Chapter 12

Trade-off Relationship between Energy Intensity-thus Energy Demand-and Income Level: Empirical Evidence and Policy Implications for ASEAN and East Asia Countries

Han Phoumin
Fukunari Kimura

Economic Research Institute for ASEAN and East Asia (ERIA)

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CHAPTER 12

Trade-off Relationship between Energy Intensity—thus Energy Demand —and Income Level: Empirical Evidence and Policy Implications for ASEAN and East Asia Countries

HAN PHOUMIN

FUKUNARI KIMURA

Economic Research Institute for ASEAN and East Asia (ERIA)

This study has been motivated by the recent shift of energy demand's gravity to Asia due to decades of robust and stable economic growth in the region. Said economic growth has correspondingly led to increases in per capita income in emerging economies in ASEAN and East Asia. Past empirical studies showed that energy intensity –thus energy demand-- tends to grow at an early stage of development. However, curbing the energy intensity remains central to green growth policy. Thus, this study formulates the hypothesis on whether energy intensity – thereby energy demand -- starts to fall as a country becomes richer. Based on this hypothesis, this study aims to investigate: (i) the non-monotonic relationship between energy demand and income levels in selected ASEAN and East Asia countries; (ii) the short- and long-run association of energy demand with price and income level; and (iii) the country performance in curbing the energy intensity. The study employs panel data model, pool-OLS, and historical time series data of individual countries with Vector Error Correction Model (ECM) for the analysis of the above objectives. The findings have suggested three major implications. One, it found that energy intensity --thus energy demand -- has a trade-off relationship with income level which contributes to the theory of energy demand. Two, energy demand has a trade-off relationship with income level, albeit the fact that each country has a different threshold level, implying that whatever the level of per capita income a particular country has, that country can curb energy intensity if it has the right policies in place. And three, countries with persistently increasing energy intensity will need to look into their energy efficiency policies more aggressively to ensure that structural changes in the economy do keep the energy efficiency policy to its core.

Keywords: energy demand, energy intensity, income, price, energy efficiency, trade-off or threshold, ASEAN and East Asia.

JEL Classification: C30, Q40, Q49

Introduction

Energy has played a vital role in human history for the advancement of human development. Many studies have proved the strong relationship between economic growth and energy consumption. It is also noted that there has been significant progress in terms of curbing energy growth through the reduction in energy intensity in the world's developed countries. Based on the International Energy Agency (IEA) publication, *World Energy Outlook*, the efficiency improvements in power and end-use sectors and the shift from energy-intensive industries could explain the reduction in the energy intensity. Although the global rate of energy intensity has declined, however, this rate has considerably slowed down from 1.2 percent per year on average between 1980 and 2000, to only 0.5 percent per year between 2000 and 2010. This slowdown can largely be explained by the shifting gravity of energy demand to developing Asia which have relatively high energy intensities due to their reliance on energy-intensive industries and on coal-fired power generation (IEA, 2012). As the result of limited access to high-end and low carbon emitting technologies in the developing world, the energy intensity expressed as the amount of energy used to produce a unit of gross domestic product (GDP) tends to be much higher in developing countries than in OECD countries. Said slowdown can also be attributed to the worsening of the energy intensity in some parts of the Middle East (which has been increasing since the 1980s) due to the low energy price that discouraged the deployment of energy efficient technologies (IEA, 2012).

In the literature, energy intensity has been investigated globally in terms of its trend as a macro indicator of energy efficiency. Some of the studies focused on the contributing factors to reduce energy intensity over time. Wu (2010) found that the energy intensity in China declined substantially due to improvements in energy efficiency, but changes in economic structures affected energy intensity modestly. Chumbo and David (2008) also investigated the energy intensity in China and found the decline of energy intensity due to technological changes. Its finding on the role of structural change, though, disagreed with Wu's finding. Ning (2008) investigated the energy intensity in three provinces of China, and the results suggested that the provinces of Ningxia and Inner Mongolia with developed renewable energy industry and clean energy technology have increasing or almost constant energy intensity, while Liaoning which has a heavy industry base and does not have much renewable energy capacity experienced an energy intensity decrease. Kumar (2003) also investigated factors that are influencing industrial energy intensity in India and its major findings were that research and development (R&D) activities are important contributors to the decline in firm level energy intensity. Metcalf (2008) investigated energy intensity in the United State of America and its conclusions were that rising per capita income and higher energy prices have played important parts in lowering energy intensity. Based on the Energy Information Administration (EIA, 2012) report, the structural changes in the economy are major movements in the composition of the economy and in any end-use sectors that can affect energy intensity but are not related to energy efficiency improvement. However, efficiency improvement in the process and equipment can contribute to observed changes in energy intensity.

Galli (1999) has made the first attempt to estimate the energy demand functions, including the energy intensity, during 1973-1990 using a quadratic function of income. This kind of non-monotonic function could explain the u-shaped patterns in energy intensity as income increases. This method has been applied elsewhere in the literature for other purpose (see Han, 2008) when there is a belief that increasing income will likely induce a trade-off relationship with dependent variables, which in this case are the energy demand and energy intensity. Adopting the work of Galli (1999) and Han (2008), this study has three objectives, namely: (i) to investigate empirical evidence of some selected ASEAN and East Asia countries to see the extent or level of economic growth wherein both energy demand and energy intensity start to fall. In other words, to what level of per capita GDP does the energy demand and energy intensity start to reverse the trend; (ii) to assess the short and long-run association between energy demand and energy intensity, on one hand, and energy price and income, on the other, to test the theory of the energy demand; and (iii) to assess the country's performance of energy intensity with the assumption that energy intensity tends to rise and fall from one period to another period, and the sum of the energy intensity growth rate shall be "negative" if the country is on better performance of curbing energy intensity. The findings provide certain policy implications that would help accelerate various economies' goal of achieving a reduction in the energy intensity. They also imply the level of the energy efficiency in respective economies that would reduce the energy intensity.

The paper is organised as follows: the next section discusses the empirical model of the inversed U shape relationship between economic growth and energy intensity and energy demand. This is followed by the section on the data used in the model, and then by the section on results and analyses. The final sections provide the conclusions and policy implications.

Empirical Model

Trade-off Relationship between Energy Demand and Energy Intensity, and Income

In the theory of energy demand, income and price are assumed to be major determinants to explain the change of the energy demand. In previous literature, energy demand is generally affected by the different states and structures of economy of individual countries and other characteristics. Causality is also expected to run from income and price to explain the energy demand in both short and long run. However, time series data are likely to be non-stationary and thus suffer by the unit root or random walk. Therefore, the series are not integrated in order I (0), but are presumably integrated of the same order I (1) after the first differentiation.

This study proves that energy intensity is in fact the energy demand function. It starts the model of energy intensity which is a function of price and income, and finally derives the energy demand function from the energy intensity function. Other unobserved variables are captured in error term in the energy demand model.

Defining E_{it} as per capita of quantity of energy demand used for national production in country i *at* year t, and in this case represented by aggregated form of total final energy consumption (TFEC) per capita; and GDP_{it} as the corresponding per capita income in country i at year t, which takes the form of Gross Domestic Product at constant price 2005;

P_{it} is the energy price which has been adjusted to constant price by GDP deflator 2005.

The study assumes that Energy Intensity EI_{it} of use is a non-monotonic function of GDP_{it} and other variables. This assumption has been employed in the past study by Galli (1999) whose study focused on the non-monotonic relationship between national aggregate energy demand and income from 1973-1990. This assumption is the result of the fact that the tendency for energy intensity is to increase with output in low-income countries, and to decrease with output in high-income economies.

For the sake of this study, it could be that for some countries, the turning point (per capita income) may get faster in terms of timeline which could be an attribute of the work of energy efficiency and aggressive policy target in the region.

Since the data in this study are the panel data of the selected countries in ASEAN and East Asia, they shall thus be written as:

$$Log(EI_{it}) = \beta_0 + \beta_{i1} Log(P_{it}) + \beta_{i2} LogGDP_{it} + \beta_{i3} (LogGDP_{it})^2 + \varepsilon_{it} \quad \text{(Eq.1)}$$

From equation (1), it is proved that the Energy Intensity is in fact the energy demand;

Since $Log(EI_{it}) = LogE_{it} - LogGDP_{it}$; thus the equation (1) can be re-written as:

$$LogE_{it} - LogGDP_{it} = \beta_0 + \beta_{i1} LogP_{it} + \beta_{i2} LogGDP_{it} + \beta_{i3} (LogGDP_{it})^2 + \varepsilon_{it} \quad \text{(Eq.2)}$$

To avoid endogeneity, $LogGDP_{it}$ was moved from the left to the right hand side of the equation (2);

Thus the energy demand function is derived:

$$\boxed{LogE_{it} = \beta_0 + \beta_{i1} LogP_{it} + (\beta_{i2} + 1) LogGDP_{it} + \beta_{i3} (LogGDP_{it})^2 + \varepsilon_{it}} \quad \text{(Eq.3)}$$

The coefficients $\beta_{i1}; \quad (\beta_{i2} + 1); \quad and \quad \beta_{i3}$ in equation (3) are of interest to this study.

The equation (3) could be regarded as a complex function and as per capita GDP grows higher, this model implies that both energy demand and energy intensity have diminishing effects. In other words, energy demand will reach a point of saturation, and energy intensity will thereby reverse its trend. However, the estimation results from the equation (3) do not reflect the behavior or trend of an individual country because it was expected that in some countries, the diminishing effects of income on energy demand and energy intensity may take different values of per capita GDP. Therefore, equation (3) was also estimated by using time series data of each individual country. The model specifications for each time series of an individual country are therefore:

$$Log(E_t) = \beta_0 + \beta_1 Log(P_t) + (\beta_2 + 1) LogGDP_t + \beta_3 (LogGDP_t)^2 + \varepsilon_t \quad \text{(Eq.4)}$$

From equations (3) to (4) above, the trade-off point or the diminishing effects of income on energy demand and energy intensity in the above dynamic function are simply the first derivative with respect to per capita income. Thus $-\frac{(\beta_2 + 1)}{2\beta_3}$ is the trade-off point that could be a U shape or inverted U shape depending on the sign of the $(\beta_2 + 1)$ & β_3.

Short and Long-run Causalities of Energy Demand and Energy Intensity

From equations 3 and 4, this study is also interested in the causalities or associations between energy demand—thus energy intensity-- with covariates of energy price and income.

In this case, it is assumed that time series data are not stationary, but all variables are integrated of the same order I (1) after first differentiation. Thus, the co-integration test (see Annex 1) will also be performed before proceeding to the estimation of the model by Vector Error Correction Model (VECM).

If such co-integration exists, the error correction term in VECM will adjust (speed of adjustment) towards both short and long-run equilibrium.

For simplicity, $Log(E_t)$ will be written as e_t, in the lower case to represent the logarithmic function. Thus, the Error Correction Model of energy demand-thus energy intensity-- of each individual country could be expressed as:

$$\Delta e_t = a_0 + b_1 \Delta e_{t-1} + c_i \Delta p_t + c_2 \Delta p_{t-1} + d_1 \Delta gdp_t + d_2 \Delta gdp_t^{\ 2} + \delta s_{t-1} + U_t \qquad \text{(Eq.5)}$$

Where $$\delta s_{t-1} = [e_{t-1} - (\phi_1 gdp_{t-1} + \phi_2 p_{t-1})]$$

If $\delta \prec 0$, then energy demand and energy intensity in the previous period overshot the equilibrium, and thus the error correction term works to push the energy demand and energy intensity back to the equilibrium. Similarly, the error correction term can induce a positive change in energy demand and energy intensity to the equilibrium (see Wooldridge, 2003).

Assessment of the Country Performance of Energy Intensity Over time

The study has been motivated by the observation that energy intensity tends to rise in one or few periods and fall in one and few periods. This phenomenon seems to be a fluctuation of rise and fall over time similar to the cycle of economic boom and bust. Therefore, one needs to have knowledge as to whether the economies are generally on a better or worse performance in terms of curbing the growth of energy intensity. With this notion in mind, the authors constructed the energy intensity growth rate with the following:

Energy intensity growth rate for any particular year,

$$EI_{growth} = \frac{EI_t - EI_{t-1}}{EI_t} \times 100 = \frac{\Delta EI_t}{EI_t} \quad \text{(Eq.7)}$$

How does one know that a country is in a better or worse performance in curbing the energy intensity if the energy intensity growth rates are likely to fluctuate from period to period? Theory says that if the percentage fall of energy intensity is greater than the percentage rise of energy intensity, the economies generally perform better in combatting the energy intensity. Therefore,

$\sum EI_{growth} \prec 0$, if the economy performs better in curbing the energy intensity; and

$\sum EI_{growth} \succ 0$, otherwise.

Data and Variables

This study uses three datasets in order to get the variables of interest in the model. The first dataset comes from the Institute of Energy Economics, Japan (IEEJ) in which few variables are obtained such as Total Final Energy Consumption (TFEC) and crude oil price of Japan. Further, this study also uses World Bank's dataset called World Development Indicators (WDI) in order to capture a few more time series variables such as Gross Domestic Product (GDP) at constant price 2005, GDP deflator at constant price 2005 and population. The variable of the energy intensity is actually derived by dividing the TFEC in TOE to the GDP at constant price 2005.

Table 12.1 describes some characteristics of the variables used in the study and the patterns of year-on-year average growth rate of those variables.

Table 12.1: GDP per capita, Energy use per capita, Energy Intensity

Country	GDP per capita (a)			Energy use per capita (b)			Energy intensity (c)			
	1971	2011	Growth%* 1971-11	1971	2011	Growth%* 1971-11	1971	2011	Growth%* 1971-11	Growth%* 2000-11
Australia	18,129	36,585	***1.78***	2.51	3.33	***.72***	1.39	.91	***-1.03***	***-1.67***
China	150	3,120	***7.94***	.22	1.07	***4.10***	14.78	3.42	***-3.50***	***-1.92***
Japan	15,671	36,160	***2.15***	1.88	2.43	***.70***	1.20	.67	***-1.40***	***-1.43***
S. Korea	2,687	21,226	***5.36***	.42	3.18	***5.38***	1.55	1.50	***-.020***	***-1.83***
Philippines	845	1,433	***1.38***	.18	.19	***.39***	2.08	1.34	***-.95***	***-4.23***
Singapore	5,193	34,378	***4.91***	.51	4.69	***6.04***	.99	1.36	***1.14***	***1.99***
Thailand	594	3,158	***4.34***	.13	1.11	***5.66***	2.20	3.53	***1.27***	***1.28***
India	271	1,085	***3.57***	.08	.26	***2.96***	3.07	2.42	***-.52***	***-1.39***
Average	***5,443***	***17,143***	***3.93***	***0.74***	***2.03***	***3.24***	***3.41***	***1.89***	***-0.63***	***-1.15***

Note: (a) GDP per capita at constant price 2005
(b) Energy use per capita (TOE per capita)
(c)Energy intensity per $US 10,000 (at constant price 2005)
* Year on year average growth rate

It is observed that countries with high GDP year-on-year average growth rate tend to also have high growth rate of energy use per capita. These include China, South Korea, Singapore and Thailand. Generally, energy intensity has declined in most countries for year-on-year average growth rate, except in a few ASEAN countries. However, it could largely be explained by data problem since this study uses IEA data and Naphtha has been included in the energy balance of Singapore and Thailand.

Results and Analyses

Table 12.2a shows the results by estimating equation 3 of the panel data in countries studied. In addition, the pooled-OLS model was run to compare the results with panel model specification in equation 3. Since the Huasman test suggested that there is enough evidence to reject the null hypothesis, the authors then accept the alternative hypothesis under the assumption that “fixed effect is appropriate”. Therefore, Table 12.2a shows only the fixed effect coefficient estimates along with the pool-OLS for the comparison purpose. Because the authors believed that each country may experience different paths or relationships between energy demand and energy intensity with increasing per capita income, equation 4 was also estimated by using each time series data as shown in Table 12.2b. Finally, Table 12.2c shows the results by estimating equation 5 for the short and long-run association of energy demand and energy intensity with its covariates using Vector Error Correction Model.

The non-monotonic relationship between national aggregate of per capita energy demand--thus the energy intensity-- and per capita income in the countries studied indicates the level of saturation of per capita energy demand due to increasing per capita income. Table 12.2a shows that ASEAN and East Asia as a group tends to have trade-off relationship between energy demand and income. However, each country may have a different path or relationship between energy demand and income.

Table 12.2b shows trade-off relationship between energy demand and income. It is shown that Australia, China, South Korea and the Philippines have reached a saturated level of per capita energy demand when per capita income had reached US$ 32,215 for Australia, US$ 3,020 for China, US$ 17,414 for South Korea, and US$ 1,185 for the Philippines. These mean that Australia, China, South Korea and the Philippines have already experienced the decline of per capita energy demand-thus the energy intensity- because per capita income in these countries in 2011 were US$ 36,585 for Australia, US$ 3,120 for China, US$ 21,226 for South Korea, and US$ 1,433 for the Philippines (see Table 12.1).

In contrast, while countries like Singapore, Thailand and India showed trade-off relationship between per capita energy demands-thus energy intensity-- with per capita income, these countries have yet to experience the decline of the per capita energy consumption because the trade-off points of these countries are exceeding the current per capita income. Table 12.2b shows that Singapore, Thailand and India shall not have reached a saturated level of per capita energy demand when per capita income has not reached US$ 51,359 for Singapore, US$ 6,214 for Thailand, and US$ 1,463 for India. These mean that Singapore, Thailand and India have not yet experienced the decline of per capita energy demand because per capita income in 2011 in these countries were US$ 34,378 for Singapore, US$ 3,158 for Thailand, and US$ 1,085 for India (see Table 12.1). Lastly, Japan seems to have experienced the decline of per capita energy demand at the early stage of development when its per capita income reached less than US$ 19,326 (see Table 12.2b). Corrolarily, it also seems that per capita income of Japan exceeding US$ 19,326 likely increases its per capita demand of energy. Therefore, the current situation seems that Japan is likely to have increased per capita energy demand.

The non-monotonic relationship between energy intensity-thus energy demand-- and per capita income in the countries studied implies a shift of structural changes in the economies towards environmental friendly energy use practices. This has been made possible through the availment of improved technologies at both demand and supply sides of energy when per capita income has reached a certain level where an individual could possibly afford better technologies and energy products such as end-use appliances.

Figure 12.1a-h explains the fluctuation rise and fall of energy intensity growth rate in the countries studied. All countries seem to have similar patterns of the rise and fall of the energy intensity growth rate. This means that countries with experience of better performance of energy intensity in one period may or may not continually lead to a better performance in the next one or two periods. When energy intensity is in the downward trend, it is expected that it will rise again soon. However, if the economies are on the level of efficiency improvement, one might expect to see that the energy intensity growth rate of "negative sign" is higher than the "positive sign". This will lead to the sum of energy intensity growth rate with "negative sign" if the country performs better in curbing energy intensity, and with "positive sign", if otherwise.

In addition, Table 12.1 shows that amongst countries studied, Australia, China, Japan, South Korea, and the Philippines have generally done well in terms of curbing the energy intensity. However, few countries in ASEAN may need to speed up policies to reduce the energy intensity so that in the long run, they could bring in the negative growth in energy intensity. There could be data problem as well when analyzing the energy intensity in some ASEAN countries as IEA data include Naphtha into the energy balance table. However, on average, countries studied as a group have achieved above 0.63 percent and 1.15 percent year-on-year of the energy intensity reduction for the period 1971-2011, and 2000-2011, respectively. It is also important to note that for all countries studied, both per capita energy consumption and income have grown. Table 12.2c shows that both coefficients in the error correction term of energy demand-thus the energy intensity-- are significant and negative. The joint t-test of the coefficients of price and its lags, and income and its lags show that they are all jointly significant. These mean that energy demand-thus energy intensity-- have both short and long-run associations with energy price and income. This is important to confirm for the theory on energy demand and to ensure that this study's model specifications of non-monotonic function of energy demand have both short and long-run associations with price and income. Table 12.2c shows that both price and income have jointly adjusted towards a long-run equilibrium to explain the energy demand at different speeds of adjustment. In this case, both price and income have induced the speed of adjustment at 23 percent for Australia, 33 percent for China, 31 percent for Japan, 15 percent for South Korea, 14 percent for the Philippines, 37 percent for Singapore, 23 percent for Thailand, and 21 percent for India towards long run equilibrium, respectively.

Table 12.2a: Coefficient Estimates of Energy Demand Functions in Pool & Panel Data

Dependent variable (Per Capita log TFEC)	**Panel specification model**	
Independent variables	Pooled-OLS	Fixed Effect Model
Log price	-.1226296*** (.0268491)	-.102571*** (.0187127)
GDP per capita	.000207*** (5.92e-06)	.0001841*** (.0000102)
Square GDP per capita	-3.92e-09*** (1.69e-10)	-3.12e-09*** (2.27e-10)
Constant	-1.585865*** (.041862)	-1.54216*** (.0563268)
Derived GDP per capita maximizing/minimizing energy demand TFEC	-26,403 $↓	-29,503 $↓

Note: Hausman Test; Prob>chi2= 0.048
Thus, it reports only the fixed effect coefficients

Table 12.2b: Coefficient Estimates of Dynamic Energy Demand Function in Each country & Derived GDP per capita Maximizing Energy Demand

Dependent variable (Per capita Log TFEC)	Australia	China	Japan	S. Korea	Philippines	Singapore	Thailand	India
Log price	.0253392** (.008107)	.0665349** (.0324817)	-.056525** (.0176486)	.1057709** (.0436353)	-.0346337** (.0149685)	.0645889** (.0275114)	-.0498082* (.0247245)	-.0790377** (.0256327)
GDP per capita	.0001018*** (.0000102)	.0009243*** (.0001217)	-.0000402**	.0003368*** (.0000298)	.0044102** (.0018216)	.0001171*** (8.23e-06)	.0011645*** (.0000852)	.0020044** (.0006159

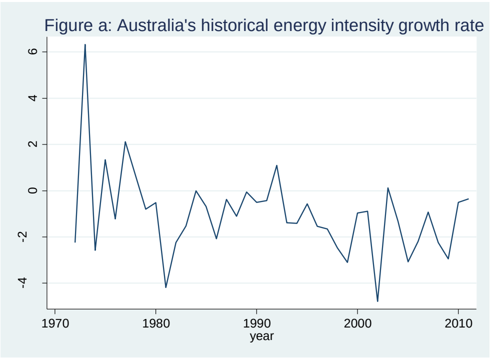
			(.000018)					)
Square GDP per capita	-1.58e-09*** (1.76e-10)	-1.53e-07** (3.70e-08)	1.04e-09*** (3.23e-10)	-9.67e-09*** (1.11e-09)	-1.86e-06** (7.74e-07)	-1.14e-09*** (2.14e-10)	-9.37e-08*** (2.19e-08)	-6.85e-07 (4.33e-07)
Constant	-.405849** (.1409007)	-1.39269*** (.0559878)	1.04472*** (.2297515)	-1.746956*** (.1544758)	-4.224989*** (1.055727)	-1.108587*** (.0538899)	-2.679416*** (.0538868)	-2.7926*** (.1819144)
Derived GDP per capita maximizing/minimizing per capita energy demand TFEC	-32,215 $↓	-3,020 $↓	+19,326 $↑	-17,414 $↓	-1,185 $↓	-51,359 $↓	-6,214 $↓	-1,463 $↓

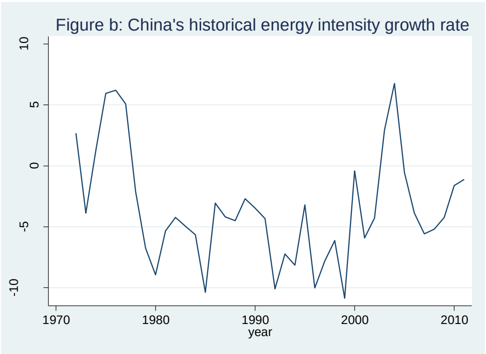
Table 12.2c: Short and Long-run associations of Energy Demand (TFEC) and its covariates using Vector Error Correction Model

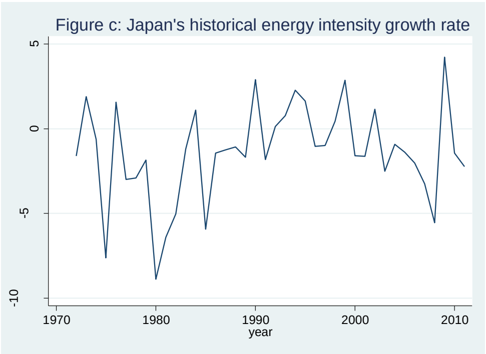
Dependent variable (Δ per capita logTFEC)	Australia	China	Japan	S. Korea	Philippines	Singapore	Thailand	India
Correction term (δ)	-.2376164*** (.0656543)	-.336133*** (.1330021)	-.3147112** (.1547952)	-.1589532** (.0585031)	.1435722*** (.0554136)	-.378682** (.1961135)	.2388997** (.0874298)	.216517** (.0797304)
Per capita log TFEC								
Lag1 Δ	.0225666 (.2324569)	.3821443** (.1893587)	.3104491 (.2145873)	-.0622279 (.1963943)	-.3980857* (.2389107)	.0969218 (.2404678)	-.1447924 (.2828087)	-.5283759* (.2488979)
Lag2 Δ	-.1177618 (.2279041)	.1253752 (.2177242)	.2654904 (.2219465)	-.0641782 (.2073006)	.0242085 (.2064197)	.6021337** (.305538)	-.6440835** (.2707831)	-.1359827 (.2049093)
Lag3 Δ	-.0384104 (.2045538)	.0960854 (.1856462)	.020561 (.1974148)		.1493083 (.2096281)	-.4100658* (.2286869)	-.3374121 (.2980484)	
Log price								
Lag1 Δ	.0215382 (.0131803)	.0010947 (.0289667)	-.0130284 (.0275418)	-.0251408 (.0296789)	-.0621567 (.0443538)	-.1173683 (.0732935)	-.0664864** (.0305541)	.0057174 (.0166403)
Lag2 Δ	-.007512 (.012565)	-.0651841 (.026296)	-.0012958 (.0253862)	-.0354396 (.0289886)	-.0396367 (.0454122)	-.0678363 (.0632702)	-.0474603 (.0354006)	-.002598 (.0156085)
Lag3 Δ	.0111533 (.0109963)	.0086231 (.0316556)	-.0014268 (.020271)		-.0151749 (.0437731)	.0206424 (.0602064)	-.0453874 (.0322574)	
GDP per capita								
Lag1 Δ	-1.16e-06 (.000043)	.0005154 (.0008917)	-.0000107 (.0000454)	8.87e-06 (.0000835)	-.0008382 (.0031362)	.0000739 (.0001112)	.0007403 (.0007127)	.0042536*** (.0011979)
Lag2 Δ	-.0000261	-.001052	-.0001256	.0001815*	-.0043108	.0000244	.0015296*	.0001643

	(.0000422)	(.0013204)	(.0000441)	(.0001017)	(.0037343)	(.000138)	(.0008914)	(.001255)
Lag3 Δ	-9.75e-06 (.0000395)	-.0003551 (.0009596)	-7.37e-06 (.0000664)		-.0120918** (.0045897)	-.0003954** (.0001691)	.0014227 (.0012595)	
Square GDP per capita								
Lag1 Δ	8.72e-11 (7.68e-10)	8.88e-08 (2.47e-07)	-3.64e-11 (6.95e-10)	3.68e-10 (2.82e-09)	1.00e-06 (1.50e-06)	-1.45e-09 (2.02e-09)	-1.09e-07 (1.31e-07)	-3.09e-06*** (8.68e-07)
Lag2 Δ	5.08e-10 (7.64e-10)	2.35e-07 (3.47e-07)	1.88e-09** (7.11e-10)	-7.52e-09* (3.56e-09)	2.23e-06 (1.84e-06)	-9.99e-10 (2.70e-09)	-2.19e-07 (1.81e-07)	-2.08e-07 (1.04e-06)
Lag3 Δ	1.45e-10 (7.38e-10)	3.30e-07 (2.75e-07)	5.27e-11 (1.12e-09)		5.97e-06** (2.35e-06)	7.77e-09** (3.53e-09)	-3.12e-07 (2.66e-07)	
Constant	-.0190092* (.0114793)	-.0308262 (.0228611)	-.0222377 (.0187129)	.1239887 (.0315359)	-.0154256 (.0178409)	.3130021*** (.087743)	-.1759208** (.0775416)	.0028049 (.0109608)

Figure 12.1 a-h: Historical Energy Intensity Year on Year growth rate in each of countries studied







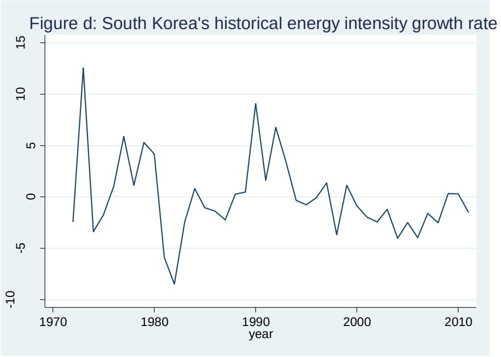


Figure d: South Korea's historical energy intensity growth rate
-10
-5
0
5
10
15
1970
1980
1990
2000
2010
year

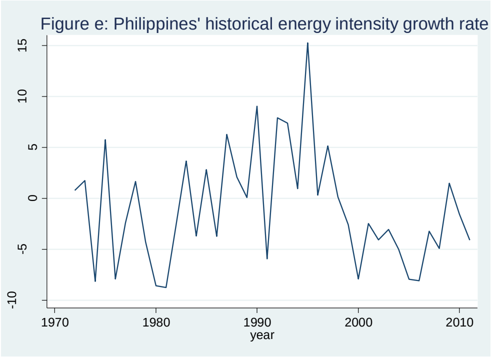


Figure e: Philippines' historical energy intensity growth rate
-10
-5
0
5
10
15
1970
1980
1990
2000
2010
year

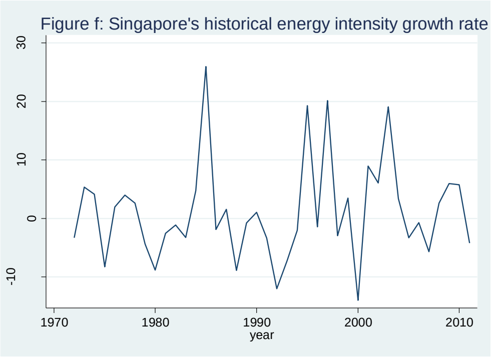


Figure f: Singapore's historical energy intensity growth rate
-10
0
10
20
30
1970
1980
1990
2000
2010
year

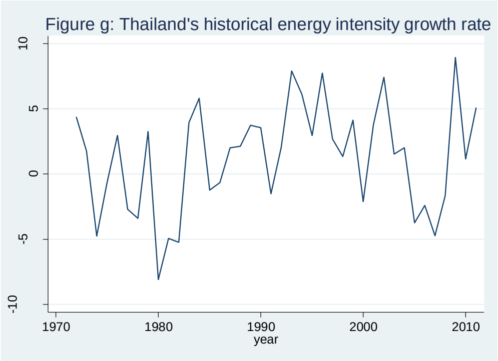


Figure g: Thailand's historical energy intensity growth rate
-10
-5
0
5
10
1970
1980
1990
2000
2010
year

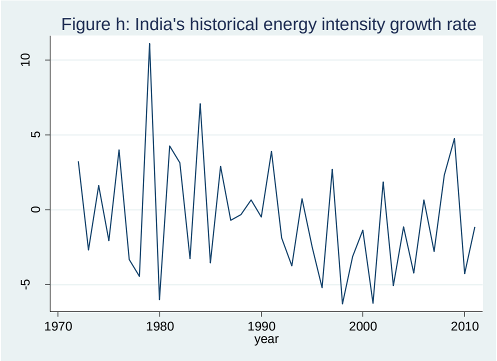


Figure h: India's historical energy intensity growth rate
-5
0
5
10
1970
1980
1990
2000
2010
year

Conclusions

As mentioned earlier, this study has been motivated by the recent shift of energy demand's gravity to Asia due to decades of robust and stable economic growth leading to the increasing energy demand in this region. The study has three objectives, namely: (i) to investigate non-monotonic relationship between energy intensity -- thus energy demand -- and income level in selected ASEAN and East Asia countries since many stakeholders, including policymakers, would like to know whether the energy intensity-thus energy demand-- is likely to fall as these countries become richer; (ii) to assess the short and long-run associations of energy demand with energy price and income level; and (iii) to assess the individual country performances in curbing energy intensity in order to ascertain whether the country is on the right track or whether it needs to revisit its overall policy to ensure that the right ones are in place.

The study shows that selected countries in ASEAN and East Asia as a group have moderately achieved 0.63 percent and 1.15 percent of energy intensity reduction during the periods 1971-2011 and 2000-2011, respectively. This energy intensity reduction rate is higher than the global average rate of 0.5 percent in the period 2000-2010. The slowdown in the global reduction rate of energy intensity could largely be attributed to the worsened performance of the energy intensity in some parts of the Middle East since the 1980s due to the low energy price that discouraged the deployment of energy efficient technologies (IEA, 2012).

ASEAN and East Asia as a group tends to have trade-off relationship between energy intensity-thus energy demand-- and income. However, each individual country in ASEAN and East Asia experiences the rise and fall of energy intensity. This is likely due to the shift in structure of the economies as some countries may move gradually from agriculture to industry-based economies while others may move from industry to service-based economies. All countries studied experience the reduced energy intensity, except for few ASEAN countries, where the increase of energy intensity may be due to data problem since this study uses IEA data in which Naphtha were included in the energy balance table.

Both per capita energy consumption and income have grown for all countries which implies the close relationship between energy demand and income growth. However, this study found that as income increases, per capita energy demand will reach a level of saturation which pushes the fall of energy demand. The study found that Australia, China, South Korea and the Philippines have already experienced the decline of per capita energy demand when per capita income have reached US$ 32,215 for Australia, US$ 3,020 for China, US$ 17,414 for South Korea, and US$ 1,185 for the Philippines. Meanwhile, countries like Singapore, Thailand and India have yet to experience the decline of the per capita energy consumption. Japan seems to have experienced the decline of per capita energy demand at the early stage of its development when per capita income was less than US$ 19,326. However, when this threshold is exceeded, Japan is likely to increase the per capita energy demand again.

This study's Error Correction Model in each country shows that energy intensity -- thus energy demand -- has both short and long-run associations with energy price and income. This is important to confirm for the theory of energy demand and to ensure that this study's model specifications of non-monotonic function of energy demand have both short and long-run associations with price and income. In this case, both price and income have induced the speed of adjustment towards long run equilibriums to jointly granger cause the energy intensity and energy demand.

Policy Implications

(a) By examining individual country's energy intensity, energy intensity-thus energy demand- declined at the initial stage where per capita income stayed below certain thresholds, but as income continues to rise above the thresholds, the energy intensity in some countries starts to rise again. ***These findings imply that it does not matter what level of per capita income a country has; as long as the country has the right policies in place, it can reduce energy intensity. Therefore, it is very important for each country to revisit its energy efficiency policies in***

different sectors to ensure that any structural changes in the economy will maintain the energy efficiency as core to its policy.

(b) The study found that Australia, China, Japan, South Korea, and the Philippines have generally done well in terms of curbing the energy intensity. However, few countries may need to speed up policies to reduce the energy intensity so that in the long run, it could bring in the negative growth of energy intensity. ***These findings imply that aggressive energy efficiency policies will need to be considered for countries with positive energy intensity.***

(c) The study's models show that energy intensity -- thus energy demand -- has both short and long-run associations with energy price and income. In this case, both price and income have induced the speed of adjustment towards a long run equilibrium to jointly granger cause the energy intensity and energy demand. ***These findings imply that energy intensity -- thus energy demand -- has a trade-off relationship with income level which contributes to the theory of energy demand.***

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Annex

Table 12.A1. Johansen Test for Cointegration

Sample: 1975 - 2011

Country	maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
Australia	0	52	-757.55603	.	49.1920	47.21
	1	59	-745.89196	0.46767	25.8639*	29.68
	2	64	-739.03545	0.30970	12.1509	15.41
	3	67	-734.34457	0.22397	2.7691	3.76
	4	68	-732.96002	0.07211		
China	0	52	-499.14894	.	59.7196	47.21
	1	59	-484.02838	0.55839	29.4785*	29.68
	2	64	-474.93792	0.38822	11.2976	15.41
	3	67	-469.58091	0.25141	0.5836	3.76
	4	68	-469.28912	0.01565		
Japan	0	52	-800.19573	.	74.9123	47.21
	1	59	-783.25648	0.59974	41.0339	29.68
	2	64	-769.84806	0.51557	14.2170*	15.41
	3	67	-763.17226	0.30292	0.8654	3.76
	4	68	-762.73955	0.02312		
South Korea	0	52	-767.58344	.	60.9483	47.21
	1	59	-752.56011	0.55606	30.9017	29.68
	2	64	-741.73285	0.44304	9.2472*	15.41
	3	67	-737.60096	0.20016	0.9834	3.76
	4	68	-737.10927	0.02623		
Philippines	0	52	-464.99959	.	63.1600	47.21
	1	59	-444.48581	0.67006	22.1324*	29.68
	2	64	-437.35594	0.31982	7.8727	15.41
	3	67	-433.60224	0.18364	0.3653	3.76
	4	68	-433.41961	0.00982		
Singapore	0	52	-868.26379	.	36.9137*	47.21
	1	59	-857.84401	0.43063	16.0742	29.68
	2	64	-853.94698	0.18994	8.2801	15.41
	3	67	-850.12063	0.18684	0.6274	3.76
	4	68	-849.80692	0.01681		
Thailand	0	52	-587.28841	.	63.5717	47.21
	1	59	-568.58052	0.63623	26.1559*	29.68
	2	64	-560.02063	0.37042	9.0361	15.41
	3	67	-556.45672	0.17522	1.9083	3.76
	4	68	-555.50256	0.05027		
India	0	52	-410.41893	.	71.8300	47.21
	1	59	-393.47337	0.59987	37.9389	29.68
	2	64	-382.15707	0.45757	15.3063*	15.41
	3	67	-375.66709	0.29588	2.3263	3.76
	4	68	-374.50394	0.06094		