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Energy Consumption and Economic Growth in South and Southeast Asian Countries: Evidence from a Dynamic Panel Data Approach

Anthony N. Rezitis[*^] and Shaikh Mostak Ahammad[+^1]

Abstract – This study examines the dynamic relationship between energy consumption and economic growth in nine South and Southeast Asian countries (*i.e.* Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Pakistan, the Philippines, Sri Lanka and Thailand) in a panel data framework. The time period for the study is 1990–2012, and the World Bank Development Indicators data set is used. This study undertakes panel cointegration analysis to investigate the relationship between energy consumption and economic growth. In addition, the panel vector error correction model (VECM) and impulse response functions (*IRFs*) are employed to examine the short- and long-run direction of causality and the effect of responses between energy consumption and economic growth. The panel cointegration analysis reveals that the long-run equilibrium relationship between real gross domestic product, energy consumption, real gross fixed capital formation and total labor force are positive and statistically significant, indicating the existence of long-run co-movement among the variables. The short- and long-run causality results support the growth hypothesis in which unidirectional causality runs from energy consumption to economic growth, meaning that the economy of these countries is energy dependent. Thus, the policy regarding energy consumption should be considered carefully. The *IRFs* show that the shocks of all the variables reach the equilibrium level within three to four years from the initial shock.

***Keywords* –** Energy use, economic growth, panel VECM, SAARC, ASEAN.

1. INTRODUCTION

The impact of energy consumption on economic growth has attracted the interest of economists in recent years. This is not only because energy consumption affects various aspects of economic activity, but also because it has an influential impact on a country's efforts to achieve long-run economic growth and improve the quality of life. The two energy crises in 1974 and 1981 have prompted numerous empirical analyses regarding the nexus between energy consumption and economic growth since the late 1970s (*e.g.*, Kraft and Kraft [1]; Erol and Yu [2]; Masih and Masih [3]; Soytas and Sari [4]; Huang *et al.* [5]; Lee and Chang [6]; Apergis and Payne [7]; Apergis and Danuletiu [8]; Georgantopoulos [9]; Kwakwa [10]. Most of these studies explored the long-run relationship and direction of short- and long-run causality between energy consumption and economic growth. The related literature has been well documented by applying both the panel data framework and time series analysis. The present study aims to explore the relationship between energy consumption and economic growth in nine South and Southeast Asian countries by applying the panel data approach. The nine South and Southeast Asian countries considered are Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Pakistan, the Philippines, Sri Lanka and Thailand. Of these nine countries, four, Bangladesh, India, Pakistan and Sri Lanka, are members of the South Asian Association for Regional Cooperation (SAARC)[1], while the remaining five, Brunei Darussalam, Indonesia, Malaysia, the Philippines and Thailand, are members of the Association of Southeast Asian Nations (ASEAN[2]. SAARC and ASEAN countries were selected since these countries are geographical neighbors. Moreover, they have some similarities in their socioeconomic profile. These two organizations encompass about 6% of the Earth's total land area and about 32% of the world's population, which are mostly shared by the aforementioned countries. These nine countries are also ranked as emerging and developing economies by the International Monetary Fund [11], indicating that they are less heterogeneous. In addition, it is widely agreed that energy consumption has a significant impact on the economic activity particularly of developing countries.

The purpose of this study is to examine the extent to which energy consumption is related to the economic

[*]Faculty of Agriculture and Forestry, Department of Economics and Management, University of Helsinki, P.O. Box 27, Latokartanokaari 5, FI-00014, Finland.

[+]Department of Accounting, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh.

[^]Department of Business Administration of Food and Agricultural Enterprises, University of Patras, G. Seferi 2, Agrinio 30 100, Greece.

[1] Corresponding author;
Tel: + 8801712083786
E-mail: shaikhmostak@yahoo.com; antonios.rezitis@helsinki.fi; arezitis@upatras.gr.

[1]In 1985, seven South Asian countries formed the South Asian Association for Regional Cooperation (SAARC). The founding member countries of the SAARC are Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka. At present, the SAARC has eight member countries, since Afghanistan joined the organization in 2007.

[2] The Association of Southeast Asian Nations (ASEAN) was established on 8 August 1967 in Bangkok, Thailand, with the signing of the ASEAN Declaration by the founding member countries of the ASEAN, namely Indonesia, Malaysia, the Philippines, Singapore and Thailand. Brunei Darussalam then joined in 1984, Viet Nam in 1995 and Lao PDR and Myanmar in 1997; Cambodia became ASEAN's tenth member in 1999.

growth in nine South and Southeast Asian countries. The identification of the relationship between energy consumption and economic growth has important implications for energy conservation policies. Empirical studies on energy consumption and economic growth have shaped different outcomes. First, if energy consumption leads economic growth, the economy is called energy dependent, indicating that energy is a stimulus for economic growth. As a result, energy conservation policies might affect the economic development. Second, if economic growth leads energy consumption or there is no relationship between energy consumption and economic growth, the economy is referred to as less energy dependent, indicating that energy is not a stimulus for economic growth. As a result, energy conservation policies may be implemented with few or no adverse effects on economic development. Based on the outcomes discussed above, the present study intends to identify the links between energy consumption and economic growth to provide policy implications for the nine aforementioned South and Southeast Asian countries.

The present study is based on an aggregate production function and employs a multivariate panel data framework with the real gross domestic product (*GDP*), energy use (*ENERGY*), real gross fixed capital formation (*GFC*) and the total labor force (*LABOR*) to capture the short- and long-run relationships between the series under consideration. In particular, the panel cointegration analysis investigates the long-run relationship between the four series. The panel vector error correction model (VECM) captures the short- and long-run direction of the relationships between energy consumption and economic growth. The panel impulse response functions (*IRF*s) examine the effect of responses between the series under consideration. The empirical results indicate that significant short- and long-run relations exist between real gross domestic product, energy use, real gross fixed capital formation and total labor force, allowing for the formulation of suggestions for policy makers. It is worth mentioning that some studies (Al-Iriani [12]; Chen *et al.* [13]; Lee and Chang [14]; Mehrara [15]; Nondo *et al.* [16]; Ozturk *et al.* [17]) have investigated the relationship between energy consumption and economic growth by using a bivariate model between energy consumption and economic growth, instead of a multivariate approach incorporating additional variables into the analysis, as in the present study. However, in the case of bivariate analysis, there is the possibility of omitted variable bias, as Lütkepohl [18] indicated.

This study contributes to the related literature in several ways. First, it might be the first study to use the panel data approach to examine the growth dynamics and causality and provide *IRFs* between energy consumption and economic growth in nine emerging and developing South and Southeast Asian countries. Thus, the present study is able to inspect the nexus between energy consumption and economic growth, direction of causality between energy consumption and economic growth, and the effect of responses of variables to a one-unit shock in a particular variable, *e.g.*, the real gross domestic product (*GDP*), energy use (*ENERGY*), real gross fixed capital formation (*GFC*) and total labor force (*LABOR*) in nine South and Southeast Asian countries. Among the previous studies, the study by Lee and Chang [6] conducted a panel cointegration and panel vector error correction model to examine the relationship between energy consumption and economic growth in sixteen Asian countries during the 1971–2002 period. More specifically, the study by Lee and Chang [6] included developing and advanced economies, while the present study uses more recent data (1990 to 2012) and selects only developing countries to investigate the relationships between energy consumption and economic growth. The selection of developing countries may ensure the panel of less heterogeneous economies. In addition, Lee and Chang [6] did not provide *IRFs* to measure the effects of impulse responses between the variables under consideration. However, the current study presents estimates of the *IRFs*, which provide measures of the impacts between real gross domestic product, energy use, real gross fixed capital formation and total labor force. These might help policy makers to take an effective, reliable and sustainable energy policy. Finally, the panel data approaches used in the present study provide increased power information in comparison with the simple time series methods because the former derive information from both time and cross-sectional dimensions and the latter derive information only from the time dimension.

The remainder of this study is presented as follows. The literature is discussed in section 2. Section 3 presents a detailed outline of the methodology and data. Section 4 reports the empirical results and discussion. Section 5 offers the conclusions of the study.

2. LITERATURE REVIEW

In the literature concerning energy consumption and economic growth, four possible hypotheses have been emphasized: the growth, conservation, feedback and neutrality hypotheses [19]. First, the growth hypothesis refers to a condition in which unidirectional causality runs from energy consumption to economic growth. It suggests that an increase in energy consumption may contribute to economic growth, while a reduction in energy consumption may adversely affect economic growth, indicating that the economy is energy dependent. The growth hypothesis also suggests that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to the labor force and capital formation. Second, the conservation hypothesis refers to a condition in which unidirectional causality runs from economic growth to energy consumption. It implies that policies designed to reduce energy consumption will not adversely affect economic growth, indicating that the economy is less energy dependent [3]. The conservation hypothesis is confirmed if an increase in economic growth causes an increase in energy consumption. Third, the feedback hypothesis refers to a condition in which causality runs in both directions, that is, from energy consumption to economic growth and from economic growth to energy consumption. It implies that energy consumption and economic growth are interconnected and may very well serve as complements to each other. Finally, the neutrality hypothesis asserts a condition in which no causality exits in either direction between energy consumption and economic growth. Similar to the conservation hypothesis, the neutrality hypothesis implies that energy conservation policies may be pursued without adversely affecting the country's economy. The neutrality hypothesis is confirmed if an increase in economic growth does not cause an increase in energy consumption and vice versa.

Previous studies relating to the relationship between energy consumption and economic growth pertaining to South and Southeast Asian countries are limited. Among the studies, Chen *et al.* [13] and Lee and Chang [6] employed a panel data approach in a multi-country study. Table 1 presents some of the most recent selected research that studied energy consumption and economic growth. Table 1 is divided into two sections: Section A presents the general literature relating to all countries while, Section B presents literature relating to only Asian countries. The literature review presented in Table 1 examined the relationship between energy consumption and economic growth from two perspectives: the energy demand function (demand side) and the aggregate production function (production side). All of the studies in Table 1 primarily focused on the aggregate production function (production side) with the exception of Mehrara [15], Azam *et al.* [20], Tang and Tan [21], Huang *et al.* [5], Apergis and Payne [22] and Apergis and Payne [23]. Mehrara [15], Azam *et al.* [20] and Tang and Tan [21] primarily focused on the energy demand function (demand side). However, Apergis and Payne [22], [23] examined the relationship between energy consumption and economic growth, primarily focusing on the carbon dioxide emissions.

Meanwhile, in the literature related to all countries (Section A of Table 1), Huang *et al.* [5] considered five variables – energy consumption, real gross domestic product, capital formation, labor force and consumer price index (CPI) – in estimating the relationship between energy consumption and economic growth. Apergis and Payne [7], [24] used four variables (*i.e.* energy consumption, real gross domestic product, labor force and capital formation) in their studies. However, Apergis and Payne [22], [23] incorporated carbon dioxide, energy consumption, the real gross domestic product and the square of the real gross domestic product into their studies to examine the relationship between energy consumption and economic growth. In addition, Lee [25], Ciarreta and Zarraga [26], Lee *et al.* [27] and Narayan and Smyth [28] preferred to use a trivariate framework with energy consumption, the real gross domestic product and capital formation, while Mahadevan and Asafu-Adjaye [29] used the consumer price index instead of capital formation in the trivariate framework. Furthermore, Adhikari and Chen [30], Lee and Chang [14], Mehrara [15], Nondo *et al.* [16] and Ozturk *et al.* [17] considered a bivariate framework with energy consumption and the real gross domestic product to evaluate the relationship between energy consumption and economic growth.

On the other hand, in the literature related to Asian countries (Section B of Table 1), Azam *et al.* [20] considered seven variables – real gross domestic product, foreign direct investment, trade openness, population growth rate, urbanization, human development index and energy consumption – in estimating the relationship between energy consumption and economic growth, while Tang and Tan [21] used five variables (*i.e.* energy consumption, real gross domestic product, relative price of energy to non-energy goods, foreign direct investment and financial development). Lee and Chang [6] preferred to use a four variate framework with energy consumption, real gross domestic product, labor force and capital formation, while Azam *et al.* [31] used the export instead of labor force in the four variate framework. Additionally, Al-Iriani [12] and Chen *et al.* [13] considered a bivariate framework with energy consumption and the real gross domestic product to evaluate the relationship between energy consumption and economic growth. It is to be noted that, the causal relationships between energy consumption and economic growth reported in Table 1 show mixed results indicating that there is not any specific pattern of direction of causality between energy consumption and economic growth in the Asian countries.

Considering the literature discussed above, the present study aims to investigate the relationships between energy consumption and economic growth in a panel data framework by incorporating additional variables, such as real gross fixed capital formation and the total labor force, in nine South and Southeast Asian countries. Furthermore, unlike many of the previous studies, the present study will discuss the causal relationship between energy consumption and economic growth in relation to the four hypotheses emphasized in the energy consumption and economic growth literature.

Table 1. Summary of selected empirical studies on energy consumption and economic growth.

Authors	Period	Countries	Methodology	Causality relationship
Section A: General countries				
Lee (2005)	1975–2001	18 developing countries	Panel VECM	EC → GDP (in the short- and long-run)
Mehrara (2007)	1971–2002	11 Oil Exporting countries	Panel co-integration	GDP → EC (in the short- and long-run)
Lee and Chang (2007)	1965–2002 1971–2002	22 Developed countries, 18 Developing countries	Panel VARs and GMM	GDP → EC (developing countries) EC ↔ GDP (developed countries)
Mahadevan and Asafu- Adjaye (2007)	1971–2002	20 Energy importers and exporters	Panel error correction model	EC ↔ GDP (developed countries) EC → GDP (in the short-run for developing countries)
Lee *et al.* (2008)	1960–2001	22 OECD countries	Panel co-integration, Panel VEC model	EC ↔ GDP (in the short- and long-run)
Huang *et al.* (2008)	1972–2002	82 Low, middle and high income countries	Panel VAR, GMM model	GDP → EC (middle and high income countries) EC — GDP (low income countries)
Narayan and Smyth (2008)	1972–2002	G-7 countries	Panel co-integration, Granger causality	EC → GDP (in the short- and long-run)
Ciarreta and Zarraga (2008)	1970–2004	12 European countries	Panel co-integration, GMM, Panel causality	ELC → GDP (in the long-run) ELC — GDP (in the short-run)
Apergis and Payne (2009a)	1980–2004	6 Central American countries	Panel co-integration, error correction model	EC → GDP (in the short- and long-run)
Apergis and Payne (2009b)	1991–2005	11 Commonwealth of Independent States (CIS) countries	Panel co-integration, Error correction model	EC ↔ GDP (in the long-run) EC → GDP (in the short-run
Apergis and Payne (2009c)	1971–2004	6 Central American countries	Panel vector error correction model	EC ↔ GDP (in the short-run)
Ozturk *et al.* (2010)	1971–2005	51 Low and middle income countries	Panel vector error correction model	GDP → EC (low income countries) EC ↔ GDP (middle income countries)
Apergis and Payne (2010)	1992–2004	11 Commonwealth of Independent States (CIS) countries	Panel co-integration, Error correction model	EC ↔ GDP (in the short-run) GDP → EC (in the long-run)
Nondo *et al.* (2010)	1980–2005	19 African countries	Panel co-integration, Granger causality	EC — GDP (in the short-run) EC ↔ GDP (in the long-run)
Adhikari and Chen (2013)	1990–2009	80 Developing countries	Panel co-integration, *DOLS*	EC → GDP (upper middle income and lower middle income countries) GDP → EC (low income countries)
Section B: Asian countries				
Al-Iriani (2006)	1970–2002	Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE)	Panel co-integration, GMM	GDP → EC
Chen *et al.* (2007)	1971–2001	China, Hong Kong, Indonesia, India, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand	Panel co-integration, ECM, Panel causality test	ELC ↔ GDP (for all countries) ELC — GDP (China, Taiwan, Thailand) GDP → ELC (India, Malaysia, Korea, Philippines, Singapore) ELC → GDP (Hong Kong, Indonesia)

Lee and Chang(2008)	1971–2002	China, Hong Kong, India, Indonesia, Iran, Japan, Jordan, South Korea, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka, the Syrian Arab Republic, Thailand and Turkey	Panel co-integration and Panel ECM	EC → GDP (in the long-run) EC ▬ GDP (in the short-run)
Tang and Tan (2014)	1972–2009	Malaysia	Johansen–Juselius co-integration, Granger causality	EC ↔ GDP (in the short- and long-run)
Azam *et al.* (2015a)	1980–2012	Indonesia, Malaysia and Thailand	Least square	GDP → ELC (Indonesia, Malaysia and Thailand)
Azam *et al.* (2015b)	1980–2012	Indonesia, Malaysia, Philippines, Singapore and Thailand	Johansen–Juselius co-integration, Granger causality	GDP → EC (Malaysia) EC ▬ GDP (Indonesia, Philippines, Singapore and Thailand)

Note: EC (ELC) → GDP means that the causality running from energy (electricity) consumption to economic growth. GDP → EC (ELC) means that the causality running from economic growth to energy (electricity) consumption. EC (ELC) ↔ GDP means that bi-directional causality exists between energy (electricity) consumption and economic growth. EC (ELC) ▬ GDP means that no causality exists between energy (electricity) consumption and economic growth.

3. METHODOLOGY

The empirical methods used in this study include, first, panel unit root tests (*i.e.* Harris and Tzavalis [32]; Im *et al.* [33]; Levin *et al.* [34]; Breitung [35] to provide information about the stationarity properties of the variables under consideration. Second, panel cointegration tests (*i.e.* Pedroni [36]) are performed to ascertain the presence of cointegration. Third, the estimation of long-run cointegration parameters is carried out based on the studies by Pedroni [37], [38]. Finally, a panel vector error correction model is used to test the short- and long-run panel causal relationship between energy consumption and economic growth followed by panel *IRFs*. Note that the estimations are done utilizing RATS 8.2 econometric software and procedures based on the work by Doan [39].

3.1. Panel Unit Root Analysis

Panel unit root tests provide information about the order of integration of the variables under consideration which is crucial in empirical analysis since applying the ordinary least square estimator in non-stationary variables results in spurious regressions. The present study employs four different panel unit root tests in order to calculate the order of integration of the variables. The first test is the one developed by Levin *et al.* [34] (henceforth LLC), the second is the Harris and Tzavalis [32] (henceforth, HT), the third is the Im *et al.* [33] (henceforth IPS), and the fourth is Breitung [35]. Most of the panel unit root tests use the following general structure:

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{L=1}^{p_i} \theta_{i,L} \Delta y_{i,t-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \qquad m = 1,2,3 \qquad (1)$$

where Δ is the first difference operator, p is the lag length, d_{mt} is a vector of deterministic variables and α_{mt} is the corresponding vector of coefficients for models m=1, 2, and 3 where d_{1t}={empty set}, d_{2t}={1} and d_{3t}={1, t}, correspondingly. $\rho_i = 0$ indicates that the y process has a unit root for individual i, while $\rho_i < 0$ indicates a stationary process. According to LLC [34], since ρ_i is fixed across i the alternative hypothesis is that the ρ_i are identical and negative. A similar but simpler test is derived for (1) by HT [32] when the time dimension of the panel is relatively short, with a null hypothesis of a unit root and an alternative with a single stationary value. Unlike the two aforementioned tests, the IPS [33] test allows the ρ_i to vary and in fact the null hypothesis implies that all series have a unit root, *i.e.* $\rho_i = 0$ for all i, while the alternative hypothesis indicates that some of the series are stationary, *i.e.* $\rho_i < 0$ for some i. An alternative set of procedures to LLC [34] is proposed by Breitung [35] with a similar null hypothesis of a unit root.

3.2. Panel Cointegration Analysis

A panel cointegration test developed by Pedroni [36] is used to test the existence of the long-run equilibrium relationship among the variables under consideration (*i.e.* ln*GDP*, ln*ENERGY*, ln*GFC* and ln*LABOR*). In particular, the testing procedure specifies a null hypothesis indicating that the series are not cointegrated, that is, that the residuals from a regression on the variables are still *I*(1). More specifically, if the alternative is that the series are cointegrated and have a common cointegrating vector, then the null is that the series are not cointegrated or they are cointegrated but do not have a common cointegrating vector. Pedroni [36], [38] develops two sets of tests for cointegration which include seven statistics. Of these seven statistics, four are based on pooling along the within-dimension (panel cointegration statistics) and the remaining three are based on pooling along the between-dimension (group mean panel cointegration statistics). The panel cointegration statistics are based on estimators that pool the autoregressive coefficient across different units for the unit root tests on the estimated residuals, while the group mean panel cointegration statistics are based on estimators that average the individually estimated coefficients for each unit *i*. With regard to the first set of statistics, three of the four statistics (panel *v*-statistic, panel *ρ*-statistic, and panel *PP*-statistic) use non-parametric corrections analogous to the work of Phillips and Perron [40], while the fourth (panel ADF-statistic) is a parametric augmented Dickey-Fuller *t*-statistic. In the second set of statistics, two of the three statistics (group *ρ*-statistic, and group *PP*-statistic) are based on non-parametric corrections while the third (group ADF-statistic) is an augmented Dickey-Fuller based test statistic. Of the seven statistics, the panel v-statistic is a one-sided test where positive values greater than the critical value reject the null hypothesis of no cointegration whereas negative values greater than the critical value for the remaining test statistics reject the null hypothesis of no cointegration. Let's denote by γ_i the autoregressive coefficient of the residuals in the *i*th unit then the null and alternative hypothesis of the panel statistics are specified as follows:

$$\begin{aligned} H_0:&\ \gamma_i = 1, \quad for \quad all \quad i, \\ H_A:&\ \gamma_i = \gamma < 1, \quad for \quad all \quad i \end{aligned} \tag{2}$$

By contrast the hypothesis of the group statistics are described as:

$$\begin{aligned} H_0:&\ \gamma_i = 1, \quad for \quad all \quad i, \\ H_A:&\ \gamma_i < 1, \quad for \quad all \quad i \end{aligned} \tag{3}$$

Note that the alternative hypothesis of the within-dimension (panel) statistics presumes a common value for $\gamma_i = \gamma$, while the between-dimension (group) statistics do not presume a common value for $\gamma_i = \gamma$ and allow an additional source of potential heterogeneity across individual units of the panel.

The long-run relationship between real gross domestic product, energy use, real gross fixed capital formation and total labor force is given by Equation (4):

$$\ln GDP_{it} = \alpha_i + \beta_{1i} \ln ENERGY_t + \beta_{2i} \ln GFC_t + \beta_{3i} \ln LABOR_t + \varepsilon_{it}$$
$$for \quad i = 1,...,N; \quad t = 1990 \text{ to } 2012 \tag{4}$$

where GDP_{it} is referred to the real gross domestic product, *ENERGY* is the energy use, *GFC* is real gross fixed capital formation and *LABOR* is the total labor force. The parameter α_i is a fixed-effect parameter while β_{1i}, β_{2i} and β_{3i} are the slope parameters. ε_{it} are the estimated residuals which represent deviations from the long-run relationship.

A number of studies written by Pedroni [36], [37], [38] are used to estimate panel cointegration among the variables in question. These studies allow not only differing short-run dynamics but also differing cointegrating vectors. Based on Pedroni [37], [38], [41] two estimators are used for estimating the long-run parameters of the cointegration relationships given by (4). These estimators are the Fully-Modified Ordinary Least Squares (*FMOLS*) which was firstly developed by Phillips and Hansen [42] and Hansen [43] and the Dynamic Ordinary Least Squares (*DOLS*) which was also proposed independently by Stock and Watson [44].[3] Note that the least squares estimated parameters in (4) suffer from simultaneity bias due to the correlation between the left-hand side variable ($\ln GDP_{it}$) and the error term (ε_{it}) and from dynamic endogeneity due to serial correlation of the error term (ε_{it}). The *FMOLS* estimator used in estimating (4) corrects for the bias of the estimated parameters, while the *DOLS* estimator deals with the endogeneity by adding the current lags and leads of the first difference of the right-hand variables (ln*ENERGY*, ln*GFC* and ln*LABOR*) to the regression of (4).

Table 6 presents the results of the panel *FMOLS* and *DOLS* estimators. In particular, Table 6 presents panel cointegration coefficients for the real gross domestic product (*GDP*) as a group as well as for each specific country *i* (*i*=1,…,9). Furthermore, the aforementioned Table is accompanied by heterogeneity tests $\left(\chi^2 - tests\right)$ for the estimated coefficients $\left(\hat{\alpha}_i,\ \hat{\beta}_{1i},\ \hat{\beta}_{2i},\ \hat{\beta}_{3i}\right)$ corresponding to the variables under consideration (intercept$_i$, ln$ENERGY_i$, lnGFC_i, ln$LABOR_i$). The null hypothesis of the heterogeneity test is that each individual coefficient is equal to the average of the group.

3.3. Data

The data used in this study consist of annual observations from 1990 to 2012. The data were obtained from the World Bank Development Indicators (http://data.worldbank.org/indicator, accessed in October 2014) for nine South and Southeast Asian countries, namely Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Pakistan, the Philippines, Sri Lanka and Thailand. The remaining countries were omitted due to the unavailability of data for all the variables (*i.e.* data from 1990 to 2012) and being classified by the IMF as advanced economies [11]. The multivariate panel data approach includes the natural logarithm of the real gross domestic product (ln*GDP*) in constant 2005 U.S. dollars, energy uses (ln*ENERGY*) in kilowatts per oil equivalent, real gross fixed capital formation (ln*GFC*) in constant 2005 U.S. dollars and the total labor force (ln*LABOR*). A detailed description of the data is presented in Table 2.

[3] Note that according to Banerjee [45], the estimates from either *FMOLS* or *DOLS* are asymptotically equivalent for more than 60 observations. The number of observations of the present study is 207.

Table 2. Data description: The real gross domestic product (*GDP*), energy use (*ENERGY*), real gross fixed capital formation (*GFC*) and total labor force (*LABOR*).

Variables	Measurement units	Definition
Real gross domestic product (*GDP*)	Constant 2005 U.S. dollars	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.
Energy use (*ENERGY*)	Kilowatts per oil equivalent	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.
Real gross fixed capital formation (*GFC*)	Constant 2005 U.S. dollars	Gross fixed capital formation includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.
Total labor force (*LABOR*)	Total	Total labor force comprises people ages 15 and older who meet the International Labor Organization definition of the economically active population: all people who supply labor for the production of goods and services during a specified period. It includes both the employed and the unemployed.

Note: The definitions of variables are provided by World Bank Development Indicators (http://data.worldbank.org/indicator, accessed in October 2014).

4. RESULTS AND DISCUSSION

4.1. Panel Unit Root Results

The panel unit root test results are presented in Table 3 and Table 4. Most of the panel unit root results show a tendency to fail to reject the null hypothesis of a panel unit root for the levels of the variables. On the contrary, most of the panel unit root results indicate rejection of the null of a panel unit root of the first-differences of the variables in support of the alternative of stationary first-differences of the variables. Thus, from the panel unit root analysis, it can be concluded that the variables are integrated of order one, suggesting a possible long-run cointegrating relation among variables such as ln*GDP*, ln*ENERGY*, ln*GFC* and ln*LABOR*. Therefore, the next step of the empirical analysis is to investigate the presence of cointegration between the variables under consideration.

Table 3. Results of panel unit root LLC and Breitung tests.

	LLC test			Breitung test		
	None	Constant	Constant and Trend	None	Constant	Constant and Trend
Variables in levels						
ln*GDP*	20.16 (1.00)	7.83 (1.00)	-2.07 (0.02)	9.45 (1.00)	8.83 (1.00)	-1.47 (0.07)
ln*ENERGY*	14.73 (1.00)	-3.38 (0.00)	-3.47 (0.00)	8.64 (1.00)	6.35 (1.00)	-4.14 (0.00)
ln*GFC*	7.65 (1.00)	-0.39 (0.35)	-2.84 (0.00)	5.76 (1.00)	3.25 (0.99)	-3.65 (0.00)
ln*LABOR*	11.74 (1.00)	-4.27 (0.00)	-0.50 (0.31)	5.74 (1.00)	1.66 (0.95)	-2.07 (0.02)
Variables in 1st differences						
Δln*GDP*	-1.26 (0.10)	-8.19 (0.00)	-6.83 (0.00)	-1.10 (0.13)	-3.26 (0.00)	-7.18 (0.00)
Δln*ENERGY*	-4.58 (0.00)	-8.11 (0.00)	-6.19 (0.00)	-4.02 (0.00)	-3.82 (0.00)	-6.07 (0.00)
Δln*GFC*	-5.31 (0.00)	-9.44 (0.00)	-3.43 (0.00)	-4.11 (0.00)	-4.08 (0.00)	-6.72 (0.00)
Δln*LABOR*	-3.66 (0.00)	-3.59 (0.00)	-5.43 (0.00)	-3.39 (0.00)	-0.39 (0.34)	-6.15 (0.00)

Note: Δ is the 1st difference operator. Numbers in parentheses are *p*-values.

Table 4. Results of panel unit root HT and IPS tests.

	HT test			IPS test	
	None	Constant	Constant and Trend	Constant	Constant and Trend
Variables in levels					
ln*GDP*	0.09 (0.53)	2.54 (0.99)	0.15 (0.56)	5.48 (1.00)	0.33 (0.63)
ln*ENERGY*	0.16 (0.56)	1.46 (0.93)	-2.14 (0.02)	-0.32 (0.37)	-0.71 (0.24)
ln*GFC*	0.09 (0.54)	1.55 (0.94)	-0.47 (0.32)	1.33 (0.91)	-0.69 (0.24)
ln*LABOR*	0.06 (0.52)	2.12 (0.98)	1.74 (0.96)	-0.43 (0.33)	2.14 (0.98)

Variables in 1st differences					
Δln*GDP*	-14.74 (0.00)	-17.71 (0.00)	-9.59 (0.00)	-4.19 (0.00)	-2.58 (0.00)
Δln*ENERGY*	-36.16 (0.00)	-23.01 (0.00)	-13.49 (0.00)	-4.10 (0.00)	-2.71 (0.00)
Δln*GFC*	-37.45 (0.00)	-18.34 (0.00)	-9.93 (0.00)	-4.78 (0.00)	-2.56 (0.01)
Δln*LABOR*	-13.45 (0.00)	-17.91 (0.00)	-10.34 (0.00)	-2.59 (0.00)	-2.41 (0.01)

Note: Δ is the 1st difference operator. Numbers in parentheses are *p*-values.

4.2. Panel Cointegration Test

The panel cointegration test results presented in Table 5 are obtained with the inclusion of time dummies. The inclusion of time dummies transforms the original data series to deviations from time period means, prior to performing the cointegration test [39]. The cointegration test results support the presence of a long-run cointegrating relation among the variables, since four test statistics (the panel *v*-statistic, panel *ADF* statistic, group *PP* statistic and group *ADF* statistic) out of seven reject the null hypothesis of no cointegration between real gross domestic product, energy use, real gross fixed capital formation and total labor force at the conventional level of significance.[4] This indicates the existence of long-run co-movement among the variables.

4.3. Long-run Equilibrium Relationship

The results of long-run elasticity are reported in Table 6. An inspection of the empirical results presented in Table 6 indicates that the *FMOLS* and *DOLS* estimators produce very similar results in terms of the magnitude and statistical significance of the parameter estimates for both the full panel and the individual countries.

The third row of Table 6 presents the estimated parameters of the cointegration vector corresponding to the full panel, that is, the whole group of nine South and Southeast Asian countries. All the coefficients of the full panel are positive and statistically significant at the 1% level of significance. The estimates of the full-panel *FMOLS* indicate that a 1% increase in energy usage increases the real gross domestic product by 0.21%; a 1% increase in capital formation increases the real gross domestic product by 0.25%; and a 1% increase in the labor force increases the real gross domestic product by 0.88%. With respect to the other panel studies reporting *FMOLS* estimates, the elasticity of energy usage for the nine South and Southeast Asian countries is within the range of other studies: Lee [25] reported the elasticity of energy usage for eighteen developing countries as 0.50%; Lee and Chang [6] reported the elasticity of energy usage for sixteen Asian countries as 0.32%; Lee *et al.* [27] reported the elasticity of energy usage for twenty-two OECD countries as 0.25%; Narayan and Smyth [28] reported the elasticity of energy usage for G7 countries as 0.12%; Apergis and Payne [7] reported the elasticity of energy usage for six Central American countries as 0.28%; and Apergis and Payne [24] reported the elasticity of energy usage for eleven CIS countries as 0.42%. On the other hand, the estimates of the full-panel *DOLS* indicate that a 1% increase in energy usage increases the real gross domestic product by 0.23%; a 1% increase in capital formation increases the real gross domestic product by 0.31%; and a 1% increase in the labor force increases the real gross domestic product by 0.76%. With respect to the other panel studies reporting *DOLS* estimates, the elasticity of energy usage for the nine South and Southeast Asian countries is again within the range of other studies: Narayan and Smyth [28] reported the elasticity of energy usage for G7 countries as 0.16% and Ozturk *et al.* [17] reported the elasticity of energy usage for fourteen low-income countries as 0.54%, the elasticity of energy usage for thirteen upper-middle-income countries as 0.48% and the elasticity of energy usage for twenty-four lower-middle-income countries as 0.58%. Note that the real gross domestic product shows a higher response to the total labor force followed by real gross fixed capital formation and energy use for both the *FMOLS* and the *DOLS* model. The *DOLS* estimates for individual countries indicate that all the individual countries' real gross domestic product responds positively (except Brunei and the Philippines) to energy use. Although the real gross domestic products of Bangladesh, Indonesia and Pakistan show a positive response to energy use, these are statistically insignificant. All the individual countries' real gross domestic product also responds positively (except Bangladesh, which is statistically insignificant) to real gross fixed capital formation. Furthermore, all the individual countries' real gross domestic product responds positively to the total labor force; however, Indonesia, Sri Lanka and Thailand's responses are statistically insignificant. The heterogeneity tests for the estimated coefficients presented in the last five rows of Table 6 reject the hypothesis of equality of the individual estimated coefficient to the corresponding average panel (group) coefficient presented in the third row of the table.

4.4. Short-run and Long-run Causality Analysis

Since the cointegration analysis can only determine the relationship among the variables, not the direction of causality, it is common practice to investigate the causal direction among the variables that are cointegrated. In this present study, a two-step procedure is applied to perform the causality test: first, estimating the long-run model (*DOLS*) specified in Equation 4 to calculate the residuals; and second, defining the one-lagged residuals as the error correction term (*ECT*), which will be included in the panel vector error correction model. In particular, the variables are considered as in first difference plus *ECT* as exogenous variables. The dynamic panel vector error correction model is estimated as follows:

[4] Pedroni [36] proposes seven tests that can be performed without allowing for structural breaks in the series. The acceptance of the null hypothesis of no cointegrating relationship with Pedroni's [36] tests could reflect the presence of structural breaks in the series [28].

$$\Delta \ln GDP_{it} = \omega_{1i} + \sum_{l=1}^{p}\gamma_{11li}\Delta \ln GDP_{i,t-l} + \sum_{l=1}^{p}\gamma_{12li}\Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p}\gamma_{13li}\Delta \ln GFC_{i,t-l} + \sum_{l=1}^{p}\gamma_{14li}\Delta \ln LABOR_{i,t-l} + \lambda_{1i}\varepsilon_{it-1} + u_{1it} \quad (5.1)$$

$$\Delta \ln ENERGY_{it} = \omega_{2i} + \sum_{l=1}^{p}\gamma_{21li}\Delta \ln GDP_{i,t-l} + \sum_{l=1}^{p}\gamma_{22li}\Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p}\gamma_{23li}\Delta \ln GFC_{i,t-l} + \sum_{l=1}^{p}\gamma_{24li}\Delta \ln LABOR_{i,t-l} + \lambda_{2i}\varepsilon_{it-1} + u_{2it} \quad (5.2)$$

$$\Delta \ln GFC_{it} = \omega_{3i} + \sum_{l=1}^{p}\gamma_{31li}\Delta \ln GDP_{i,t-l} + \sum_{l=1}^{p}\gamma_{32li}\Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p}\gamma_{33li}\Delta \ln GFC_{i,t-l} + \sum_{l=1}^{p}\gamma_{34li}\Delta \ln LABOR_{i,t-l} + \lambda_{3i}\varepsilon_{it-1} + u_{3it} \quad (5.3)$$

$$\Delta \ln LABOR_{it} = \omega_{4i} + \sum_{l=1}^{p}\gamma_{41li}\Delta \ln GDP_{i,t-l} + \sum_{l=1}^{p}\gamma_{42li}\Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p}\gamma_{43li}\Delta \ln GFC_{i,t-l} + \sum_{l=1}^{p}\gamma_{44li}\Delta \ln LABOR_{i,t-l} + \lambda_{4i}\varepsilon_{it-1} + u_{4it} \quad (5.4)$$

$$for \quad i = 1,...,9; \quad t = 1990 \text{ to } 2012$$

where Δ is the first-difference operator; p is the lag length set at one based on the Schwarz Bayesian Criterion (SBC) proposed by Schwarz [46]; ε_{it} is the residuals from the panel *DOLS* estimation of Equation 4; and u_{it} is the serially uncorrelated error term. In the real gross domestic product (*GDP*) equation (Equation 5.1), short-run causality from energy usage, real gross fixed capital formation and the total labor force to the real gross domestic product is tested, based on $H_0 : \gamma_{12li} = 0\forall_{li}$, $H_0 : \gamma_{13li} = 0\forall_{li}$ and $H_0 : \gamma_{14li} = 0\forall_{li}$, respectively.

Table 5: Panel cointegration test.

Variables	Panel (Within dimension)				Group (Between dimension)		
	v-statistic	*ρ*-statistic	*PP*-statistic	*ADF*-statistic	*ρ*-statistic	*PP*-statistic	*ADF*-statistic
ln*GDP*, ln*ENERGY*, ln*GFC*, ln*LABOR*	4.43***	1.12	-1.25	-1.91**	1.91	-2.56***	-2.71***

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% level of significance, respectively. The statistics are asymptotically significant as standard normal.

Table 6. Panel cointegration coefficients of nine South and Southeast Asian countries.

	Panel FMOLS				Panel DOLS			
	Intercept	ln*ENERGY*	ln*GFC*	ln*LABOR*	Intercept	ln*ENERGY*	ln*GFC*	ln*LABOR*
ln*GDP*	1.57***	0.21***	0.25***	0.88***	1.73***	0.23***	0.31***	0.76***
(full panel)	(8.30)	(14.47)	(25.44)	(19.37)	(21.93)	(6.25)	(39.07)	(28.25)
ln*GDP*	-9.53	0.61*	-0.16	1.77	-19.55	0.21	-0.17	2.57*
(Bangladesh)	(0.63)	(2.02)	(0.76)	(1.45)	(1.32)	(0.60)	(0.95)	(2.14)
ln*GDP*	14.90***	-0.02	0.004	0.68***	14.72***	-0.15***	0.02**	0.74***
(Brunei)	(23.36)	(0.60)	(0.22)	(13.09)	(63.60)	(12.66)	(2.63)	(37.12)
ln*GDP*	-0.32	0.99***	0.19***	0.48***	-1.64**	0.82***	0.24***	0.61***
(India)	(0.59)	(25.66)	(10.16)	(13.58)	(2.71)	(15.78)	(9.88)	(14.19)
ln*GDP*	-11.29**	-0.35	0.48***	1.61***	3.77	0.34	0.51***	0.31
(Indonesia)	(2.77)	(1.47)	(17.39)	(4.52)	(0.66)	(1.07)	(27.12)	(0.62)
ln*GDP*	-0.45	0.31***	0.23***	1.06***	7.41***	0.73***	0.18***	0.36**
(Malaysia)	(0.26)	(3.95)	(12.25)	(6.99)	(5.95)	(12.46)	(6.95)	(3.94)
ln*GDP*	1.78**	0.11	0.26***	0.91***	0.05	0.05	0.39***	0.88***
(Pakistan)	(2.24)	(1.31)	(6.69)	(11.31)	(0.15)	(0.95)	(21.81)	(20.54)
ln*GDP*	-4.32***	-0.87***	0.47***	1.59***	-3.48**	-0.77***	0.86***	0.95***
(Philippines)	(4.83)	(5.49)	(4.33)	(8.27)	(4.49)	(9.34)	(8.13)	(4.62)
ln*GDP*	9.20***	0.34***	0.62***	-0.15	5.85*	0.18*	0.65***	0.12
(Sri Lanka)	(3.98)	(3.97)	(18.26)	(0.80)	(2.32)	(2.32)	(35.52)	(0.55)
ln*GDP*	14.17***	0.80***	0.15***	-0.07	8.40	0.68***	0.15***	0.34
(Thailand)	(4.40)	(14.07)	(7.77)	(0.32)	(1.62)	(7.58)	(6.13)	(1.04)
Heterogeneity Test (χ_8^2 -test) for the estimated coefficients								
Intercept	484.98 [0.000]				1801.46 [0.000]			
ln*ENERGY*	471.60 [0.000]				684.79 [0.000]			
ln*GFC*	377.19 [0.000]				1556.00 [0.000]			
ln*LABOR*	99.12 [0.000]				51.13 [0.000]			

Note: Three lags and one lead were set for the panel DOLS estimator. Numbers in parenthesis are the absolute values of t-statistics while those in brackets are *p*-values. ***, **, * indicate statistical significance at 1%, 5% and 10% level of significance, respectively.

In the energy usage (*ENERGY*) equation (Equation 5.2), the short-run causality from the real gross domestic product, real gross fixed capital formation and total labor force to energy usage is tested, based on $H_0 : \gamma_{21li} = 0\forall_{li}$, $H_0 : \gamma_{23li} = 0\forall_{li}$ and $H_0 : \gamma_{24li} = 0\forall_{li}$, respectively. In the capital formation (*GFC*) equation (Equation 5.3), the short-run causality from the real gross domestic product, energy usage and total labor force to real gross fixed capital formation is tested, based on $H_0 : \gamma_{31li} = 0\forall_{li}$, $H_0 : \gamma_{32li} = 0\forall_{li}$ and $H_0 : \gamma_{34li} = 0\forall_{li}$, respectively. Finally, in the total labor force (*LABOR*) equation (Equation 5.4), the short-run causality from the real gross domestic product, energy usage and capital formation to the total labor force is tested, based on $H_0 : \gamma_{41li} = 0\forall_{li}$, $H_0 : \gamma_{42li} = 0\forall_{li}$ and $H_0 : \gamma_{43li} = 0\forall_{li}$, respectively. The null hypothesis of no long-run causality in each equation (Equations (5.1)–(5.4)) is tested by examining the significance of the t-statistic for the coefficient on the respective error correction term (ε_{it}) represented by λ_i.

Table 7 presents the results of the short- and long-run causality tests for the panel data set under consideration.

Based on Table 7, the short-run dynamics in Equation 5.1 indicate that energy use (*ENERGY*) and real gross fixed capital formation (*GFC*) have an impact on the real gross domestic product (*GDP*), since their F-statistics are statistically significant at the 1% and 10% levels of significance, respectively. On the other hand, the total labor force (*LABOR*) has no impact on the real gross domestic product since its F-statistic is statistically insignificant. The results of Equation 5.2 indicate that the real gross domestic product, real gross fixed capital formation and total labor force do not have any impact on energy use, since their F-statistics are statistically insignificant. In terms of Equation 5.3, it appears that the real gross domestic product has an impact on real gross fixed capital formation, since its F-statistic is statistically significant at the 1% level of significance, while the energy use and total labor force do not have any impact on real gross fixed capital formation, since their F-statistics are statistically insignificant. The results of Equation 5.4 show that the real gross domestic product, energy use and real gross fixed capital formation do not have any impact on the total labor force, since their F-statistics are statistically insignificant. Therefore, it is implied that the short-run causality relationships between energy consumption and economic growth in the nine South and Southeast Asian countries are unidirectional, running from energy consumption to economic growth, supporting the growth hypothesis. This finding is also supported by the results of the studies by Lee [25], Mahadevan and Asafu-Adjaye [29], Narayan and Smyth [28] and Apergis and Payne [7] [24]. With respect to long-run causality, the results of Equation 5.1 in Table 7 indicate that the real gross domestic product is adjusting to the deviation from the long-run equilibrium, since its error correction term (*ECT*) is statistically significant at the 10% level of significance, meaning that in the long-run energy use, real gross fixed capital formation and the total labor force cause the real gross domestic product. The results of Equation 5.2 indicate that energy use is not adjusting to the deviation from the long-run equilibrium, since its *ECT* is statistically insignificant. The results of Equation 5.3 show that real gross fixed capital formation is adjusting to the deviation from the long-run equilibrium, since its *ECT* is statistically significant at the 1% level of significance, indicating that the real gross domestic product, energy use and total labor force cause real gross fixed capital formation. The results of Equation 5.4 show that the total labor force is adjusting to the deviation from the long-run equilibrium, since its *ECT* is statistically significant at the 10% level of significance, indicating that the real gross domestic product, energy use and real gross fixed capital formation cause the total labor force. Thus, in the long-run, the causal relationships between energy consumption and economic growth in the nine South and Southeast Asian countries are again unidirectional, running from energy consumption to economic growth, supporting the growth hypothesis. This finding is consistent with those of Lee [25], Ciarreta and Zarraga [26], Lee and Chang [6], Narayan and Smyth [28] and Apergis and Payne [7]. The results of the short- and long-run causality tests suggest that an increase in energy consumption may contribute to economic growth, while a reduction in energy consumption may adversely affect economic growth in the nine South and Southeast Asian countries, indicating that the aforementioned countries' economies are energy dependent. Finally, it can be concluded that, in the short and the long run, energy is an important component of economic development in the nine South and Southeast Asian countries. Thus, policy regarding energy consumption in South and Southeast Asian countries should be considered carefully.

Table 7. Panel causality test results of nine South and Southeast Asian countries.

Dependent variable	Sources of causation (independent variables) Sort-run $\Delta\ln GDP$	$\Delta\ln ENERGY$	$\Delta\ln GFC$	$\Delta\ln LABOR$	Long-run *ECT*
(5.1) $\Delta\ln GDP$	-	10.740(0.00)*** ←	3.031(0.08)* ←	0.404(0.53) ▬	1.758(0.08)* ←
(5.2) $\Delta\ln ENERGY$	1.654(0.20) ▬	-	0.109(0.74) ▬	0.032(0.86) ▬	0.879(0.38) ▬
(5.3) $\Delta\ln GFC$	12.754(0.00)*** ←	0.009(0.92) ▬	-	0.169(0.68) ▬	4.187(0.00)*** ←
(5.4) $\Delta\ln LABOR$	1.7843(0.18) ▬	0.5360(0.47) ▬	0.016(0.90) ▬	-	1.725(0.09)* ←

Notes: ECT represents the error correction term. Numbers of short-run causality are F-statistics and numbers of long-run causality are t-statistics while numbers in parentheses are p-values. ***, **, * indicate statistical significance at 1%, 5% and 10% levels of significance, respectively. The symbol ← indicates the presence of causality, while ▬ indicates that causality does not exist.

4.5. Panel Multivariate Impulse Response Functions (IRFs)

The panel impulse response functions (*IRF*s) are created by generating unit shocks to all the variables: real gross domestic product (*GDP*), energy use (*ENERGY*), real gross fixed capital formation (*GFC*) and total labor force (*LABOR*). Figure 1 shows the panel *IRFs* for the four variables of the nine South and Southeast Asian countries. The variable shocked is presented in the column, while the target variable is in the row. From Figure 1, it can be observed that most of the shocks of all the variables reach the equilibrium level within three to four years.

The first row of Figure 1 shows the impulse responses of variables to a one-unit shock in the real gross domestic product. From the graph, it is apparent that a one-unit shock in the real gross domestic product positively affects the energy use and real gross fixed capital formation, while it negatively affects the total labor force. This graph also shows that the highest responses of all the variables occur within one year from the initial shock and they require about three years to reach their long-run equilibrium level.

The second row of Figure 1 shows the impulse responses of variables to a one-unit shock in energy use. From the graph, it is evident that a one-unit shock in energy use negatively affects the real gross domestic product and real gross fixed capital formation, while it positively affects the total labor force. This graph also shows that the highest responses of all the variables occur within one year from the initial shock and they require about three years to reach their long-run equilibrium level.

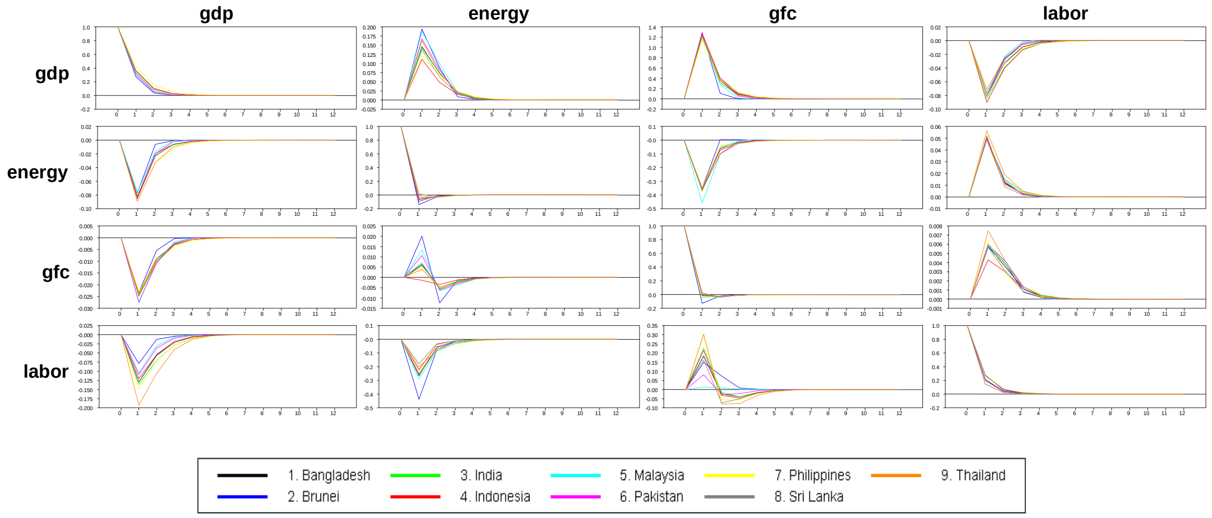

Fig. 1. Panel *IRFs* comparison of nine South and Southeast Asian countries.

Note: GDP is real gross domestic product, *ENERGY* is energy use, *GFC* is real gross fixed capital formation and *LABOR* is total labor force.

The third row of Figure 1 shows the impulse responses of the variables to a one-unit shock in real gross fixed capital formation. The graph indicates that a one-unit shock in real gross fixed capital formation negatively affects the real gross domestic product but positively affects the total labor force. This graph also shows that the highest responses of the real gross domestic product and total labor force occur within one year from the initial shock and they require about four years to reach their long-run equilibrium level. The response of energy use is different in this case; in one year from the initial shock, energy use shows a positive response, but from the second year, it responds negatively and it requires about four years to reach its long-run equilibrium level.

The fourth row of Figure 1 shows the impulse responses of the variables to a one-unit shock in the total labor force. From the graph, it can be seen that a one-unit shock in the total labor force negatively affects the real gross domestic product and energy use and they need about four years to reach their long-run equilibrium level. Furthermore, it positively affects real gross fixed capital formation, which is the highest within one year from the initial shock and requires about four years to reach its long-run equilibrium level.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This study examines the relationship between energy consumption and economic growth in nine South and Southeast Asian countries using the panel data approach. In bivariate analysis, a common problem that might occur is the omitted variable bias (Lütkepohl [18]). To avoid this problem, the present study evaluates the relationship between energy consumption and economic growth within a multivariate panel data framework by including real gross fixed capital formation and the total labor force. This study undertakes panel cointegration analysis to estimate the dynamic relationships, the panel vector error correction model to detect the direction of short- and long-run causality and panel *IRFs* to examine the effect of responses between energy consumption and economic growth.

Keeping in mind that the time period covered by the data is 23 years for each of nine countries, the Pedroni's [36] test used to test for panel cointegration in the absence of structural breaks in the data, the following general conclusions can be made. The panel cointegration analysis reveals that the long-run equilibrium relationships between real gross domestic product, energy consumption, real gross fixed capital formation and total labor force are positive and statistically significant, indicating the existence of long-run co-movement among the variables. The panel short- and long-run causality results support unidirectional causality running from energy consumption to economic growth in the nine South and Southeast Asian countries. This causality is referred to as the 'growth hypothesis,' suggesting that an increase in energy consumption may contribute to the economies of South and Southeast Asian countries and a reduction in energy consumption may adversely affect the economies of South and Southeast Asian countries, indicating that the economies of these countries are energy dependent. The growth hypothesis also suggests that energy consumption plays an important role in economic growth both directly and indirectly in the production process as a complement to the labor force and capital formation of these countries. The panel multivariate impulse response functions indicate that: (i) the responses to shocks of all the variables reach the equilibrium level within three to four years in the time period,(ii) a one-unit shock in the gross domestic product positively affects energy use and gross fixed capital formation but negatively affects the total labor force, (iii) a one-unit shock in energy use negatively affects the gross domestic product and gross fixed capital formation but positively affects the total labor force, (iv) a one-unit shock in gross fixed capital formation positively affects energy use and the total labor force but negatively affects the gross domestic product; and (v) a one-unit shock in the total labor force negatively affects the gross domestic product and energy use but positively affects gross fixed capital formation.

Finally, the empirical results of the present study might give policymakers a better understanding of the relationship between energy consumption and economic growth to formulate energy policies in the nine South and Southeast Asian countries. The investigation of the dynamic relationship between energy consumption and economic growth has important policy implications. The dynamic relationships between energy consumption and economic growth of the present study clearly indicate that energy consumption has a significant impact on economic growth. This means that continuous energy consumption may contribute to a continuous increase in economic growth and a continuous reduction in energy consumption may compromise economic growth, indicating that economic growth is fundamentally motivated by energy consumption. However, the excessive consumption of energy may create long-run environmental consequences. As a result, to avoid negative shocks to economic development in the nine South and Southeast Asian countries, policymakers should formulate well-planned short- and long-run energy policies taking into consideration the possible long-run environmental impacts.

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