

*Temporal Causality between Energy Consumption and Income in
Six Asian Emerging Countries*

Shuddhasattwa Rafiq*

and

Ruhul A. Salim

* Corresponding author. Australian Centre for Sustainable Business and Development (ACSBD), University of Southern Queensland, P. O. Box 4196, Springfield Central, QLD 4300, Australia. E-mail: Shuddhasattwa.Rafiq@usq.edu.au .

Temporal Causality between Energy Consumption and Income in Six Asian Emerging Countries

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 a unidirectional short- and long-run causality running from energy consumption to GDP for China, a unidirectional short-run causality from output to energy consumption for India, whilst a bi-directional short-run causality for Thailand. Neutrality between energy consumption and income is found for Indonesia, Malaysia and Philippines. Following causality results India may contribute to the fight against global warming directly implementing energy conservation measures. For China, where causality runs from energy consumption to output, the country should focus on technological developments and mitigation policies. Since a bi-directional causality is found in Thailand, a balanced combination of alternative policies seems to be appropriate. Nevertheless, all the countries may initiate environmental policies aimed at decreasing energy intensity, increasing energy efficiency, developing a market for emission trading.

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

JEL classifications: C22; Q43, Q48

Temporal Causality between Energy Consumption and Income in Six Asian Emerging Countries

1. Introduction

A number of industrialized and developing countries agreed to the terms of Kyoto protocol to conserve energy and reduce emission. However, with increased demand for energy in developing countries, especially 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. 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. 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. Nevertheless, the direction of causality between energy consumption and economic growth has remained empirically elusive and controversial across time, countries and methodologies. 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.

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 Asia. 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).

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 inclusion of price levels in the specification is a significant contribution to the existing literature because of three main reasons. One, it helps ameliorate omitted variable problem. Two, price levels play an important role in energy consumption as long as the concerned economies are highly dependent on energy. Three, price levels indicate the degree of efficiency with which the economies are functioning (Akinlo, 2008).

The rest of the article proceeds 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. Review of literature

There is an impressive body of 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). These authors find 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) come up with the same outcome on Sri Lankan data from 1960 to 1998 that electricity production causes economic growth. Chen et al. (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 finding a 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. Soytaş & Sari (2003) examine

G-7 and 10 emerging economy's data 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 is found in case of Turkey, Germany, France and Japan over the period from 1950 to 1992. Other studies that also come up with bi-directional causality 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 conservation 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).

Narayan and Smyth (2008) extends panel data analysis in this field by employing Westerlund's (2006) cointegration test which accommodates multiple structural breaks within the panel system. In this study the authors analyze the relationship between energy consumption and GDP in G-7 countries within a tri-variate model where the third variable included is capital formation. According to panel cointegration and Granger causality tests the study finds that all the variable in the system are cointegrated and long-run Granger-causality runs from capital formation and energy consumption to real GDP. Some of the other studies, such as Lee (2005), Al-Iriani (2006) and Joyeux and Ripple (2007) also used panel-data analysis. However, Narayan and Smyth's conclusions are not much different than those of earlier studies on panel data analysis.

Ang (2008) adds a new dimension to energy consumption and output relationship by including carbon emission as the third variable in his study for the Malaysian economy.

Through Granger causality test in the error correction framework the study finds that energy consumption and pollution are positively related to output in the long-run. The study further finds that there is a unidirectional causality running from economic growth to energy consumption growth in both the short-run and the long-run.

In addition to the above studies based on cointegration and vector error correction modeling, most recently Salim *et al.*(2008) finds a bi-directional causality between energy consumption and income in Malaysia, while a unidirectional causality from output to energy consumption in China and Thailand and energy consumption to output in India and Pakistan. In this study, Bangladesh remains as an energy neutral economy confirming the fact that it is one of the lowest energy consuming countries in Asia. However, the main weakness of Salim *et al.* study is the use of short data period (1980-2005). Therefore, their results should be treated with caution.

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.

3. 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 *dxtime* data CD ROM 2007. 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: This article employs a vector error-correction (VEC) model (due to Engel and Ganger 1987) of the following form:

$$\begin{bmatrix} \Delta LY_t \\ \Delta LE_t \\ \Delta LP_t \end{bmatrix} = \begin{bmatrix} \mu_{LY} \\ \mu_{LE} \\ \mu_{LP} \end{bmatrix} + \Gamma(L) \begin{bmatrix} \Delta LY_{t-1} \\ \Delta LE_{t-1} \\ \Delta LP_{t-1} \end{bmatrix} + \Pi \begin{bmatrix} \Delta LY_{t-1} \\ \Delta LE_{t-1} \\ \Delta LP_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{LY} \\ \varepsilon_{LE} \\ \varepsilon_{LP} \end{bmatrix} \quad (1)$$

where LY , LE and LP represents log of GDP, energy consumption and price levels, respectively and μ 's are intercepts. $\Gamma(L)$ denotes a 3×3 polynomial matrix of coefficients to be estimated, where Γ is the short-run adjustments among the variables across the three equations in the system and L is the lag operator. Π represents the error-correction components in levels. Δ denotes the first difference operator and ε 's are the white noise error terms. 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. Sources of causality can be identified through three different channels: (i) the lagged ECT's by a t-test; (ii) the significance of the coefficients of each explanatory variable by a joint Wald F or χ^2 test (weak or short-run Granger causality); (iii) a joint test of the terms in (i) and (ii) by a Wald F or χ^2 test (strong or long-run Granger causality).

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 and Bloch, 2007). To account for such structural breaks Perron (1997) develops a procedure that allows 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).

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.

4. 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 results¹ of the tests reveal that all the concerned variables are non-stationary at level but stationary at their first differences. However, as mentioned earlier 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.

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.

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

¹ Results not reported considering space limitation. However, results will be provided upon request.

	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 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). 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 cointegrating 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 2.

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	Test Statistics	
				Max-eigen value	Trace Stat.
China	$r = 0$	$r > 0$		22.41**	34.95**
	$r \leq 1$	$r > 1$	2	11.54	15.54
	$r \leq 2$	$r = 3$		3.99	3.99
India	$r = 0$	$r > 0$		33.89**	56.13**
	$r \leq 1$	$r > 1$	2	15.06	20.22
	$r \leq 2$	$r = 3$		7.17	7.17
Indonesia	$r = 0$	$r > 0$		41.17**	53.79**
	$r \leq 1$	$r > 1$	3	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	$r = 0$	$r > 0$		35.69**	59.62**
	$r \leq 1$	$r > 1$	2	17.37**	23.92**
	$r \leq 2$	$r = 3$		6.55	6.55
Thailand	$r = 0$	$r > 0$		34.28**	52.90**
	$r \leq 1$	$r > 1$	2	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.

As indicated by Masih & Masih (1996, 1997), Asafu-Adjaye (2000), Oh & Lee (2004), column 3, 4 and 5 in Table 3 indicate ‘short-run’ causality in the sense that dependent variable responds only to short-term shocks to the stochastic environment. Column 6 and 7 identifies whether the variable is involved in the long-run adjustment process and the speed of such adjustment. Column 8, 9 and 10 represents strong or long-run Granger causality. The results for China imply a unidirectional 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. The causality direction is similar to that of Shiu and Lam (2004) where the authors find unidirectional causality running from electricity consumption to GDP in China. 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. In case of India, Masih and Masih (1996) and Asafu-Adjaye (2000) find opposite results than those of this study *i.e.*, unidirectional causality from energy consumption to output. The reason behind these conflicting results may be due to the greater time span considered in this study and the dramatic change in overall economic activities in India in recent years.

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 Granger 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. Both Asafu-Adjaye (2000) and Fatai *et al.*(2004) also find similar evidence (bi-directional causality) in Thailand.

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

Countries	Dependent variables	Short-run effects			Source of causation				
		ΔY	ΔLE	ΔLP	ECT(s) only		$\Delta Y, ECT$	$\Delta LE, ECT$	$\Delta LP, ECT$
		Wald χ^2 -statistics			t-ratio		Wald χ^2 -statistics		
China	ΔY	-	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	ΔY	-	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	ΔY	-	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	ΔY	-	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	ΔY	-	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	ΔY	-	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 2) and a constant. *, **, and *** indicate significant at 10%, 5%, and 1% level, respectively.

5. Conclusions and Policy Implications

This paper investigates the relationship between energy consumption and income in a tri-variate *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. The empirical results show a unidirectional 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 unidirectional causality from output to energy consumption is found. However, there is no evidence of long-run causality between the variables in India. The results also find a long-run unidirectional causality from energy consumption to output in Philippines while bi-directional causality between energy consumption and income in the short-run in Thailand. Further, the empirical results find evidence for the neutrality of energy in both short- and long-run for the other countries *i.e.*, Indonesia and Malaysia. 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. Masih and Masih (1996) also identifies that the neutrality hypothesis to be true for the Malaysian economy. 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 Thailand 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.

References

- Abosedra, S., and H. Baghestani. 1989. New Evidence on the causal relationship between United States energy consumption and gross national product. *Journal of Energy Development* 14: 285-292.
- Akinlo, A. E. 2008. Energy consumption and economic growth: evidence from 11 Sub-Saharan African countries. *Energy Economics* 30 (5): 2391-2400.
- Al-Iriani, M. A. 2006. Energy-GDP relationship revisited: An example from GCC countries using panel causality. *Energy Policy* 34 (17): 3342-3350.
- Altinay, G., and E. Karagol. 2005. Electricity consumption and economic growth: Evidence from Turkey. *Energy Economics* 27 (6): 849-856.
- Ang, J. B. 2008. Economic development, pollutant emissions and energy consumption in Malaysia. *Journal of Policy Modeling* 30: 271-278.
- Asafu-Adjaye, J. 2000. The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. *Energy Economics* 22 (6): 615-625.
- Chen, S.-T., H.-I. Kuo, and C.-C. Chen. 2007. The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy* 35 (4): 2611-2621.
- Engle, R. F., and C. W. J. Ganger. 1987. Cointegration and error correction representation, estimation and testing. *Econometrica* 55 (1): 26.
- Fatai, K., L. Oxley, and F. G. Scrimgeour. 2004. Modeling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand. *Mathematics and Computers in Simulation* 64 (3-4): 431-445.
- Granger, C. W. J. 1969. Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* 37 (3): 424-438.
- Hacker, R. S., and A. Hatemi-J. 2005. The effect of regime shifts on the longrun relationships for Swedish money demand. *Applied Economics* 37: 1131-36.
- Johansen, S. 1988. Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 12 (2-3): 231-254.
- Johansen, S., and K. Juselius. 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. *Oxford Bulletin of Economics & Statistics* 52 (2): 169-210.
- Joyeux, R., and R. D. Ripple. 2007. Household energy consumption versus income and relative standard of living: a panel approach. *Energy Policy* 35: 50-60.
- Kraft, J., and A. Kraft. 1978. On the relationship between energy and GNP. *Journal of Energy Development* 3: 401-403.
- Lee, C.-C. 2005. Energy consumption and GDP in developing countries: A cointegrated panel analysis. *Energy Economics* 27: 415-427.
- Lee, C.-C., and C.-P. Chang. 2005. Structural breaks, energy consumption, and economic growth revisited: Evidence from Taiwan. *Energy Economics* 27 (6): 857-872.
- Masih, A. M. M., and R. Masih. 1996. Energy consumption, real income and temporal causality: Results from a multi-country study based on cointegration and error-correction modeling techniques. *Energy Economics* 18 (3): 165-183.
- Masih, A. M. M., and R. Masih. 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* 19 (4): 417-440.

- Masih, A. M. M., and R. Masih. 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* 30 (10): 1287-1298.
- Mehrara, M. 2007. Energy consumption and economic growth: The case of oil exporting countries. *Energy Policy* 35 (5): 2939-2945.
- Morimoto, R., and C. Hope. 2004. The impact of electricity supply on economic growth in Sri Lanka. *Energy Economics* 26 (1): 77-85.
- Mozumder, P., and A. Marathe. 2007. Causality relationship between electricity consumption and GDP in Bangladesh. *Energy Policy* 35 (1): 395-402.
- Narayan, P. K., and R. Smyth. 2005. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. *Energy Policy* 33 (9): 1109-1116.
- Narayan, P. K., and R. Smyth. 2008. Energy consumption and Real GDP in G7 countries: new evidence from panel cointegration with structural breaks. *Energy Economics* 30 (5): 2331-2341.
- Oh, W., and K. Lee. 2004a. Causal relationship between energy consumption and GDP revisited: The case of Korea 1970-1999. *Energy Economics* 26 (1): 51-59.
- Oh, W., and K. Lee. 2004b. Energy consumption and economic growth in Korea: testing the causality relation. *Journal of Policy Modeling* 26 (8-9): 973-981.
- Perron, P. 1989. The great crash, the oil price shocks, and the unit root hypothesis. *Econometrica* 57 (6): 1361-1401.
- Perron, P. 1997. Further evidence on breaking trend functions in macroeconomic variables. *Journal of Econometrics* 80 (2): 355-385.
- Salim, R. A., and H. Bloch. 2007. Business expenditure on R & D and trade performances in Australia: Is there a link? *Applied Economics* November: 1-11.
- Salim, R. A., S. Rafiq, and A. F. M. K. Hassan. 2008. Causality and Dynamics of Energy Consumption and Output: Evidence from Non-OECD Asian Countries. *Journal of Economic Development* 33 (2): Forthcoming.
- Salman, A. K., and G. Shukur. 2004. Testing for Granger causality between industrial output and CPI in the presence of regime shift: Swedish data. *Journal of Economic Studies* 31 (5/6): 492-499.
- Shiu, A., and P.-L. Lam. 2004. Electricity consumption and economic growth in China. *Energy Policy* 32 (1): 47-54.
- Sims, C. A. 1972. Money, income, and causality. *American Economic Review* 62 (4): 540-552.
- Soytas, U., and R. Sari. 2003. Energy consumption and GDP: Causality relationship in G-7 countries and emerging markets. *Energy Economics* 25 (1): 33-37.
- Stern, D. I. 1993. Energy and economic growth in the USA : A multivariate approach. *Energy Economics* 15 (2): 137-150.
- Stern, D. I. 2000. A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy Economics* 22 (2): 267-283.
- Westerlund, J. 2006. Testing for panel cointegration with multiple structural breaks. *Oxford Bulletin of Economics & Statistics* 68: 101-132.
- Wolde-Rufael, Y. 2004. Disaggregated industrial energy consumption and GDP: The case of Shanghai, 1952-1999. *Energy Economics* 26 (1): 69-75.
- Wolde-Rufael, Y. 2006. Electricity consumption and economic growth: A time series experience for 17 African countries. *Energy Policy* 34 (10): 1106-1114.
- Yoo, S.-H. 2005. Electricity consumption and economic growth: Evidence from Korea. *Energy Policy* 33 (12): 1627-1632.

- Yu, E. S. H., and B.-K. Hwang. 1984. The relationship between energy and GNP : Further results. *Energy Economics* 6 (3): 186-190.
- Zivot, E., and D. W. K. Andrews. 1992. Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics* 10 (3): 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: 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 and LP of Six Developing Asian Countries

