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The Relationship between Energy Consumption and Economic Growth in South and Southeast Asian Countries: A Panel Vector Autoregression Approach and Causality Analysis

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ABSTRACT

This study investigates 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) using a panel data framework. The period for the study is 1990-2012, and the World Bank Development Indicators dataset is used. This study applies a panel vector autoregression model to provide impulse response functions (*IRFs*), which enable the impact of shocks to be examined between real gross domestic product, energy use, real gross fixed capital formation, and total labor force. In addition, panel Granger causality tests are employed to examine the direction of causality between energy consumption and economic growth. The *IRFs* show that the shocks of all the variables require a long period to reach the long-run equilibrium level and the greatest response of each variable is attributed to its own shock. The panel Granger causality results evidence bidirectional causality effects between energy consumption and economic growth, which supports the feedback hypothesis, meaning that these variables have strong interdependency between each other. Therefore, policy regarding energy consumption should be considered carefully.

Keywords: Panel Vector Autoregression, Panel İmpulse Response Functions, Panel Granger Causality, SAARC, Association of Southeast Asian Nations

JEL Classifications: C01, C33, O53

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1. INTRODUCTION

The impact of energy consumption on economic growth has attracted the interests 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, 1978; Erol and Yu, 1987; Masih and Masih, 1997; Soytas and Sari, 2003; Huang et al., 2008; Lee and Chang, 2008; Georgantopoulos, 2012; Kwakwa, 2012). 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 vector autoregression (VAR) model. 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[2], while the remaining five, Brunei Darussalam, Indonesia, Malaysia, the Philippines and Thailand, are members of the Association of Southeast Asian Nations (ASEAN)[3]. 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 (IMF, 2011), 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 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 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 dynamic relationships between the series under consideration. In particular, the panel VAR model used in the present study provides impulse response functions *(IRF*s) that enable the effect of responses between the series under consideration to be examined. The Granger causality tests capture the direction of the relationships between energy consumption and economic growth. The empirical results indicate that significant dynamic relations exist between real *GDP*, *ENERGY*, real *GFC* formation, and *LABOR*, allowing suggestions for policy makers to be formulated. It is worth mentioning that some studies (Al-Iriani, 2006; Chen et al., 2007; Lee and Chang, 2007; Mehrara, 2007; Nondo et al., 2010; Ozturk et al., 2010) 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 that incorporates 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 (1982) indicated.

This study contributes to the related literature in several ways. First, this study uses the panel VAR approach to examine the dynamic relationships and provide *IRFs* and the panel Granger causality between energy consumption and economic growth in nine emerging and developing South and Southeast Asian countries. The previous study by Lee and Chang (2008) conducted a panel cointegration and causality analysis to examine the relationship between energy consumption and economic growth in 16 Asian countries during the period 1971-2002. More specifically, the study by Lee and Chang (2008) included both developing and advanced economies, while the present study uses more recent data (1990-2012) and selects only developing countries to investigate the relationships between energy consumption and economic growth. In addition, the panel unit root results of the present study do not provide a uniform conclusion that the null of the unit root can be rejected for the levels of the dataset used[4]. Taking into consideration the studies by Hamilton (1994), Sims (1980), and Sims et al. (1990), which recommend avoiding differencing even if the variables contain a unit root (Enders, 2010), the present study uses a panel VAR approach to the levels of the variables. Enders (2010) also indicates that, "the main argument against differencing is that it "throws away" information concerning the co-movements in the data." Second, the current study presents estimates of the *IRFs,* which provide measures of the impacts between real *GDP*, *ENERGY*, real *GFC* formation, and *LABOR*. Third, the current study presents Granger causality test results for groups (panels) of nine countries as well as for individual countries. Finally, the panel data approach used in the present study provides increased power information in comparison with simple time series methods because the former derives information from both time and cross-sectional dimensions and the latter derives 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 the empirical model and the data, while Section 4 provides the econometric methods and the empirical results. The conclusions are drawn in Section 5.

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 (Ozturk, 2010). First, the growth hypothesis refers to a condition in which unidirectional causality runs from energy consumption

2 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.

3 The Association of Southeast Asian Nations (ASEAN) was established on 8 August 1967 in Bangkok, Thailand, with the signing of the ASEAN Declarationby 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.

4 Results are available upon request from the authors.

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 (Masih and Masih, 1997). 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.

A wide number of studies have investigated the dynamic relationships between energy consumption and economic growth in a panel data approach. For example, Huang et al. (2008) examined the causal relationship between energy consumption and economic growth in 82 countries during the period from 1972 to 2002. They employed a generalized method of moment (GMM) system approach for the estimation of the panel VAR model in each of the four groups of countries (i.e., low income group, lower middle income group, upper middle income group, and high income group). This study discovered that: (i) the causal relationship between energy consumption and economic growth in the low income group supports the neutrality hypothesis; (ii) the causal relationship between energy consumption and economic growth in the lower middle income group, upper middle income group, and high income group is unidirectional running from economic growth to energy consumption, which supports the conservation hypothesis and provides validation that the aforementioned groups of countries' economies are less energy dependent. Lee and Chang (2007) examined the relationship between energy consumption and economic growth in 22 developed and eighteen developing countries in a bivariate model. They adopted the GMM techniques developed by Arellano and Bond (1991) to estimate the panel VAR models. The empirical results of the study indicated that the causal relationship between energy consumption and economic growth in developed countries is bidirectional, supporting the feedback hypothesis, but that this relationship in developing countries is unidirectional running from economic growth to energy consumption, supporting the conservation hypothesis.

Lee and Chang (2008) utilized the panel cointegration and panel-based error correction models to investigate the relationship between energy consumption and economic growth within a multivariate framework for 16 Asian countries. The empirical results of the study reported that in the short-run, there is no causal relationship between energy consumption and economic growth, supporting the neutrality hypothesis; however, in the long-run there is unidirectional causality running from energy consumption to economic growth, which supports the growth hypothesis. Lee (2005) estimated the causal relationship between energy consumption and economic growth in eighteen developing countries employing the panel cointegration and panel-based error correction models. The study reported that there is a unidirectional causality running from energy consumption to economic growth, supporting the growth hypothesis for both the short run and the long run. Narayan and Smyth (2008) investigated the relationship between energy consumption and economic growth in G7 countries by employing panel cointegration and Granger causality tests. The empirical results of the study revealed that the short-run and long-run relationships between energy consumption and economic growth support the growth hypothesis. Ciarreta and Zarraga (2008) investigated the relationship between electricity consumption and economic growth in 12 European Union countries. The study employed panel cointegration and panel causality analysis. The empirical results of the study revealed that there is no causal relationship between the variables in the short run, supporting the neutrality hypothesis; however, there in the long run there is cointegration between the variables under consideration. Mahadevan and Asafu-Adjaye (2007) applied the panel error correction model to examine the relationship between energy consumption and economic growth in 20 energy importing and exporting countries. The findings of the study were that there is a unidirectional causality running from energy consumption to economic growth for developing countries, supporting the growth hypothesis. In addition, the causal relationship between energy consumption and economic growth for developed countries is bidirectional, supporting the feedback hypothesis.

Ozturk and Uddin (2012) used the Johansen–Juselius maximum likelihood procedure to examine the relationship between carbon emission, energy consumption and economic growth for India. The empirical results supported the feedback hypothesis between energy consumption and economic growth indicating that the level of economic activity and energy consumption of India is interconnected and may very well serve as complements to each other. Yildirim et al. (2014) employed both panel data and time series analysis to investigate the causal relationship between per capita energy consumption and per capita real *GDP* in five ASEAN countries. The empirical results of the study indicated that the Philippines, Indonesia, Malaysia and Thailand supported the conservation hypothesis while, Singapore supported the neutrality hypothesis. Apergis and Ozturk (2015) examined the presence of environmental Kuznets curve (EKC) hypothesis in 14 Asian countries. They adopted the GMM technique in a multivariate panel data framework. The empirical results of the study supported the presence of EKC hypothesis and also revealed a unidirectional causal relationship running from income to emissions for the 14 Asian countries. Al-Mulali and Ozturk (2015) used panel cointegration and Granger causality tests to investigate the main events that caused the environmental degradation in Middle East and North Africn countries. The empirical results implied that energy consumption, urbanization, trade openness, industrial development and the political stability have short-run and long-run effects on the environmental degradation.

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 *GFC* formation and the *LABOR*, 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.

3. MODEL AND DATA

Based on the previous discussions, real *GDP* is expected to be related to *ENERGY*, real *GFC* formation and total labor force (*LABOR*). The empirical analysis is based on panel VAR models, which are useful for examining the dynamics of the variables under consideration. As in the case of the simple VAR models, all the variables of the panel VAR are assumed to be endogenous and independent, but a cross-sectional element is added to the representation of the panel VAR. Panel VARs have been used to create average effects across heterogeneous panel units and to examine unit-specific differences relative to the average. Furthermore, panel VAR models help to study a variety of transmission issues across individual panel units (members) that cannot be dealt with in simple VAR models. The study by Canova and Ciccarelli (2013) presents a detailed review of panel VAR models.

The panel VAR model used in the present paper is based on the panel VAR approach developed by Canova et al. (2007) and Canova and Ciccarelli (2009) and is given as:

$$y_{\text{it}} = \alpha_{\text{it}} + A_{\text{it}}(L)Y_{\text{t}-1} + u_{\text{it}} \qquad u_{\text{it}} \sim \left(0, \sigma_{\text{i}}^2\right) \tag{1}$$

For $i = 1,\ldots, N$ $t=1,\ldots,T$

Where $Y_t = \left(y_{1t}', y_{2t}', \ldots y_{Nt}'\right)'$ is a stacked version of y_{it}, which is a vector of G variables for each unit $i=1,\ldots,N$. α_{it} is a $G\times1$ vector of intercepts, $A_{\text{it,l}}$ are $G\times NG$ matrices for each lag l and u_{it} is a $G\times1$ vector of random disturbances. It is assumed that there are p lags for the G endogenous variables. Note that Y_t includes variables that account for cross-sectional interdependencies and $E\left(u_{\text{it}}u_{\text{jÄ}}\right) = 0 \quad \forall i \neq j$, all t, τ. Furthermore, model (1) exhibits three important characteristics: first, the coefficients of the model are allowed to vary over time; second, the dynamic relationships are allowed to be unit-specific; and third, dynamic feedback across units is possible and this allows for cross-unit lagged interdependencies. Model (1) can be written in a simultaneous equation format as follows:

$$Y_{\text{t}} = X_{\text{t}}\delta_{\text{t}} + E_{\text{t}} \qquad E_{\text{t}} \sim N(0, \Omega) \tag{2}$$

Where $\delta_{\text{t}} = \left(\delta_{1\text{t}}, \delta_{2\text{t}}, \ldots, \delta_{\text{Nt}}\right)$ stocks together matrix A_{it} and vector α_{it} so that each δ_{it} is of dimension $G(NGp+1)\times1$. Since δ_{t} varies across cross-sectional units in different time periods, it cannot be estimated using classical methods. It is assumed that δ_{t} can be factored as:

$$\delta_{\text{t}} = \Xi_1\lambda_{\text{t}} + \Xi_2\gamma_{\text{t}} + \Xi_3\rho_{\text{t}} + \varepsilon_{\text{t}} \tag{3}$$

Where Ξ_1, Ξ_2, Ξ_3 are lower dimensional matrices, λ_{t} captures variations in the coefficient vector that are common across units and variables, γ_{t} captures unit-specific variations in the coefficient vector and ρ_{t} captures variable-specific variations in the coefficient vector. Note that (3) can be written compactly as:

$$\delta_{\text{t}} = \Xi\theta_{\text{t}} + \varepsilon_{\text{t}} \qquad \varepsilon_{\text{t}} \sim N\left(0, \Sigma \otimes V\right) \tag{4}$$

Where $\Xi = \left[\Xi_1, \Xi_2, \Xi_3\right]$, $\theta_{\text{t}} = \left[\lambda_{\text{t}}, \gamma_{\text{t}}, \rho_{\text{t}}\right]$, V is a $k\times k$ matrix and θ_{t} evolves over time as a random walk as:

$$\theta_{\text{t}} = \theta_{\text{t}-1} + \eta_{\text{t}} \qquad \eta_{\text{t}} \sim N\left(0, \bar{B}\right) \tag{5}$$

It is assumed that $\Sigma = \Omega$ and $V = \sigma^2 I_k$, where σ^2 is known. Note that $\bar{B}$ is a block diagonal matrix. Factorization (3) transforms an over parameterized panel VAR into a parsimonious SUR model, with the regressors as the averages of the right-hand side variables of the VAR model. Substituting (4) into (2), the estimated empirical model has the following state space structure:

$$\begin{aligned} Y_{\text{t}} &= \left(X_{\text{t}}\Xi\right)\theta_{\text{t}} + v_{\text{t}} \\ \theta_{\text{t}} &= \theta_{\text{t}-1} + \eta_{\text{t}} \end{aligned} \tag{6}$$

Where $v_{\text{t}} \sim \left(0, \sigma_{\text{t}}\Omega = \left(1 + \sigma^2 X_{\text{t}}' X_{\text{t}}\right)\Omega\right)$. Model (6) can be estimated with both classical and Bayesian methods. The latter approach is employed in the present study because it provides more accurate estimates given the relatively small N in the case of the present study. Note that the estimations are done utilizing RATS 8.2 econometric software and procedures based on the work by Doan (2012).

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 i.e., 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 (IMF, 2011). The multivariate panel data approach includes the natural logarithm of the real *GDP* (ln*GDP*) in constant 2005 U.S. dollars, energy uses (ln*ENERGY*) in kilowatts per oil equivalent, real *GFC* formation (ln*GFC*) in constant 2005 U.S. dollars and the total labor force (ln*LABOR*).

4. METHODS AND FINDINGS

4.1. Univariate Autoregression and Findings

First, the univariate autoregression case is considered, where y_{it} corresponds to the real *GDP* of *i*. In other words, *G*=1. For instance, in the case of *GDP*, model(1) becomes:

$$\ln GDP_{it} = \alpha_i + \sum_{l=1}^{p} \beta_{li} \ln GDP_{i,t-1} + u_{it} \tag{7}$$

For $i = 1,\ldots,9$; $t = 1990$ to 2012

Note that similar models to (7) are developed for the rest of the variables (*ENERGY*, *GFC* and *LABOR*). The Hannan-Quinn criterion (HQ) proposed by Hannan and Quinn (1979) and Schwarz Bayesian Criterion (SBC) proposed by Schwarz (1978) support two lags for the univariate autoregression models. The estimation of the aforementioned models is based on the shrinkage estimators for univariate autoregression presented by Doan (2012). This approach is based upon the literature on Bayesian VAR's using a prior (Minnesota prior) on the difference between β_i and the common β (pooled estimate). One of the advantages of the Bayesian panel VAR approach used in the present study is that it is more feasible compared to classical panel VAR approaches in the case of small *N*. In the univariate autoregression case, the lag coefficients are independent of the scale of the variable; for this reason, the univariate autoregression model is relatively easy to estimate. It also provides univariate *IRFs*, which show the responses to unit shocks to the (Gibbs) mean estimates for each variable.

4.1.1. Univariate IRFs

Figures 1-4 provide the *IRFs* obtained from the estimation of univariate autoregression models, such as model (7). Figures 1-4 correspond to the *GDP*, *ENERGY*, *GFC*, and *LABOR*, respectively. Specifically: Real *GDP*: Figure 1 shows the *IRFs* of the *GDP* of nine South and Southeast Asian countries and indicates that in the 12 years from the initial shock, the highest *GDP* response is attributed to the Philippines with about 152%, followed by Sri Lanka with about 136%, Bangladesh with about 133%, and India with about 125%. Furthermore, these highest responses also show the greatest persistence, with an upward tendency in the long-run. They are followed by Indonesia with about 108%, Pakistan with about 103%, Malaysia with about 70%, and Thailand with about 67%, which is retained 12 years after the initial shock. Energy use (*ENERGY*): Figure 2 shows the *IRFs* of the *ENERGY* of nine South and Southeast Asian countries and indicates that, after the initial shock, the greatest response by each country is attributed to its own initial shock. Furthermore, the greatest persistence is shown by India followed by Bangladesh, Sri Lanka, Brunei Darussalam, Thailand, Malaysia, Indonesia, and Pakistan, which retained 12 years after the initial shock about 97%, 73%, 57%, 52%, 48%, 47%, 46%, and 45% of the initial response, respectively. Real *GFC* formation: Figure 3 shows the *IRFs* of the *GFC* of nine South and Southeast Asian countries and indicates that in the 2nd year after the initial shock most of the countries showed their highest level of response, except for Bangladesh, Sri Lanka, and India. The highest response is Bangladesh's with about 122% in the 3rd year, which is followed by Sri Lanka with about 117% in the 4th year and India with about 116% in the 11th year. Furthermore, the greatest persistence is shown in India, followed by Sri Lanka, Bangladesh, the Philippines, Indonesia, and Pakistan, which retained 12 years after the initial shock about 116%, 115%, 113%, 53%, 37%, and 18% of the initial response, respectively. Total labor force (*LABOR*): Figure 4 shows the *IRFs* of the *LABOR* of nine South and Southeast Asian countries and indicates that in the 3 years from the initial shock, the highest level of response is attributed to Brunei Darussalam with about 148%, followed by Bangladesh with about 146%, Pakistan with about 146% Thailand with about 144%, India with about 140%, Malaysia with about 138%, the Philippines with about 132%, Indonesia with about 130%, and Sri Lanka with about 124%. Furthermore, the greatest persistence of the total labor force change is shown by Pakistan, followed by Bangladesh, Thailand, Malaysia, Brunei Darussalam, the Philippines, India and Indonesia, which retained 12 years after the initial shock about 146%, 141%, 133%, 113%, 104%, 109%, 96%, and 87% of the initial response, respectively.

4.2. Full Panel VAR and Findings

In the case of the full panel VAR, the same aforementioned nine South and Southeast Asian countries are considered but in this case *G*=4 (*GDP*, *ENERGY*, *GFC* and *LABOR*). Thus, for example, model (7) becomes as follows:

$$\ln GDP_{it} = \alpha_{1i} + \sum_{l=1}^{p} \beta_{11li} \ln GDP_{i,t-1} + \sum_{l=1}^{p} \beta_{12li} \ln ENERGY_{i,t-l} + \sum_{l=1}^{p} \beta_{13li} \ln GFC_{i,t-1} + \sum_{l=1}^{p} \beta_{14li} \ln LABOR_{i,t-1} + u_{1it} \tag{8.1}$$

$$\ln ENERGY_{it} = \alpha_{2i} + \sum_{l=1}^{p} \beta_{21li} \ln GDP_{i,t-1} + \sum_{l=1}^{p} \beta_{22li} \ln ENERGY_{i,t-1} + \sum_{l=1}^{p} \beta_{23li} \ln GFC_{i,t-1} + \sum_{l=1}^{p} \beta_{24li} \ln LABOR_{i,t-1} + u_{2it} \tag{8.2}$$

$$\ln GFC_{it} = \alpha_{3i} + \sum_{l=1}^{p} \beta_{31li} \ln GDP_{i,t-1} + \sum_{l=1}^{p} \beta_{32li} \ln ENERGY_{i,t-1} + \sum_{l=1}^{p} \beta_{33li} \ln GFC_{i,t-1} + \sum_{l=1}^{p} \beta_{34li} \ln LABOR_{i,t-1} + u_{3it} \tag{8.3}$$

Figure 1: Univariate impulse response functions comparison of the gross domestic product of nine South and Southeast Asian countries

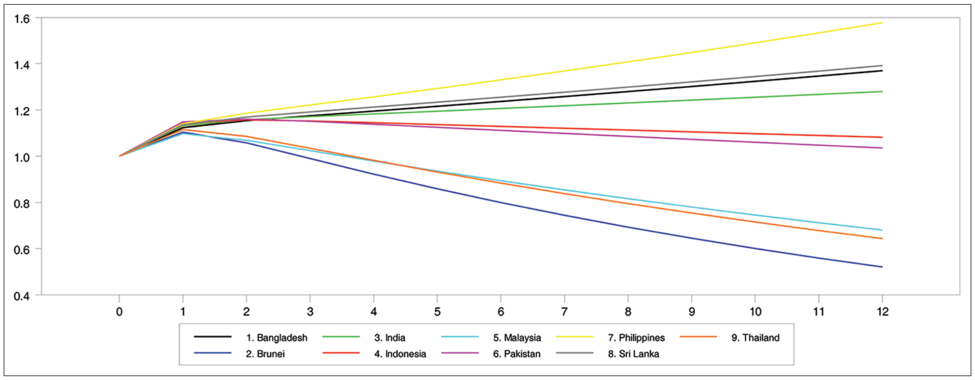


Figure 2: Univariate impulse response functions comparison of the energy use of nine South and Southeast Asian countries

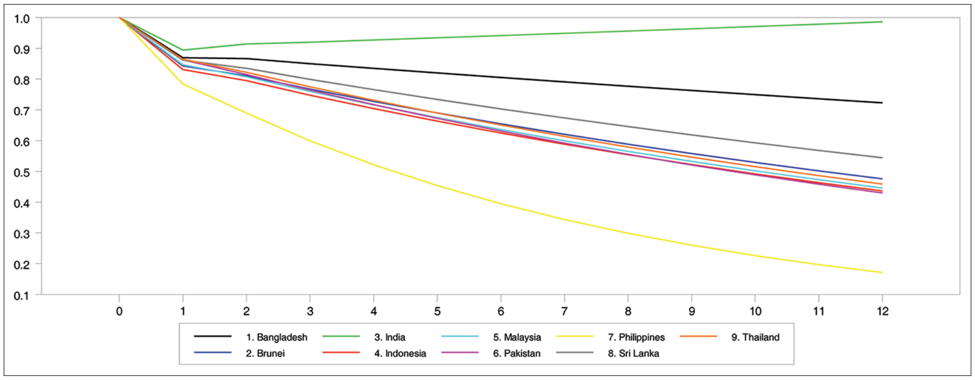


Figure 3: Univariate impulse response functions comparison of the gross fixed capital of nine South and Southeast Asian countries

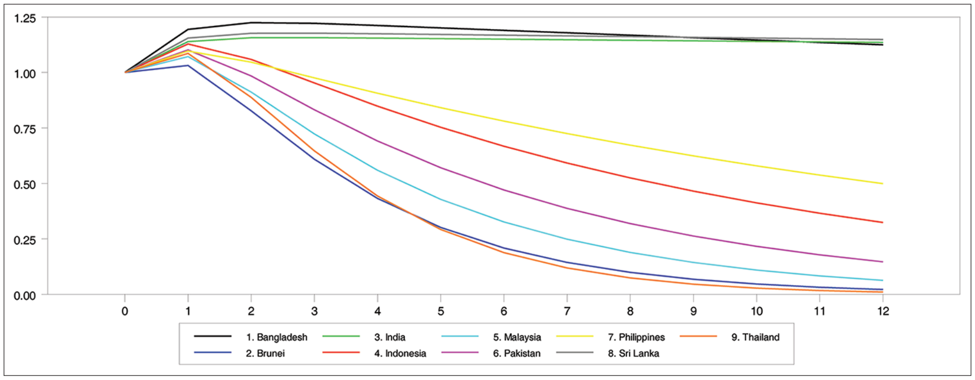
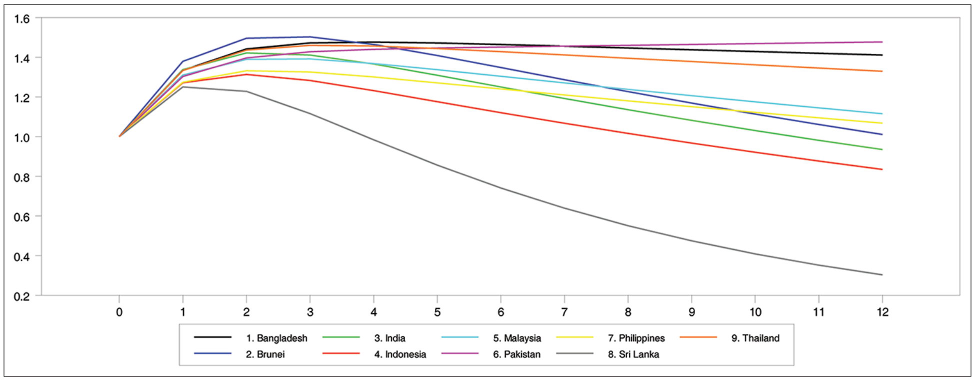


Figure 4: Univariate impulse response functions comparison of the total labor force of nine South and Southeast Asian countries



$$\ln LABOR_{it} = \alpha_{4i} + \sum_{l=1}^{p} \beta_{41li} \ln GDP_{i,t-1} + \sum_{l=1}^{p} \beta_{42li} \ln ENERGY_{i,t-1} + \sum_{l=1}^{p} \beta_{43li} \ln GFC_{i,t-1} + \sum_{l=1}^{p} \beta_{44li} \ln LABOR_{i,t-1} + u_{4it} \quad (8.4)$$

For i = 1,…,9; t = 1990 to 2012

The empirical results of the present paper were obtained based on the ordering of variables presented in models (8.1-8.4). Two numbers of lags are selected based on the HQ information criterion and the SBC. The estimation of models (8.1-8.4) is based on the shrinkage estimators of the full panel VARs presented by Doan (2012). In this case, as opposed to the univariate autoregression, the coefficients are scale-dependent. Again, the Minnesota prior is used and it starts with an ordinary least square univariate autoregression on each of the dependent variables in order to adjust the scale. The *IRFs* are created by generating unit shocks to all the variables. Figure 5 presents the *IRFs* corresponding to the four variables (*GDP*, *ENERGY*, *GFC* and *LABOR*). The variable shocked is presented in the column, while the target variable is in the row.

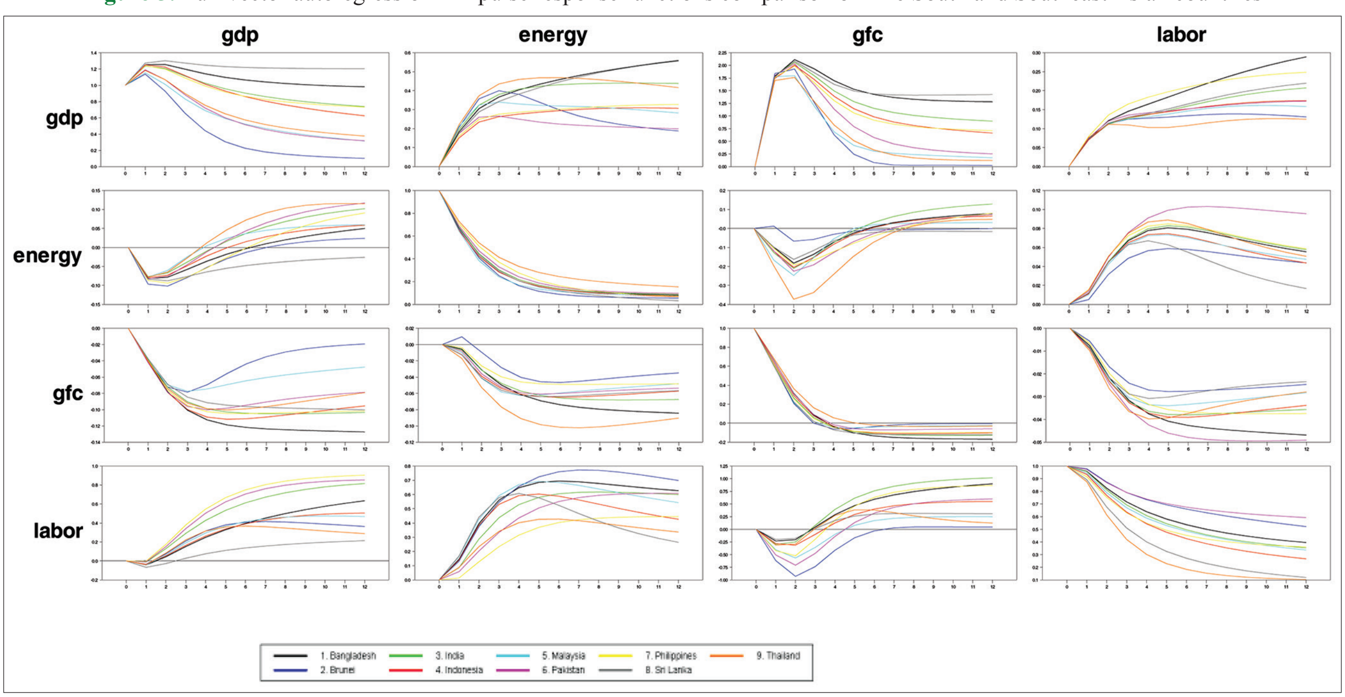
Table 1 presents panel Granger causality tests between each variable (*GDP*, *ENERGY*, *GFC*, and *LABOR*) for full panel and individual unit. The aforementioned Granger causality test results are obtained following Doan (2012). The null hypothesis is that there is no Granger causality in an individual member of the panel, while the alternative is that there is Granger causality in at least one. In the case of model (8.1), the null hypothesis that energy use (*ENERGY*) Granger cause real *GDP* could be described by the following joint test: $\beta_{12li} = 0$ for all i = 1,…,9. Meanwhile, the alternative hypothesis holds when at least one of the β_{12li} for i = 1,…,9 is different from zero. Rejection of the null of non-causality means that causality is found in some (though not necessarily all) of the individual members of the panel. For this reason, it is worth displaying the results of both the joint test and the individual tests. Furthermore, it is possible for all the individual tests to be insignificant at conventional significance levels while the joint test is strongly significant. According to Doan (2012), this is not unexpected, since the joint test is based on the whole panel and thus provides more and better information than the individual tests, which are based on individual members (samples) of the panel.

4.2.1. Panel multivariate IRFs

Figure 5 shows the *IRFs* for the four variables of real *GDP*, *ENERGY*, real GFC formation, and *LABOR* for the nine South and Southeast Asian countries. The greatest response shown by each variable is attributed to its own shock. These results are in accordance with those obtained in the univariate autoregression case (Model 7).

The first row of Figure 5 shows the impulse responses of the variables to a one-unit shock in the real *GDP*. From the graph, it is apparent that a one-unit shock in the *GDP* positively affects the remaining variables (i.e., *ENERGY*, *GFC*, and *LABOR*) for all countries. Specifically, the greatest persistence of the one-unit shock in *GDP* is shown by energy use (*ENERGY*) and the total labor force (*LABOR*), while shock in real *GFC* formation shows comparatively less persistence.

Figure 5: Full vector autoregression - impulse response functions 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 second row of Figure 5 shows the impulse responses of the variables to a one-unit shock in *ENERGY*. From the graph, it is evident that a one-unit shock in *ENERGY* negatively affects *GDP* and *GFC*, but it positively affects *LABOR* at the initial stage for all countries. Furthermore, *GDP* and *GFC* show positive effects after about 6 years from the initial shock. The greatest persistence of the one-unit shock in *ENERGY* is attributed to *LABOR*.

The third row of Figure 5 shows the impulse responses of the variables to a one-unit shock in *GFC*. The graph indicates that a one-unit shock in *GFC* negatively affects *GDP*, *ENERGY*, and *LABOR* for all countries. These effects remain negative for a long time. The greatest persistence of the one-unit shock in *GFC* is attributed to *GDP* and *LABOR*.

The fourth row of Figure 5 shows the impulse responses of the variables to a one-unit shock in *LABOR*. The graph shows that a one-unit shock in *LABOR* positively affects *GDP* and *ENERGY* and negatively affects *GFC* for all countries. Later on, *GFC* starts to increase, and within about 3 years from the initial shock it shows a positive response. The greatest persistence of the one-unit shock in *LABOR* is attributed to *ENERGY*.

4.2.2. Panel and individual Granger causality tests

Table 1 presents the results from the panel Granger causality tests which were estimated using a panel data method. Table 1 also presents the individual Granger causality tests corresponding to each country. This is because rejection of the null hypothesis of non-causality indicates that causality is present in at least some of the individual members of the panel; thus, it is necessary to display the results of the joint (panel) Granger causality test as well as the individual Granger causality tests. Note that it is possible for all the individual Granger causality tests to be statistically insignificant while the joint Granger causality test is statistically significant. This is because the joint test gives more and better information than the individual tests, which are based on the individual samples, since the joint test is based on the whole sample.

With regard to the full panel, equation (8.1) of Table 1 shows that *ENERGY* and *LABOR* Granger cause real *GDP*, while real *GFC* formation does not Granger cause real *GDP*. It means that *ENERGY* and *LABOR* have a predictive power to forecast the *GDP* whereas *GFC* does not have predictive power to forecast the *GDP*. The results of equation (8.2) show that *GDP*, *GFC*, and *LABOR* Granger cause *ENERGY*, meaning that *GDP*, *GFC*, and *LABOR* play a role in forecasting the *ENERGY*. Similarly, the results of equation (8.3) indicate that *GDP*, *ENERGY*, and *LABOR* Granger cause *GFC*, meaning that *GDP*, *ENERGY,* and *LABOR* have a predictive power to forecast the *GFC*. Furthermore, equation (8.4) provides information that *GDP*, *ENERGY*, and *GFC* have a predictive power to forecast the *LABOR*. Thus, the Granger causality results reported in Table 1 indicate bidirectional causality between energy consumption and economic growth in the nine South and Southeast Asian countries. This implies that energy consumption and economic growth are interconnected and may very well serve as complements to each other, which also supports the feedback hypothesis indicating that the nine South and Southeast Asian countries' economies are energy dependent, which in turn suggests that the policy regarding energy conservation should be considered carefully. This finding is also supported by the results of the studies of Chen et al. (2007), Lee and Chang (2007), Lee et al. (2008), Mahadevan and Asafu-Adjaye (2007), Nondo et al. (2010) and Ozturk et al. (2010). The majority of the individual Granger causality results reported in Table 1 (six out of nine) show that the individual countries support the findings obtained from the full panel, indicating that these economies are energy dependent. In particular, there is a unidirectional causality running from energy consumption to economic growth in Bangladesh, Brunei Darussalam, India, and Thailand. This is referred to as the growth hypothesis, which suggests that an increase in energy consumption may contribute to economic growth, while a reduction in energy consumption may adversely affect economic growth; thus, it indicates that the aforementioned countries' economies are energy dependent.

The causality relationships between energy consumption and economic growth in Sri Lanka support the conservation hypothesis. The conservation hypothesis refers to a condition in which the unidirectional causality runs from economic growth to energy consumption. It implies that policies designed to reduce energy consumption in Sri Lanka might not adversely affect economic growth, indicating that Sri Lanka's economy is less energy dependent. The causality relationships between energy consumption and economic growth in Malaysia and the Philippines support the feedback hypothesis. The feedback hypothesis refers to a condition where causality runs in both directions; that is, from energy consumption to economic growth, and from economic growth to energy consumption. This hypothesis implies that the energy consumption and economic growth of these two countries are interconnected and may very well serve to complement to each other. The causality relationships between energy consumption and economic growth in Indonesia and Pakistan support the neutrality hypothesis. This implies that the energy conservation policies of Indonesia and Pakistan may be pursued without adversely affecting these two countries' economies.

5. CONCLUSIONS AND POLICY IMPLICATIONS

This study investigates 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, 1982). 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 *GFC* formation and the *LABOR*. The present study undertakes the panel VAR method to investigate the dynamic relationship between energy consumption and economic growth. In particular, this study uses panel VAR models to obtain univariate *IRFs*, full VAR *IRFs* (i.e., multivariate impulse responses), and panel as well as individual Granger causality tests between the variables under consideration.

Table 1: Panel and individual Granger causality test results of nine South and Southeast Asian countries

Dependent variable	Sources of causation (independent variables)			
	ln*GDP*	ln*ENERGY*	ln*GFC*	ln*LABOR*
Full panel				
(8.1) ln*GDP*	-	51.715*** (0.00) ←	20.882 (0.29) —	69.576*** (0.00) ←
(8.2) ln*ENERGY*	38.720*** (0.00) ←	-	41.862*** (0.00) ←	47.031*** (0.00) ←
(8.3) ln*GFC*	36.792*** (0.01) ←	30.611** (0.03) ←	-	42.647*** (0.00) ←
(8.4) ln*LABOR*	50.812*** (0.00) ←	31.010** (0.03) ←	75.339*** (0.00) ←	-
Bangladesh				
(8.1) ln*GDP*	-	7.496** (0.02) ←	0.344 (0.84) —	2.628 (0.27) —
(8.2) ln*ENERGY*	3.571 (0.17) —	-	6.561** (0.04) ←	16.633*** (0.00) ←
(8.3) ln*GFC*	2.309 (0.32) —	0.359 (0.84) —	-	6.113** (0.05) ←
(8.4) ln*LABOR*	1.851 (0.39) —	3.707 (0.16) —	1.852 (0.39) —	-
Brunei Darussalam				
(8.1) ln*GDP*	-	9.871** (0.01) ←	0.609 (0.74) —	19.425*** (0.00) ←
(8.2) ln*ENERGY*	1.462 (0.48) —	-	3.096 (0.21) —	2.524 (0.28) —
(8.3) ln*GFC*	1.330 (0.51) —	4.720* (0.09) ←	-	3.978 (0.14) —
(8.4) ln*LABOR*	1.048 (0.59) —	3.014 (0.22) —	17.395*** (0.00) ←	-
India				
(8.1) ln*GDP*	-	9.270** (0.01) ←	6.347** (0.04) ←	12.869*** (0.00) ←
(8.2) ln*ENERGY*	1.401 (.049) —	-	2.801 (0.25) —	8.582*** (0.01) ←
(8.3) ln*GFC*	0.443 (0.80) —	0.082 (0.96) —	-	2.069 (0.36) —
(8.4) ln*LABOR*	6.965** (0.03) ←	2.085 (0.35) —	13.218*** (0.00) ←	-
Indonesia				
(8.1) ln*GDP*	-	0.916 (0.63) —	4.000 (0.14) —	4.764* (0.09) ←
(8.2) ln*ENERGY*	2.465 (0.29) —	-	1.607 (0.45) —	4.994* (0.08) ←
(8.3) ln*GFC*	7.500** (0.02) ←	1.355 (0.51) —	-	12.762*** (0.00) ←
(8.4) ln*LABOR*	12.148*** (0.00) ←	0.346 (0.84) —	10.380*** (0.01) ←	-
Malaysia				
(8.1) ln*GDP*	-	16.571*** (0.00) ←	1.081 (0.58) —	8.816*** (0.01) ←
(8.2) ln*ENERGY*	8.280** (0.02) ←	-	4.277 (0.12) —	5.437* (0.07) ←
(8.3) ln*GFC*	4.697* (0.09) ←	17.473*** (0.00) ←	-	2.761 (0.25) —
(8.4) ln*LABOR*	15.035*** (0.00) ←	13.241*** (0.00) ←	11.906*** (0.00) ←	-
Pakistan				
(8.1) ln*GDP*	-	0.100 (0.95) —	0.474 (0.79) —	1.248 (0.54) —
(8.2) ln*ENERGY*	2.474 (0.29) —	-	1.161 (0.56) —	2.110 (0.35) —

(*Contd*)

Table 1: ***(Continued....)***

Dependent variable	Sources of causation (independent variables)			
	ln*GDP*	**ln*ENERGY***	**ln*GFC***	**ln*LABOR***
(8.3) ln*GFC*	11.110*** (0.00) ←	1.552 (0.46) ▬	-	3.908 (0.14) ▬
(8.4) ln*LABOR*	3.374 (0.19) ▬	1.768 (0.41) ▬	5.761* (0.06) ←	-
Philippines				
(8.1) ln*GDP*	-	6.722** (0.03) ←	0.321 (0.85) ▬	7.252** (0.03) ←
(8.2) ln*ENERGY*	5.388* (0.07) ←	-	9.763*** (0.01) ←	0.433 (0.81) ▬
(8.3) ln*GFC*	0.085 (0.96) ▬	3.512 (0.17) ▬	-	1.430 (0.49) ▬
(8.4) ln*LABOR*	7.382** (0.02) ←	3.190 (0.20) ▬	5.441* (0.07) ←	-
Sri Lanka				
(8.1) ln*GDP*	-	0.551 (0.76) ▬	1.251 (0.53) ▬	2.720 (0.26) ▬
(8.2) ln*ENERGY*	9.542** (0.01) ←	-	6.190** (0.05) ←	4.642* (0.09) ←
(8.3) ln*GFC*	8.260** (0.02) ←	0.866 (0.65) ▬	-	1.216 (0.54) ▬
(8.4) ln*LABOR*	2.423 (0.29) ▬	1.792 (0.41) ▬	2.751 (0.25) ▬	-
Thailand				
(8.1) ln*GDP*	-	0.218*** (0.00) ←	6.455** (0.04) ←	9.853*** (0.00) ←
(8.2) ln*ENERGY*	4.138 (0.13) ▬	-	6.405** (0.04) ←	1.675 (0.43) ▬
(8.3) ln*GFC*	1.058 (0.59) ▬	0.691 (0.71) ▬	-	8.411*** (0.01) ←
(8.4) ln*LABOR*	0.586 (0.75) ▬	1.866 (0.39) ▬	6.634** (0.04) ←	-

F-statistics are reported while numbers in parentheses are *P* values. ***,**,*Statistical significance at 1%, 5% and 10% levels of significance, respectively. The symbol← the presence of Granger causality, while ▬ that Granger causality does not exist

The univariate *IRFs* provide information about the response and persistence of variables (i.e., *GDP*, *ENERGY*, *GFC*, and *LABOR)* following unit shocks to the mean estimates of each variable under consideration. The multivariate impulse responses are obtained by creating unit shocks to all the variables under consideration (i.e. *GDP*, *ENERGY*, *GFC*, and *LABOR*). In general, the empirical results of the panel VAR multivariate impulse responses indicate that: (i) the greatest response of each variable is attributable to itself; (ii) the responses of all variables to a one-unit shock in *GDP* are positive, while the responses of all variables to a one-unit shock in *GFC* are negative; (iii) the responses of *GDP* and *GFC* are negative, while the response of *LABOR* is positive to a one-unit shock in *ENERGY*; (iv) the responses of *GDP* and *ENERGY* are positive while the response of *GFC* is negative to a one-unit shock in *LABOR*. The panel Granger causality results indicate bidirectional causality between energy consumption and economic growth in nine South and Southeast Asian countries. These causality relationships imply that energy consumption and economic growth are interconnected and may very well complement each other, which also support the feedback hypothesis. The majority of the Granger causality results for the individual countries support the findings obtained from the full panel, which is that economies are energy dependent. In particular, the causal relationship between energy consumption and economic growth in Bangladesh, Brunei Darussalam, India, and Thailand support the growth hypothesis. Malaysia and the Philippines support the feedback hypothesis. Sri Lanka supports conservation hypothesis, and a neutrality hypothesis is present in the cases of Indonesia and Pakistan. Thus, it might be concluded that the economies of Bangladesh, Brunei Darussalam, India, Malaysia, the Philippines, and Thailand are energy dependent, which indicates that the energy conservation policies of these countries may adversely affect the growth of their economies. The economies of Indonesia, Pakistan, and Sri Lanka are less energy dependent, indicating that energy conservation policies may be pursued without adversely affecting these countries' economies. However, the conclusion based on individual country specific Granger causality results differ from the panel Granger causality results, which suggest that the economies of the nine South and Southeast Asian countries under consideration are energy dependent. This is not surprising because the use of short spans of time series data and country specific characteristics may yield diverse results for individual countries (Lee, 2005; Chen et al., 2007). But as neighboring countries, these nine South and Southeast Asian countries' economy might have interrelations between each other. So, it might be said that, as a group, the nine South and Southeast Asian countries' economies are energy dependent.

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. With regard to the full panel, 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. Furthermore, the dynamic relationships between energy consumption and the economic growth of individual countries show that the results for majority of countries support the full panel results. However, to avoid negative shocks to economic development in the nine South and Southeast Asian countries, policymakers should formulate well planned short-term and long-term energy policies taking into consideration the country-specific links between energy consumption and economic growth, as well as the possible long-term environmental impacts.

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