The Linkage between Energy Consumption and Income in Six Emerging Economies of Asia: An Empirical Analysis [1]

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Abstract

This article examines the short- and long-run causal relationship between energy consumption and GDP of six emerging economies of Asia. Based on cointegration and vector error correction modeling the empirical results show that there exists unidirectional short- and long-run causality running from energy consumption to GDP for China, uni-directional short-run causality from output to energy consumption for India, whilst bi-directional short-run causality for Thailand. Neutrality between energy consumption and income is found for Indonesia, Malaysia and Philippines. Both the generalized variance decompositions and impulse response functions confirm the direction of causality. These findings have important policy implications for the countries concerned. The results suggest that while India may directly initiate energy conservation measures, China and Thailand may opt for a balanced combination of alternative polices.

Keywords: Energy conservation, Cointegration, Error correction model, Generalized variance decompositions, Generalized impulse response functions.

JEL classifications: C22; Q43, Q48

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1. Introduction

With soaring energy prices and increased demand for energy in developing countries, specially from emerging economies like China and India, studies on identifying statistically significant association between energy consumption and economic activities in developing economies are regaining momentum these days. However, it still remains an unsettled issue whether economic growth is the cause or effect of energy consumption. Standard economic theories do not provide any clear-cut answer to this. Although standard growth models do not include energy as an input of economic growth, the importance of energy in modern economy is undeniable. Different studies have reached at different conclusions on different countries with different study periods and various measures of energy. However, no consensus has yet been established. The aim of this article is to contribute to this debate by analyzing causal link between energy consumption and output by using a *demand side* multivariate cointegration analysis.

The importance of identifying the direction of causality emanates from its relevance in national policy-making issues regarding energy conservation. Energy conservation issue is more important when energy acts as a contributing factor in economic growth than when it is used as a result of higher economic growth. Furthermore, many economists and social scientists are claiming that the increased demand for energy from developing countries like China and India is one of the major reasons for the energy price hikes in recent times. In this backdrop, it is justified to search causal relationship between energy consumption and national output (GDP) of some developing countries from Asia. Thus the present paper attempts to identify the direction of causality between energy consumption and output in the context of six major energy dependent emerging countries, namely, China, India, Indonesia, Malaysia, Philippines and Thailand from Asian. Moreover, it is to be mentioned here that statistical evidence reveal that all these economies have experienced double digit growth in energy consumption in last one decade from 1996 to 2006, with China and India experiencing a growth of almost 80% and 56%, respectively (Appendix Table 1). However, since the traditional bivariate approach suffers from omitted variable problems (Stern, 1993, Masih and Masih, 1996 and Asafu-Adjaye, 2000), this paper employs a trivariate *demand side approach* consisting of energy consumption, income and prices. The countries selected for this purpose are China, India, Indonesia, Malaysia, Philippines and Thailand.

The rest of the article is structured as follows. The next section provides a critical review of earlier literature, followed by a description of data sources and methodologies. Section 4 examines the time series properties, followed by an analysis of empirical results. Conclusions and policy implications are given in the final section.

2. Energy Consumption and Policies in Selected Asian Emerging Economies

Six emerging economies of Asia have been selected for this study based on the recent history of economic growth, the rate of increase in oil demand, the projected increase in oil consumption demand, trade openness and the recent pace of industrialization. Available statistics show that these six countries constitute almost 22.98% of the world's aggregate energy consumption in 2007 (Appendix Table 2).

The Chinese economy experienced phenomenal growth in the last three decades. Since the initiation of market reforms in late 1970s, China's growth was about 9.70% per annum (World Bank 2009). Being the world's most populous country with a population of over 1.3 billion, this rapid economic growth has enabled China to lift several hundred million people out of absolute poverty level. However, with strong economic growth, China's demand for energy is surging rapidly, so as China's output of pollutant emission (Figure 1). According to British Petroleum (2008), China was the second largest consumer of energy products in the world behind the United States and also second largest consumer of energy consuming of 16.79% of world total in 2007 (Appendix Table 2). In addition to that, consumption of all fuel types in China has increased significantly in recent years to support this increasing trend in economic growth. Crompton & Wu (2005) show that China consumed 31% of the world's total coal, 7.6% of oil, 10.7% of hydroelectricity and 1.2% of world's total gas in 2003. Consumption figures for all of the fuels types increased in recent years, for example, China accounted for 41.27% of world's coal consumption, 9.31% of oil consumption, 15.41% of hydroelectricity consumption and 2.30% of gas consumption in 2007 (Appendix Table 2). However, the growth of output and energy consumption has its consequences; during this period pollutant emission has also increased raising much concern to world's environmentalists. In addition to coal, oil, gas, and hydroelectricity, the Chinese economy also consumes a significant amount of primary solid and liquid biomass including fuel wood and biogas. Two of the major energy consuming sectors in China are the transportation and industrial sectors. The Chinese retail prices for petroleum products are regulated according to locations and the types of consumers. The Government maintains domestic price ceilings on the finished petroleum products which have not been consistent with the soaring international energy prices. Furthermore, the refineries get government subsidies to ease the gulf between low domestic prices compared to international oil price trends.

Rapid economic expansion also drives up India's energy demand boosting the country's share of global energy consumption. Being the largest democracy in the world with more than 1.1 billion people, India has also experienced an unprecedented economic growth in recent decades (from 2006 to 2007 the growth was about 8.4%). Figure 1 indicates that this rapid economic growth is associated with significant growth in energy consumption, and carbon emission, thereof. Since the Indian government heavily subsidizes domestic prices of energy products, such as diesel, LPG (Liquefied Petroleum Gas) and kerosene for its consumers, the demand for petroleum products in India are influenced by the government's pricing schemes. With 3.6% of world's total consumption of aggregate energy in 2007 (Appendix Table 2), India is the fourth largest energy consumer in the world followed by the United States, China, and Japan. However, since India lacks sufficient domestic energy sources, she must import much of her growing energy demand. The combination of rising energy consumption and relatively flat production has left India increasingly dependent on imports to meet its energy demand. However, India also consumes a significant amount of primary solid biomass which includes fuel wood.

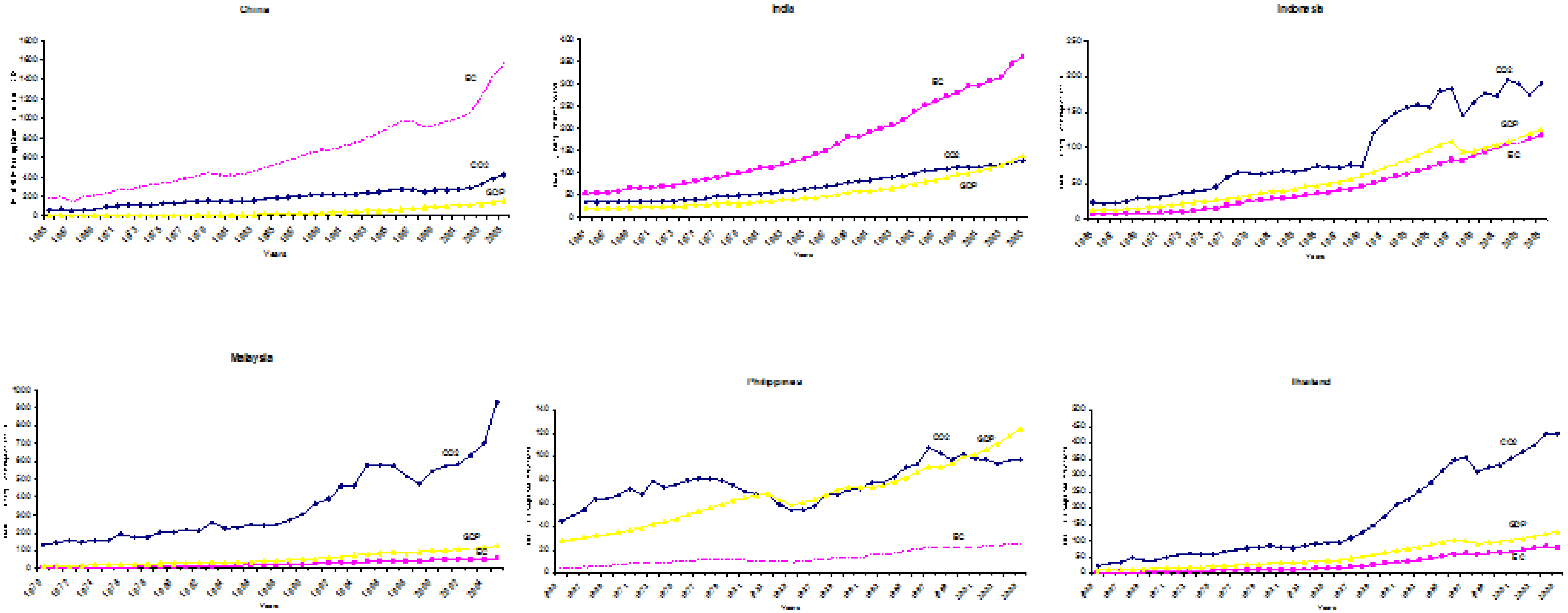
Historically, Indonesia has always subsidized oil prices for domestic retail fuel consumers, with selling energy products at a discounted price well below the world market parity prices. In addition to fossil fuels (like oil, coal and natural gas) and hydroelectric sources, Indonesia also consumes renewable energy sources like, primary solid biomass including fuel wood and geothermal sources. According to the Figure 1, economic growth, energy consumption and pollutant emission increased steadily in the periods covered in this study.

Since the 1997 crisis, Malaysian economy has recovered convincingly. Real GDP grew to 6.3% in 2007 from 5.9% in 2006 due to the increase in domestic demand. Gross investment has also reached at 10.2% in 2007- a three fold increase from 2002. Being consistent with the increasing trend in real GDP, both energy consumption and pollutant emission also show increasing trend (Figure 1). In 2007, Malaysia consumed 0.52% energy of the world (Appendix Table 2). The country is a significant producer of oil and natural gas in the Southeast Asia. Malaysia is the only net oil exporting country among the considered countries in this study. Similar to other considered countries, the Malaysian government also significantly subsidizes domestic energy prices. In addition to crude oil, natural gas, coal and hydroelectric, primary solid biomass is also used in a minimal level.

Despite increasing political instability and market volatility, the Philippines economy has been experiencing steady economic expansion in recent years. The growth in recent years in Philippines is associated with growth in energy consumption and carbon emission. Figure 1 shows the increasing trends in output along with the rise in oil consumption and carbon emission trends. The energy industry in the Philippines is mostly deregulated, except for the price setting of petroleum products where oil companies are required to seek government's consent in setting up oil prices, especially the prices of diesel. There is an informal cap on weekly price increases of 50 centavos per litter. The Philippines economy also consumes primary solid biomass and geothermal energies in their industrial and agricultural sectors.

The Thai economy has also shown a persistent economic growth after the financial crisis of 1997. Despite of political uncertainty and economic crisis, Thailand has also made substantial progress in social development like, higher income for the people and greater access to health care. With all these increasing socio economic trends, oil consumption and pollutant emission also show a steady increasing trend over time (Figure 1). The Thai energy consumption portfolio is dominated by oil consuming approximately 50.30% of total energy consumption followed by natural gas. Crude oil production and exploration activities have increased in recent years but the increased effort in P&E have not been able to catch up with the increase in domestic consumption demand by the industrial and transportation sectors. Thailand also uses a significant amount of biomass including fuel wood.

Figure 1: Real GDP, Energy Consumption and carbon Emission in Six Asian Emerging Economies



Note: GDP, EC and CO2 represent real output, energy consumption in million tonnes oil equivalent and carbon emission in hundred million tones, respectively. Real output and carbon emission data are collected from World Development Indicators (WDI) by World Bank, while energy consumption data is found from BP (2008).

From the above discussion some important observations emerge. One, in recent years all the concerned economies have experienced substantial economic developments. Two, these development efforts are considerably linked with increased consumption of energy and increased pollutant emission. Three, the dependence of these economies on energy is expected to rise in the future to ensure sustainable economic growth.

3. Review of Literature

Despite the extensive empirical work examining the role of energy in the growth process, the mainstream theory of economic growth pays little attention to the contribution of energy or other natural resources in promoting and facilitating economic growth. The neoclassical literature on growth and resources differs in its approaches to address the energy-growth relationship. Some studies attempt to ascertain the impact of energy on the economic activities under different assumption scenarios within the growth model, whereas some other attempt to find out the appropriate conditions for sustainable use of energy.

To identify the impact of access to non-renewable energy on aggregate real output, Solow (1978) analyses the following production function:

$$F(K,L,R)=[aR^{(\sigma-1)/\sigma}+bC^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}$$

where, R is the current flow of natural resources, C is the composite index of labour and capital inputs, *i.e.* $C = f(K, L)$, a and b are intrinsic measures of the relative "importance" of R and C, respectively. The elasticity of substitution between R and C is represented by σ. Nevertheless, a major fraction of neoclassical literature on growth and resources concentrates on finding the appropriate conditions that enable continuing growth or intergenerational sustainability of the level of consumption and utility. According to the literature, this sustainability depends on technical and institutional conditions. The initial capital and natural resources endowment, easy substitutability among inputs, and the mix of both renewable and non-renewable resources are the key technical conditions. The institutional conditions include values concerning welfare of the future generation, market structure (competitive vs. central planning), and the property right infrastructure (commonly owned vs. private owner property system).

According to Solow (1974), intergenerational sustainability in consumption is achievable under the model where non-renewable natural resources are finite with no extraction cost and non-depreciating capital. In this model, the elasticity of substitution between natural resources and labour goods and capital goods is unity. Growth in consumption can occur indefinitely when the utility of individuals is given identical weight irrespective of time, and the objective is to maximize the sum of utilities over time. Stiglitz (1974a) further argues that even in an economy in which natural resources are limited in supply, exhaustible and essential, sustained growth in per capita income is feasible. In this study the author also derives an optimum rate of resource utilization for the economy. However, the same model of economic growth under competition results in exhaustion of the resource with consumption and social welfare falling to zero (Stieglitz, 1974b).

Dasgupta and Heal (1979) stress the need for capital investment to overcome the depletion of natural resources. Assuming a constant discount rate, they assert that the efficient growth path will eventually lead to depletion of natural resources and the economy will collapse if insufficient capital is invested to replace the natural resources depletion. Hartwick (1977) also shows that intergenerational equity is possible if an economy invests all profits or rents from exhaustible natural resources in other forms of reproducible capital, which in turn can substitute for resources. Later , Hartwick (1995) and Dixit *et al*. (1980) extend the model to open economies and multiple capital stocks, respectively. However, the model they use is hard to apply as the model requires that the rents and capital are valued at sustainability compatible prices (Asheim, 1994, Stern, 1997, and Asheim *et al*., 2003).

A common result emerges from the body of work discussed above is that most of the neoclassical economists are primarily interested in what institutional arrangement, and not what technological arrangement (*i. e.* substitutability between energy and capital, both human and physical, and substitutability among different energy sources itself), will lead to sustainability. Thus, they typically assume *a priori* that sustainability is technically feasible and then analyze under what sort of institutional arrangements sustainability is possible. Solow (1993, 1997) also suggests that there is a tendency among mainstream economists to assume that sustainability is technically feasible unless proven otherwise.

As mentioned earlier, there is an impressive body of empirical literature on the relationship between energy consumption and economic growth. Research on this issue has primarily been aimed at providing significant policy guideline in designing efficient energy conservation policies. The pioneering research in this area was conducted by Kraft and Kraft (1978). The authors found a unidirectional causality running from national product to energy consumption in the USA over the period 1947-1974.

Following Kraft and Kraft (1978), research on this subject has been flourished in the context of both developed and developing countries. However, these studies do not arrive at any unique conclusion as to the direction of causality between energy consumption and economic growth. This may arise from three different sources: first, they differ in the econometric methodologies employed; second, they consider different data with different countries and time spans and third, there may be possible problem created by non-stationarity of data.

Some studies find unidirectional causality running from output to energy consumption. Following Kraft & Kraft (1978), Abosedra & Baghestani (1989) find unidirectional causality from output to energy consumption using extended data set on the USA spanning from 1947 to 1987. Unidirectional causality from output to energy has also been found in many other studies. For example, Narayan & Smyth (2005) examine Australia's data on electricity, GDP and employment; Al-Iriani (2006) examines energy consumption and GDP data of 6 GCC (Gulf Cooperation Council) countries over the period from 1971-2002; Mozumder & Marathe (2007) examine Bangladesh's data on electricity consumption and GDP from 1971-1999; Mehrara (2007) examine the energy consumption and economic growth data of 11 oil exporting countries from 1971-2002; and so on.

Contrary to the above, some studies find that there is unidirectional causal relationship that runs from energy consumption to output. Wolde-Rufael (2004) finds that over the period from 1952 to 1999 energy consumption in Shanghai Granger causes GDP. Morimoto & Hope (2004) came up with the same outcome on Sri Lankan data from 1960 to1998 that electricity production causes economic growth. Chen, Kuo & Chen (2007) use GDP and electric power consumption data of Asia's 10 newly industrialized countries (NICs) over the period from 1971 to 2001. Other studies find the similar unidirectional causality from energy consumption to income include Masih & Masih (1998), Stern (2000) and Shiu & Lam (2004).

Bi-directional causality has also been found in some studies. Masih & Masih (1997) investigate causal link between energy and output for Korea and Taiwan over the period from 1955 to 1991 and 1952 to 1992 respectively and conclude that there is bi-directional causal relationship between these variables. Soytas & Sari (2003) examine G-7 and 10 emerging economy's data except China and find bi-directional causal relationship between per capita GDP and energy consumption in Argentina over the period from 1950 to 1990. However, in the same study they find two different results for other countries. In case of Italy, from 1950 to 1992 and Korea, from 1953 to 1991 they find that causality runs from GDP to energy consumption, whereas the opposite was found in case of Turkey, Germany, France and Japan over the period from 1950 to 1992. Other studies that also come up with same conclusions are Asafu-Adjaye (2000), Oh & Lee (2004a), Yoo (2005) and Wolde-Rufael (2006). Although most of these studies find significant causal link between energy and output, some earlier studies, such as, Yu & Hwang's (1984) study on US data from 1947 to 1979 and Stern's (1993) study on US data from 1947 to 1990 conclude that there is no causal relationship between these two variables.

In addition to causality analysis, some studies examine whether the underlying time series data have undergone any structural break. For example, Lee & Chang (2005) examine Taiwan's data and find the structural break in gas and GDP data. With regard to causality they conclude that energy causes growth and energy conservation may harm economic growth. Altinay & Karagol (2005) examine Turkish data and find similar result to that of Lee & Chang (2005). They find structural break in the electricity and income series and unidirectional causality running from electricity consumption to income. This finding also implies that energy consumption may be harmful for future economic growth.

Most of the previous studies in this field performed bivariate Granger causality test to ascertain the direction of causality. However, in one of the pioneering works in multivariate studies Stern (1993) questions the appropriateness of such bivariate approach in the light of omitted variable problems. The traditional bivariate causality tests may fail to identify additional channels of impact and can also lead to conflicting results. Afterwards, multivariate studies in this field take two different dimensions: *demand side approach* with energy consumption, GDP and prices; and *supply or production side approach* with energy consumption, GDP, capital and labor. Examples of demand side approach are Masih and Masih (1997) and Asafu-Adjaye (2000); while of production side approach are Stern (1993), Stern (2000) and Oh and Lee (2004b).

From the above discussion some important conclusions emerge. First, the relationship between energy consumption and economic growth is not unique. Second, different studies use different measures of energy. Third, in most of these studies time series property of underlying variables (structural break) has not been considered properly. Fourth, multivariate approaches are superior to bivariate approach. Fifth, multivariate studies on Asian countries are not profound. And sixth, studies identifying both short-and long-run causality between energy consumption and income are limited. The present article is an attempt to overcome some of these deficiencies in the earlier studies. It differs from previous studies on the following grounds: to the authors' knowledge this is the first paper considering two of the fastest growing economies (India and China) of the world using the same multivariate framework. Instead of using any single energy source (such as, electricity or gas or coal) this article uses a broad measure of energy consumption, million tones oil equivalent.

The importance of this paper lies in three points. One, prior to analyzing the econometric model this study performs a battery of pre-testing procedures one of which is the test of unknown structural break in the underlying time series data. Second, instead of using Engel-Granger two step method, this study employs cointegration test proposed by Johansen (1988) and Johansen and Juselius (1990). Third, this study examines causality among the variables within the error correction model formulation to identify both the direction of short- and long-run causality and within-sample Granger exogeneity and endogeneity of each variable. Fourth, for testing the robustness of results this study presents variance decompositions and impulse response functions which provide information about the interaction among the variables beyond the sample period.

4. Data Sources and Methodology

Data sources: The paper uses annual data from 1965 to 2006 for all selected countries (China, India, Indonesia, Malaysia, Philippines and Thailand). Time series data on energy consumption is obtained from *BP statistical review of world energy 2007* and gross domestic product (GDP) and consumer price index (CPI) data are collected from the World Bank. Energy is measured as million tones oil equivalent of the final use of coal, natural gas, petroleum, electric power, and bio-fuels. GDP data refers to the real GDP (2000 = 100) in their respective national currencies while the base year for CPI is also 2000. Since energy prices are not available, this variable is proxied by the consumer price index (CPI) of the respective countries. All the series are taken in their logarithmic form. Visual presentation of these series is given in Appendix Figure 1.

Methodology: Following Masih and Masih (1997), this article employs a vector error correction (VEC) model (due to Engel and Ganger, 1987) of the following forms:

$$\Delta y_t = \alpha_1 + \sum_{i=1}^{l} \beta_{1i} \Delta x_{t-i} + \sum_{i=1}^{m} \gamma_{1i} \Delta y_{t-i} + \sum_{i=1}^{n} \delta_{1i} \Delta z_{t-i} + \sum_{i=1}^{r} \xi_{1i} ECT_{i,t-1} + \mu_{1t} \qquad (1)$$

$$\Delta x_t = \alpha_2 + \sum_{i=1}^{l} \beta_{2i} \Delta x_{t-i} + \sum_{i=1}^{m} \gamma_{2i} \Delta y_{t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta z_{t-i} + \sum_{i=1}^{r} \xi_{2i} ECT_{i,t-1} + \mu_{2t} \qquad (2)$$

$$\Delta z_t = \alpha_3 + \sum_{i=1}^{l} \beta_{3i} \Delta x_{t-i} + \sum_{i=1}^{m} \gamma_{3i} \Delta y_{t-i} + \sum_{i=1}^{n} \delta_{3i} \Delta z_{t-i} + \sum_{i=1}^{r} \xi_{3i} ECT_{i,t-1} + \mu_{3t} \qquad (3)$$

where y_t, x_t *and* z_t represents log of GDP, price levels and energy consumption, respectively, denoted by *LY, LP and LE. ECTs* are the error correction terms derived from long-run cointegrating relationship via Johansen maximum likelihood procedure, and $u_{i,t}$'s (for i = 1,2,3) are iid (independently and identically distributed) white noise error terms with zero mean. For the estimation purpose of this paper Equation (1) is used to test causation from prices and energy consumption to income. Equation (2) is used to test causality from income and energy consumption to prices, while Equation (3) identifies causality from income and prices to energy consumption.

Through the error correction term (ECT), the model opens up an additional channel of causality which is traditionally ignored by the standard Granger (1969) and Sims (1972) testing procedures. According to Masih and Masih (1997) sources of causality can be identified through three different channels: (i) the lagged *ECT*'s (ξ's) by a t-test; (ii) the significance of the coefficients of each explanatory variable (β's, γ's and δ's) by a joint Wald *F* or χ^2 test (weak or short-run Ganger causality); (iii) a joint test of all the set of terms in (i) and (ii) by a Wald *F* or χ^2 test, that is, taking each parenthesized terms separately: the (γ's, ξ's) and (δ's, ξ's) in Equation (1); the (β's, ξ's) and (δ's, ξ's) in Equation (2); and the (β's, ξ's) and (γ's, ξ's) in Equation (3) (strong or long-run Granger causality).[2]

Before implementing the above model it is imperative to ensure first that the underlying data are non-stationary or I(1) and there exists at least one cointegrating relationship among the variables. Two of the most widely used unit root tests in this regard are Augmented Dickey-Fuller (*ADF*) and Phillips Perron (*PP*) unit root tests. However, these standard tests may not be appropriate when the series contains structural break (Salim & Bloch, 2007). Furthermore, to account for events like cultural revolution in China and Asian Financial Crisis in Thailand, Indonesia, Malaysia and Philippines it is well justified to scrutinize data for possible structural break(s) during these times. To identify such structural breaks Perron (1997) develops a procedure that allows

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[2] For further clarification on weak or short-run Ganger causality and strong or long-run Granger causality please consult Soytas and Sari (2006).

endogenous break points in series under consideration. Thus, this paper employs *ADF* and *PP* unit root testing procedure as well as the test for unknown structural break due to Perron (1997).

Perron (1997) develops a procedure that allows endogenous break points in series under consideration. The following regression (Perron, 1997) is used here to examine the stationarity of time series allowing for unknown structural breaks:

$$y_t = \mu + \beta t + \gamma DT_t^* + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \, . \qquad (3.22)$$

where DT_t^* is a dummy variable and $DT_t^* = 1(t > T_b)(t - T_b)$. Here T_b indicates break point(s). The break point is estimated by OLS for $T_b = 2, ..., T-1$, thus, $(T-2)$ regressions are estimated and the break point is obtained by the minimum t statistic on the coefficient of the autoregressive variable (t_α).

Engle and Granger (1987) suggest that a vector of non-stationary time series, which may be stationary only after differencing, may have stationary linear combination without differencing and then the variables are said to have cointegrated relationship. If the variables are non-stationary and not co-integrated, the estimation result of regression model gives rise to what is called ‘spurious regression’. The traditional OLS regression approach to identify cointegration cannot be applied where the equation contains more than two variables and there is a possibility of having multiple cointegrating relationships. In that case VAR based cointegration test is appropriate. Therefore, this article uses the Johansen (1988) and Johansen and Juselius (1990) maximum likelihood estimation procedures.

This paper employs both generalized variance decompositions and generalized impulse response approaches proposed by Koop et al.(1996) and Pesaran and Shin (1998). The reason behind employing the generalized versions of these two techniques is that the results from these analyses are invariant to the ordering of the variables entering the VAR system.

5. Empirical Analyses

Time series properties of data: Augmented Dickey-Fuller (*ADF*) and Phillips Perron (*PP*) unit root tests are first employed to examine the stationarity of underlying time series data. The results[3]of the tests reveal that all the concerned variables are non-stationary at level but stationary at their first differences. However, as mentioned earlier

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[3] Results not reported considering space limitation. However, results will be provided upon request.

that the traditional unit root tests cannot be relied upon if the underlying series contains structural break(s). Many authors discuss this limitation of the conventional unit root tests (Perron, 1989, 1997; Zivot & Andrews, 1992). Following Perron and Zivot & Andrews, a number of empirical studies were conducted in recent years, such as Salman and Shukur (2004), Hacker and Hatemi-J (2005), Narayan and Smyth (2005), and Salim and Bloch (2007) among others. This study uses Perron (1997) unit root test that allows for structural break and the test results are summarized in Table 1.

Table-1: Perron Innovational Outlier model with change in both intercept and slope.

Country	Series	T	T_b	k^1	$t_{\hat{\beta}}$	$t_{\hat{\theta}}$	$t_{\hat{\gamma}}$	$t_{\hat{\delta}}$	$\hat{\alpha}$	t_α	Inference
China	LGDP	12	1976	1	5.359	-4.249	3.568	1.685	0.249	-5.266	NS
	LEC	31	1995	2	4.372	-4.171	3.912	3.046	0.600	-5.013	NS
	LP	20	1984	8	1.687	-3.476	3.534	2.349	0.436	-4.038	NS
India	LGDP	20	1984	3	4.079	-3.952	3.993	1.089	-0.438	-4.026	NS
	LEC	21	1985	0	3.345	1.973	-0.182	-0.944	0.595	-3.221	NS
	LP	37	2001	1	3.943	1.091	-1.203	-0.028	0.542	-3.931	NS
Indonesia	LGDP	32	1996	0	5.809	0.309	-1.448	5.531	0.466	-5.275	NS
	LEC	23	1987	5	3.854	4.019	-3.859	-2.187	0.218	-4.047	NS
	LP	11	1975	0	2.724	1.943	-2.273	0.552	0.650	-2.699	NS
Malaysia	LGDP	18	1982	8	5.632	2.031	-2.092	2.242	-1.316	-5.225	NS
	LEC	23	1987	1	5.545	5.316	-5.622	-1.498	0.286	-5.262	NS
	LP	15	1979	3	5.318	4.760	-4.218	-1.144	0.393	-5.147	NS
Philippines	LGDP	18	1982	5	3.648	-1.375	-1.598	4.753	0.653	-3.818	NS
	LEC	16	1980	6	2.793	0.644	2.793	-1.489	0.409	-3.611	NS
	LP	18	1982	0	5.824	6.625	-6.376	-3.766	0.544	-5.284	NS
Thailand	LGDP	37	2001	7	4.427	3.171	-3.262	-1.631	-0.118	-4.482	NS
	LEC	14	1978	7	4.353	2.919	-2.839	-0.009	0.461	-4.173	NS
	LP	7	1971	0	-0.403	1.623	1.301	-2.767	0.804	-3.775	NS

Note: 1%, 5% and 10% critical values are -6.32, -5.59 and -5.29, respectively (Perron, 1997). The optimal lag length is determined by t -sig with $k_{\max} = 8$. NS stands for Non-stationary at levels. . LY, LE and LP stand for log of GDP, energy consumption and price level, respectively.

The Perron test results provide further evidence of the existence of unit roots in three series of different countries when breaks are allowed. When the underlying series is found non-stationary the selected value of T_b is likely to no longer yield a consistent estimate of the break point (Perron, 1997). Therefore, it may be concluded that the underlying data are non-stationary at level but stationary at their first differences.

Co-integration and Granger causality: As the variables are level non-stationary and first difference stationary, the Johansen (1988) and Johansen and Juselius (1990) maximum likelihood co-integration test is employed to examine if the variables are co-integrated and the test results are reported in Table 2. The superiority of Johansen's approach compared to Engle and Granger's residual based approach lies in the fact that Johansen's approach is capable of detecting multiple cointegrating relationships among variables (Asafu-Adjaye, 2000).

Table-2: Johansen's Test for Multiple Cointegrating Relationships and Tests of Restrictions on Cointegrating Vector(s) [Intercept, no Trend]

Country	Null Hypothesis	Alternative Hypothesis	Optimal lag in VAR	Max-eigen value	Trace Stat.
China	$r=0$	$r>0$	2	22.41**	34.95**
	$r\leq 1$	$r>1$		11.54	15.54
	$r\leq 2$	$r=3$		3.99	3.99
India	$r=0$	$r>0$	2	33.89**	56.13**
	$r\leq 1$	$r>1$		15.06	20.22
	$r\leq 2$	$r=3$		7.17	7.17
Indonesia	$r=0$	$r>0$	3	41.17**	53.79**
	$r\leq 1$	$r>1$		9.23	12.62
	$r\leq 2$	$r=3$		3.39	3.39
Malaysia	$r=0$	$r>0$	3	22.94**	40.08**
	$r\leq 1$	$r>1$		13.65	17.14
	$r\leq 2$	$r=3$		3.48	3.48
Philippines	$r=0$	$r>0$	2	35.69**	59.62**
	$r\leq 1$	$r>1$		17.37**	23.92**
	$r\leq 2$	$r=3$		6.55	6.55
Thailand	$r=0$	$r>0$	2	34.28**	52.90**
	$r\leq 1$	$r>1$		10.01	18.62
	$r\leq 2$	$r=3$		8.62	8.62

Note: *r* indicates number of cointegrations. The optimal lag length of VAR is selected by Schwarz Bayesian Criterion. Critical values are based on Johansen and Juselius (1990). *, **, and *** indicate significant at 10%, 5%, and 1% level respectively.

It is apparent from Table 2 that, for China, India, Indonesia, Malaysia and Thailand, there is a single cointegrating relationship while for Philippines, the test results suggest the presence of two cointigating relationships. These results suggest that there is long run equilibrium relationship among output, energy consumption and price levels. Moreover, the cointegrating relationships among the variables indicate the existence of Granger causality in at least one direction. Thus to identify the direction of causality the error correction model is consulted. The results of vector error correction model are summarized in Table 3. The ECM does not only provide an indication of the direction of causality, it also enables to distinguish between short-run and long-run Granger causality. However, before discussing the ECM results it is worth to note that in constructing the ECM it is very important to select the appropriate lag length for the model. This paper employs Schwarz Bayesian information criteria for this purpose and the results are reported in Appendix Table 3.

The results for China imply uni-directional causality running from energy consumption to output both in the short- and long-run. The results further indicate that both energy consumption and income adjust to restore the long-run equilibrium relationship whenever there is a deviation from equilibrium cointegrating relationship. For India in the short-run the direction of causality is just the opposite, from income to energy consumption. However, there is no evidence of causality in the long-run. All three variables interact to restore the long-run equilibrium relationship. The results for Indonesia are similar to Asafu-Adjaye (2000). There is no evidence of causality between energy consumption and income both in the short- and long-run indicating neutrality between energy consumption and income. The explanation of this neutrality lies in the fact that since Indonesia is a net energy exporter it enjoys greater immunity from energy shocks. Furthermore, in Indonesia, both output and price levels appear to bear the burden of adjustment towards the long-run equilibrium in response to a short-run deviation. No Ganger causality between energy consumption and output is found with respect to Malaysia and Philippines. However, for both of these countries output and energy interact together to restore the long-run equilibrium. In Thailand the results show bi-directional causality between energy consumption and income in the short-run. Energy consumption seems to restore the long-run equilibrium alone. In most of the countries price levels seem to be less active. The results for Malaysia and Thailand, prices appear to be an exogenous variable in both the models.

Test for Source of Variability: Granger causality test suggests which variables in the models have significant impacts on the future values of each of the variables in the system. However, the result will not, by construction, be able to indicate how long these impacts will remain effective in the future. Variance decomposition and impulse response functions give this information. Hence this paper conducts generalized variance decompositions and generalized impulse response functions analysis proposed by Koop et al (1996) and Pesaran and Shin (1998). The unique feature of these approaches is that the results from these analyses are invariant to the ordering of the variables entering the VAR system.

Generalized Variance Decomposition: Variance decomposition gives the proportion of the movements in the dependent variables that are due to their "own" shocks, versus shocks to the other variables. The results of variance decomposition over a period of 20-year time horizon for different countries for the variables are presented in Appendix Table 5. Results for most of the countries are similar to the outcomes of causality analysis. Among others some of the significant findings are as follows. For China energy consumption explains a fair portion of variation in output (after 20 years, energy consumption explains almost 55% variations in output) confirming the existence of uni-directional causality from energy to output. From 1 to 20 years output explains energy consumption by 25.60% to 39.90%, respectively in India. Thus the result of India supports uni-directional causality from income to energy consumption in India. Generalized Variance Decomposition results for Indonesia, Malaysia and Philippines indicate the neutrality of energy and output as none of the variables show much power to explain the other. In Thailand, energy explains approximately 40% variations in output whereas output explains more than 60% variations in energy throughout the 20 year horizon. However, the results suggest that for most of the countries price level is comparatively less active than income and energy consumption in explaining variations in other variables.

Generalized Impulse Response Function: The generalized impulse response functions trace out responsiveness of dependent variables in the VAR to shocks to each of the variables. For each variable from each equation separately, a unit shock is applied to the error, and the effects upon the VAR system over time are noted (Brooks, 2002). The results of the impulse response functions are presented in Appendix Figure 2. Some of the significant findings are presented below. For China, in response to a unit standard error (SE) shock in energy consumption, future income increases up to 15% at the end of 20 year horizon supporting the result of uni-directional causality from energy consumption to output. Whereas, in India, in response to the shock in output energy consumption reaches up to 8% by the 20th year. There is not much response in output and energy in response to a one S. E. shock in each other for Indonesia, Malaysia and Philippines.

Table-3: Temporal Causality Results Based on Parsimonious Vector Error Correction Models (VECM)

Countries	Dependent variables	Short-run effects			Source of causation				
		ΔLY	ΔLE	ΔLP	ECT(s) only		ΔLY, ECT	ΔLE, ECT	ΔLP, ECT
		Wald χ^2-statistics			t-ratio		Wald χ^2-statistics		
China	ΔLY	-	7.54***	0.585	4.209***		-	17.99***	4.134**
	ΔLE	0.968	-	0.008	3.198***		0.0356	-	1.098
	ΔLP	1.194	3.260*	-	-.434		1.982	5.929**	-
India	ΔLY	-	1.248	1.490	-2.258**		-	0.527	0.145
	ΔLE	4.766**	-	0.546	-2.490**		2.514	-	0.774
	ΔLP	10.597***	1.143	-	-6.120***		16.735***	1.296	-
Indonesia	ΔLY	-	0.029	0.482	-3.149***		-	0.286	2.334
	ΔLE	0.204	-	1.108	-1.550		0.362	-	0.079
	ΔLP	3.148*	.002	-	-4.652***		4.769**	0.979	-
Malaysia	ΔLY	-	2.261	0.982	4.695***		-	0.459	2.879*
	ΔLE	0.064	-	4.078**	2.585**		0.016	-	5.719**
	ΔLP	1.237	1.326	-	-0.048		1.358	1.624	-
Philippines	ΔLY	-	2.711	3.393*	3.803***	-.480	-	3.241***	2.416
	ΔLE	1.694	-	6.584**	6.520***	1.383	1.469	-	7.161***
	ΔLP	0.640	4.929**	-	-1.063	-2.749***	0.882	4.855**	-
Thailand	ΔLY	-	4.060**	0.578	-0.758		-	0.005	0.209
	ΔLE	3.304*	-	6.16**	-4.862***		0.747	-	11.12***
	ΔLP	0.581	0.152	-	-0.208		0.459	0.088	-

Note: The vector error correction model (VECM) is based on an optimally determined (Schwarz Bayesian Information Criterion) lag structure (Appendix Table 4) and a constant.
*, **, and *** indicate significant at 10%, 5%, and 1% level respectively.

For Thailand, one S. E. shock in output increases energy consumption by almost 30% at the end of 20th year. Similarly, in response to a S. E. shock in energy consumption output increases by 15% at the end of 20 years. Thus, with a few exceptions the results from impulse response functions also confirm the identified directions of causality for different countries.

6. Conclusions and Policy Implications

This paper investigates the relationship between energy consumption and income in a trivariate *demand side framework*. Six emerging economies from Asia (such as, China, India, Indonesia, Malaysia, Philippines and Thailand) are selected for this purpose. The error-correction mechanism (ECM) is used to examine both short- and long-run Granger causality. Furthermore, generalized variance decompositions and impulse response functions are employed to confirm the robustness of causality tests. The empirical results show a uni-directional causality running from energy consumption to income for China for both short-and long-run. In India the results are opposite, i. e. short-run uni-directional causality from output to energy consumption is found. However, there is no evidence of long-run causality between the variables. In Philippines there exists a long-run uni-directional causality from energy consumption to output. While for Thailand bi-directional causality exists between energy consumption and income in the short-run. And for the rest of the countries, i. e. Indonesia and Malaysia the results find evidence for the neutrality of energy in both short- and long-run. However, neutrality between energy and income is expected in Indonesia since it is a net energy exporter and therefore, she seems to be more prepared to manage probable energy shocks because of their energy supply security. Another significant finding of this paper is that except for China and Philippines, for all the countries the hypotheses of neutrality of energy hold in the long-run. Prices seem to be less influential for most of the countries and in the model for Malaysia and Tailand it proves to be an exogenous variable

The policy implications for these findings are as follows. For India, where unidirectional causality from income to energy is found, she may contribute to the fight against global warming directly implementing energy conservation measures. The direction of causality indicates that the conservation policies can be initiated with little or no effects on economic growth. The country can also enhance the use of renewable energy sources. Moreover for India, energy conservation offers a practical means of achieving development goals. It enhances the international competitiveness of industry in world markets by reducing the cost of production. It optimizes the use of capital resources by diverting lesser amounts in conservation investments as against huge capital investment in power sector. It helps environment in the short run by reducing pollution and in the long run by reducing the scope of global climatic changes. Energy conservation also implies the substitution of costly imported energy by cheaper and more plentiful indigenous sources to supplement conventional sources.

For China, where causality runs from energy consumption to output, the country should focus on technological developments and mitigation policies. Since energy is a critical determinant of economic growth in China, its shortage may retard economic growth. However, in order to achieve high economic growth rates, multidimensional policies are required and these policies should not ignore the energy sector. To facilitate the availability of energy and balance of payment position, alternative sources of energy should also be developed. For Thailand, where bi-directional causality is found, a balanced combination of alternative policies seems to be appropriate. Furthermore, the finding of a bi-directional causality between energy consumption and output in the long-run imply that Thailand is also an energy dependent economy.

The results of the causality test have important implications for policy makers in China and Thailand who aspire to transform the economies into fully industrialized nations in the near future. Economic growth is the outcome of growth in inputs and increases the productivity of inputs. Hence, rapid industrialization requires higher and/or more efficient consumption of energy products. However, despite the above findings, policymakers of these two countries should be mindful that a persistent decline in environmental quality may exert negative externality to the economy through affecting human health, and thereby reduce productivity in the long-run.

Nevertheless, all of these countries may initiate environmental policies aimed at decreasing energy intensity, increasing energy efficiency, developing a market for emission trading. These countries can invest in research and development to innovate technology that makes alternative energy sources more feasible, thus mitigating pressure in environment. They can, furthermore, increase utilization of public transportation and establish a price mechanism which may encourage the use of renewable and environmental friendly energy sources. Finally, as far as policy implications are concerned given the directions of causality between the variables it is suggestive that the policy makers of different countries should design their energy policies in the light of individual country's demand structure and energy mix.

References

Abosedra, S & Baghestani, H 1989, 'New Evidence on the causal relationship between United States energy consumption and gross national product', *Journal of Energy Development*, vol. 14, pp. 285-92.

Al-Iriani, MA 2006, 'Energy-GDP relationship revisited: An example from GCC countries using panel causality', *Energy Policy*, vol. 34, no. 17, pp. 3342-50.

Altinay, G & Karagol, E 2005, 'Electricity consumption and economic growth: Evidence from Turkey', *Energy Economics*, vol. 27, no. 6, pp. 849-56.

Asafu-Adjaye, J 2000, 'The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries', *Energy Economics*, vol. 22, no. 6, pp. 615-25.

Asheim, GB 1994, 'Net national product as an indicator of sustainability', *Scandinavian Journal of Economics* vol. 96, pp. 257-65.

Asheim, GB, Buchholz, W & Withagen, C 2003, 'The Hartwick rule: Myths or facts', *Environmental and Resource Economics*, vol. 25, no. 2, pp. 129-50.

Brooks, C 2002, *Introductory Econometrics for Finance*, Cambridge University Press.

Chen, S-T, Kuo, H-I & Chen, C-C 2007, 'The relationship between GDP and electricity consumption in 10 Asian countries', *Energy Policy*, vol. 35, no. 4, pp. 2611-21.

Dasgupta, PS & Heal, GM 1979, *Economic theory and exhaustible resources*, Cambridge University Press., Oxford.

Dixit, A, Hammond, P & Hoel, M 1980, 'On Harrtwick's rule for regular maximin paths of capital accumulation and resource depletion', *Review of Economic Studies*, vol. 47, pp. 551-6.

Engle, RF & Ganger, CWJ 1987, 'Cointegration and error correction representation, estimation and testing', *Econometrica*, vol. 55, no. 1, p. 26.

Granger, CWJ 1969, 'Investigating causal relations by econometric models and cross-spectral methods', *Econometrica*, vol. 37, no. 3, pp. 424-38.

Hacker, RS & Hatemi-J, A 2005, 'The effect of regime shifts on the longrun relationships for Swedish money demend', *Applied Economics*, vol. 37, pp. 1131-36.

Hartwick, JM 1977, 'Intergenerational equity and the investing of rents from exhaustible resources', *American Economic Review*, vol. 67, no. 5, pp. 972-4.

Hartwick, JM 1995, 'Constant consumption paths in open economies with exhaustible resources', *Review of International Economics*, vol. 3, no. 3, pp. 275-83.

Johansen, S 1988, 'Statistical analysis of cointegration vectors', *Journal of Economic Dynamics and Control*, vol. 12, no. 2-3, pp. 231-54.

Johansen, S & Juselius, K 1990, 'Maximum likelihood estimation and inference on cointigration with applications to the demand for money', *Oxford Bulletin of Economics & Statistics*, vol. 52, no. 2, pp. 169-210.

Koop, G, Pesaran, MH & Potters, SM 1996, 'Impulse response analysis in nonlinear multivariate models', *Journal of Econometrics*, vol. 74, no. 1, pp. 119-47.

Kraft, J & Kraft, A 1978, 'On the relationship between energy and GNP', *Journal of Energy Development*, vol. 3, pp. 401-3.

Lee, C-C & Chang, C-P 2005, 'Structural breaks, energy consumption, and economic growth revisited: Evidence from Taiwan', *Energy Economics*, vol. 27, no. 6, pp. 857-72.

Masih, AMM & Masih, R 1996, 'Energy consumption, real income and temporal causality: Results from a multi-country study based on cointegration and error-correction modeling techniques', *Energy Economics*, vol. 18, no. 3, pp. 165-83.

Masih, AMM & Masih, R 1997, 'On the temporal causal relationship between energy consumption, real income, and prices: Some new evidence from Asian-energy dependent NICs Based on a multivariate cointegration/vector error-correction approach', *Journal of Policy Modeling*, vol. 19, no. 4, pp. 417-40.

Masih, AMM & Masih, R 1998, 'A multivariate cointegrated modeling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs', *Applied Economics*, vol. 30, no. 10, pp. 1287-98.

Mehrara, M 2007, 'Energy consumption and economic growth: The case of oil exporting countries', *Energy Policy*, vol. 35, no. 5, pp. 2939-45.

Morimoto, R & Hope, C 2004, 'The impact of electricity supply on economic growth in Sri Lanka', *Energy Economics*, vol. 26, no. 1, pp. 77-85.

Mozumder, P & Marathe, A 2007, 'Causality relationship between electricity consumption and GDP in Bangladesh', *Energy Policy*, vol. 35, no. 1, pp. 395-402.

Narayan, PK & Smyth, R 2005, 'Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests', *Energy Policy*, vol. 33, no. 9, pp. 1109-16.

Oh, W & Lee, K 2004a, 'Causal relationship between energy consumption and GDP revisited: The case of Korea 1970-1999', *Energy Economics,* vol. 26, no. 1, pp. 51-9.

Oh, W & Lee, K 2004b, 'Energy consumption and economic growth in Korea: testing the causality relation', *Journal of Policy Modeling,* vol. 26, no. 8-9, pp. 973-81.

Perron, P 1989, 'The great crash, the oil price shocks, and the unit root hypothesis', *Econometrica,* vol. 57, no. 6, p. 41.

Perron, P 1997, 'Further evidence on breaking trend functions in macroeconomic variables', *Journal of Econometrics,* vol. 80, no. 2, pp. 355-85.

Pesaran, MH & Shin, Y 1998, 'Generalized impulse response analysis in linear multivariate models', *Economics Letters,* vol. 58, no. 17-29.

Salim, RA & Bloch, H 2007, 'Business expenditure on R & D and trade performances in Australia: is there a link?' *Applied Economics* vol. November, pp. 1-11.

Salman, AK & Shukur, G 2004, 'Testing for Granger causality between industrial output and CPI in the presence of regime shift: Swedish data', *Journal of Economic Studies,* vol. 31, no. 5/6, pp. 492-9.

Shiu, A & Lam, P-L 2004, 'Electricity consumption and economic growth in China', *Energy Policy,* vol. 32, no. 1, pp. 47-54.

Sims, CA 1972, 'Money, income, and causality', *American Economic Review,* vol. 62, no. 4, pp. 540-52.

Sims, CA 1980, 'Macroeconomics and reality', *Econometrica,* vol. 48, pp. 1-48.

Solow, RM 1974, 'Intergenerational equity and exhaustible resources', *Review of Economic Studies,* vol. 41, no. 128, pp. 29-46.

Solow, RM 1978, 'Resources and economic growth', *American Economist,* vol. 22, no. 2, pp. 5-11.

Solow, RM 1993, 'An almost practical step toward sustainability', *Resources Policy,* vol. 19, pp. 162-72.

Solow, RM 1997, 'Reply: Georgescu-Roegen versus Solow/Stiglitz', *Ecological Economics,* vol. 22, pp. 267-8.

Soytas, U & Sari, R 2003, 'Energy consumption and GDP: Causality relationship in G-7 countries and emerging markets', *Energy Economics,* vol. 25, no. 1, pp. 33-7.

Stern, DI 1993, 'Energy and economic growth in the USA : A multivariate approach', *Energy Economics,* vol. 15, no. 2, pp. 137-50.

Stern, DI 1997, 'The capital theory approach to substitutability: A critical appraisal', *Journal of Economic Issues*, vol. 31, pp. 145-73.

Stern, DI 2000, 'A multivariate cointegration analysis of the role of energy in the US macroeconomy', *Energy Economics*, vol. 22, no. 2, pp. 267-83.

Stiglitz, JE 1974a, 'Growth with exhaustible natural resources: Efficient and optimal growth paths', *Review of Economic Studies*, vol. 41, no. 128, pp. 123-37.

Stiglitz, JE 1974b, 'Growth with exhaustible natural resources: The competitive economy', *Review of Economic Studies*, vol. 41, no. 128, pp. 139-52.

Wolde-Rufael, Y 2004, 'Disaggregated industrial energy consumption and GDP: The case of Shanghai, 1952-1999', *Energy Economics*, vol. 26, no. 1, pp. 69-75.

Wolde-Rufael, Y 2006, 'Electricity consumption and economic growth: A time series experience for 17 African countries', *Energy Policy*, vol. 34, no. 10, pp. 1106-14.

World Energy Outlook 2007, 'China and India insight'. International Energy Agency, France.

Yoo, S-H 2005, 'Electricity consumption and economic growth: Evidence from Korea', *Energy Policy*, vol. 33, no. 12, pp. 1627-32.

Yu, ESH & Hwang, B-K 1984, 'The relationship between energy and GNP : Further results', *Energy Economics*, vol. 6, no. 3, pp. 186-90.

Zivot, E & Andrews, DWK 1992, 'Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis', *Journal of Business and Economic Statistics*, vol. 10, no. 3, p. 20.

Appendix Table 1: Country Profile: Socio-Economic and Energy Consumption Fact Sheet (2006)

Indicator(s)	China	India	Indonesia	Malaysia	Philippines	Thailand
Population, total (Millions)	1311.80	1109.81	223.04	26.11	86.26	63.44
Population growth (annual %)	0.56	1.38	1.12	1.78	1.99	0.70
GDP (current US$, Billions)	2644.68	911.81	364.79	150.67	117.56	206.34
GDP growth (annual %)	10.70	9.20	5.48	5.90	5.45	5.02
Exports of goods and services (% of GDP)	40.14	22.97	30.88	116.98	46.38	73.74
Foreign direct investment, net inflows (BoP, current US$, Millions)	78094.67	17453.10	5579.69	6063.55	2345.00	9010.19
Energy consumption (quadrillion BTU)	1697.8	423.2	114.3	67.0	25.2	86.1
Growth in Energy consumption from 1996 to 2006	79.93%	55.88%	42.69%	78.02%	18.97%	48.36%

Source: Data of all the indicators except energy consumption is found from World Development Indicator by World Bank while energy consumption data is from Energy Information Administration (EIA).

Appendix Table 2: Primary Energy Consumption by Fuel in the Studied Countries (million tonnes oil equivalent)

Country/ Region	Oil	Natural Gas	Coal	Nuclear Energy	Hydro-electric	2007 Total	% of World
China	367.97	60.57	1311.41	14.22	109.26	1863.44	16.79
India	128.53	36.16	208.00	4.03	27.70	404.42	3.64
Indonesia	54.42	30.42	27.81	-	1.95	114.60	1.03
Malaysia	23.59	25.43	6.93	-	1.43	57.38	0.52
Philippines	13.90	3.09	5.93	-	1.94	24.86	0.22
Thailand	43.03	31.82	8.86	-	1.84	85.55	0.77
Total Sample	631.43	187.50	1568.95	18.26	144.11	2550.25	22.98
World	3952.82	2637.74	3177.54	622.02	709.22	11099.34	100.00

Source: BP (2008)

Note: Primary energy comprises commercially traded fuels only. Excluded, therefore, are fuels such as wood, peat and animal waste which, though important in many countries, are unreliably documented in terms of consumption statistics. Also excluded are wind, geothermal and solar power generation. Oil consumption is measured in million tonnes; other fuels in million tonnes of oil equivalent. '% of World' represents percentage of total world consumption for the same fuel type, while '% of Country' represents percentage of aggregate fuel consumption of the country for all the five fuel types together.

Appendix Table 3: World Primary Energy Demand by Region (Mtoe)

	2005	**2015**	**2030**	**2005 to 2030***
OECD	**5 542**	**6 135**	**6 663**	**0.7%**
North America	2 786	3 139	3 501	0.9%
Europe	1 874	2 011	2 118	0.5%
Pacific	882	986	1 045	0.7%
Transition economies	**1 080**	**1 266**	**1 422**	**1.1%**
Russia	645	767	873	1.2%
Developing countries	**4 635**	**7 045**	**10 433**	**3.3%**
China	1 742	3 135	4 691	4.0%
India	537	804	1 508	4.2%
Other Asia	749	986	1 272	2.1%
Middle East	503	748	1 138	3.3%
Africa	606	729	954	1.8%
Latin America	500	643	869	2.2%
World**	**11 429**	**14 636**	**18 739**	**2.0%**
European Union	1 814	1 923	2 002	0.4%

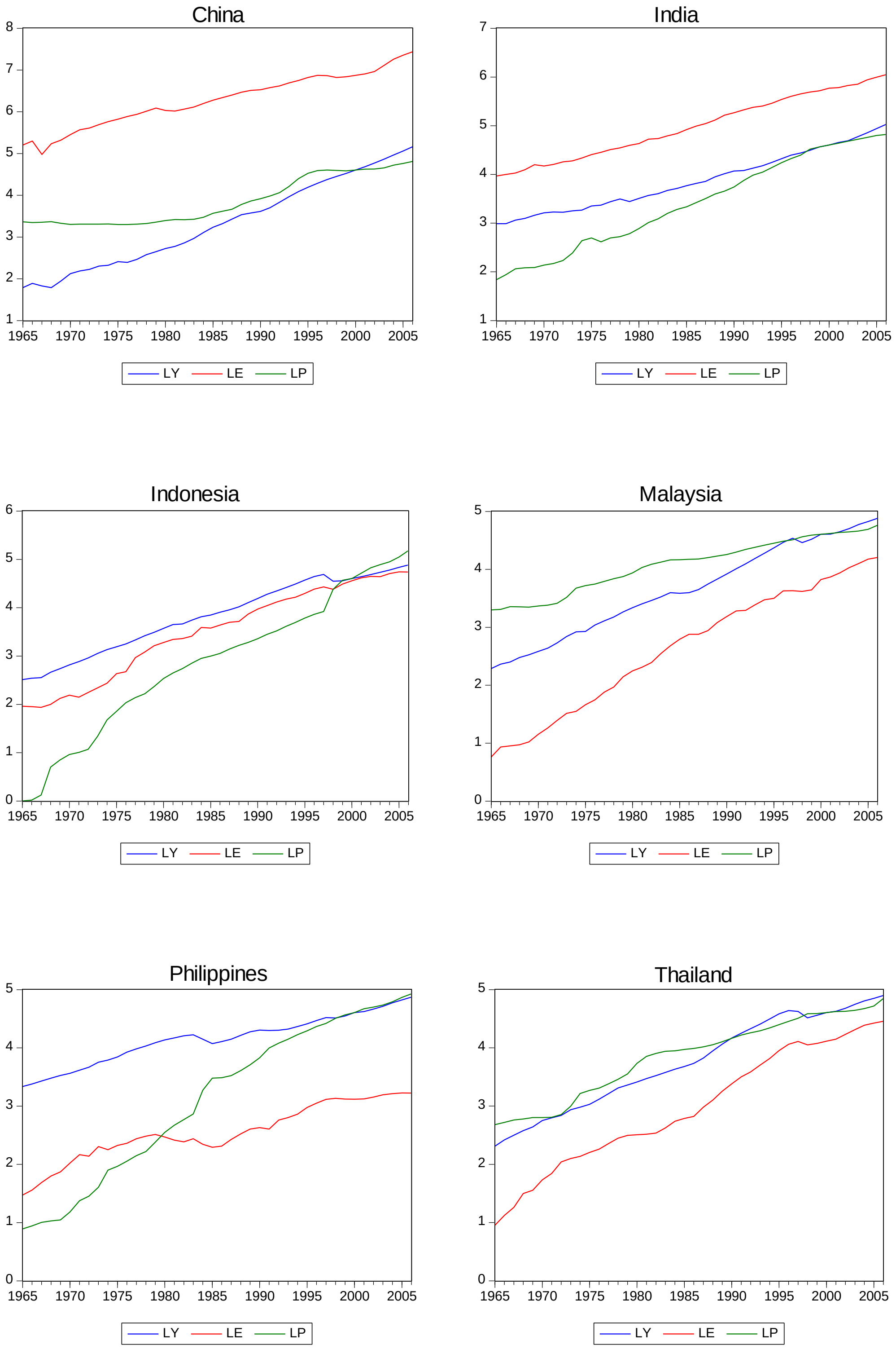
* Average annual rate of growth.
**Includes international marine bunkers.
Source: World Energy Outlook 2007

Appendix Table 4: Optimum lag length selection (Schwarz Bayesian Criterion)

Lag	China	India	Indonesia	Malaysia	Philippines	Thailand
0	-132.3077	-85.2943	-100.3507	-99.9383	-127.5513	-80.2591
1	191.3457	207.4023	144.8194	190.7302	169.7859	200.7385
2	202.7137*	213.6193*	137.1892	182.5704	175.4349*	206.3374*
3	190.2971	196.5400	156.9631*	198.8387*	163.7096	204.3640
4	181.7002	191.1689	127.3568	170.9280	154.7514	202.3608
5	170.9609	184.9696	122.9478	163.6072	145.6290	197.9532
6	162.8667	181.6448	112.0577	155.4805	132.5520	198.2773

* indicates optimum lag length

Appendix Figure 1: LY LE LP of Six Developing Asian Countries



Appendix Table 5: Findings from Forecast Error Variance Decomposition

a. China

Years	Variance Decomposition of LY			Variance Decomposition of LE			Variance Decomposition of LP		
	LY	LE	LP	LY	LE	LP	LY	LE	LP
1	0.962	0.333	0.012	0.157	0.993	0.013	0.014	0.158	0.873
5	0.882	0.363	0.013	0.159	0.979	0.009	0.046	0.266	0.802
10	0.719	0.449	0.033	0.183	0.894	0.058	0.047	0.317	0.758
15	0.650	0.478	0.129	0.189	0.717	0.192	0.040	0.356	0.716
20	0.465	0.554	0.153	0.173	0.707	0.171	0.033	0.393	0.667

b. India

Years	Variance Decomposition of LY			Variance Decomposition of LE			Variance Decomposition of LP		
	LY	LE	LP	LY	LE	LP	LY	LE	LP
1	0.945	0.201	0.008	0.256	0.867	0.022	0.232	0.004	0.851
5	0.952	0.266	0.021	0.249	0.869	0.008	0.309	0.139	0.602
10	0.868	0.221	0.051	0.277	0.827	0.020	0.625	1.123	0.252
15	0.869	0.283	0.069	0.391	0.794	0.037	0.844	0.080	0.093
20	0.872	0.212	0.080	0.399	0.771	0.050	0.893	0.092	0.054

c. Indonesia

Years	Variance Decomposition of LY			Variance Decomposition of LE			Variance Decomposition of LP		
	LY	LE	LP	LY	LE	LP	LY	LE	LP
1	0.995	0.195	0.236	0.183	0.979	0.019	0.388	0.054	0.953
5	0.977	0.180	0.365	0.099	0.963	0.006	0.484	0.102	0.911
10	0.961	0.160	0.411	0.117	0.977	0.013	0.477	0.127	0.910
15	0.946	0.144	0.144	0.159	0.981	0.034	0.456	0.148	0.905
20	0.932	0.131	0.131	0.209	0.973	0.063	0.432	0.168	0.888

d. Malaysia

Years	Variance Decomposition of LY			Variance Decomposition of LE			Variance Decomposition of LP		
	LY	LE	LP	LY	LE	LP	LY	LE	LP
1	0.989	0.084	0.048	0.081	0.792	0.215	0.142	0.005	0.969
5	0.767	0.293	0.065	0.023	0.765	0.205	0.202	0.067	0.845
10	0.761	0.264	0.187	0.011	0.632	0.318	0.143	0.221	0.669
15	0.701	0.258	0.224	0.019	0.694	0.340	0.088	0.201	0.666
20	0.766	0.265	0.231	0.030	0.561	0.459	0.056	0.243	0.604

e. Philippines

Years	Variance Decomposition of LY			Variance Decomposition of LE			Variance Decomposition of LP		
	LY	LE	LP	LY	LE	LP	LY	LE	LP
1	0.971	0.129	0.122	0.128	0.935	0.129	0.021	0.376	0.947
5	0.958	0.218	0.148	0.186	0.815	0.316	0.059	0.266	0.854
10	0.927	0.244	0.221	0.291	0.755	0.507	0.126	0.207	0.758
15	0.808	0.280	0.232	0.235	0.808	0.549	0.163	0.253	0.693
20	0.705	0.298	0.259	0.252	0.891	0.563	0.153	0.368	0.654

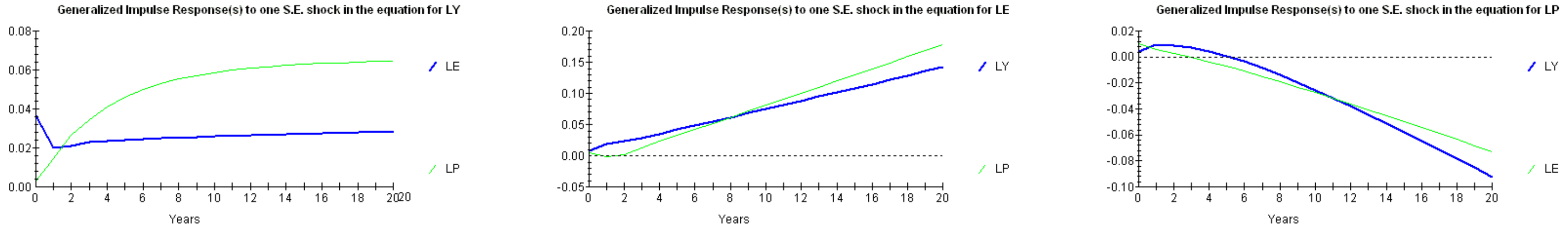
e. Thailand

Years	Variance Decomposition of LY			Variance Decomposition of LE			Variance Decomposition of LP		
	LY	LE	LP	LY	LE	LP	LY	LE	LP
1	0.999	0.431	0.014	0.619	0.828	0.340	0.005	0.155	0.986
5	0.998	0.402	0.011	0.756	0.652	0.351	0.094	0.047	0.822
10	0.996	0.399	0.020	0.805	0.582	0.312	0.309	0.029	0.570
15	0.993	0.402	0.031	0.828	0.551	0.386	0.491	0.057	0.385
20	0.989	0.404	0.039	0.841	0.533	0.469	0.616	0.091	0.268

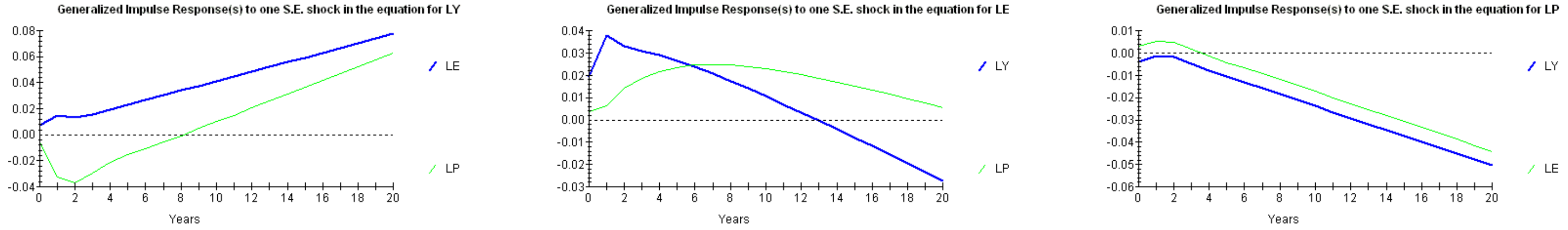
Note: All the figures are estimates rounded to three decimal places.

Appendix Figure 2: Findings from Impulse Response Function

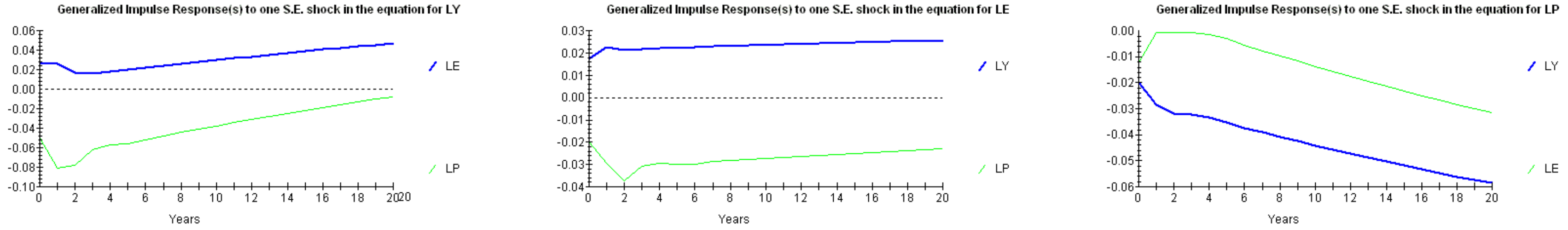
a. China



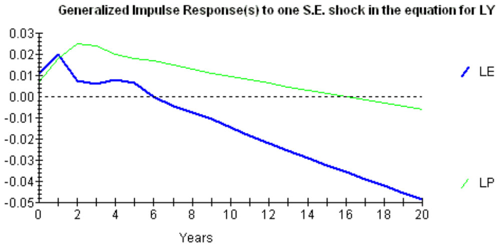
b. India

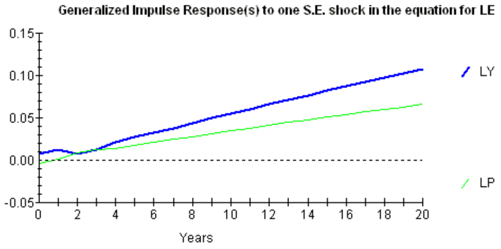


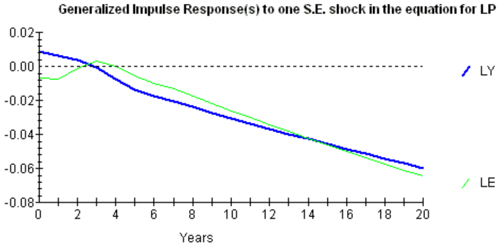
c. Indonesia



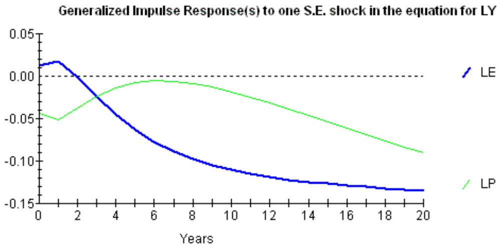
d. Malaysia

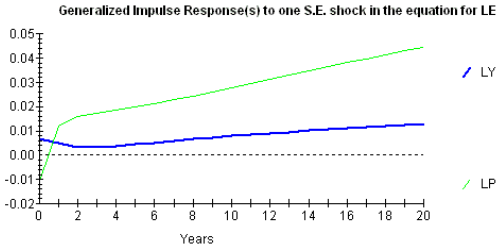

Generalized Impulse Response(s) to one S.E. shock in the equation for LY

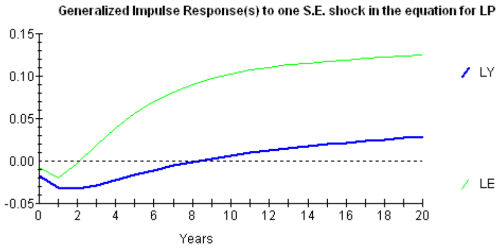

Generalized Impulse Response(s) to one S.E. shock in the equation for LE


Generalized Impulse Response(s) to one S.E. shock in the equation for LP

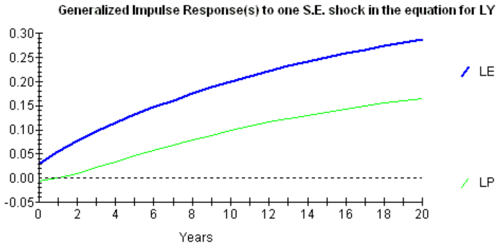
e. Philippines

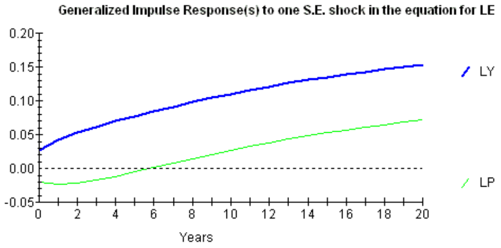

Generalized Impulse Response(s) to one S.E. shock in the equation for LY

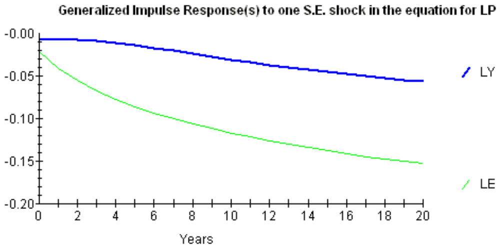

Generalized Impulse Response(s) to one S.E. shock in the equation for LE


Generalized Impulse Response(s) to one S.E. shock in the equation for LP

f. Thailand


Generalized Impulse Response(s) to one S.E. shock in the equation for LY


Generalized Impulse Response(s) to one S.E. shock in the equation for LE


Generalized Impulse Response(s) to one S.E. shock in the equation for LP