Analysis of Relationship between Energy Intensity and Income Per Capita: A Comparative Study on Ten Asia Pacific Countries[1]

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Abstract

Energy availability and consumption play an important and strategic role in generating economic growth. One common measurement used in analyzing energy-GDP relationship is energy intensity, which is the amount of energy required to produce a unit of income (GDP). This research examines relationship between energy intensity and income per capita for ten Asia Pacific countries with various economic performances over the period of 1980-2005. Using static and dynamic panel data models, energy consumption and energy intensity are expressed as quadratic logarithmic function of income per capita, squared income per capita, and energy price. As a result, the long run coefficient of income per capita is greater than one and the long run coefficient of squared income per capita is negative. It describes that energy intensity has quadratic relationship with income per capita, and indicating a change in trend of energy intensity. This research also analyzes responses of energy consumption and energy intensity to the change of energy price and income per capita in both the short run and long run. The price elasticity is negative and very inelastic; it means the response of energy consumption with respect to the change in energy price is relatively low.

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However, the estimation results are also show that the income elasticity is positive but tends to decrease slightly over time. Here, the estimated value of income elasticity varies across countries where the high income countries have lower elasticities than those of the middle-low income countries.

Keywords: *dynamic panel data, static panel data*, *energy intensity, income per capita, dematerialization JEL Classification*: Q40, Q43, Q48

I. Introduction

Energy availability and consumption play an important and strategic role in generating economic growth. Energy use is a key to industrialization, development of industrial and infrastructural facilities. Some infrastructures like roads, bridges, factories, and transportations networks are among the most energy intensive of these facilities. Chontanawat, Hunt, and Pierse (2006) suggest that energy plays an essential role in an economy on both demand and supply sides. On the demand side, energy is one of the products a consumer decides to buy to maximize his or her utility. On the supply side, energy is a key factor of production in addition to capital, labor and materials and is seen to play a vital role in the economic and social development of countries, being a key factor in increasing economic growth and living standards.

The paradox when dealing with energy is that it is needed for human lives and development process, at the same time, unplanned developmental activities focusing on fossil fuel are affecting the environment. Moreover, the rapid growth of human population, the economic growth, and the way countries develop lead to an increasing demand for energy. The common problems arise with expanding energy consumption are twofold. First, pollution associated with energy usage increases, leading to unknown changes in world climate that could have tremendous repercussions. Second, the fossil fuels commonly used are not renewable, so it could lead to energy scarcity in the future.

Nonetheless, energy is an essential input to running economic activities in a country. From its activities then will be produced an output (goods and services), which is an important parameter to measures an economic growth. Therefore, energy use is a key and crucial determinant in the process of economic growth. One common measurement used in analyzing energy use-GDP relationship is energy intensity, which is the amount of energy required to produce a unit of income (GDP). The concept of energy intensity (the ratio of energy consumption to gross domestic product), and energy elasticity (the ratio of the percentage change in energy consumption to that of GDP), have been used frequently in predicting energy needs, in comparing energy use efficiency, and in assessing the impact of energy on the economy. In addition, energy intensity can be used to show the capability of a country in term of managing its energy use to produce a unit of GDP.

The impact of more efficient energy use in reducing energy consumption and the overall prospects for restraining energy consumption growth are important issues in the context of environmental policy. Energy intensity is directly related to price signals, whereas energy efficiency depends more on the diffusion of the most cost effective technologies. It is important to point out where the losses of energy are the highest in order to reduce them. Some developed countries have lower or similar energy consumption per capita and a much higher per-capita gross domestic product (GDP) than certain developing countries. Energy services will be fulfilled only if GDP grows in a sustainable manner. Such economic growth will require the provision of corresponding energy-related services at an affordable price with no reasonable expectation to break the linear relationship between GDP growth and the increase in the energy demand that has been experienced so far[5].

The Asia Pacific countries were investigated in this research has been growing rapidly in economic during last decade, although with various economic performance across-countries. There are many new industries were developed and growth that not only gave an impact to their domestic economic but also to the regional and the world economic. The rapid economic growth and industrial development in these countries on eventually become a main factor that increases energy demand not only in the Asia Pacific region but also in the world. In addition, there are several developed countries in this region that consume the most energy on the world, namely United States, Canada, and Japan. Therefore, the dynamics of energy consumption in this region along with its influence factors become more interesting to analyze.

The increasing of world energy demand, in fact, coincides with increasing in world crude oil price. Energy Information Administration (EIA) noted that since 1980s, although the world crude oil price fluctuated, but it tends to increase over time. And since 1999, the price

[5] See World Energy Council in Ramachandra et al. (2006)

experience in significant increased and run consistently for around next eight years. This condition, at last, caused many countries have been tried to find other energy sources and lead up their conventional energy (fossil fuel) consumption to their own energy source that they can produce.

The dynamics of world energy demand, especially due to the crude oil demand in Asia Pacific countries is seen by many economists as crucial to the outlook for world oil price. It's thus important and crucial for short to long forecast of global energy market in order to planning energy requirement for the future. One of the efforts that can be done is with analyzing the trend of energy intensity to know the dynamics of energy consumption as well as its influence factors.

Across countries, energy intensity does not appear to be constant. Malenbaum (1978) suggested hypothesis of "intensity of use" and states that income is the main factor that explains the consumption of energy and materials. That is, during the process of economic development, countries would tend to increase consumption of energy and materials at the same rate as growth in income, until one defined critical level of income is reached. In this case, energy intensity would increase along with the increasing of income. But then, further increase in the level of income will no longer be followed by increase of energy and material consumption. In this case, energy intensity would decrease along with the increasing of income. This phenomenon can be described by inverted-U shape curve or known as Environmental Kuznets Curve (EKC).

The objectives of this paper are to analyze the dynamics of energy intensity and energy consumption in the relation with income per capita and energy price, to know whether the relationship between energy intensity and income per capita appropriate with the EKC hypothesis, to know response of energy consumption per capita toward change in income per capita and energy price both in short run and long run on ten Asia Pacific countries, and try to formulate policy recommendations according to the three point of results analysis above.

II. The Theory of Environmental Kuznets Curve (EKC)

The relationship between economic development and various indicators of environmental degradation (i.e. emission level, pollution, energy intensity, etc) is a very strategic issue. Natural resources provide various inputs in order to produce many goods and services. Meanwhile, goods and services that produced in an economic are determinant of economic activities in a country which is measure through economic growth. Therefore, natural resource availability becomes an important and a strategic factors for economic in a country. On the other hand, natural resource usage requires fulfilled the principles of environmentally friendly. If the methods of production were not changed (to be more efficient and environmentally friendly), then it could cause environmental degradation. And, if it's not anticipated, then the damage to the environment would be linked to the scale of global activity.

In the last few years, several studies have tried to identify empirical problem due to the reducing impact of economic development to the environmental degradation. Some studies found that at very low level of economic activity, environmental impact are generally relatively low. This condition generally occurs in pre-industrial countries which are based on agriculture. But along with the development proceeds, environmental degradation increases rapidly. This condition generally occurs in developing countries. At higher level development, economic growths eventually redress the environmental impact of the early stages of the development and that growth lead to further environmental improvements or tend to fix environmental problems. This situation generally occurs in developed countries. At this stage development, the forces leading to change in the composition and techniques of production may be sufficiently strong to offset the adverse effects of increased economic activity on the environment.

The phenomenon above can be described through Environmental Kuznets Curve (EKC). EKC is a hypothesis about relationship between various indicators of environmental degradation and stage of development as indicated by income per capita. One of the studies that discussing about EKC have tried to analyze relationship between energy intensity and income per capita (Janicke *et al.* (1989), Ausubel *et al.* (1993), Simon *et al.* (1994), Galli (1998), Galli (2001), and Fisher-Vanden *et al.* (2003).

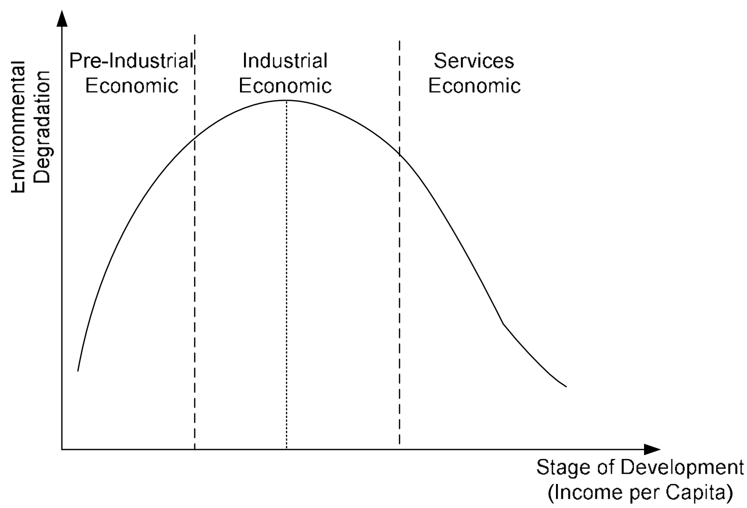

Figure 1. Environmental Kuznets Curve: Relationship between Economic Development and Environmental Degradation
(Source: Panayotou 1993)

III. Energy Intensity and Its Determinants

Intensity of energy use, known as energy intensity is defined as ratio of energy consumption (usually is measured by total final energy consumption in tons of oil equivalent (TOE), or other physical units, that the economy consumes) to gross domestic product (GDP). Energy intensity also represents the amount of energy required to produce one unit of GDP. The relationship between energy consumption and GDP which is described as energy intensity is relevant not only for it affects future trends of development of all economies, but especially because it brings to discussion the issue of sustainability.

The concept of energy intensity predicts that the amount of energy consumed in an economy depends on two relationships (Chima *et al.* 2007). The first assumes that energy intensity is a function of its level of economic development as indicated by income per capita (GDP/P). For any given year, this relationship is represented by

$$IE = f\left(GDP/P\right) \qquad (1)$$

Here, *IE*, *GDP*, and *P* denote energy intensity, gross domestic product, and population respectively.

Empirically, the exact specification or nature of equation (1) can be determined, but would vary from one energy source to another (Chima *et al.* 2007). Generally, the basic shape of energy intensity model is represented by an inverted U-shaped curve, equivalent with the EKC. In the energy intensity model (see Figure 2), the horizontal axis of the graph usually represents real per capita income (GDP per capita), whereas the vertical axis represents energy intensity.

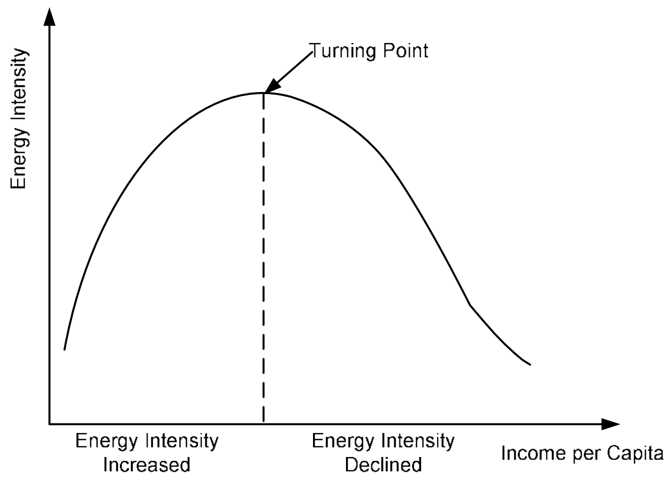

Figure 2. Environmental Kuznets Curve: Relationship between income per Capita and Energy Intensity

(Source: Chima *et al.* 2003)

The implication of the energy intensity model is that at the early stages of economic development, when income per capita is still relatively low, energy consumption is also relatively low. This condition usually occurs in agrarian country where main economic activity is based on agriculture. But this condition is no longer continue, as industrialization occurs, there are many investments in basic industry, infrastructure, and other energy, where all of these activities require higher energy consumed than before. This situation in turn will cause energy consumption per unit income to rise sharply and reflected by sloping part of the inverted-U shaped curve. As economic growth and development continues, the demand for infrastructures such as roads, factories, bridges, railway track and other facilities are eventually satisfied, and the composition of national output shifts gradually towards services.

The second relationship advanced by the energy intensity concept is the identity equation where country's consumption energy (D) in any year *t*, to the product of energy intensity (IE) and its GDP (see equation (2)).

$$D = (IE) \cdot (GDP) \qquad (2)$$

The *IE* is composed of two determinants, the product composition of GDP (mix goods and services that economic produces) and the energy composition products (the amount of energy consume in economy to produce the mix of goods and services).

A comprehensive study of the possible explanations for the change of trend in resource (energy and materials) intensity is suggested by Bernardini and Galli (1993). They point out three fundamental factors leading to the decline in intensity of use of energy and materials. The first fundamental factor is changes in structures of final demand. This factor describes that as national economies developed, the structure of final demand changes and this changes the intensity of energy and material use. The second fundamental factor leading to decline in intensity of use is the increase in the efficiency of use of energy and materials enabled by technological progress. And, the third fundamental factor for the decline in intensity of resource use is the substitution of more efficient materials and fuels.

IV. Data and Data Collections

The analysis of relationship between energy intensity and income per capita undertaken in this paper is based on secondary data that collected from various sources. These are panel data, which pool time series (1980-2005) and cross-section ten Asia Pacific countries with various economic performance, namely Philippines, Hongkong, Indonesia, Japan, South Korea, Malaysia, Singapore, Taiwan, Thailand, and USA.

The number of effective observation for each variable is thus 26 X 10 = 260 observations.

The data consist of variables as follows: population, real GDP, real per capita GDP, total final energy consumption, total final energy consumption per capita. Our measure of real per capita GDP comes from the Penn World Table (mark 6.2) which use Laspeyres index in 2000 international price and adjusted by purchasing power parity with 2000 as base year. According to Galli (1998), this is the best measure of income per capita available for cross-country studies because it avoids problem of using current exchange rates to convert income in local price to a common currency.

The variable we are interested in explaining and predicting is energy intensity which defined as ratio between total final energy consumption to real GDP. Energy consumption is measured in tons of oil equivalent (TOE) and then divided by population to give a per capita series so that it can be compared across-countries. Here, the final energy consumption that used in this study consists of energy types as follows: coal and coal products, crude oil and petroleum products, gas, and electricity. Meanwhile, the energy price being used in this paper is the average price of main fuel (gasoline and diesel oil) in domestic currency and then converted to US dollar, and adjusted with purchasing power parity to get a real price. The mnemonics of variables and their source are summarized in Table 1.

Table 1. Basic Variables Analyzed in This Study

Mnemonics	Variable	Measurement Unit	Source
GDP	Real GDP (PPP adjusted, 2000=100)	US$	PWT (Mark 6.2)
Pop	Population	Thousand people	PWT (Mark 6.2) and EIA
P	Energy price (average price of main fuel, PPP adjusted, 2000=100)	US$ per liter	ADB and CEIC
Q	Total final energy consumption	Thousand TOE	IEEJ
GDP/Pop	Real per capita GDP (PPP adjusted, 2000=100)	US$ per people	PWT (Mark 6.2) and EIA
Q/Pop	Total final energy consumption	TOE per 10000 people	PWT (Mark 6.2), BP, and EIA
Q/GDP	Energy intensity	TOE per $10000 GDP	PWT (Mark 6.2) and EIA

V. The Statistical Model and Estimation Methods

The model that widely used to examines EKC hypothesis is a logarithmic quadratic model (Grossman & Krueger 1991, Stern & Common 2001). The model is represented by function of indicator of environmental degradation to per capita GDP. Meanwhile, Galli (1998) appends a domestic energy price variable to the model in order to examine EKC hypothesis due to the relationship between per capita energy consumption and energy intensity. The model that will be used on this study is based on Galli (1998). Here, that model is represented by:

$$\ln\left(\frac{Q}{Pop}\right)_{it} = \alpha_0 + \alpha_1 \ln\left(\frac{GDP}{Pop}\right)_{it} + \alpha_2 \left(\ln\left(\frac{GDP}{Pop}\right)_{it}\right)^2 + \alpha_3 \ln P_{it} + v_{it} \qquad (3)$$

Here, $\left(\frac{Q}{Pop}\right)_{it}$, $\left(\frac{GDP}{Pop}\right)_{it}$, P_{it} denote per capita energy consumption, real per capita GDP, and energy price for country *i* and year *t* respectively. In addition, v_{it} denotes disturbance.

The formulating of static and dynamic panel data model on this study is based on Galli (1998) that used Error Correction Model (ECM) approach. Furthermore, from equation (3), disequilibrium error could be expressed by:

$$e_{it} = \ln\left(\frac{Q}{Pop}\right)_{it}^{*} - \ln\left(\frac{Q}{Pop}\right)_{it} \qquad (4)$$

Where

$$\ln\left(\frac{Q}{Pop}\right)_{it}^{*} = \alpha_0 + \alpha_1 \ln\left(\frac{GDP}{Pop}\right)_{it} + \alpha_2 \left(\ln\left(\frac{GDP}{Pop}\right)_{it}\right)^2 + \alpha_3 \ln P_{it} + v_{it} \qquad (5)$$

denotes long run equilibrium values for per capita energy consumption and $\ln\left(\frac{Q}{Pop}\right)_{it}$ denotes actual values for per capita energy consumption. And then, from equation (5), could be derived function of energy intensity in the long run as:

$$\ln\left(\frac{Q}{GDP}\right)_{it}^{*} = \varphi_0 + (\varphi_1 - 1)\ln\left(\frac{GDP}{Pop}\right)_{it} + \varphi_2 \left(\ln\left(\frac{GDP}{Pop}\right)_{it}\right)^2 + \varphi_3 \ln P_{it} \qquad (6)$$

According to Galli (1998), because equations (5) and (6) was a long run equilibrium values for per capita energy consumption and energy intensity, then this model allowing for an adjustment toward such long run equilibrium, if it exist, as well as for flexible short-run dynamics. Therefore, we use an ECM representation, in which energy demand is adjusted in response to the change in per capita GDP and energy price, and to the difference between long run equilibrium and actual per capita energy consumption in the previous period. Furthermore, ECM representation for static panel data model is expressed by:

$$\begin{aligned}\Delta \ln\left(\frac{Q}{Pop}\right)_{it} &= \beta_0 + \beta_1 \Delta \ln\left(\frac{GDP}{Pop}\right)_{it} + \beta_2 \Delta \ln P_{it} \\ &+ \lambda_1 \left(\ln\left(\frac{Q}{Pop}\right)^{*}_{i,t-1} - \ln\left(\frac{Q}{Pop}\right)_{i,t-1} \right) + \varepsilon_{1it}\end{aligned} \tag{7}$$

whereas dynamic panel data model (expanded from equation (7)) is formulated by:

$$\begin{aligned}\Delta \ln\left(\frac{Q}{Pop}\right)_{it} &= \psi_0 + \psi_1 \Delta \ln\left(\frac{GDP}{Pop}\right)_{it} + \psi_2 \Delta \ln P_{it} \\ &+ \lambda_2 \left(\ln\left(\frac{Q}{Pop}\right)^{*}_{i,t-1} - \ln\left(\frac{Q}{Pop}\right)_{i,t-1} \right) + \gamma \Delta \ln\left(\frac{Q}{Pop}\right)_{i,t-1} + \varepsilon_{2it}\end{aligned} \tag{8}$$

In equations (7) and (8), λ_1 and λ_2 are the speed of adjustment toward the long run level. By substituting $\ln\left(\frac{Q}{Pop}\right)^{*}_{i,t-1}$ in equation (5) to equations (7) and (8), then it could be obtained the new ECM representation for static panel data model as:

$$\begin{aligned}\Delta \ln\left(\frac{Q}{Pop}\right)_{it} &= \delta_0 + \beta_1 \Delta \ln\left(\frac{GDP}{Pop}\right)_{it} + \beta_2 \Delta \ln P_{it} + \beta_3 \ln\left(\frac{GDP}{Pop}\right)_{i,t-1} \\ &+ \beta_4 \ln P_{it} + \beta_5 \ln\left(\frac{Q}{Pop}\right)_{i,t-1} + \beta_6 \left(\ln\left(\frac{GDP}{Pop}\right)_{i,t-1} \right)^2 + \varepsilon_{1it}\end{aligned} \tag{9}$$

whereas the new ECM representation for dynamic panel data model is formulated by

$$\Delta \ln\left(\frac{Q}{Pop}\right)_{it} = \eta_0 + \psi_1 \Delta \ln\left(\frac{GDP}{Pop}\right)_{it} + \psi_2 \Delta \ln P_{it} + \psi_3 \ln\left(\frac{GDP}{Pop}\right)_{i,t-1} + \psi_4 \ln P_{it}$$
$$+ \psi_5 \ln\left(\frac{Q}{Pop}\right)_{i,t-1} + \psi_6 \left(\ln\left(\frac{GDP}{Pop}\right)_{i,t-1}\right)^2 + \gamma \Delta \ln\left(\frac{Q}{Pop}\right)_{i,t-1} + \varepsilon_{2it} \quad (10)$$

The long run coefficients for static panel data model could be obtained from equations (5), and (9), that is:

$\varphi_1 = -\beta_3/\beta_5$, $\varphi_2 = -\beta_6/\beta_5$, and $\varphi_3 = -\beta_4/\beta_5$ (10a)

where, $\lambda_1 = -\beta_5$ and $\delta_0 = (\beta_0 - \beta_5\varphi_0)$.

Meanwhile, by substituting equations (5) and (10), the long run coefficients for dynamic panel data model are obtained by:

$\varphi_1 = -\psi_3/\psi_5$, $\varphi_2 = -\psi_6/\psi_5$, and $\varphi_3 = -\psi_4/\psi_5$ (10b)

where, $\lambda_2 = -\psi_5$ and $\eta_0 = (\psi_0 - \psi_5\varphi_0)$.

The non-linearity (quadratic) of the relationship between per capita energy consumption (and energy intensity) and per capita GDP implies that per capita GDP elasticity of per capita energy consumption (and energy intensity) depends on per capita GDP level. In terms of equation (5), the long run per capita GDP elasticity of per capita energy consumption is $\varphi_1 + 2\varphi_2\left(\ln\left(\frac{PDB}{Pop}\right)\right)$, whereas the long run per capita GDP elasticity of per capita energy intensity is $(\varphi_1 - 1) + 2\varphi_2\left(\ln\left(\frac{PDB}{Pop}\right)\right)$, and the long run price elasticity of per capita energy consumption is φ_3. Based on theoretical expectation, we expect $\varphi_3 < 0$, i.e., the long run price elasticity is negative, and $\varphi_1 > 1, \varphi_2 < 0$, i.e., the long run per capita GDP rises and then fall with income; as discussed above. Meanwhile, the turning point per capita GDP, where energy intensity is at a maximum, is given by:

$$\left(\frac{GDP}{POP}\right)_{it}^{**} = \exp\left(\frac{(1-\varphi_1)}{2\varphi_2}\right) \quad (11)$$

At the turning point (equation (11)), the long run per capita GDP of per capita energy consumption equals unity. As long as $\varphi_2 < 0$ and $\varphi_1 > 1$, when $\left(\frac{GDP}{Pop}\right)_{it} < \left(\frac{GDP}{Pop}\right)_{it}^{**}$, energy intensity is increasing and the effect of per capita GDP growth on energy consumption is more than proportional. The opposite is true for $\left(\frac{GDP}{Pop}\right)_{it} > \left(\frac{GDP}{Pop}\right)_{it}^{**}$.

As discussed above, our model is based on panel data using both static and dynamic approach. The application of estimation methods which exploit so-called panel data model have become increasingly prominent in both theoretical and applied microeconometric literature. This popularity is in a part a consequence of the increased availability of data of this type, coupled with the ability for panel data studies to answer questions not possible either from a cross-section context or with a pure time series.

Furthermore, the estimation methods in order to get parameter estimation on both models are divided into two sections. *First*, three basic estimation methods are used to estimate parameter in static panel data model (equation (9)), that is, pooled Ordinary Least Square (OLS), Fixed Effects Model (FEM), and Random Effects Model (REM). In the OLS methods, perhaps this is the simple approach to the estimates of static panel data model assumes the individual effect are fixed and common across economic agents. This leads straightforwardly to a classical linear regression formulation, for which OLS will produce consistent and efficient estimator. When the individual effects are fixed but not common across economic agents, the pooled estimator is evidently biased through the misspecification of the mean equation (static panel model). Therefore, to solve this problem, it can be used the FEM specifications.

The fixed effects model (FEM) is appropriate when differences between individual agents may reasonably be viewed simply as parametric shifts in the regression function itself. This might be considered reasonable if the cross-sectional used in estimation represents a broadly exhaustive sample of the population of economic agents, as might be the case in a study which covers a full sample of countries, or in a study of the performance of firms in a particular industry, where the sample of firms represents a broadly complete coverage of those within the industry. If, on the other hand, the cross-section is drawn from a larger population (so that the sample of cross-sectional agents may not reasonably be considered exhaustive) then it may be more appropriate to view the individual-specific terms in the sample as randomly distributed effects across the full cross-section of agents, and this would suggest a random effects model (REM).

Second, in dynamic panel data model, due to the presence of the lagged dependent variable as a regressor (see equation (10)), obtaining unbiased and consistent estimates requires the application of an instrumental variables estimator or known as Generalized Methods of Moments (GMM). We adopt here the estimator proposed by Arellano and Bond (1991) who argue that additional instruments can be obtained in a dynamic model from panel data if we utilize the orthogonality conditions between lagged values of the dependent and the disturbances. This is a

GMM estimator, which is a non-linear instrumental variables estimator. It relies on the assumption that the disturbances in the equation are uncorrelated with aset of instrumental variables. This GMM estimator is robust, as it does not require information of the exact distribution of the disturbances. The estimators considered in this paper exploit optimally all the linear moment restrictions that follow from particular specifications and offer significant efficiency gains compared to simpler instrumental variables alternatives.

VI. Estimation Results

Table 2 provides the estimates of the coefficients in both static (equation (9)) and dynamic (equation (10)) panel data model. The estimation coefficients of static panel data model are obtained by applying three estimation methods, namely OLS, FEM, and REM. Meanwhile, the estimation coefficients of dynamic panel data model are gained by imposing Arellano-Bond GMM procedure. Generally, the estimates of the coefficients resulted from four estimation methods are relatively well behaved. These are shown by all of the estimates of the coefficients which almost significant at three conventional significance levels (0.01, 0.05, and 0.10). On the other hand, the signs of the coefficients are appropriate with theoretical expectation.

For static panel data model, which are three estimation methods (OLS, FEM, and REM) are imposed; the FEM is more favor than OLS and REM. It can be seen from the values of Chow-test statistic (4.44) and Hausman-test statistic (27.29) which are significant at 1% level. The result of Chow-test indicates FEM is more favor than OLS, whereas the result of Hausman test indicates FEM is more favor than REM.

Meanwhile, the validity and consistency of estimator is shown by AB-GMM estimation in dynamic panel specifications. It can be seen from the value of Sargan-test statistic (219.05). This result indicates that instrumental variables imposed on estimation are valid for 1% level. In addition, the consistency of estimators of AB-GMM are shown by the values of m_1 statistics (-2.01) and m_2 statistics (0.72) which are significant at 5% level and insignificant at 5% level respectively.

Table 2 . Estimation Results of Real per Capita Energy Consumption Function

	Static Model			Dynamic Model
	OLS	FEM	REM	AB-GMM
Constant	-1.711 ***	-2.381 ***	-1,671 ***	-3,442 **
	(0.543)	(0.798)	(0,566)	(1,352)
$\Delta \ln\left(GDP/Pop\right)_{it}$	0.578 ***	0.538 ***	0,570 ***	0,550***
	(0.093)	(0.094)	(0,093)	(0 ,096)
$\Delta \ln P_{it}$	-0.038 *	-0.055 ***	-0,039 **	-0,065 ***
	(0.019)	(0.019)	(0,019)	(0,020)
$\ln\left(GDP/Pop\right)_{i,t-1}$	0.405 ***	0.673 ***	0,396 ***	0,976***
	(0.122)	(0.188)	(0,128)	(0,316)
$\ln P_{i,t-1}$	0.001	-0.013	0,001	-0,016 *
	(0.006)	(0.008)	(0,007)	(0,010)
$\ln\left(Q/Pop\right)_{i,t-1}$	-0.025 ***	-0.158 ***	-0,026 ***	-0,226 ***
	(0.009)	(0.029)	(0,009)	(0,039)
$\left(\ln\left(GDP/Pop\right)_{i,t-1}\right)^2$	-0.021 ***	-0.027 ***	-0,020 ***	-0,040 ***
	(0.006)	(0.014)	(0,007)	(0,016)
$\Delta \ln\left(GDP/Pop\right)_{i,t-1}$	-	-	-	0,004
				(0,051)
F-Test	11.12 [0.000]	10.85 [0.000]	-	-
Wald Test	-	-	61,75 [0,000]	80,83 [0,000]
Chow F-Test		4.44 [0.000]		-
Breusch-Pagan LM Test		0.77 [0.381]		-

Hausman Test	27.29 [0.000]	-
Sargan Test	-	219.05 [0.040]
Arellano-Bond m_1	-	-2.021 [0.043]
Arellano-Bond m_2	-	0.718 [0.473]

Note:

*** 1% significance level

** 5% significance level

* 10% significance level

Values in ( ) and [ ] denote standard error and p-value respectively

The long run coefficients for static and dynamic panel data model could be obtained by imposing the estimation results presented in Table 2 into equations (10a) and (10b). These long run coefficients are summarized in Table 3. As can be seen from Table 3, p-value for income per capita and squared income per capita variables are lower than 1% significance level whereas variable of energy price is only significant at 10% level.

Table 3. Long Run Coefficients

	Fixed Effects	AB-GMM
Income per Capita	4.264***	4.309***
	(1.010)	(1.080)
Squared Income per Capita	-0.175***	-0.179***
	(0.055)	(0.058)
Energy Price	-0.083*	-0.074*
	(0.050)	(0.042)

Note:

*** 1% significance level

* 10% significance level

Values in ( ) denotes standard error

6.1. Responses of per Capita Energy Consumption to the Changes of Energy Price

As can be seen from table 2, the short run price elasticity is -0.055 (FEM) and -0.065 (AB-GMM). These results describe that, in the short run, on average (in a typical country), an increase in energy price by 1% would reduce per capita energy consumption by 0.055% (FEM) and 0.065% (AB-GMM), *ceteris paribus*, and the opposite is true. Meanwhile, according to table 3, the long run price elasticity is -0.083 (FEM) and -0.074 (AB-GMM), these results mean that, in the long run, on average (in a typical country), an increase in energy price by 1% would reduce per capita energy consumption by 0.083% (FEM) and 0.074% (AB-GMM), *ceteris paribus*, and the opposite is true. The values of the price elasticity are relatively similar across two procedures (FEM and AB-GMM).

The absolute values of energy price elasticity which is below unity (close to zero) both in the short run and long run implies that per capita energy consumption is very inelastic. In other words, energy consumption is less responsive to the price changes. In addition, the estimation results show that long run energy consumption elasticity is more elastic than short run energy consumption elasticity. From this result, we may say that energy is still considered as a strategic commodity in a country besides food, which is relatively difficult to be found its substitution in the short run than in the long run.

6.2. Responses of per Capita Energy Consumption to the Changes of Income per Capita

According to table 2, the short run per capita income elasticity is 0.538 (FEM) and 0.550 (AB-GMM). These results means, in the short run, on average (in a typical country), an increase in income per capita by 1% would increase per capita energy consumption by 0.538% in FEM and 0.550% in AB-GMM. The values of these short run per capita income elasticities are relatively similar across two procedures (FEM and AB-GMM) and significant at 1% level.

In the quadratic model, the long run per capita income elasticities are determined by the long run per capita income and squared per capita income coefficients together with the income level, and are therefore country and year-specific. The long run per capita income elasticities in country *i* and year *t* is determined by equation $4,264+2(-0,175)y_{it}$ in FEM and $4,309+2(-0,179)y_{it}$ in AB-GMM. The long run per capita elasticities which resulted from that both procedures (FEM and AB-GMM) are summarized in table 4.

Table 4. The Long Run per Capita Income Elasticities

Negara	FEM			AB-GMM		
	1985	1995	2005	1985	1995	2005
Filipina	1,471***	1.432***	1,358***	1,454***	1,414***	1,338***
	(0,144)	(0,134)	(0,114)	(0,157)	(0,151)	(0,122)
Hongkong	0,876***	0,695***	0,622***	0,845***	0,659***	0,585***
	(0,091)	(0,136)	(0,156)	(0,077)	(0,127)	(0,149)
Indonesia	1,559***	1,378***	1,324***	1,544***	1,358***	1,303***
	(1,106)	(0,119)	(1,106)	(0,184)	(0,122)	(0,112)
Jepang	0,847***	0,752***	0,718***	0,815***	0,718***	0,684***

	(0,096)	(0,121)	(0,130)	(0,084)	(0,110)	(0,120)
Korea	1,209***	0,945***	0,822***	1,186***	0,915***	0,789***
	(0,081)	(0,079)	(0,103)	(0,081)	(0,063)	(0,091)
Malaysia	1,239***	1,066***	0,945***	1,216***	1,039***	0,916***
	(0,087)	(0,068)	(0,078)	(0,089)	(0,057)	(0,064)
Singapura	0,911***	0,716***	0,624***	0,881***	0,682***	0,588***
	(0,084)	(0,130)	(0,156)	(0,070)	(0,120)	(0,148)
Taiwan	1,135***	0,896***	0,770***	1,110***	0,866***	0,737***
	(0,071)	(0,087)	(0,116)	(0,066)	(0,073)	(0,105)
Thailand	1.419***	1.182***	1,086***	1,401***	1,158***	1,060***
	(0,130)	(0,077)	(0,068)	(0,141)	(0,075)	(0,059)
USA	0,723***	0,622***	0,581***	0,688***	0,626***	0,544***
	(1,129)	(0,145)	(0,168)	(0,118)	(0,137)	(0,162)

Note:
*** 1% significance level
Values in ( ) denotes standard error

As shown in table 4, the long run per capita income elasticities tend to decrease over three points of times, namely 1985, 1995, and 2005. These results indicate that the increasing in per capita income would increase per capita energy consumption, and yet with levels which tend to decrease over that period. Meanwhile, the long run per capita income elasticities in developed countries are likely to be found less than those of emerging countries. Generally, the long run per capita income elasticities in the developed countries were below unity while in the emerging countries were greater than one. Here, the developed countries had experience in dematerialization during the period of 1980-2005, whereas the emerging countries were still in the materialization periods.

6.3. The Relationship between Energy Intensity and Income per Capita

As can be seen from the estimation results above, the fact that the long run coefficient of per capita income is greater than one (4.264 in FEM and 4.309 in AB-GMM) and the long run coefficient of squared income is negative (-0.175 in FEM and -0.179 in AB-GMM) with both methods and significant at conventional level, are consistent with the hypothesis that energy intensity has a quadratic relationship with per capita income.

Furthermore, the turning point (where the energy intensity reaches maximum point for given income per capita) can be derived from the long run coefficients as shown by table 3, that is US$ 11,268 in FEM and US$ 10,414 in AB-GMM. These results show that the emerging countries investigated in the Asia Pacific region, namely Philippines, Indonesia, and Thailand were still in the materialization process while their per capita income had not reached the turning point. In 2005, their per capita incomes were US$ 4,050 (Philippines), US$ 4.460 (Indonesia), and US$ 8.813 (Thailand). It means that countries were still in the stage of economic development where the ratio of energy use to a unit of output was relatively high. Meanwhile, the rest of the countries, that is, Malaysia (US$ 13,812), South Korea (US$ 18,765), Hongkong (US$ 33,198), Singapore (US$ 33,002), Japan (US$ 25,212), and USA (US$ 37,322) had experience in the dematerialization process. In this case, those countries had been able to reduce their energy use to a unit of GDP in a certain stage of economic development.

VII. Conclusion and Policy Implications

This paper analyzes the relationship between energy intensity and income per capita for ten Asia Pacific countries with various economic performances. The objectives, in addition to examines the long term behavior of energy intensity, but also to investigates the quadratic relationship between energy intensity (and energy consumption per capita) and income per capita. This analysis also encloses energy price in order to see its impact toward per capita energy consumption. We focus on the Asia Pacific countries because they are playing an increasingly important role in the world energy markets, and it is therefore interesting to know whether their energy intensity in the relation with income per capita is appropriate with the EKC hypothesis.

According to the explanations above, we can conclude several points as follows:

1. Based on the estimation results, the sign of the long run coefficients of per capita income is above unity and the long run coefficient of squared income is negative as well as significant at conventional level on both procedures (FEM and AB-GMM). These results are consistent with the EKC hypothesis where energy intensity has a quadratic relationship (inverted-U shape) with income per capita and indicating a change in trend of energy intensity.
2. The values of turning point obtained by two procedures, FEM and AB-GMM are US$ 11.268 and US$ 10.414 respectively. According to the GDP per capita (PPP adjusted) data year 2005, the countries such as USA, Japan, Hongkong, Singapore, Taiwan, South Korea, and Malaysia had passed the turning point, whereas the rest of countries,

namely Indonesia, Thailand, and Philippines still striving to reach the turning point.

3. The estimation results show that the long run coefficients of energy price both in the long run and the short run significantly affect per capita energy consumption. Here, the coefficient of energy price is negative and very inelastic; it means the response of energy consumption with respect to the change in energy price is relatively low. In addition, the estimation results show that long run energy consumption elasticity is more elastic than short run energy consumption elasticity. Here, we may conclude that energy is still considered as a strategic commodity in a country besides food, which is relatively difficult to be found its substitution in the short run than in the long run.
4. The estimation results show that the long run per capita income elasticity tend to decrease slightly over 1980-2005 periods. This estimation results also describe that the increasing of per capita income would tend to increase per capita energy consumption but with the downturn levels. One interesting point to consider is thus the long run income elasticity in the high income countries have lower elasticities than those of the middle-low income countries. The long run decreasing trend in energy intensity is mainly caused by the shift in stage of development in those countries.

7.1. Policy Implication

According to the explanations and conclusions above, we may suggest several policy recommendations as follows:

1. In the long run, energy is still a strategic commodity besides food. The relevance of this argument is twofold. First, energy consumption is less responsive to the energy price changes. Second, energy consumption is tends to increase although its growth levels is tend to decrease. In line with the scarcity of the conventional energy (fossil fuel) reserves while the tendency of energy consumption is seems to keep on increase, has arises an energy security issues. Therefore, every country is necessary to carry out a policy which can assure sustainable supply of energy for sustainable development in the future. Some efforts which can be done in order to fulfill sustainable supply of energy and to minimize the using of conventional energy (fossil fuel) are energy conservation and energy diversification.
2. The level of energy use has a tight dependability to environmental quality. In this case, the possible and plausible solutions for this problem cannot be done partially. Therefore, in order to fulfill their energy needed, every country should considers the principals of environmentally friendly by getting prioritizes their energy development to alternative renewable energy which more friendly to the environment.
3. Generally, the constraint likely to be found on alternative energy development is uncompetitive cost of production than this of conventional energy. Therefore, every country is necessary to carry out technological innovation which can be able to make new energy sources become more competitive and plausible. In addition, the development of alternative energy is should be considered to the

domestic energy sources in order to minimize dependency on energy which comes from other countries in the future.

4. The estimation results show that the dynamics of energy consumption is less responsive to the energy price changes. It can be seen from its elasticity values which is relatively low (close to zero) both in the short run and the long run. This situation implies that the admission policy for domestic energy consumption may be less effective if only relying on pricing policy. Therefore, energy policy is should not merely focusing on supply sides, but it should be considered from demand sides such as the policy for energy efficiency which must be implemented by all society entities in a country.
5. Energy has a strong relevancy to the sustainable development. In the recent years, the growth rate of CO_2 emission in the developing countries is 3.7% per year while in the developed countries is only 1.1% per year[6]. Here, the developed countries have passed the industrialization era while the developing countries (or emerging countries) were still on the industrialization periods. Based on the fact that, and under the apprehension that emerging countries and developed countries are strategic partners, so it is likely to be needed a strategic collaboration due to the transfer of clean, cheap, and safety technology from developed countries to emerging countries.
6. In line with the technological injection from developed countries to emerging countries, at the end, is not only encourage an increase in productivity but also would reduce negative impacts from

[6] See Yusgiantoro (2000)

industrialization process in emerging countries to the environment. Under the apprehension that the emerging countries were still experience in materialization process (depart for the turning point), so with the presence of the technological injection, it would accelerate their energy intensity path to the dematerialization phase.

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