomposition of LGDP

Period	LDGP	LEPC	LFDI	LCAP
1	**100.000**	0.0000	0.0000	0.0000
2	98.5066	0.8401	0.5931	0.0601
3	98.4183	0.8527	0.6772	0.0515
4	98.5376	0.7689	0.6588	0.0345
5	98.5860	0.6998	0.6881	0.0259

Variance Decomposition of LEPC

Period	LDGP	LEPC	LFDI	LCAP
1	73.9825	**26.0174**	0.0000	0.0000
2	87.5518	11.1616	1.2211	0.0652
3	91.5818	7.3068	0.8952	0.2161
4	93.3935	5.7549	0.5225	0.3289
5	94.3302	4.9078	0.3494	0.4125

Variance Decomposition of LFDI

Period	LDGP	LEPC	LFDI	LCAP
1	11.8212	4.0791	**84.0995**	0.0000
2	8.6776	3.0231	88.0688	0.2302
3	11.0190	3.9923	84.7932	0.1952
4	16.8567	3.2717	79.5505	0.3209
5	17.6746	2.8822	79.1549	0.2881

Variance Decomposition of LCAP

Period	LDGP	LEPC	LFDI	LCAP
1	77.9010	0.2663	0.3737	**21.4587**
2	89.9888	0.0815	1.7635	8.1660
3	92.2522	1.2033	2.3786	4.1658
4	91.2006	2.0717	3.5708	3.1566
5	90.2740	2.0001	4.8327	2.8930

From the table, it can be seen that in the 5 years horizon, GDP is the most exogenous while Capital formation is shown to be the most endogenous. This means that policymakers can set GDP as the intermediate target to subsequently influence the trade openness (FDI), energy power consumption (EPC) and then capital formation (CAP). Furthermore, we observe that the trade openness (FDI) has an effect on energy power consumption (EPC) given that it has higher ranked. These findings are seeming to be align with VDCs findings in which we found one endogenous variable, capital formation, have the lowest ranking.

4.5 Impulse Response Functions (IRFs)

After test the VDCs test, the next test will be on the impulse response function. The impulse response function (IRF) displays the impact of a shock of one variable on others and validate the degree of response and how long it would take to normalize. IRFs gives us the same information as VDC but in graphical form, while VDCs in numbering form as per table 6 above. Figure 5, 6 and 7 are the graph for IRFs for the period of 10, 20 and 30 years. When there is a shock to endogeneity variable, the exogenous variables are highly affected it takes shorter period to normalize. Based on these 3 graphs, when the capital is shock, we can see the fast response from the other three exogenous variables. However, the rest of the variables shock takes longer response, with normalize can be only seen when impulse for 20 to 30 years.

Figure 5. Impulse Response Functions (IRFs) results – 10 years

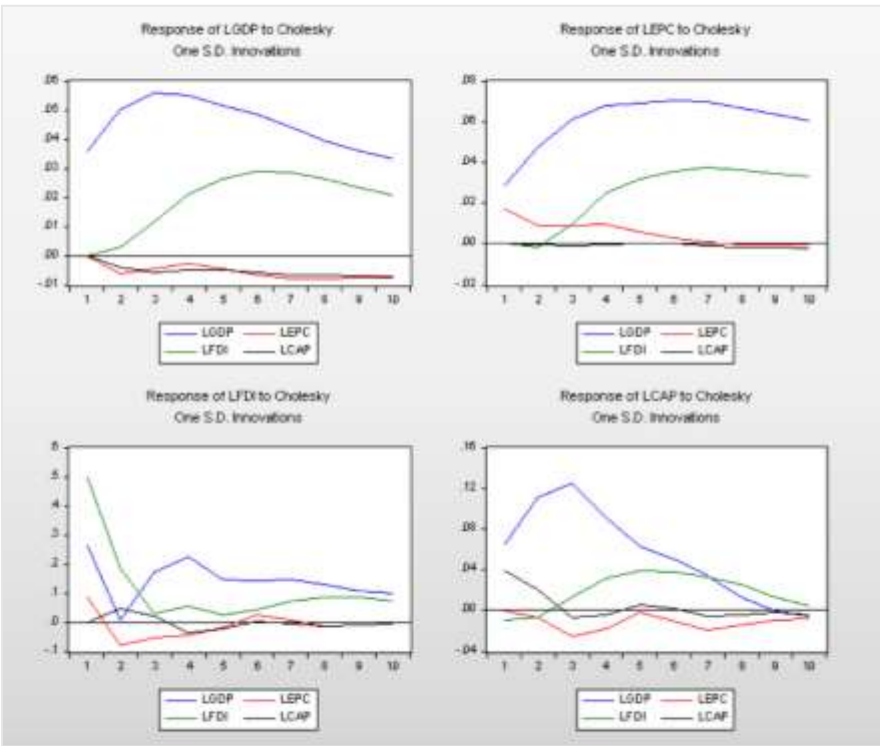


Figure 6. Impulse Response Functions (IRFs) results – 20 years

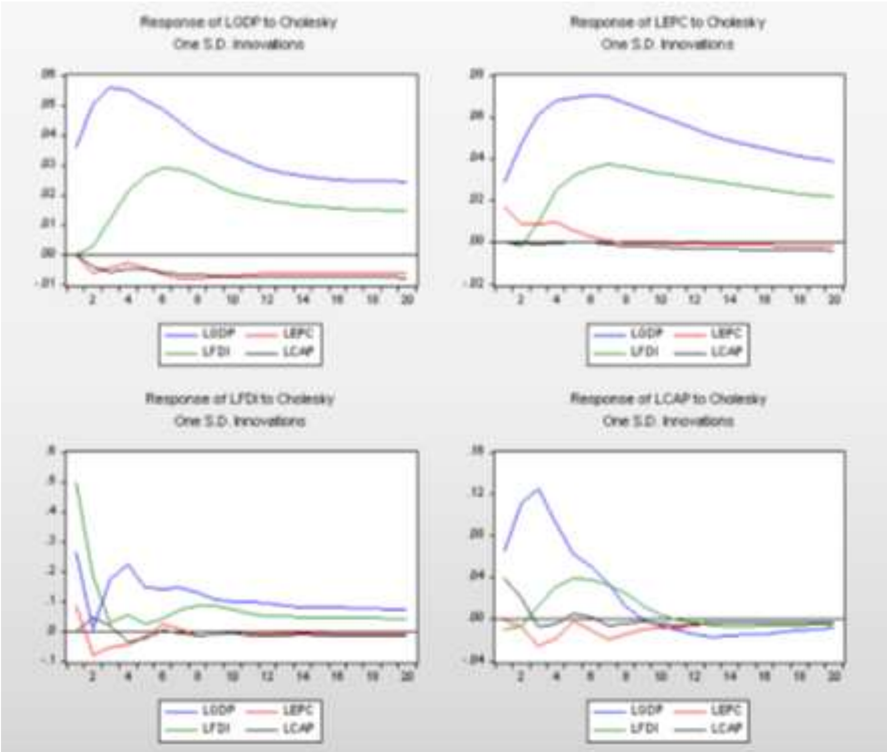
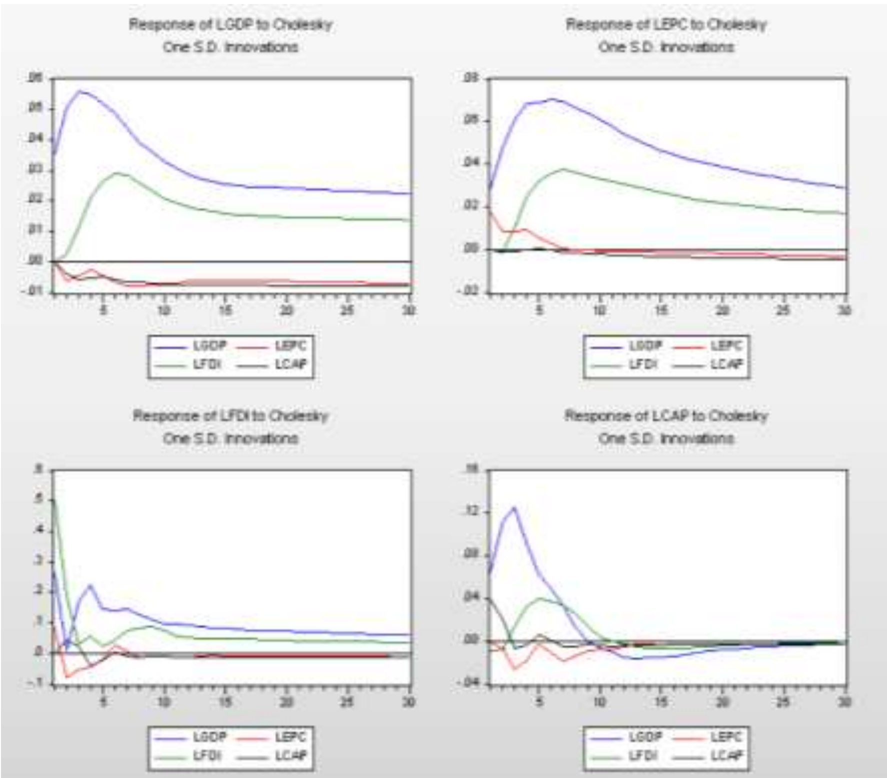


Figure 7. Impulse Response Functions (IRFs) results – 30 years



5. Conclusions and policy implications

This paper investigated the relationship between economic growth and energy consumption using annual time series data covering the period of 1976 – 2014 of Thailand. For this paper, we employed the nonlinear ARDL cointegration approach developed by Shin et al. (2014) and test the causal relationship between the variables by employing VECM, VDCs and IRF techniques. The empirical results provide strong support for the presence of an asymmetric cointegration association between the variables under study. The causality results also show the importance of considering asymmetry, as we will demonstrate below.

If we only relied on symmetric analysis, we would be unable to conclude that negative and positive shocks in energy consumption have impacts on economic growth. This finding is important because it suggests that reduction and increase of energy consumption in Thailand will improve the economic growth in Thailand, but with different reaction. Our findings indicate reduction of the usage of energy consumption will have huge impact compared to increase in energy power consumption. In this case, the Thai government should reduce energy power consumption if the country wants to enhance their economic growth. To do so, the government can make efforts to encourage the use of more energy-saving technologies in various sectors' production and consumption activities and encourage more the usage of renewable energy.

As for the interaction between trade openness and economic growth, the results show that taking asymmetry into account is important. Indeed, a positive shock in trade openness does not affect economic growth, but a negative shock in trade openness hampers domestic economic output.

As regards capital formation, we find that positive shocks in capital formation always have positive effects on economic growth, which implies that capital is vital for achieving long-run economic growth. Positive shock to capital formation will result in greater long-term fiscal investments in infrastructure development and therefore increases economic growth in the long term. For sustainable economic growth, we suggest that fiscal policies in Thai invest more money in establishing better infrastructure development. If collaboration and better understanding between fiscal policies and policymakers in Thai succeed, then the Thai economy is more likely to grow and prosper.

Finally, our causality findings indicate that policymakers should impact GDP to influence trade openness and energy consumption. This could be done with the help of the growth in manufacturing industry in Thai which led to increase of GDP 2.8% in year 2015. Since Electricity consumption is the third exogenous variable in our study, thus, the government and policy makers should also advocate and promote restructuring of the electricity supply industry. This may lead to more supply of electricity as more players will be allowed entry into this industry. Therefore, the policymakers should select electricity policies which will support economic growth in Thai.

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