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## THE IMPACT OF NATURAL GAS DEMAND ON RENEWABLE ENERGY DEVELOPMENT: A PANEL INVESTIGATION OF SIX ASIAN COUNTRIES

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**Abstract:** The aim of this study is to assess the causal relationship of natural gas demand on the development of renewable energy in East and Southeast Asia. Specifically, the study examines the growth of natural gas and renewable energy consumption in both regions, determine the correlation of both energies and then measure the significant magnitude of the macroeconomic indicators in order to determine the development of renewable energy. The focus of the study was one Asian country including China, Japan, South Korea to represent East Asia and Malaysia, Indonesia and Thailand to represent Southeast Asia. These countries are selected since they have contributed to the largest consumption in natural gas among other Asian countries. Although each of these countries has large potential renewable energy resources, this research found there are similar potential resources among the countries in each region. The quantitative research approach was applied to suit the time series secondary data collection. Panel data model then applied to enable researcher to determine the significance of macroeconomic indicators towards the development of renewable energy in East and Southeast Asia. With a total of 90 observations, the macroeconomic variables include: natural gas consumption, GDP per capita, economic growth, exchange rate and access to electricity from period 2000-2014. Based on regression analysis, the findings revealed there is a significant coefficient between natural gas consumption on renewable energy development. A high consumption of natural gas would drive up the share of renewable energy to total final energy consumed. It is because these energy sources are not competitors yet complementary. However, the coefficient magnitude in Southeast Asia is higher than in East Asia. Consequently, other macroeconomic indicators such as exchange rate, GDP and electricity consumption has different effect on each region. These indicators can help the policy makers to improve the renewable energy policy which is currently being implemented in order to induce the pace of renewable energy development in Asia.

**Keywords:** Natural gas demand; Renewable energy; Macroeconomic variables.

**JEL Classification:** Q21, Q20, E01.

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## Introduction

Stimulated by the oil price crashed in 1998 where the price hits at the lowest by 12.28 USD per barrel, the similar case occurred again recently in

2016 where it hits the lowest price at 40.68 USD per barrel from 105.87 USD per barrel in 2013 (Statista 2018).

The events have given impact on natural gas and other energy sectors and it led to a global recession (Setser, 2004). Based on the investigation done by Oxford Institute for Energy Studies, the first reason to the crisis in 1998 are the high level of oil inventories although it is not as high as it was declared. The second reason is the signs of economic situation in Asia with economic stagnation in Japan will not improve for a long time (Fattouh and Mahadeva 2013). Klass (2003) also added that the investigation of energy demand is a crucial input to the analysis of future energy usage and the impact of regulations responses.

To understand the dynamics of the natural gas market, the element of economic and socio-political aspects cannot be separated. Especially in Asia, the natural gas market can be classified into different ranges. As suggested by Kaygusuz et al (2007), Kaygusuz (2007) and Aspergis and Payne (2010), the government's incentive to establish tradable renewable energy can bring potential benefits for an expansion in the renewable energy sector. Similarly in Asia, according to Stern (2017), there are four determinants that drive the growth of natural gas in Asian gas market. First, the potential decline in production or pipeline gas imports. Second, security supply, environmental policies and energy mix are favourable to the country. Third, upstream investment issues with less sufficient development growth and the last one is the affordability in domestic gas price including the production and import restrictions. These characteristics will be assessed in the next chapter.

In the era where the world is shifting to sustainable energy, several countries have started to put attention on renewable energy through socio-political and finance elements. Particularly in government instrument, it is believed by many experts to be essential for the development of renewable energy. Several countries in Asia are adopting similar regulation. For instance, Malaysian and Thailand's cabinet have started to support the growth of Renewable Energy Industry by approving the implementation of renewable energy act for Feed-in-Tariff (FiT), which means the consumers are accountable for higher charge for higher electricity consumption due to higher carbon emissions (Ahmad et al. 2011). Technical wise, Malaysia has started the development through hydrogen production utilization by utilizing the palm oil solid waste each year. However, Malaysia's renewable capacity was less than 1% of the total installed capacity in 2012 (Ahmad and Tahar, 2014). In overall, Malaysian's government had collaborated with the private sector and announced the short, medium and long term plan to develop renewable energy (Hosseini et al. 2015). Other Asian country like Japan have also disclosed their commitments to reduce greenhouse gas through the similar framework (Kumar et al. 2011).

Despite the renewable resource and sustainable energy system represent environmentally friendly also cost-effective means of providing electricity, issues with renewable energy development is still relatively slow and the extensive potential renewable resource in Asia may potentially bring benefit to the economic growth.

There have been numerous academic research conducted relating natural gas demand in different countries and region. It is acknowledged that the empirical literature on the energy consumption growth nexus is still limited. Apergis and Payne (2010) conducted a panel investigation of natural gas consumption and economic growth of 67 countries. The multivariate framework used is similar to this study which includes GDP (constant 2000 US dollars), real gross fixed capital formation, natural gas consumption and total labour force. By using a heterogeneous panel co-integration test, the correlation revealed bidirectional causality between natural gas consumption and economic growth in short and long run.

Another study conducted by Reynolds and Kolodzieji (2008) who examined the relationship between natural gas, oil, and coal production and GDP in the former Soviet Union. Through Granger-causality tests within a bivariate framework, the study revealed unidirectional causality from oil production to GDP and unidirectional causality between GDP and coal production as well as natural gas production, respectively. However, Malik (2009) verified in the modelling renewable energy consumption research that it has been found that gas reserve as one of the macro-economic variables becomes significant with a negative sign in pooled and period fixed effect.

Another study conducted by Sensfuß, Ragwitz and Genoese (2008) who examined the price effect created by renewable energy for electricity share. It is mentioned in the study that gas price disproportionately has a high impact on the growth of the merit-order effect in the growing renewable electricity generation.

Similarly, Berry (2005) argues that the volatility of natural gas is high and by hedging wind energy can deliver cost-effective against natural gas price increase. The study examined five cases using analysis of the cost marginal conventional generation with probability distribution of the gas prices, cost of wind energy, wind integration cost, wind capacity value, wind transmission cost and environmental benefits of wind for a hypothetical utility. The study revealed that the effectivity to hedge against natural gas price increase depends on the conventional generation system and the cost of wind energy. The study suggests that higher electricity reliance on natural gas implies better hedge on wind energy and vice versa.

The rising energy consumption for electricity, precarious nature of dependency of fossil fuel has enforced many countries to look into renewable energy to sustenance the energy source. According to Dincer (2000), renewable energy resources seem to be one of the most efficient and effective solutions to air pollutions. Moreover, zero emission production by renewable energy is believed to be the efficient solution to reduce the climate change and capable to replace conventional sources in various applications at a competitive price (Aras et al. 2004). However, investing in one from various renewable can become a robust project for the stakeholders. Beck and Martinot (2004) stated that economic barriers in renewable including the lack of subsidy, barriers in legal is inadequate legal frameworks for energy power sources and the financial barriers including lack of economic support such as commercial information, access to credit for both customers and investors.

In the current sustainability development, renewable energy still requires a lot of effort may it be through government support or investment. Beck and Martinot (2004) stated that economic barriers in renewable including the lack of subsidy, barriers in legal is inadequate legal frameworks for energy power sources and the financial barriers including lack of economic support such as commercial information, access to credit for both customers and investors.

In energy demand study, usually developing countries have a higher contribution on the growth rather than developed as they account for a larger share of GDP and less efficient energy usage. Therefore, the main contribution of this study is to pull together the data that differs across individual countries using panel data analysis. Through this analysis, it allows the researcher to study the dynamics of change on natural gas demand and the renewable energy consumption for each region within 14 year time period. The selected countries are based on two regions in Asia which represent developed and developing countries. First, it attempts to determine the correlation between natural gas and renewable energy. Since Asia has a high contribution in natural gas, it is important to understand to estimate the significance renewable energy consumption to the level of natural gas demand. Then, this paper applied general leased square (GLS) estimation to find the causation of renewable energy demand based on natural gas consumption and selected macroeconomic indicators for both regions. Thus, the result will allow the researcher to develop recommendations for policy makers in order to enhance the pace of renewable energy development in Asia.

## **Research Method**

### **Panel Data**

In panel data, the same cross-sectional unit, such as country, is collected over time (Gujarati, 2004). Typically, it has a relatively large number of observations. Panel data approach has several advantages (Baltagi, 2005). Not only it provides more variability, less collinearity among explanatory variables, more degrees of freedom, and more variation which result in more efficient estimators but also it can test more complex behavioural models than a single cross-section or time series. However, panel data is not perfect as it assumes that units of observation will have similar behaviour.

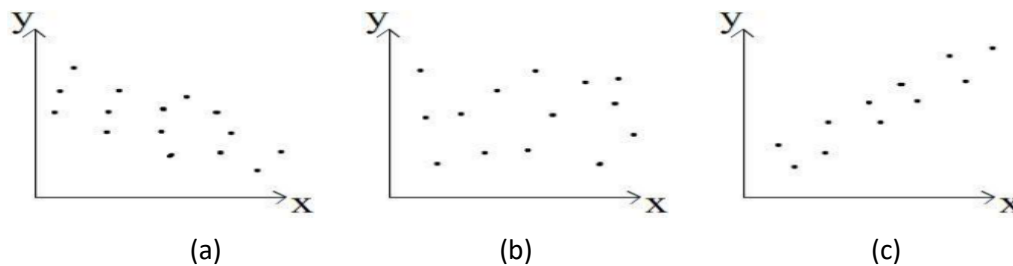
### **Data Collection**

This study seeks to analyse information on the magnitude of renewable energy demand with respect to other types of energy and macroeconomic indicators. Secondary data is chosen to gather data for this research analysis. Secondary data collection defined as gathering the present data from various sources such as textual material, online journals and articles which enable researcher arrives at the solution of the research (Rew et al. 2000). In this quantitative research, panel data are collected through several online websites. By referring to the popularity of the author and authoritative is important in bringing credibility to the research project. (Rajaseka et al. 2006).

The data for this study covers six selected countries in a period of 15 years from 2000 to 2014. These countries consist of China, Japan, South Korea, Indonesia, Malaysia and Thailand. Data on renewable energy consumption, gross domestic product (GDP) per capita at constant price 2000, economic growth, access to electricity and real exchange rate are taken from World Bank. Further, data on natural gas consumption are retrieved from the United Nations (UN). These reliable resources have been cited in numerous studies.

**Correlation**

In quantitative research, it is often of interest to consider a pair of variables and determine if there is a relationship between the two. Such a relationship is called a correlation. There are three types of correlation based on what happens to other variables if one variable increases. A positive correlation implies that another variable is likely to incline as well. A negative correlation means that other variable is likely to decline. No correlation shows that another variable does not have a tendency to either increase or decrease. In a scatterplot, these types of correlation can be shown as follows.



**Figure 1** Scatterplot Diagrams for (a) negative correlation; (b) no correlation; (c) positive correlation

Statistically, Pearson’s correlation coefficient is used to measure the direction and strength of a linear relationship between paired data. It is denoted by r which ranges from -1 to 1. Positive values are attributed to a positive linear correlation. Negative values show a negative linear correlation. Zero value denotes no linear correlation but it does not necessarily imply that there is no relationship between the variables. While the closer the value to get to 1 or -1, the stronger the linear correlation. The formula for Pearson’s correlation coefficient can be written as follows.

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \tag{1.1}$$

Correlation measures an effect size which enables us to describe the strength of the correlation. Based on guide from Evans (1996) the absolute value of r: very weak (0.00 - 0.19), weak (0.20 - 0.39), moderate (0.40 - 0.59), strong (0.60 - 0.79), and very strong (0.80 - 1.00). For instance, a coefficient correlation of 0.45 implies a moderate positive correlation (Benzer, Benzer and Günal 2017).

### Specification of the Model (Random Effect)

In this study, the renewable energy consumption equation is written in logarithm form as shown in Equation (1.2). The dependent variable here is  $REC_{it}$  or renewable energy consumption as a percentage of total final energy consumption. It approximates the amount of renewable energy that people are willing and able to consume in a particular period. One important factor which influences renewable energy demand is the price itself. However, as there is no statistical information about it, the author cannot include this factor in the model.

$$REC_{it} = \beta_0 + \beta_1 \log(NGC_{it}) + \beta_2 \log(Y_{it}) + \beta_3 GR_{it} + \beta_4 AE_{it} + \beta_5 \log(RER_{it}) + \beta_6 D_i + \varepsilon_{it} \quad (1.2)$$

|                    |                                |
|--------------------|--------------------------------|
| REC                | : Renewable energy consumption |
| $\beta_0$          | : Intercept                    |
| NGC                | : Natural gas consumption      |
| Y                  | : GDP per capita               |
| GR                 | : Economic growth              |
| AE                 | : Access to electricity        |
| RER                | : Real exchange rate           |
| $D_i$              | : Dummy variables              |
| $\varepsilon_{it}$ | : Error term                   |
| I                  | : Individual unit (country)    |
| T                  | : Time                         |

As the main interest in this study, natural gas consumption is used as an explanatory variable. However, its relationship with renewable energy consumption is still inconclusive, whether it is complementary or substitute, depending on the context. While, real GDP per capita ( $Y_{it}$ ) is used to quantify income elasticity. Apparently, there are other macroeconomic factors that are included in the model as it potentially influences renewable energy consumption, including economic growth ( $GR_{it}$ ) and the real exchange rate ( $RER_{it}$ ). The control variables in this model include access to electricity ( $AE_{it}$ ) and also dummy variable ( $D_i$ ) which is applied to capture the different pattern of renewable energy consumption between Southeast Asia and East Asia. In the model, the subscript  $i$  refer to the observational unit, which is country, and the subscript  $t$  for time index.

However, there are many other explanatory variables which probably affect renewable energy consumption, such as energy policies and innovations. Since such variables are difficult to approximate, they will be captured in error terms ( $\varepsilon_{it}$ ). Data associated with the equation (1.2) are compiled and then estimated by multiple regression models in order to obtain unknown parameters ( $\beta$ ). The renewable energy equation is estimated both simultaneously and separately for each region.

Basically, there are three types of models in estimating panel data: pooled effect, fixed effect, and random effect. Pooled effect model does not consider any cross-section heterogeneity among the countries. It assumes a common intercept and the same slope coefficients. The pooled effect model can be written in the equation (1.3) where  $y_{it}$  is the dependent variable for the individual  $I$  at time  $t$ ,  $X1_{it}$  and  $X2_{it}$  are the time-variant inde-

pendent variables;  $\beta_0$  is the intercept;  $\beta_1$  and  $\beta_2$  are coefficients of the slope and  $\varepsilon_{it}$  is the error term.

$$y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \varepsilon_{it} \quad (1.3)$$

The assumption of a common intercept is then relaxed for the regression. In order to distinguish between different effects, equation (1.3) can be rewritten as follows where  $\alpha_i$  is unobservable individual effect and  $u_{it}$  is the error term.

$$y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \alpha_i + u_{it} \quad (1.4)$$

Fixed effect model and random effect model attempt to deal with the unobservable individual effect. Fixed effect model assumes that  $\alpha_i$  is not independent of  $X_{1it}$  and  $X_{2it}$ . The intercept can differ across individuals but the individual-specific effects cannot vary over time (Gujarati, 2004). This model does not allow the coefficients of the explanatory variables to fluctuate over time or across individuals. Fixed effect model incorporates the individual-specific effects as dummy variables. If it includes too many dummy variables, the model will suffer from losing a number of degrees of freedom. With these limitations, fixed effect model would be less suitable for this study.

Different from fixed effect, random effect model assumes that  $\alpha_i$  is independent of  $X_{1it}$  and  $X_{2it}$  and  $u_{it}$  is a randomly distributed individual specific effect with mean 0 and variance  $\sigma^2$  (Balestra and Nerlove, 1966). The individuals-specific effects are treated as error components in random effect. The random effect has an advantage over fixed effect as it generates estimates for all coefficients with no exception of time-invariant ones and uses few degrees of freedom.

Since this study uses panel data, heteroscedasticity may arise if the variances of the errors are not constant. Autocorrelation problem may also occur if the error in one period is correlated with the error in the subsequent period. Even though both problems do not cause bias, the standard errors may be underestimated which in turn lead to non-reliable results due to inefficient result coefficients. The bias of the standard errors can be corrected with robust standard errors by using generalized least square (GLS) to take into account of heteroscedasticity and autocorrelation problem in panel data regression.

### Trend Analysis

After conducting the panel data analysis, some implications are made and linked to the current development of renewable energy consumption. Trend analysis emphasizes the changes and normally used to anticipate the future outcome of renewable energy demand. Trend analysis in this research will be conducted by collecting information about renewable energy consumption from multiple time periods and plotting them on a horizontal line for further review. Trend analysis will be useful for complementary analysis in this study as it intends to spot actionable patterns in the reported information. The trend analysis in this research will indicate 14 years of consumption of renewable energy within the time period of 2000 to 2014. Through this analysis, the trend of renewable energy development can be illustrated.

## Result and Discussion

### Data Description

**Table 1** Descriptive Statistics of Selected Variables

|                                             | Mean    | Std. Dev. | Min    | Max     |
|---------------------------------------------|---------|-----------|--------|---------|
| Renewable energy consumption (Million tons) |         |           |        |         |
| East Asia                                   | 8.83    | 22.07     | 0      | 102.28  |
| Southeast Asia                              | 5.77    | 5.49      | 0.24   | 23.62   |
| Natural gas consumption (Million tons)      |         |           |        |         |
| East Asia                                   | 45.16   | 33.62     | 17.03  | 161.96  |
| Southeast Asia                              | 48.64   | 25.39     | 18.22  | 105.25  |
| Real GDP per capita (billion USD)           |         |           |        |         |
| East Asia                                   | 3811.69 | 2360.17   | 710.03 | 8333.29 |
| Southeast Asia                              | 398.05  | 215.08    | 162.52 | 942.18  |
| Economic growth (%)                         |         |           |        |         |
| East Asia                                   | 5.01    | 4.21      | -5.42  | 14.23   |
| Southeast Asia                              | 4.87    | 2.16      | -1.51  | 8.86    |
| Access to electricity (% population)        |         |           |        |         |
| East Asia                                   | 99.30   | 1.45      | 94.80  | 100     |
| Southeast Asia                              | 94.35   | 5.21      | 82.1   | 100     |

**Source:** World Bank (2015) and British Petroleum Statistics Review (2015)

Table 1 presents the descriptive statistics of variables of interest in this study from 2000 to 2014. As a proxy of renewable energy development, renewable energy consumption in East Asia is higher than that of Southeast Asia. Differently, Southeast Asia slightly has higher natural gas consumption than that of East Asia. Since natural gas and renewable energy contribute in electricity share, in terms of macroeconomic conditions East Asia has larger real GDP per capita and faster economic growth, indicating that the region is wealthier and grows faster even though it has more variability in the data. East Asia also has more percentage of population with access to electricity.

#### *Objective 1: Correlation of Renewable Energy and Natural Gas Consumption*

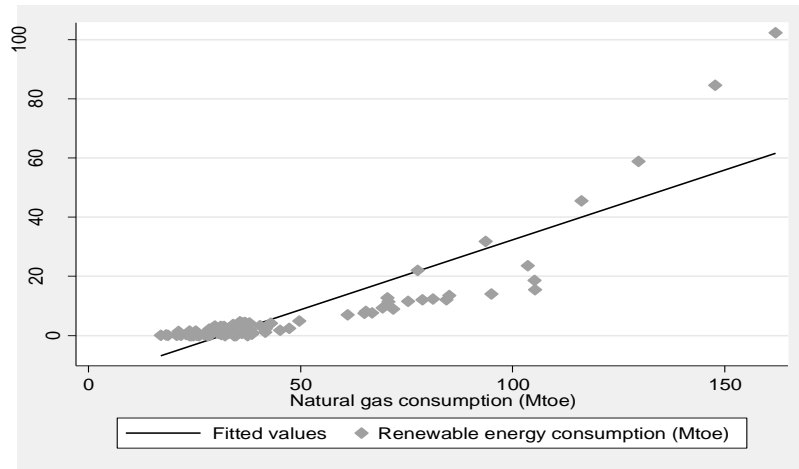
This section seeks to answer the first research question through the use of scatter diagram and coefficient correlation. Figure 1 describes the relationship between renewable energy consumption and natural gas consumption. Here, renewable energy consumption is calculated as the sum of consumption in solar, wind, geothermal, biomass and other renewables, while natural gas consumption exclude its conversion to liquid fuels but includes coal derivatives and gas-to-liquids transformation. Both energy consumptions are denoted in million tons oil equivalent.

If we aggregate all selected countries, the relationship between renewable energy consumption and natural gas consumption seems to be positive. As shown by the fitted line in panel (a), higher natural gas consumption is associated with higher renewable energy consumption. Formally, in order to check a statistical relationship between both variables, Pearson correlation coefficient is calculated. It is found that the correlation coefficient is 0.872. This statistical measure indicates strong relationship between renewable energy and natural gas consumption as its value approaches one.

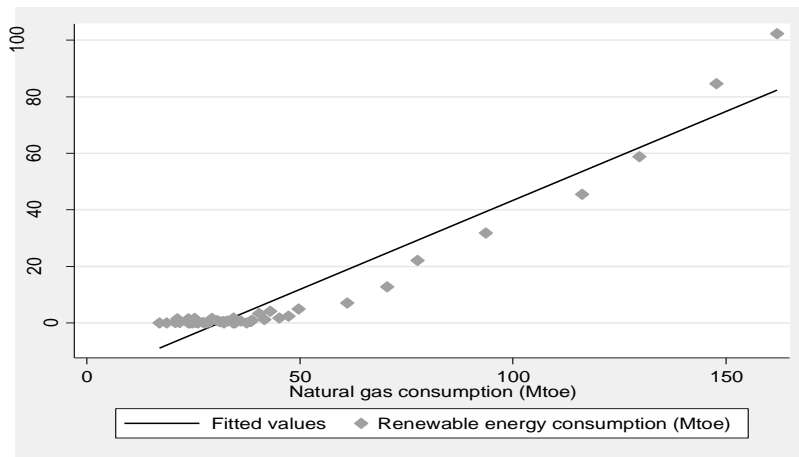


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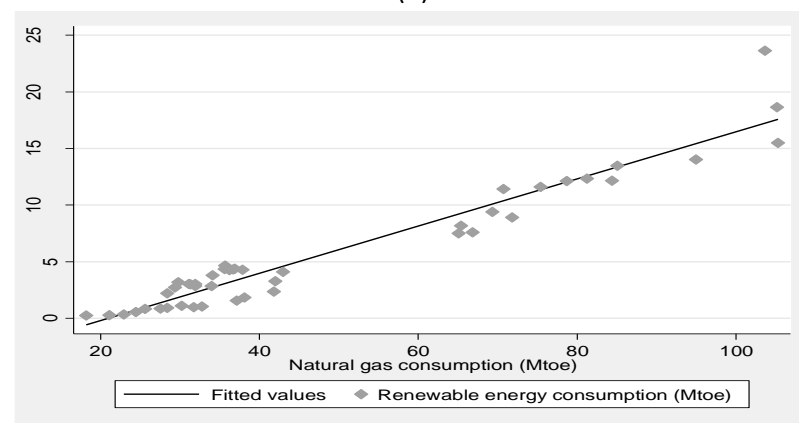
The Impact of Natural Gas Demand on Renewable Energy Development: ...



(a)



(b)



(c)

**Figure 2** Renewable Energy and Natural Gas Consumption in (a) Selected Asian Countries; (b) Selected East Asian Countries; (c) Selected Southeast Asian Countries

If we split the observations into two sub-samples the relationship between both variable looks more apparent. Both in East Asia and Southeast Asia, there seems to be a positive link between renewable energy and natural gas consumption as observed by the fitted lines in panel (b) and (c). In terms of Pearson correlation coefficient, the relationship between both variables indicated there is a slight stronger correlation in Southeast Asia with coefficient of 0.964 than in East Asia with 0.959. Nevertheless, these statistical figures do not imply that more consumption of natural gas causes higher share of renewable energy consumption in total energy demand, or otherwise. Since correlation does not necessarily mean causation, regression technique is then used to identify the causal effect of natural gas consumption to renewable energy demand.

*Objective 2 and 3: Regression Analysis & Causal Relationship.*

This section attempts to answer the second and third question of this study in subsection A and B, consecutively. A multiple regression model is then estimated by generalized least square (GLS) to find the causation of renewable energy demand based on natural gas consumption and selected macroeconomic indicators. The relevant variables are converted to logarithms. The dependent variable is renewable energy consumption, while the explanatory variables include natural gas consumption, real GDP per capita, economic growth, real exchange rate, access to electricity, and dummy variable for region.

The estimation results for each Asian region are shown in Table 1. Basically, the table presents the estimated coefficients for the parameter in the model. As mentioned in the previous section, autocorrelation and heteroscedasticity are common problem in panel data. In order to anticipate this issue, the standard errors are corrected to be robust for analysis as shown in the parentheses.

**Table 2** Summary of Regression Results

| Variables                                 | All Samples           | East Asia           | Southeast Asia       |
|-------------------------------------------|-----------------------|---------------------|----------------------|
| Log Natural Gas Consumption               | 2.476***<br>(0.319)   | 2.913***<br>(1.400) | 4.429***<br>(0.573)  |
| Log real GDP per capita                   | -0.406***<br>(0.135)  | -0.668<br>(0.637)   | 0.548<br>(0.353)     |
| Economic Growth (%)                       | 0.029<br>(0.034)      | -0.027<br>(0.035)   | -0.009<br>(0.010)    |
| Log Real Exchange Rate                    | -0.085<br>(0.053)     | 0.113<br>(0.199)    | -0.337***<br>(0.114) |
| Access to Electricity (% population)      | 0.057*<br>(0.032)     | -0.070<br>(0.654)   | -0.090***<br>(0.018) |
| Dummy (Southeast Asia = 1, East Asia = 0) | 0.424<br>(0.267)      |                     |                      |
| Constant                                  | -13.618***<br>(2.363) | -1.080<br>(58.827)  | -8.468***<br>(1.418) |
| R2                                        | 0.817                 | 0.843               | 0.846                |
| Observations                              | 90                    | 45                  | 45                   |

\*, \*\*, \*\*\*: significant at 10%, 5%, 1%

### **A. The Effect of Natural Gas Consumption on Renewable Energy Consumption**

Table 1 reveals that most of the coefficients are found to be statistically significant. The coefficient for natural gas consumption is positive and considerably high, particularly in the Southeast Asia. A rise in natural gas consumption by 1% will drive up the consumption for renewable energy by 4.43% in Southeast Asia on average, and up to 2.48% in all samples. This result indicates that an increase in natural gas consumption will be followed by a rise in renewable energy demand, implying that these energy sources are not competitors. They are not mutually exclusive yet rather complementary in many respects. Electricity generation from natural gas has low upfront capital costs and variable fuel costs, while renewable energy generators have higher fixed costs but zero fuel costs (Kim et al., 2012). Natural gas is the main input for production of corn starch ethanol fuel, and technology experiences could use of both forms of energy in vehicles.

Economically, natural gas is affordable and available on demand. It provides important support in the absence of sunshine or the wind. A Cal-Berkeley Professor, Richard Muller, stated that natural gas makes solar and wind energy penetrate electricity markets more easily through the provision of backup that those intermittent sources need. By nature it is clean and even it is the cleanest-burning fossil fuel. Natural gas emits around half as much carbon dioxide, one-fifth of carbon monoxide, and almost no sulphur dioxide or mercury. For these reasons, the consumption growth of natural gas and renewable energy is interdependent. That is why the result of this study exhibits that both of renewable energy and natural gas consumption seem to move together in the same direction over time.

Therefore, this finding implies that synergies between the natural gas and renewable energy industries should be encouraged. The business collaboration that capitalizes on both forms of energy can access new revenue flows including wholesale market opportunities for the distribution, arbitrage opportunities from shared infrastructure for upstream and downstream level, and energy services that offer reduced costs (Cochran et al., 2014). Policy makers can use this foundation to design complementary energy policies to guide the development of energy industry. Continued reliance on natural gas will support sustainable use of renewable energy in the energy market and help to reduce carbon emissions.

### **B. The Effect of Macroeconomic Indicators on Renewable Energy Consumption**

In the context of macroeconomic indicators, the real GDP per capita, which refers to country income, is shown to be inelastic and negative in all samples.

Even though the result is less apparent for the breakdown sub-samples, Asian countries tend to forego renewable energy consumption when their country income increases. As shown by negative coefficient, renewable energy can be regarded as inferior types of energy in Asian countries. It is estimated that 1% increase in GDP per capita will lower the renewable energy consumption by 0.406% on average in all samples. This result is different from similar studies which reveal that increase in real GDP per capita has a

positive impact on renewable energy consumption in emerging markets (Sadorsky, 2009; Apergis and Payne, 2010). This difference due to various reasons, such as differences in number of samples, methodology, and time-period. Sadorsky (2009) conducted larger sample of 18 countries whilst Apergis and Payne (2010) conducted a sample of 13 countries (1992 -2007). Although this research conducted with lesser sample, the time series data employed in this research is 2000-2014 which considered far recent than the previous studies. Sadorsky (2009) raw data collected with six years lesser than this study with time period of 1994-2003, whilst Apergis and Payne (2010) used data series period 1992-2007. Therefore, these differences may have accounted for the dissimilarity of the result.

Nonetheless, the coefficients for economic growth are insignificant implying that higher economic growth does not have any impact on the demand for renewable energy. This insignificant result may result from typical Asian countries as growing economies which shift from primary industrial sectors to less energy intensive of service sectors (Squall, 2007). Besides, there are numerous barriers and risks of taking up renewable energy technology. Compared to conventional generation technologies using fossil fuel, renewable energy technology has higher financial cost. By its nature, renewable energy technology is normally categorized by large up-front fixed costs even though its on-going operational costs are low since the fuel is free with minimal maintenance. For example, around 75% of the total cost for a wind turbine is associated with upfront cost, including the foundation, cost of turbine, electrical appliances, and grid-connection. Typically, wind power may be sold on long-term agreement with duration of 15-25 years to minimize the investment risks.

Moreover, long-term funding is often difficult to obtain in Asian Countries, which may be partly due to government control or other restrictions on long-term lending. Not only long-term financing but also access funds on a project finance basis become another issue to address in renewable energy technology. This financing issue will deter the use of renewable energy, especially in countries with main concern in affordability regardless the higher income or economic growth. Besides, lack of familiarity and experience with renewable energy technology becomes another barrier which makes policy makers unable to evaluate the feasibility and risks of the projects with confidence. Although the implication of renewable energy policy such as FiT and RPS can help to induce the renewable energy development in Asia with greater percentage, the performance and effectiveness of the scheme should be evaluated continuously. In significant to the result (table 1), policy makers should highlight the importance of GDP inelasticity plays an important role in helping to explain the renewable energy consumption.

The real exchange rate depreciation has impact on the renewable energy consumption only in Southeast Asia. The estimation shows that 1% currency depreciation will reduce the consumption of renewable energy by 0.337% on average in Southeast Asia. This negative coefficient implies that Southeast Asian countries would substitute with non-renewable energy when their respective domestic currency depreciates. One way to finance renewable energy investment is through foreign debt. If the debt is denominated in USD, unexpected depreciation in domestic currency would put a lot of pressure in re-

renewable energy project, make the investment more costly. As a consequence, renewable energy becomes less competitive than conventional fossil fuel energy while generating power project.

### C. The Role of Control Variables

The estimates also include the vector of controls. The table 1 shows that access to electricity is negatively associated with renewable energy consumption in East Asia. This finding implies that the more population covered by electricity, the less indication of their need for renewable energy. An exception is for Southeast Asia, where the coefficient of access to electricity is positive. More electricity access would drive these countries to demand for renewable energy. This result can be explained by the different characteristics of electricity access in East Asia and Southeast Asia in which most of East Asian countries have the whole population accessing the electricity. Majority of Southeast Asian people are living in rural areas, while most of them utilize traditional biomass.

The result estimates that any 1% increase in access to electricity will lead to lower the renewable energy consumption by 0.09% in Southeast Asia. Meanwhile, the insignificant estimate in dummy region shows that there are no different patterns of renewable energy consumption between East Asia and Southeast Asia. It is different from Southeast Asian countries that still require more demand for an alternative energy to generate electricity power which is expected to accommodate the entire population. Meanwhile, the insignificant estimate in dummy region shows that there are no different patterns of renewable energy consumption between East Asia and Southeast Asia.

### D. Goodness of Fit (R<sup>2</sup>)

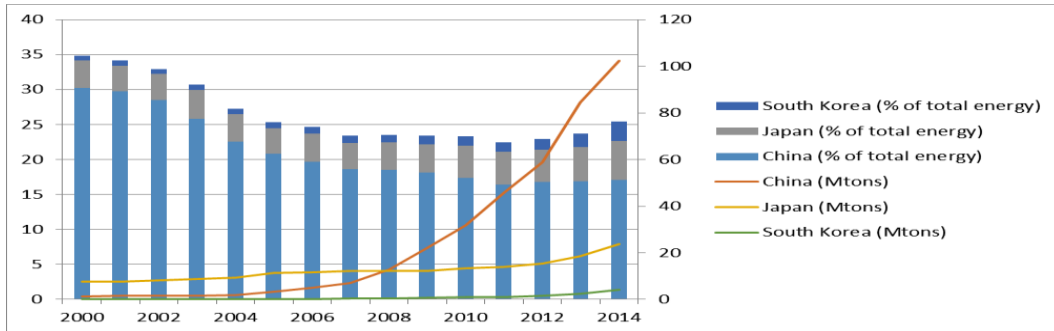
This statistics measures of how fit the data are to the regression line based on the percentage of the dependent variable variation explained by a regression model. It is also called as the goodness of fit. The value of R<sup>2</sup> is always between 0 and 100%. The closer the R<sup>2</sup> to 0 defines the less variability of the response data is around its mean. While the closer R<sup>2</sup> to 100%, it means the more variability of the response data around its mean. Generally, when the R<sup>2</sup> gets higher, the better the model fits the data. In this model, the R<sup>2</sup> values are quite high as shown in the table. The selected variables account for more than 80% of the variation in renewable energy consumption, while the remaining 20% is attributed to unknown. Hence, it can be said that the regression model here fits the data well.

#### *Objective 4: Trend Analysis*

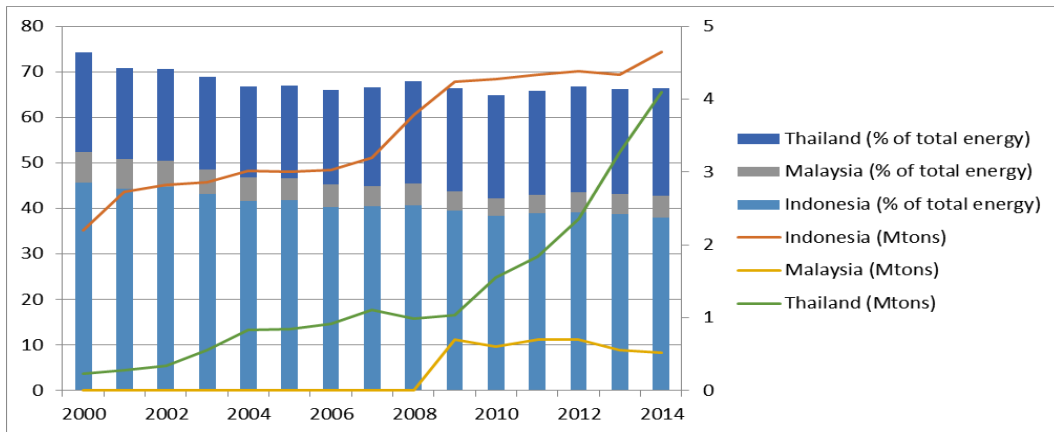
Basically, this section attempts to answer the fourth question of this study. Figure 2 shows the development of renewable energy consumption during the last fifteen years in East Asian countries and Southeast Asian countries. It can be seen that East Asian countries tend to have positive trend of renewable energy consumption. However, its shares to total consumption of final energy are relatively stagnant after its gradual declines from 2000 to 2006.

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**Figure 2** Renewable Energy Consumption in Selected East Asian Countries  
**Source:** BP Statistical Reviews (2015) and World Bank (2015)



**Figure 3** Renewable Energy Consumption in Selected Southeast Asian Countries  
**Source:** BP Statistical Reviews (2015) and World Bank (2015)

From the graph, it can be seen that renewable energy is less preferable in East Asian countries as its shares to total final energy consumption are relatively low, ranging from 3% to 17% in 2014. It is probably due to intermittent and inconsistent characteristics of wind and solar which makes them difficult to control.

Indicated from the graph, In Southeast Asia (the selected countries) have similar pattern to that of East Asia as shown by positive trend in renewable energy consumption in Figure 3. In terms of its shares to total final energy consumption, renewable energy seems to be more favorable to use in Southeast Asia rather than East Asia. In Indonesia, the renewable energy shares in total energy consumption reach up to 40%, while its shares are more than 20% in Thailand. However, similar to East Asia, the trend of renewable energy shares is relatively stagnant and does not change substantially.

Such consumption pattern indicates that significant investments in renewable energy are required. A study from IRENA and ACE in 2016 asserts that USD 290 billion of total investment in renewable energy capacity is essential to achieve the target of securing 23% of primary energy from renewable sources by 2025 in Southeast Asia. The study suggests

that the Southeast Asian countries should invest around USD 27 billion per year to achieve the recommended amount. Instead of utilizing existing government plans, investments from fossil fuels can be redirected and more mobilization of the fund will be required. Hence, investment in renewable energy needs to be scaled up, particularly by selecting appropriate financial instruments. Efficiency thus becomes a key to choose suitable financial instruments to support investment in renewable energy. The objective should be to use any instruments that bring the largest amount of private financing for the smallest amount of public funds. Also, instruments must be selected by taking into account the capabilities of local agencies and local financial markets.

## **Conclusion**

The first evidence shows result suggesting that there is a significant correlation between natural gas and renewable energy consumption. The relationship between both variables indicated there is a slight stronger correlation in Southeast Asia with coefficient of 0.964 than in East Asia with 0.959. Nevertheless, these statistical figures do not imply that more consumption of natural gas causes higher share of renewable energy consumption in total energy demand, or otherwise. Since correlation does not necessarily mean causation. A rise in natural gas consumption by will drive up the consumption for renewable energy in both regions. In contrast, the increase in economic growth would increase the portion of renewable energy in East Asia and oppositely in Southeast Asia.

The Second result estimated that 1% increase in GDP per capita will lower the renewable energy consumption by 0.406% on average in all samples. Positive result indicated in the previous studies conducted by Sadorsky (2009) Apergis and Payne (2010) which revealed positive impact on renewable energy consumption in emerging markets. This difference due to various reasons, such as differences in sample countries, methodology, and time-period. Although the previous studies conducted with bigger sample, this study employed the recent data.

The third result is on the trend of renewable energy consumption in both East and Southeast Asia. The pattern exposed that Southeast Asia has a higher consumption percentage than East Asia in period 2000 to 2014. Although the consumption in Southeast Asia is higher, it shows that Malaysia and Indonesia consumption is slightly sloping down while Thailand is steadily sloping upward. In this respect, Thailand has implemented FIT earlier in 2007 than Malaysia in 2011 and Indonesia in 2014. This may have caused the development of renewable energy in Thailand more eager than Malaysia and Indonesia. Regardless, the growth enhancing and energy policies should varies in accordance to their own characteristics (dominant resources, major sectors, population).

Natural gas consumption is expected to continuously increase and is still largely used in Asia. With the contribution from renewable energy, both energy can feed the demand for electricity. A set of recommendations are constructed to enhance the speed of renewable energy development: Natural gas and renewable energy are not mutually exclusive but rather complementary in many respects. Employing renewable energy project for natural

gas producers could bring benefits since both natural gas and renewable energy could produce electricity. This could be attained by collaboration of expert from both natural gas and renewable energy and consider the important elements such as: technology, economy, environment, energy quality and socio-political.

Enhance the collaboration between private stakeholders and public sectors by sharing information across countries relating technologies, potential resources and most importantly the financing and investment strategies in order to develop the renewable resources.

Proactive in promoting renewable energy policies such as FiT and RPS in order to attract investors for electricity installation generated from renewable energy. The benefits may promote the expansion of renewable energy development. The characteristic of FiT and RPS may varies in each countries. Designing effective renewable energy in Asia requires a good understanding of the relationship between GDP and renewable energy consumption. In relation to the mentioned result, policy makers could imply attractive rate for PV installation. Nevertheless, mechanism such as tax should be transparently communicated.

### Research Limitation

This research has limitation in the methodology. Firstly, the author conducted the analysis with single method quantitative while combination of qualitative and quantitative research method will allow better result although it may require complex analysis and require more time. Through qualitative method, this will allow the author to study the real and major barrier to renewable energy from the investors' point of view.

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