# The Energy-Growth Nexus in Thailand: Does Trade Openness Boost up Energy Consumption?

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**Abstract:** The nexus between trade openness and energy demand is hot topic of discussion among academicians and researchers, and numerous studies are available in existing literature while investigating the nexus between trade openness and energy demand. This paper explores the relationship between energy consumption, trade openness and economic growth in case of Thailand. In doing so, we have applied Bayer and Hanck cointegration approach to test whether the long run relationship exists between the variables. Our results confirm the presence of cointegration between the variables. Energy consumption stimulates economic growth. Trade openness adds in economic growth. The causality analysis reveals that energy consumption Granger causes economic growth and in resulting, economic growth Granger causes energy consumption. Trade openness and energy consumption are interdependent i.e. trade openness Granger causes energy consumption and in return, energy consumption Granger causes trade openness. This paper openness up new directions for policy making authorities in Thailand to design a comprehensive energy and trade policies to sustain economic growth for long run.



**Keywords: Energy, Trade, Growth, Thailand**

## 1. Introduction

The causal relationship between energy consumption and economic growth has been gained attention from researchers and policy makers for more than three decades. In order to attempt to identify the direction of causality between these two variables, many authors used various methods using different time periods for different countries. However, the empirical results on causality relationship between two variables are not conclusive[1]. The direction of causality between energy consumption and economic growth could summarize into four hypotheses (Ozturk and Acaravci, [1]): (1) The *neutrality hypothesis*: This hypothesis shows that there is an absence of causal relationship between these two variables. (2) The *conservation hypothesis*: This hypothesis shows the unidirectional causality running from economic growth to energy consumption. Energy conservation policies have no effect on economic growth in this case. (3) The *growth hypothesis*: This hypothesis implies that the unidirectional causality running from energy consumption to economic growth. It shows that energy consumption plays an important role in boosting economic growth. Any policy related with reduction in energy consumption may have negative impact on economic growth. (4) The *feedback hypothesis*: This hypothesis shows the bidirectional causality between two variables. The reduction in energy supply will affect economic growth negatively which in resulting lower energy demand. Therefore, the direction of causality between energy consumption and economic growth is important for policy makers in order to implement energy policy for sustainable economic growth in the country (Ozturk, [2]).

The energy sector is overseen by the Ministry of Energy. However, there are several government agencies are responsible for energy. Concerning about energy industry structure, there are three

[1] According to the survey, 31.15% supports the neutrality hypothesis, 27.87% supports the conservation hypothesis, 22.95% supports the growth hypothesis and 18.03% supports the feedback hypothesis (Ozturk, [2]; Payne, [3]2010).

major state enterprises in the oil and gas sector: Petroleum Authority of Thailand (PTT), PTT Exploration and Production Co. Ltd (PTTEP), and Bangchak Petroleum Public Co. Ltd. Electricity is generated by the Electricity Generating Authority of Thailand (EGAT) and Independent Power Producer (IPP), Small Power Producers (SPP). EGAT also own the whole transmission system but electricity distribution and retailing is conducted by the Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) (Sahid et al. [4]). Concerning about energy problem, Thai government has formatted two important plans. First is the 20 year National Energy Conservation Plan (NCEP) of 2011-2030. Second is 15 year Alternative Energy Development Plan (AEDP) of 2008-2022 (Ministry of Energy, [88, 89]). The main aim of NCEP is efficiency improvement of energy. NECP has target to save electricity consumption of 86,150 GWh in three economic sectors: industrial, commercial and residential sector. In addition, the main purpose of AEDP is to promote renewable energy utilization. In AEDP have target to improve the total installed capacity of renewable energy to 5608 MW which could produce 26,500 GWh of power negation by the year 2022 (Promjiraprawat and Limmeechokchai, [5]).

Energy demand in Thailand is projected to economic growth fast with account to about 5 % per year, according to the Institute of Energy Economic Japan (IEE, [6]). It reflects the population growth, economic growth and urbanization[2]. In order to meet high demand for energy, it is extremely challenging for Thailand. Thailand is export-led growth economy (Warr, [8]). Thai economy was hit by Asian financial crisis in 1997 and faced political instability in 2006, and was suffered from Global Financial Crisis in 2008. As a result exports dropped substantially which

[2] During 1993 to 2009 (15 year), electricity consumption increased from 56,279 to 135, 420 GWh and peak demand from 9730 to 23,051 MW. Electricity consumption is categorized by economic sectors: residential (22.5%), commercial (24.2%), industrial (44.1%), agricultural (0.2%), direct customer (2.1%) and other (6.9%) (Sawangphol and Pharino, [7])

lead to economic depression. In order to restore the economy, Thai government implemented various emergency rescue packages including revision in its 10th National Economic and Social Development Plan (2007-2011) (Arouri et al. [9]). Thailand primary energy consumption was fossil fuels including coal, oil and gas which account for about 80% in 2011. Manufacturing sector was the highest final energy consumption sector in Thailand which account for 36%, second highest sectors was transportation (35%), the third was residential (15%) in 2010. The main energy problem of Thailand was limitation of fossil fuel resources. Natural gas which is the main of energy sources will run dry in 20 years. Increase electricity from power generation is facing difficulties due to public opposition. Secondly, the role of hydropower is limited. Despite having high potentials of development of hydropower but it is not impossible to use them. Therefore, Thailand imports hydro electricity from neighboring countries. Thirdly, energy is not used very efficiently (Hasanbeigi et al. [10]). The energy intensity is still high compared to industrialized and neighboring countries. Fourthly, the institutional environment, specifically the electricity generation, transmission, and distribution sector are also the main issues in Thailand. In addition, increasing risk premium in electricity sector due to policy instability and frequent policy changes (Jarvis, [11]).

Thai economy has been grown for the past fifty years[3]. This growth is remarkable, the annual growth rate of real GDP was more than six percent from 1962 to 2009 (Tharnpanich and McCombie, [12]). Warr, [8]) assessed the Thai economy into four categories: (1) pre-boom, 1962-86; (2) boom, 1987-96; (3) crisis, 1997-98; and (4) post-crisis, 1999-2009. During pre-boom period, the annual growth rate of real GDP was about 7 percent. During the boom period, Thai economy growth was very impressive. The annual growth rate of real GDP was about 9 percent. During this period, Thai economy was among the fastest growing countries in the world (Tharnpanich and McCombie, [12]). Remarkable economic growth period was end due to the

[3] The main reason for remarkable growth performance was export-led growth (Warr, [8])

Asian Financial Crisis in 1997. Asian Financial Crisis has serve impacts on Thai economy in history. The economic growth during crisis period was negative i.e. 6 percent. GDP per capita also experienced negative impacts, it was declined to minus 7 percent during two years (1997-1998). Thailand has been recovered from Asian Financial Crisis gradually. The annual economic growth was about 4 percent during post-crisis. The main reason for recovering is the resilient export sector. Trade has been the main driving force of Thai economy. Export has been the main engine of growth of Thailand. During the pre-crisis period (1962-1996), export grew at 11 percent per year. However, export growth has been slow down since post Asian Financial Crisis (1999-2009), it fell to 5 percent per year during this period. Even though Thailand had high export growth during post-crisis, import has exceeded export which caused current account deficits. The current account deficit accounts for 5 percent of GDP. However, it was financed by capital inflows especially from foreign direct investment (Tharnpanich and McCombie, [12]). However, exports seem to play more important role than capital inflows. The share of exports was 84 percent which compare to 10 percent of capital inflows over the period 1975-2009. Therefore, it is clear that exports were predominant foreign exchange earner and the sources of grown in Thailand. Despite strong fundamental economy, but political unrests and natural disasters as such serve flooding are main course of economic down-turn in Thailand because investor and consumer do not confidence in political situation (Kuo et al. [13]).

Despite large studies on the relationship between energy consumption and economic growth in developed and developing countries, there is only one study investigated the direction of causality between energy consumption and economic growth in Thailand. Yoo [14] used EGC and Hsiao's of Granger causality to investigate the relationship between two variables in

Thailand. It support "*conservation hypothesis*" which implies the unidirectional causality running from economic growth to electricity consumption. The main objective of this study is to examine the direction of causality between energy consumption and economic growth over the period of 1971-2012. This paper contributed to literature in three ways. First is study focus on study of Thailand, which her economy is export-led growth and electricity demand is high. Second, newly developed Bayer and Hanck cointegration analysis was used. Third is Granger causality from the VECM framework and impulse respond function are used to investigate direction of causality. We found that the variables are cointegrated for long run relationship. Energy consumption and trade openness add in economic growth. The causality results indicated that relationship between energy consumption and economic growth is bidirectional. The feedback effect is found between trade openness and energy consumption.

## 2. Material and Methods

### 2.1 Literature Review

#### 2.1.1 Economic Growth and Energy Consumption

Numerous studies found the relationship between energy consumption and economic growth but with inconclusive findings (Omri, [15]). For example, Farhani and Rejeb [16] used the panel data of 95 countries and concluded that the unidirectional Granger causality is found in long run running from economic growth to energy consumption for low and high income countries while the bidirectional Granger causality exists between both variables for lower-middle and upper-middle income countries. Akkemik and Göksal [17] also reported the feedback effect between energy consumption and economic growth. Similarly, Apergis and Payne [18] found long-run and short-run causality between energy consumption and economic growth in case of South

America (energy consumption), twenty-five OECD countries (coal consumption), sixty-seven countries (natural gas consumption), sixteen countries (nuclear energy consumption), and eleven countries of the Commonwealth of Independent States. Jinke et al. [19] investigated the relationship between energy consumption and economic growth and found the unidirectional causality running from coal consumption and economic growth in case of Japan and China. They reported the neutral effect between both variables for India, USA, South Africa and South Korea.

Apergis and Payne, [20] applied panel error correction model to explore the relationship between energy consumption (renewable and non-renewable energy consumption) and economic growth in case of 80 countries using multivariate framework by incorporating capital and labor in Cob-Douglas production function. They applied Pedroni, [21] panel cointegration and found the long run relationship between the variables. Their findings showed that renewable and non-renewable energy consumption boost economic growth and, capital and labor are also important to enhance economic growth. The panel causality results indicated that renewable (non-renewable) energy consumption and economic growth are Granger caused each other in long run and short run. This suggests that renewable and non-renewable energy may be used as substitutes for each other. Tugcu et al. [22] also revisited the relationship between renewable (non-renewable) energy consumption and economic growth applying neoclassical augmented production function in case of G7 countries namely Canada, France, Italy, USA, Germany, England and Japan. They augmented the production function by incorporating human capital and research & development expenditures. Their results showed cointegration between the variables. They noted that energy consumption (renewable and non-renewable) does matter for economic growth. The impact of human capital research & development on economic growth is positive and significant. The results of asymmetric causality developed by Hetemi, [23] revealed the bidirectional causal relationship between renewable energy consumption and economic growth and same inference is drawn for non-renewable energy consumption and economic growth. Kahsai et al. [24] considered the relationship between energy consumption and economic growth by applying panel cointegration and causality approaches in case of Sub-Saharan African countries. They used consume prices index as measure of energy prices. Their results found panel cointegration between the variables. They found that energy consumption has positive impact on economic growth and consumer prices decline it. The panel causality results found feedback effect between energy consumption and economic growth in long run while in short run, energy consumption Granger causes economic growth. Ouedraogo [25] estimated energy and electricity demand functions in case of West African states. The cointegration was confirmed by Johansen-Juselius, [26] between the variables. The panel error correction based causality analysis found that energy consumption Granger causes economic growth in long run but in short run, economic growth Granger causes energy consumption. Similarly, the unidirectional causality is running from electricity consumption to economic growth in long run but neutral effect exists between both variables. Hossein et al. [27] used data of oil exporting countries namely Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela to examine causality between energy consumption and economic growth by using multivariate model by incorporating energy prices. In long run, energy consumption Granger causes economic growth in all countries but the unidirectional causality is found from energy consumption and energy prices to economic growth in Iran, Iraq, Qatar, United Arab Emirates and Saudi Arabia. Coers and Sanders [28] exposed that economic growth Granger causes energy consumption and energy consumption does not affect economic growth i.e. no use of energy efficiency. Chontanawat et al. [29] reported that there is more causality between energy consumption and economic growth in OECD developed countries rather than non-OECD countries using 100 countries data.

In single countries, Glasure and Lee [30] examined the direction of causality between both variables using bivariate model for Singapore and Korean economies. They found the feedback effect between energy consumption and economic growth for both countries. Stern [31] notices the importance of capital and labor in production function while investigating the relationship between energy consumption and economic growth. The empirical results of multivariate function show the presence of neutral effect between both the variables. Aqeel and Butt [32] investigated the relationship between energy consumption and economic growth in case of Pakistan. They reported that economic growth leads energy consumption. Hondroyiannis et al. [33] applied energy demand function by employing the vector error-correction model for empirical analysis. Their empirical analysis indicated that economic growth is Granger cause of energy consumption and prices. Glasure, [34] reinvestigated the relationship between energy consumption and economic growth using Korean data and noted that real money supply, government expenditures and energy consumption have positive impact on economic growth.

Sari et al. [35] incorporated employment as potential determinant of economic growth and energy consumption to avoid the variable omission problem. They reported that industrial production increases energy demand but employment declines it. Belloumi [36] applied the Johansen cointegration technique to examined the relationship between total energy consumption and gross domestic production. The results show that the feedback effect is found between both variables in Tunisia. Yuan et al. [37] applied Granger causality test to examine the relation between variables and reported that economic growth increases energy consumption. Tsani, [38] investigated the relationship energy consumption and economic growth using the data of Greek economy. The empirical evidence indicates that real GDP is cause of energy consumption. Wang et al. [39] used multivariate model by including capital and labor in production function to avoid the problem of misspecification. They reported that energy consumption, capital and labor stimulate domestic production and hence economic growth. Dagher and Yacoubian, [40] applied bivariate model to test energy-growth hypothesis in case Lebanon. They reported that energy plays an important role in promoting economic growth as the feedback effect is found between the series. In Algerian economy, Eddrief-Cherfi and Kourbali, [41] explored the relationship between total energy consumption and economic growth and found that energy consumption is cause of economic growth.

Stern and Enflo, [42] used Swedish time series data over the period of 1850-2000 to probe the relationship between economic growth and energy consumption by using production and energy demand functions. They found mixed results on direction of causality of both variables. Saatci and Dumrul, [43] reinvestigated the relationship between energy consumption and economic growth by applying Kejriwal cointegration test for long run. Their results indicated the long run relationship between both the series and energy consumption has positive impact on economic growth. In case of Greece, Dergiades et al. [44] applied the parametric and non-parametric causality test to reexamine the direction of causal relationship between energy consumption and economic growth. They noted that economic growth is cause of energy consumption. Baranzini et al. [45] probed the relationship between energy consumption and economic growth by applying bounds testing approach for long run. Their empirical exercise showed inverted-U shaped relationship between both the variables. This indicates that economic growth increases energy consumption initially and energy demand is declined after the threshold level of income per capita. Kocaaslan [46] applied the Markov switching Granger causality test to examine the direction of causal relationship between energy consumption and economic growth in case of US economy. The results indicated that output growth is cause of energy consumption growth. For Turkish economy, Ocal and Aslan [47] investigated the linkage between renewable energy consumption and economic growth and found that renewable energy consumption is Granger cause of economic growth. In case of BRICS countries, Maamar and Ousama [48] showed that renewable energy consumption and economic growth interdependent and renewable energy consumption plays key role in stimulating economic activity[4]. Menegaki [50] applied meta-analysis to examine the relationship between energy consumption and economic growth and he found that 1% increase in economic growth leads energy consumption by 0.85%.

### 2.1.2 Trade Openness and Energy Consumption

The existing energy economics literature also provides studies investigating the relationship between trade openness and energy consumption with ambiguous results. For example, Shahbaz et al. [51] collected data of high, middle and low income countries to examine the relationship between trade openness and energy consumption. They have employed Homogenous non-causality, Homogenous causality and Heterogeneous causality approaches and reported the inverted U-shaped relationship between trade openness and energy consumption in high income countries. The relationship between trade openness and energy consumption is U-shaped in

[4] Hassaballa [49] reported that foreign direct investment leads energy demand.

middle and low income countries. Their findings reveal that energy consumption is Granger cause of trade openness[5]. Nasreen and Anwer [52] investigated the relationship between trade openness and energy consumption by incorporating oil prices and economic growth in energy demand function using data of Asian countries. In case of Thailand, they found that trade openness increases energy consumption but statistically insignificant. Oil prices reduce energy demand in Thailand. Their panel causality analysis reveals that the feedback effect is found between trade openness and energy consumption. Sbia et al. [53] examined the relationship between clean energy, foreign direct investment, trade openness, carbon emissions, and economic growth in case of UAE. They applied the ARDL bounds testing for long run and the VECM Granger causality to test the causality between the variables. They noted that foreign direct investment and trade openness are negatively linked to energy consumption and the bidirectional causality exists between trade openness and energy consumption. Farhani et al. [54] examined the relationship between natural gas consumption and economic growth by incorporating trade openness as potential determinant of gas consumption and economic growth in case of Tunisia. They found the existence of cointegration between the variables and trade openness Granger causes natural gas consumption. Shahbaz et al. [55] used Chinese time series data to investigate the relationship between economic growth, financial development, trade openness and energy consumption. They noted that trade openness (measured by trade, exports and imports) Granger causes energy demand. Shahbaz et al. [56] used production function for Pakistan to examine the relationship between economic growth, natural gas consumption and exports. Their analysis indicated that natural gas consumption causes economic growth and

[5] Shahbaz et al. [51] reported the neutral effect between trade openness and energy consumption in the case of Bangladesh.

exports. Nnaji et al. [57] investigated the impact of domestic energy consumption on exports using Nigerian data over the period of 1970-2009. They found the long run relationship between both variables and causality analysis indicated that exports are Granger cause of domestic energy consumption. Katircioglu, [58] investigated the interaction between imports and energy consumption using the data of the Singapore economy. The empirical evidence showed the presence of cointegration between both variables and economic growth Granger causes imports.

Ghani [59] used data of developing countries to check the impact of trade liberalization on energy demand and noted that trade liberalization has not impacted on energy consumption in case of developing countries. Sadorsky [60] used data of South American countries for the period of 1980-2007, to examine the relationship between trade and energy consumption. The empirical exercise indicated that economic growth, capital, labor and trade openness are cointegrated for long run relationship. In the short run, energy consumption Granger causes exports and in resulting, exports lead energy consumption. The neutral effect is found between imports and energy consumption. In the case of Turkey, Erkan et al. [61] exposed that shocks in energy consumption have positive response on shocks stemming in exports and there is unidirectional causality running from energy consumption to exports. Halicioglu [62] revisited the relationship between income, exports and energy using time series data over the period of 1968-2008. The empirical results indicated the neutral effect between exports and energy consumption but in the short run, the feedback effect exists between the both variables. Sadorsky [63] investigated the impact of trade (exports and imports) and oil prices on energy consumption in Middle Eastern countries. The empirical analysis shows the presence of cointegration between the variables and exports and imports add in energy consumption while oil prices decline it. The causality analysis that in short run, the relationship between imports and energy consumption but exports Granger cause energy consumption. Using Japanese data over the period of 1960-2007, Sami [64] applied trivariate model to examine the relationship between economic growth, exports and electricity consumption. The empirical analysis indicates the unidirectional directional causality running from exports and economic growth to electricity demand. Sami and Makun [65] examined the linked between exports and electricity consumption using data for the period of 1971-2007 in case of Brazil. They found that electricity consumption and exports have positive and significant impact on economic growth. Sultan [66] incorporated exports to examine the relationship between economic growth and energy consumption in using Mauritius economy. The results showed the cointegration between the series while economic growth is Granger causes of electricity consumption and exports.

Using Malaysian data, Lean and Smyth [67] reported that exports are Granger cause of electricity generation but the neutral relationship between electricity consumption and exports is reported by Lean and Smyth [68]. Narayan and Smyth [69] used data of Middle Eastern countries to examine the relationship between exports, energy consumption and economic growth. They found that neither energy consumption Granger causes exports nor exports Granger cause energy consumption.

Overall existing literature shows no study investigating the relationship trade and energy using data of Thai economy except Arouri et al. [9]. Arouri et al. [9] investigated the relationship between trade openness and energy consumption using data of high, middle and low income countries including Thailand. They found that energy consumption is Granger cause of trade in

Thai economy. The study by Arouri et al. [9] may provide biased results due to use of bivariate model. Lütkepohl [70] that causal relationship between the variables is affected due to omission of relevant variables. This indicates the importance of trivariate function for consistent and reliable empirical evidence. We have included trade openness to examine the relationship between economic growth and energy consumption keeping capital and labor constant in case of Thailand.

### 2.2 The Data and Econometric Modelling

The main aim of present study is to investigate the relationship between economic growth, trade openness and energy consumption by employing the production function. The general form is given as following:

$$Y = AE^{\alpha_1} K^{\alpha_2} L^{\alpha_3} e^{u} \qquad (1)$$

where, real output, energy, capital and labor is denoted by $Y, E$ , $K$ and $L$ respectively. Technology is denoted by the term $A$ and $e$ is error term which is supposed to be normally distributed. The $\alpha_1, \alpha_2$ and $\alpha_3$ are elasticity estimates with respect to energy consumption, capital and labor respectively. We use constant return scale ($\alpha_1 + \alpha_2 + \alpha_3 = 1$) model by keeping impact of technology on output constant. We apply augmented production function where technology is endogenously established by the level of trade openness. Trade openness provides routes to transfer advanced technology as well as managerial skills (Shahbaz, [71]). Trade openness promotes technological advancements and helps in its diffusion. Thus, model can be given as following:

$$A(t) = \phi.TR(t)^{\alpha} \tag{2}$$

where $\phi$ is time-invariant constant, TR is indicator of trade openness. Substituting equation-2 into equation-1:

$$Y(t) = \phi.E(t)^{\delta_1} F(t)^{\delta_2} TR(t)^{\delta_3} K(t)^{\beta} L(t)^{1-\beta} \tag{3}$$

All the variables are transformed into log form and the linearized production function is given as following:

$$\ln Y_t = \beta_1 + \beta_E \ln E_t + \beta_{TR} \ln TR_t + \mu_t \tag{4}$$

where, $\ln Y_t$, $\ln E_t$ and $\ln TR_t$ are real GDP per capita, energy consumption per capita and real trade openness (real exports per capita + real imports per capita). The $\mu_t$ is a error term.

The world development indicators (CD-ROM, 2014) is used to collect data on real GDP, real trade (real exports + real imports) and energy consumption (kg of oil equivalent). We have converted real GDP, real trade openness and energy consumption into per capita terms by dividing them on total population (Lean and Smyth, [67]; Shahbaz and Lean, [72]). The time period of study is 1971-2012 in case of Thailand.

## 2.3 Estimation Strategy

### 2.3.1 Bayer and Hanck Cointegration Analysis

In econometric analysis, for time series data, it is said to be cointegrated if two or more series are individually integrated, but some linear combination has a lower order of integration. Engle and Granger [73] developed the first approach of cointegration. This approach provides more efficient results if time series data is large. Later on, Johansen maximum eigen value test was developed by Johansen ([74, 75]). Since it permits more than one cointegrating relationship, this test is more generally applicable after Engle–Granger cointegration test but it requires that series should be integrated at unique order of integration. Another approach of cointegration which is based on residuals is Phillips–Ouliaris cointegration test developed by Phillips and Ouliaris [76]. Other important approach is the Error Correction Model (ECM) based on F-test developed by Peter Boswijk [77], and the ECM based t-test of Banerjee et al. [78].

However, different cointegration tests might suggest different conclusions. To enhance the power of cointegration test, with the unique aspect of generating a joint test-statistic for the null of no cointegration based on Engle and Granger, Johansen, Peter Boswijk, and Banerjee tests, Bayer and Hanck [79] proposed new cointegration approach termed as combined cointegration. This approach allows us to combine various individual cointegration test results to provide more conclusive findings. We also apply this approach to examine the presence of cointegrating relationship among energy consumption, trade openness and economic growth in the case of

Thailand. Following, Bayer and Hank [79], the combination of computed significance level (p-value) of individual cointegration test, the Fisher's formulas as follows:

$$EG-JOH=-2[\ln(p_{EG})+(p_{JOH})] \tag{5}$$

$$EG-JOH-BO-BDM=-2[\ln(p_{EG})+(p_{JOH})+(p_{BO})+(p_{BDM})] \tag{6}$$

Where $p_{EG}, p_{JOH}, p_{BO}$ and $p_{BDM}$ are $p$-values of various individual cointegration tests respectively. It is assumed that if the estimated Fisher statistics exceed the critical values provided by Bayer and Hank [79], the null hypothesis of no cointegration is rejected.

After examining the long run relationship between the variables, we use Granger causality test to determine the causality between the variables. If there is cointegration between the series then the vector error correction method (VECM) can be developed as follows:

$$\begin{bmatrix}\Delta \ln E_t \\ \Delta \ln O_t \\ \Delta \ln Y_{tt}\end{bmatrix}=\begin{bmatrix}b_1 \\ b_2 \\ b_3\end{bmatrix}+\begin{bmatrix}B_{11,1}\ B_{12,1}\ B_{13,1}\ B_{14,1}\ B_{15,1} \\ B_{21,1}\ B_{22,1}\ B_{23,1}\ B_{24,1}\ B_{25,1} \\ B_{31,1}\ B_{32,1}\ B_{33,1}\ B_{34,1}\ B_{35,1}\end{bmatrix}\times\begin{bmatrix}\Delta \ln E_{t-1} \\ \Delta \ln O_{t-1} \\ \Delta \ln Y_{t-1}\end{bmatrix}+\ldots+\begin{bmatrix}B_{11,m}\ B_{12,m}\ B_{13,m}\ B_{14,m}\ B_{15,m} \\ B_{21,m}\ B_{22,m}\ B_{23,m}\ B_{24,m}\ B_{25,m} \\ B_{31,m}\ B_{32,m}\ B_{33,m}\ B_{34,m}\ B_{35,m}\end{bmatrix}$$
$$\times\begin{bmatrix}\Delta \ln E_{t-1} \\ \Delta \ln O_{t-1} \\ \Delta \ln Y_{t-1}\end{bmatrix}+\begin{bmatrix}\zeta_1 \\ \zeta_3 \\ \zeta_3\end{bmatrix}\times(ECM_{t-1})+\begin{bmatrix}\mu_{1t} \\ \mu_{2t} \\ \mu_{3t}\end{bmatrix} \tag{7}$$

Where difference operator is $(1-L)$ and $ECM_{t-1}$ is the lagged error correction term, generated from the long run association. The long run causality is found by significance of coefficient of lagged error correction term using t-test statistic. The existence of a significant relationship in first differences of the variables provides evidence on the direction of short run causality. The joint $\chi^2$ statistic for the first differenced lagged independent variables is used to test the direction of short-run causality between the variables. For example, $B_{12,i} \neq 0 \forall_i$ shows that trade openness Granger causes energy consumption and trade openness is Granger of cause of energy consumption if $B_{11,i} \neq 0 \forall_i$.

## 3. Results and Discussion

We have presented descriptive statistics and pair-wise correlation analysis in Table-1. The results show that economic growth, energy consumption and trade openness are normally distributed confirmed by Jarque-Bera test statistics. In pair-wise correlation analysis, we find that energy consumption and trade openness are positively correlated with economic growth. Trade openness has positive correlation for energy consumption.

Testing the unit root properties of variables is necessary condition before applying any standard cointegration approach (Shahbaz et al. [80, 81]). For this purpose, we have used Ng-Perron unit root test to check the stationarity of time series data in logarithmic form. The results of Ng-Perron test have been presented in Table-2. According to these results variables of energy consumption, economic growth and trade openness are not stationary at level. But by taking the first difference the variable of energy consumption is stationary at 1 percent level of significance and economic growth and trade openness are stationary at 5 percent level of significance. This shows that the null hypothesis of unit root for all variables is rejected when we use the first difference of the variables.

**Table-1: Descriptive Statistics and Correlation Matrix**

| Variables | $\ln Y_t$ | $\ln E_t$ | $\ln O_t$ |
|---|---|---|---|
| Mean | 3.1260 | 2.8433 | 1.9186 |
| Median | 3.1889 | 2.9215 | 1.9617 |
| Maximum | 3.4424 | 3.3626 | 2.1536 |
| Minimum | 2.7243 | 2.0798 | 1.6835 |
| Std. Dev. | 0.2375 | 0.4048 | 0.1679 |
| Skewness | -0.2659 | -0.3138 | -0.0877 |
| Kurtosis | 1.5981 | 1.6869 | 1.3469 |
| Jarque-Bera | 3.9342 | 3.7070 | 4.8357 |
| Probability | 0.1398 | 0.1566 | 0.0891 |
| $\ln Y_t$ | 1.0000 | | |
| $\ln E_t$ | 0.7554 | 1.0000 | |
| $\ln O_t$ | 0.4219 | 0.3987 | 1.0000 |

**Table-2: Ng-Perron Unit Root Test**

| Variables | MZa | MZt | MSB | MPT |
|---|---|---|---|---|
| $\ln E_t$ | -4.9036 (1) | -1.31543 | 0.26826 | 17.2801 |
| $\ln Y_t$ | -7.7942 (2) | -1.85623 | 0.23815 | 11.9768 |
| $\ln O_t$ | -10.0257 (1) | -2.14806 | 0.21426 | 9.49205 |
| $\Delta \ln E_t$ | -32.4035 (7)* | -4.02491 | 0.12421 | 2.81349 |
| $\Delta \ln Y_t$ | -22.8676 (3)** | -3.37749 | 0.14770 | 4.00831 |
| $\Delta \ln O_t$ | -22.3688 (2)** | -3.34239 | 0.14942 | 4.08530 |
| Note: * and ** show significant at 1% and 5% levels respectively. () indicates lag length | | | | |

**Table-3: Lag Length Selection**

| VAR Lag Order Selection Criteria | | | | | | |
|---|---|---|---|---|---|---|
| Lag | LogL | LR | FPE | AIC | SC | HQ |
| 0 | 81.41383 | NA | 3.21E-05 | -4.6714 | -4.5816 | -4.6407 |
| 1 | 206.3345 | 227.7965 | 2.62E-08 | -11.7843 | -11.5150 | -11.6925 |
| 2 | 214.8204 | 14.4759* | 2.02e-08* | -12.0482* | -11.5993* | -11.8951* |
| 3 | 216.7581 | 3.0776 | 2.29E-08 | -11.9269 | -11.2984 | -11.7126 |
| 4 | 220.8998 | 6.0906 | 2.31E-08 | -11.9352 | -11.1272 | -11.6597 |
| 5 | 224.8854 | 5.3923 | 2.36E-08 | -11.9344 | -10.9467 | -11.5976 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 225.9703 | 1.3401 | 2.90E-08 | -11.7629 | -10.5957 | -11.3649 |
| * indicates lag order selected by the criterion<br>LR: sequential modified LR test statistic (each test at 5% level)<br>FPE: Final prediction error<br>AIC: Akaike information criterion<br>SC: Schwarz information criterion<br>HQ: Hannan-Quinn information criterion | | | | | | |

This order of integration of the variables leads us to apply the Bayer and Hanck combined cointegration tests such as EG-JOH, and EG-JOH-BO-BDM tests. It is necessary to select the appropriate lag length of the variables to compute Fisher-statistic to examine whether cointegration exists among the series. The Fisher-statistic is sensitive with lag length selection (Shahbaz et al. [82]). We choose lag order 2 following the minimum value of Akaike information criterion due to its superior properties. The results are reported in Table-3. The results of unit root test shows that all variables follow the $I(1)$, the same cointegration tests are proceeded. Table-4 illustrates the same cointegration tests including the EG-JOH, and EG-JOH-BO-BDM tests. The result reveals that Fisher-statistics for EG-JOH and EG-JOH-BO-BDM tests, in case of $Y_t$, $E_t$ and $O_t$ are greater than 5% critical values indicating that both EG-JOH and EG-JOH-BO-BDM tests statistically reject the null hypothesis of no cointegration between variables. This implies that long run relationship exists between economic growth, energy consumption and trade openness over the selected period in case of Thailand.

**Table-3: The Results of Bayer and Hanck Cointegration Analysis**

| Estimated Models | EG-JOH | EG-JOH-BO-BDM | Cointegration |
|---|---|---|---|
| $Y_t = f(E_t, O_t)$ | 11.483 | 21.624 | Yes |
| $E_t = f(Y_t, O_t)$ | 10.922 | 21.717 | Yes |
| $O_t = f(Y_t, E_t)$ | 11.207 | 21.934 | Yes |
| Note: ** represents significant at 5 per cent level. Critical values at 5% level are 10.576 (EG-JOH) and 20.143 (EG-JOH-BO-BDM) respectively. | | | |

**Table-4: Long Run Analysis**

| Dependent Variable = $\ln Y_t$ | | | | |
|---|---|---|---|---|
| Long Run Analysis | | | | |
| Variables | Coefficient | Std. Error | T-Statistic | Prob. |
| Constant | 1.3510* | 0.0509 | 26.5360 | 0.0000 |
| $\ln E_t$ | 0.5283* | 0.0252 | 20.9542 | 0.0000 |
| $\ln O_t$ | 0.1422** | 0.0607 | 2.3403 | 0.0245 |
| $R^2$ | 0.9951 | | | |
| Adj. $R^2$ | 0.9949 | | | |
| F-Statistic | 40.2490* | | | |
| Short Run Analysis | | | | |
| Constant | -0.0056** | 0.0027 | -2.0520 | 0.0475 |
| $\Delta \ln E_t$ | 0.7409* | 0.0771 | 9.6083 | 0.0000 |
| $\Delta \ln O_t$ | 0.0587 | 0.0496 | 1.1842 | 0.2441 |
| $ECM_{t-1}$ | -0.2415** | 0.0961 | -2.5133 | 0.0166 |
| $R^2$ | 0.7417 | | | |
| Adj. $R^2$ | 0.7201 | | | |
| F-Statistic | 34.4590 | | | |
| Diagnostic Checks | | | | |
| Test | F-statistic | | | |
| $\chi^2 NORMAL$ | 1.8782 | | | |
| $\chi^2 ARCH$ | 0.0098 | | | |
| $\chi^2 REMSAY$ | 1.1175 | | | |
| Note: * and ** show significant at 1% and 5% levels respectively. | | | | |

The next step is to examine the marginal impact of energy consumption and trade openness on economic growth after having cointegration between the series. Table-4 reveals that energy consumption puts significant impact on economic growth at 1 per cent level of significance. Other things remaining constant, a 1 per cent increase in energy consumption leads economic growth by 0.5283 percent in case of Thailand. In case of trade openness relationship, trade openness put positive impact on economic growth of Thailand and it is has significant relations with economic growth at 5 percent level of significance. The results show that 1 percent increase in trade openness put 0.1422 percent increase in economic growth in of Thailand.

The short run analysis are presented in lower part of Table-5, we find that energy consumption have positive relation with economic growth in case of Thailand for the period of short run. The short run results show that 1 percent increase in energy consumption puts 0.7409 percent increase in economic growth in case of Thailand and it has 1 per cent level significance. The short run relation of trade openness and economic growth is positive but insignificant in case of Thailand. The negative sign of coefficient of $ECM_{t-1}$ is -0.2415 and it is statistically significant at 5 per cent level of significance. This confirms our established long run relationship among the variables of the model. The coefficient of error term indicates the speed of adjustment from short run towards long run equilibrium path. We find that short run deviations in previous period are corrected by 0.2415 per cent in future in case of Thailand. It may consume almost 5 years to reach at long run equilibrium path using growth function. The short run model shows that error term is normally distributed with zero mean and constant variance. There is no problem of autoregressive conditional heteroskedisticity and short run model is well constructed.

**Table-5: The Granger Causality Analysis**

| Variables | Direction of Granger Causality | | | |
|---|---|---|---|---|
| | Short Run | | | Long Run |
| | $\ln Y_t$ | $\ln E_t$ | $\ln O_t$ | $ECT_{t-1}$ |
| $\ln Y_t$ | .... | 26.1655* [0.0000] | 1.2619 [0.2964] | -0.2330** [-2.1587] |
| $\ln E_t$ | 14.5450* [0.0000] | .... | 2.0267 [0.1478] | -0.1123** [-2.2311] |
| $\ln O_t$ | 2.1693 [0.1303] | 0.0464 [0.9543] | .... | -0.2700** [-2.3950] |
| Note: * and ** show significant at 1% and 5% levels respectively. | | | | |

In the long run, the results of Granger causality analysis reveal the feedback effect between energy consumption and economic growth i.e. energy consumption Granger causes economic growth and economic growth Granger causes energy consumption in Thailand (Table-5). The relationship between energy consumption and economic growth is bidirectional and same is true between trade openness and economic growth. The bidirectional causality is found between economic growth and trade openness in long run in case of Thailand. So, overall results show that economic growth Granger causes energy consumption and trade openness. The feedback effect exists between energy consumption and economic growth and same is true between trade openness and economic growth.

The main problem with the VECM Granger causality is that it only captures the relative strength of causality within a sample period and cannot explain anything out of the selected time period. Further, the VECM Granger approach is unable to identify the exact magnitude of feedback from one variable to another variable (Shan, [83]). To solve this issue, Shan [83] introduced the new term of Innovative Accounting Approach (IAA) i.e. variance decomposition approach and impulse response function. Under the umbrella of IAA, variance decomposition method (VDM) points out the exact amount of feedback in one variable due to innovative shocks occurring in another variable over the various time horizons. The variance decomposition is considered a substitute of the impulse response function (IRF). The variance decomposition approach indicates the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period. It is pointed by Pesaran and Shin [84] that the generalized forecast error variance decomposition method shows proportional contribution in one variable due to innovative stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock affects. Engle and Granger [73] and Ibrahim [85] argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches.

**Table-6: Variance Decomposition Approach**

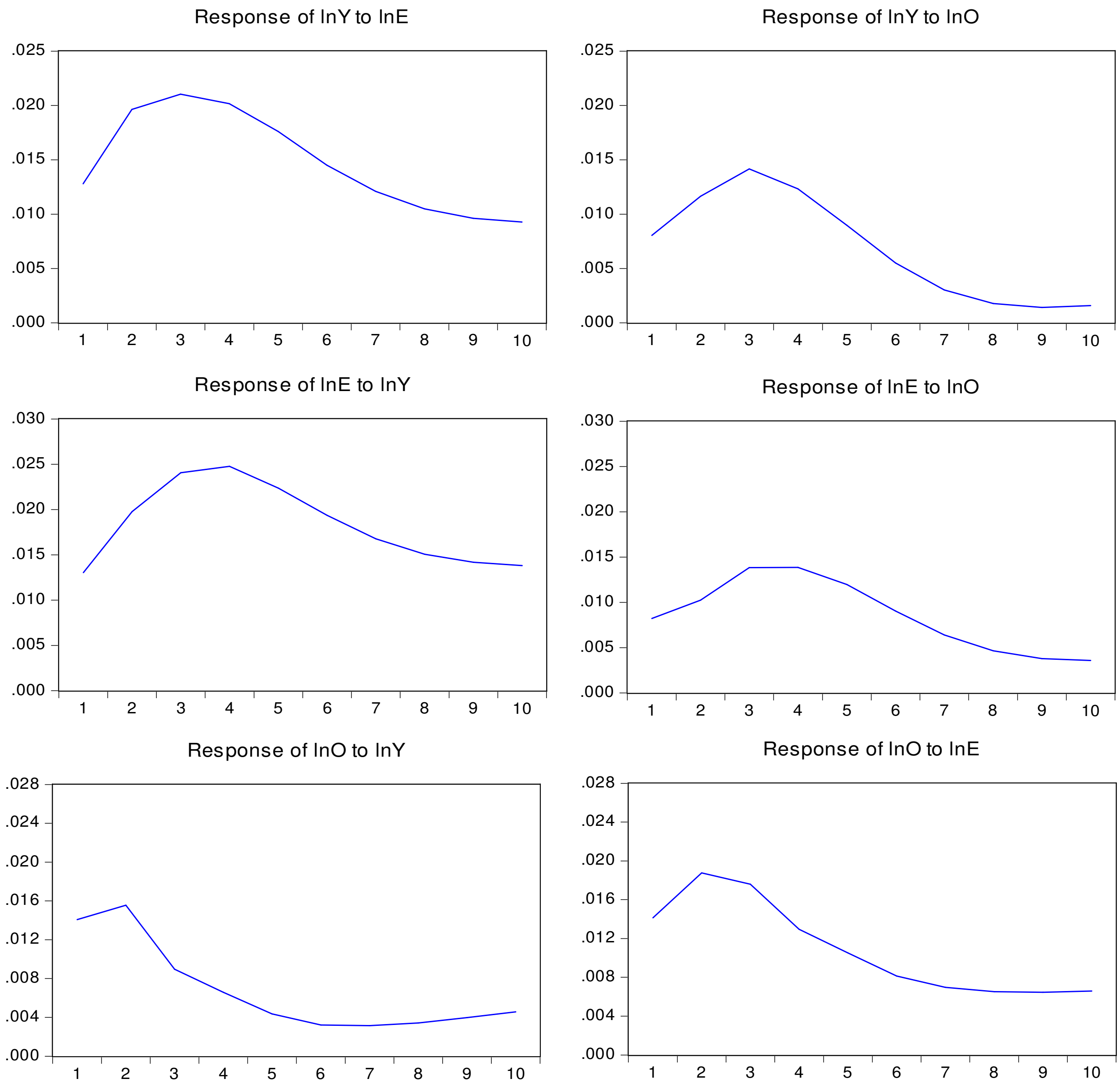
| Variance Decomposition of $\ln Y_t$ | | | | |
|---|---|---|---|---|
| Period | S.E. | $\ln Y_t$ | $\Delta \ln E_t$ | $\ln O_t$ |
| 1 | 0.0158 | 100.0000 | 0.0000 | 0.0000 |
| 2 | 0.0268 | 97.6050 | 2.3920 | 0.0028 |
| 3 | 0.0354 | 96.4162 | 3.1850 | 0.3987 |
| 4 | 0.0413 | 95.1537 | 4.4924 | 0.3538 |
| 5 | 0.0451 | 93.1168 | 6.5610 | 0.3221 |
| 6 | 0.0474 | 91.1658 | 8.2542 | 0.5799 |
| 7 | 0.0491 | 89.3401 | 9.5036 | 1.1561 |
| 8 | 0.0504 | 87.8475 | 10.3101 | 1.8423 |
| 9 | 0.0515 | 86.7323 | 10.8044 | 2.4632 |
| 10 | 0.0525 | 85.9252 | 11.1303 | 2.9443 |
| Variance Decomposition of $\Delta \ln E_t$ | | | | |
| Period | S.E. | $\ln Y_t$ | $\Delta \ln E_t$ | $\ln O_t$ |
| 1 | 0.0160 | 65.4711 | 34.5289 | 0.0000 |
| 2 | 0.0281 | 70.5301 | 28.8904 | 0.5793 |
| 3 | 0.0387 | 75.8130 | 23.8711 | 0.3157 |
| 4 | 0.0473 | 78.0197 | 21.7408 | 0.2394 |
| 5 | 0.0538 | 77.6319 | 22.0739 | 0.2940 |
| 6 | 0.0585 | 76.5080 | 22.9109 | 0.5810 |
| 7 | 0.0621 | 75.1549 | 23.7258 | 1.1192 |
| 8 | 0.0650 | 73.9715 | 24.2464 | 1.7820 |
| 9 | 0.0675 | 73.1019 | 24.4683 | 2.4297 |
| 10 | 0.0697 | 72.5309 | 24.4918 | 2.9772 |
| Variance Decomposition of $\ln O_t$ | | | | |
| Period | S.E. | $\ln Y_t$ | $\Delta \ln E_t$ | $\ln O_t$ |
| 1 | 0.0276 | 25.9019 | 2.8525 | 71.2455 |
| 2 | 0.0354 | 35.0462 | 10.5194 | 54.4342 |
| 3 | 0.0415 | 30.1727 | 25.5903 | 44.2369 |
| 4 | 0.0441 | 28.9381 | 31.2702 | 39.7915 |
| 5 | 0.0459 | 27.6416 | 35.5917 | 36.7665 |
| 6 | 0.0470 | 26.8504 | 37.9840 | 35.1655 |
| 7 | 0.0477 | 26.4550 | 39.2942 | 34.2506 |
| 8 | 0.0483 | 26.3073 | 40.0805 | 33.6121 |

| | | | | |
|---|---|---|---|---|
| 9 | 0.0488 | 26.4116 | 40.5025 | 33.0857 |
| 10 | 0.0493 | 26.7349 | 40.6846 | 32.5804 |

The results of variance decomposition approach are reported in Table-7 reveal that a 85.92 per cent portion of economic growth is explained by its own innovative shocks while innovative shocks of energy consumption and trade openness contribute to economic growth by 11.13 per cent and 2.94 per cent respectively. The role of economic growth and trade openness is 72.53 per cent and 2.97 per cent respectively. The rest is contributed by innovative shocks itself in economic growth. The contribution of economic growth and energy consumption to explain trade openness is 26.73 per cent and 40.68 per cent respectively. A 32.58 per cent portion of trade openness is explained by its own innovative shocks. Overall, we conclude that economic growth causes energy consumption and trade openness. Trade openness is cause of energy consumption.

**Figure-1: Impulse Response Function**

Response to Generalized One S.D. Innovations




The impulse response function is alternative to variance decomposition method shows how long and to what extent dependent variable reacts to shock stemming in the independent variables (Figure-1). The results indicate that the response in economic growth due to forecast error stemming in energy consumption and trade openness is inverted U-shaped i.e. economic growth increases initially with an increase in energy consumption and trade openness and then declines. The contribution of economic growth and trade openness is increasing till $4^{th}$ time horizon and then declines. Trade openness responds positively due to forecast error in economic growth and energy consumption.

## 4. Conclusion and Policy Implications

This paper employed the production function to examine the relationship between economic growth, energy consumption and trade openness in case of Thailand. The study covers the period of 1971-2012. We applied Bayer-Hanck combined cointegration approach test for the long run relationship. The direction of causal relationship between the variables is investigated by applying the VECM Granger causality approach. We note the confirmation of cointegration between the variables. Energy consumption stimulates economic growth. Trade openness boosts up economic activity and hence raises economic growth. The causality analysis indicates the feedback effect between energy consumption and economic growth. The relationship between trade openness and energy consumption is bidirectional. Trade openness Granger causes economic growth and in resulting, economic growth leads trade openness. In such as environment, reduction in energy supply will retard economic growth which will affect trade openness and in resulting energy demand is declined as bidirectional causality exists between economic growth and energy consumption. Our empirical analysis reveals that trade openness promotes economic growth and in return, economic growth leads trade openness. The feedback effect is found between trade openness and energy consumption.

Energy demand in Thailand has been increased every year to respond for increase population and economic growth. The main sources of energy are gas and oil which account for 70 percent in 2010. Thailand is the second largest net oil importer in Southeast Asia behind Singapore. There are three policy recommendations. First is strengthening regional economic cooperation for energy market and cooperation is crucial in order to secure the energy as sources of economic growth and diversify the energy sources. The ASEAN will establish the ASEAN Economic Community (AEC) in 2015. ASEAN Energy Market Integration (AEMI) is an important element to support AEC. AEM will promote the distribution, consumption and production of energy in ASEAN countries. AEMI does not only promote economic development in Thailand but it also generate a more dynamic and competitive economy for ASEAN member. In addition, energy sector is key areas for the Greater Mekong Sub-region (GMS) economic cooperation (Yu, [86]. GMS countries have rich energy resources (gas, water and coal) for producing electricity. Therefore, promotion of Greater Mekong Sub-region (GMS) cooperation has high potentials and possibilities for development of energy not only for Thailand but also for GMS regions. Second is improvement of the energy efficiency, government should encourage domestic investors to adopt energy efficient technology. This not only saves energy but also enhances the capacity of an economy by providing saved energy to energy deficient sectors of the country. In this regard, trade openness is viable rout to import advanced and energy efficient technology not only lowers energy intensity but also enhances the capacity of Thai economy to export more to her trading partners in international market. This in resulting will improve the economic performance of the country. Third is increasing hydropower exploitation and development and promotion of power generation from biomass and solar energy. The hydropower generation is significant potential in ASEAN region. Currently, only 9 percent of the region's hydropower potential is developed

(Karki et al. [87]). In addition, increasing production of renewable energy is also important for Thailand. Biomass resources and in the forms of agricultural residues are abundant in Thailand.

In order to implementation of policy, there are important actions issues as follows. Firstly, despite having regional agreement in ASEAN, implementation of agreement seems face difficulty because energy sector dominate by State Own Enterprises (SOEs) and high sensitive sectors. Deregulation allowing more competition and privatize energy sectors should be consideration. Secondly, raising awareness of the benefits and potential of energy efficiency is important. In addition, several energy efficiency policies including fiscal policies and technical information dissemination policies and programs should take place. Implementation of Energy management system also improves energy efficiency. Thirdly, Private Public Partnership (PPP) in hydropower generation in regions should be promoted. In addition, supports and cooperations from international organization such as the World Bank and Asian development is necessary to ensure social and environmental protection. In order to support renewable energy, it is important to provide the financial incentives, improve regal framework and promote the competition in this sectors.

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