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

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***A*bstract:** This study examines the dynamic relationship between energy consumption and the three major sectoral outputs (agricultural, manufacturing and service) in thirteen South and Southeast Asian countries using a panel data framework for the period 1971–2012. It undertakes panel cointegration analysis to investigate the long-run relationship between the variables. Also, the panel vector error correction model (PVECM) 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 the three sectoral outputs. The empirical results reveal that the long-run equilibrium relationship between energy consumption and the three sectoral outputs is positive and statistically significant, indicating the existence of long-run co-movement among the variables. The short- and long-run causality results support the existence of bidirectional causality between energy consumption and the three sectoral outputs except for the short-run causality between energy consumption and service sector output, which is unidirectional, running from service sector output to energy consumption. The IRFs show that all variables reach the equilibrium level within three to seven years from the initial shock.

Keywords: Panel cointegration; Panel vector error correction model; Panel causality; Panel impulse response functions; SAARC; ASEAN

JEL Classifications: O47, O53, Q43

1. Introduction

The crucial role of energy consumption and its impact on economic growth have attracted the interest of economists in recent years. The two energy crises in 1974 and 1981 have prompted numerous empirical analyses regarding the relationships between energy consumption and aggregate 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; Ozturk *et* *al*., 2010; Georgantopoulos, 2012). The related literature has been well documented by applying both the panel data framework and time series analysis. However, in the literature, the evidence of studies investigating the relationship between energy consumption and major economic sectoral outputs (agricultural, manufacturing, service) is limited. Among the studies investigating the relationships between energy consumption and sectoral outputs are those by Jumbe (2004), Chebbi and Boujelbene (2008), Jamil and Ahmad (2010), Kwakwa (2012) and Nathan *et al*. (2013).

The present study explores the relationship between energy consumption and three major sectoral outputs (agricultural, manufacturing and service) in thirteen South and Southeast Asian countries by applying the panel data approach. The thirteen South and Southeast Asian countries considered are Bangladesh, India, Nepal, Pakistan, Sri Lanka, Indonesia, Malaysia, the Philippines, Thailand, Singapore, Brunei Darussalam, Myanmar and Vietnam. Of these thirteen countries, five (Bangladesh, India, Nepal, Pakistan and Sri Lanka) are members of the South Asian Association for Regional Cooperation (SAARC), while the remaining eight (Indonesia, Malaysia, the Philippines, Thailand, Singapore, Brunei Darussalam, Myanmar and Vietnam) are members of the Association of Southeast Asian Nations (ASEAN). 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.

The purpose of this study is to examine the extent to which energy consumption is related to the agricultural, manufacturing and service sector outputs in thirteen South and Southeast Asian countries. Following Mehrara (2007), the present study is based on an energy demand function and employs a multivariate panel data framework with energy consumption (*ENERGY*), agricultural sector output (*AGR*), manufacturing sector output (*MAN*) and service sector output (*SER*) 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 (PVECM) captures the short- and long-run direction of the relationships between energy consumption and the three sectoral outputs. It is worth mentioning that some studies (Jumbe, 2004; Zamani, 2007; Chebbi and Boujelbene, 2008; Kouakou, 2011; Liew *et al*., 2012; Nawaz *et al*., 2012; and Nwosa and Akinbobola, 2012) have investigated the relationship between energy consumption and various sectoral outputs by using a bivariate model between energy consumption and a particular economic sector, instead of a multivariate approach 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 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 agricultural sector, manufacturing sector and service sector outputs in thirteen South and Southeast Asian countries. Among the previous studies, the study by Jamil and Ahmad (2010) used individual time series techniques (i.e. cointegration and the vector error correction model) to examine the relationship between electricity consumption and economic growth on aggregated and disaggregated (residential, commercial, manufacturing and agricultural) levels in Pakistan during the period 1960–2008. Second, 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. Finally, the approach of this study extends the shrinkage estimator of the panel Vector Autoregressive (VAR) model developed by Canova and Ciccarelli (2009) and Canova *et al*. (2007) to a panel vector error correction model (PVECM). In particular, the framework of analysis of the panel VAR approach of Canova and

Ciccarelli (2009) and Canova *et al*. (2007) is Bayesian in nature, with time variation, unit-specific dynamics and cross-unit interdependencies. The PVECM of the present study does not assume full homogeneity across individual supply chains, because different panel members are characterized by different structure governing the relationship between energy consumption and output growth and thus will very likely have different short-run price dynamics. Based on Doan (2012), the shrinkage panel estimator provides more reliable estimates of the short-run dynamics that would be obtained using simple individual-by-individual approaches.

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, the causal relationship between energy consumption and economic growth could be categorized into four possible hypotheses: the growth, conservation, feedback and neutrality hypotheses (Ozturk, 2010). First, the growth hypothesis refers to a condition whereby energy consumption leads 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. Second, the conservation hypothesis refers to a condition whereby economic growth leads 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 whereby 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 whereby 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.

The previous studies relating to the relationship between energy consumption and economic sectoral outputs (agricultural, manufacturing and service) pertaining to South and Southeast Asian countries are inadequate. Among these studies, Jamil and Ahmad (2010), Zaman *et al*. (2011), Liew *et al*. (2012), Qazi *et al*. (2012) and Ahmed and Zeshan (2014) employed a time series analysis to investigate the relationship between energy consumption and economic sectoral outputs in Pakistan, and Nathan *et al*. (2013) employed the same approach for India. Table 1 presents some of the most recent research that studied energy consumption and various economic sectoral outputs using time series analysis. In particular, the Johansen cointegration test proposed by Johansen and Juselius (1990), the Engle–Granger co-integration test proposed by Engle and Granger (1987) and the autoregressive distribution lag (ARDL) bound testing proposed by Pesaran *et al*. (2001) have been used to estimate the cointegration between the variables under consideration. The Granger causality test proposed by Granger (1969) and the vector error correction model (VECM) have been used to test the direction of causality. The majority of the studies presented in Table 1 examined the relationship between energy consumption and various economic sectoral outputs by conducting a bivariate analysis.

Table 1. Summary of empirical studies on energy consumption and major economic sectoral outputs in time series data approach

Authors	Period	Countries	Methodology	Causality relationship
Jumbe (2004)	1970–1999	Malawi	VECM, Granger causality	NGR → ELC AGR ▬ ELC
Zamani (2007)	1967–2003	Iran	VECM, Granger causality	IND → IEC (in short- and long-run) AGR ↔ AEC (in long-run)
Chebbi and Boujelbene (2008)	1971–2003	Tunisia	Johansen co-integration, VECM	AGR → EC MAN → EC SER → EC
Jamil and Ahmad (2010)	1960–2008	Pakistan	Johansen co-integration, VECM	MAN → EC (in long-run) AGR → EC (in long-run)
Kouakou (2011)	1971–2008	Cote d'Ivoire	Autoregressive Distribution Lag (ARDL) bound testing, VECM	ELC → IND (in the short-and long-run)
Zaman *et al*. (2011)	1980–2009	Pakistan	ADF based co-integration, Granger causality	IND ↔ EC AGR ▬ EC
Kwakwa (2012)	1971–2007	Ghana	Johansen co-integration, VECM	AGR → ELC (in the short- and long-run) AGR →Fossil (in the long-run) MAN ↔ ELC (in the short- and long-run) MAN ↔ Fossil (in the long-run) MAN → Fossil (in the short-run)
Liew *et al*. (2012)	1980–2007	Pakistan	Johansen co-integration, Granger causality	AGR ↔ EC SER → EC IND → EC
Nawaz *et al*. (2012)	1977–2010	Pakistan	Dynamic Ordinary Least Square, Granger causality	EC → AGR IND → EC SER → EC
Nwosa and Akinbobola (2012)	1980–2010	Nigeria	Engle-Granger co-integration, Vector Autoregression (VAR)	AGR ↔ EC MAN ▬ EC SER → EC
Qazi *et al*. (2012)	1972–2010	Pakistan	Johansen co-integration, VECM	TEC → IND (in the long-run) IND ↔ OIL (in the short-run) IND → COAL (in the short-run)
Sebri and Abid (2012)	1980–2007	Tunisia	Johansen co-integration, VECM	EC → AGR (in the short- and long-run)
Nathan *et al*. (2013)	1980–2009	India	Johansen co-integration, Granger causality	SER → EC (in the short-run) EC → AGR (in the short-run) IND ▬ EC (in the short-run)
Nelson *et al*. (2013)	1970–2010	Kenya	Johansen co-integration, VECM	MAN → ELC (in the short- and long-run) PEC → MAN (in the short- and long-run
Ahmed and Zeshan (2014)	1972–2012	Pakistan	Structural VAR, Granger causality	AGR ▬ EC
Enu (2014)	1980–2012	Ghana	Ordinary Least Square (OLS)	AGR ▬ EC MAN ▬ EC SER ▬ EC

Note: The symbols → and ↔ indicate unidirectional and bidirectional causality, respectively, while ▬ indicates that causality does not exist. AGR = agricultural output, MAN = manufacturing output, SER = service sector output, IND = industrial output, NGR = non agricultural output, EC = energy consumption, ELC = electricity consumption, AEC = Agricultural energy consumption, IEC = Industrial energy consumption, PEC = Petroleum energy consumption, TEC = total energy consumption, Fossil = fossil energy consumption, OIL = oil consumption, COAL = coal consumption.

Meanwhile, Qazi *et al*. (2012), Ahmed and Zeshan (2014) and Enu (2014) considered four variate analyses to examine the relationship between energy consumption and sectoral outputs. In particular, Qazi *et al*. (2012) considered industrial output, total employment, the consumer price index (CPI) and aggregated and disaggregated energy consumption; Ahmed and Zeshan (2014) focused on agricultural, industrial and service sector outputs and energy consumption; and Enu (2014) investigated energy consumption, labor and capital formation to examine the relationship between various sectoral outputs and energy consumption. In addition, Jamil and Ahmad (2010), Kwakwa (2012), Sebri and Abid (2012) and Nelson *et al*. (2013) used trivariate analyses in their studies. Specifically, Jamil and Ahmad (2010) considered electricity consumption, its price and the GDP on aggregated and disaggregated levels; Kwakwa (2012) examined electricity consumption, fossil energy consumption and the GDP on aggregated and disaggregated (agricultural and manufacturing) levels; Sebri and Abid (2012) considered agricultural output, trade openness and energy consumption on aggregated and disaggregated (oil and electricity) levels; and Nelson *et al*. (2013) investigated manufacturing growth, electricity consumption and petroleum consumption. Furthermore, Jumbe (2004), Zamani (2007), Chebbi and Boujelbene (2008), Kouakou (2011), Zaman *et al*. (2011), Liew *et al*. (2012), Nawaz *et al*. (2012) and Nwosa and Akinbobola (2012) considered a bivariate framework with energy or electricity consumption and particular sectoral outputs to evaluate the relationship between energy consumption and various economic sectoral outputs.

Considering the literature discussed above, the present study aims to investigate the relationships between energy consumption and major economic sectoral outputs (agricultural, manufacturing and service sector) in a panel data framework by incorporating a multivariate analysis in thirteen South and Southeast Asian countries. Furthermore, unlike many of the previous studies, the present study will discuss the causal relationship between energy consumption and the three major economic sectoral outputs in relation to the four hypotheses categorized in the energy consumption and economic growth literature.

3. Methodology

To facilitate a practical analysis of the relationship between sectoral growth and energy consumption, this study uses several empirical methods, which include, first, panel unit root tests (i.e. Harris and Tzavalis, 1999; Breitung, 2000; Levin *et al.*, 2002; Im *et al.*, 2003) to provide information about the stationarity properties of the variables under consideration. Second, panel cointegration tests (i.e. Pedroni, 1999) are performed to determine the presence of cointegration. Third, the long-run cointegration parameters are estimated based on the studies by Pedroni (2001, 2004). Finally, a PVECM is used to test the short- and long-run panel causal relationship between energy consumption and three major economic sectoral outputs (agricultural, manufacturing and service) followed by panel *IRFs*. Note that the estimations are performed based on the procedures developed in the work by Doan (2012) using the RATS 8.2 econometric software.

3.1 Panel unit root analysis

The determination of the stationarity properties of the variables under consideration is an important step in an empirical analysis, since applying the usual ordinary least square estimator in non-stationary variables results in spurious regressions. To determine the order of integration of the variables, the present study utilizes four different panel unit root tests. The first is the Levin, Lin and Chu (LLC) test developed by Levin *et al*. (2002), the second is the Harris and Tzavalis (HT) test developed by Harris and Tzavalis (1999), the third is the Im, Pesaran and Shin (IPS) test developed by Im *et al*. (2003) and the fourth is the Breitung test developed by Breitung (2000).

3.2 Panel cointegration analysis

To test the existence of the long-run equilibrium relationship among the variables under consideration (i.e. ln*ENERGY*, ln*AGR*, ln*MAN* and ln*SER*), a panel cointegration test proposed by Pedroni (1999) is used. Pedroni (1999, 2004) developed two sets of tests for cointegration, which include seven statistics. In the first set, four out of the seven are based on pooling along the within-dimension, which is known as panel cointegration statistics: they are the panel v-statistic, panel ρ-statistic, panel *PP*-statistic and panel ADF-statistic. With regard to the second set, the remaining three are based on pooling along the between-dimension, which is known as group mean panel cointegration statistics: they are the group ρ-statistic, group *PP*-statistic and group ADF-statistic.

The long-run relationship between energy consumption and the three sectoral outputs (e.g. agricultural sector, manufacturing sector and service sector) is given by Equation (1):

$$\ln ENERGY_{it} = \alpha_i + \beta_{1i} \ln AGR_t + \beta_{2i} \ln MAN_t + \beta_{3i} \ln SER_t + \varepsilon_{it}$$
$$for \quad i = 1, ..., N; \quad t = 1971 \text{ to } 2012 \qquad (1)$$

where 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. $ENERGY_{it}$ refers to the energy consumption, *AGR* is the real gross domestic product of the agricultural sector, *MAN* is the real gross domestic product of the manufacturing sector and *SER* is the real gross domestic product of the service sector.

Based on a number of studies written by Pedroni (2000, 2001, 2004, 2007), the current study employs two estimators to estimate the long-run parameters of the cointegration relationships, which is given by Equation (1). The first estimator is the fully modified ordinary least squares (*FMOLS*), which was originally developed by Phillips and Hansen (1990) and extended by Hansen (1992). The second estimator is the dynamic ordinary least squares (*DOLS*), which was proposed by Stock and Watson (1993). It is worth mentioning that the least squares estimated parameters in Equation (1) suffer from simultaneity bias due to the correlation between the left-hand side variable ($\ln ENERGY_{it}$) 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 Equation (1) corrects the estimates and covariance matrix for endogeneity, while the *DOLS* estimator eliminates the endogeneity by including the current lags and leads of the first difference of the right-hand variables (ln*AGR*, ln*MAN* and ln*SER*) in the regression of Equation (1).[1]

3.3 Panel 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 usual practice to examine the causal direction among the variables once cointegration is established. The current study employs a two-step procedure to test the causality. The first step is to estimate the long-run model (*FMOLS*) specified in Equation (1) to calculate the residuals. The second step is to define 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 the first difference plus the error correction term (*ECT*) as an exogenous variable. The dynamic PVECM can be formulated as follows:

[1] Time trend is not included in Equation (1) because it was not found to be statistically significant.

$$\Delta \ln ENERGY_{it} = \omega_{1i} + \sum_{l=1}^{p} \gamma_{11li} \Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p} \gamma_{12li} \Delta \ln AGR_{i,t-l} + \sum_{l=1}^{p} \gamma_{13li} \Delta \ln MAN_{i,t-l}$$

$$+ \sum_{l=1}^{p} \gamma_{14li} \Delta \ln SER_{i,t-l} + \lambda_{1i} \varepsilon_{it-1} + u_{1it} \tag{2.1}$$

$$\Delta \ln AGR_{it} = \omega_{2i} + \sum_{l=1}^{p} \gamma_{21li} \Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p} \gamma_{22li} \Delta \ln AGR_{i,t-l} + \sum_{l=1}^{p} \gamma_{23li} \Delta \ln MAN_{i,t-l}$$

$$+ \sum_{l=1}^{p} \gamma_{24li} \Delta \ln SER_{i,t-l} + \lambda_{2i} \varepsilon_{it-1} + u_{2it} \tag{2.2}$$

$$\Delta \ln MAN_{it} = \omega_{3i} + \sum_{l=1}^{p} \gamma_{31li} \Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p} \gamma_{32li} \Delta \ln AGR_{i,t-l} + \sum_{l=1}^{p} \gamma_{33li} \Delta \ln MAN_{i,t-l}$$

$$+ \sum_{l=1}^{p} \gamma_{34li} \Delta \ln SER_{i,t-l} + \lambda_{3i} \varepsilon_{it-1} + u_{3it} \tag{2.3}$$

$$\Delta \ln SER_{it} = \omega_{4i} + \sum_{l=1}^{p} \gamma_{41li} \Delta \ln ENERGY_{i,t-l} + \sum_{l=1}^{p} \gamma_{42li} \Delta \ln AGR_{i,t-l} + \sum_{l=1}^{p} \gamma_{43li} \Delta \ln MAN_{i,t-l}$$

$$+ \sum_{l=1}^{p} \gamma_{44li} \Delta \ln SER_{i,t-l} + \lambda_{4i} \varepsilon_{it-1} + u_{4it} \tag{2.4}$$

$$for \quad i = 1,...,13; \quad t = 1971 \text{ to } \ 2012$$

where Δ is the first-difference operator; *p* is the lag length set at two based on the satisfaction of the classical assumptions on the error term;[2] ε_{it} is the residuals from the panel *FMOLS* estimation of Equation (1); and u_{it} is the serially uncorrelated error term. In the energy consumption (*ENERGY*) Eq. (2.1), the short-run causality from agricultural sector output, manufacturing sector output and service sector output to energy consumption is examined, 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. In the agricultural sector output (*AGR*) Eq. (2.2), the short-run causality from energy consumption, manufacturing sector output and service sector output to agricultural sector output is examined, 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 manufacturing sector output (*MAN*) Eq. (2.3), the short-run causality from energy consumption, agricultural sector output and service sector output to manufacturing sector output is examined, 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 service sector output (*SER*) Eq. (2.4), short-run causality from energy consumption, agricultural sector output and manufacturing sector output to service sector output is examined, 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 long-run causality in each Eq. (2.1)–(2.4) is examined by investigating the statistical significance of the *t*-statistic for the coefficient on the respective error correction term (ε_{it}).[3]

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[2] Lee and Chang (2008) showed the procedure to identify the optimal lag. For the selection of the optimal lag, the test process is started by lag one (*P* = 1) and it continues until the error terms are free of serial correlation. In this study, lag two (*P* = 2) satisfies the classical assumptions on the error term.

[3] Time trends are not included in Equations (2.1)-(2.4) because they were not found to be statistically significant.

3.4 Data

The data used in this study consist of annual observations from 1971 to 2012. The energy consumption data were obtained from the World Bank Development Indicators and the remaining three sectors' (agricultural, manufacturing and service) data were obtained from the United Nations' National Accounts Main Aggregates Database for thirteen South and Southeast Asian countries, namely Bangladesh, India, Nepal, Pakistan, Sri Lanka, Indonesia, Malaysia, the Philippines, Thailand, Singapore, Brunei Darussalam, Myanmar and Vietnam. The remaining countries were omitted due to the unavailability of data for all the variables (i.e. data from 1971 to 2012). The multivariate panel data approach includes the natural logarithm of energy use (ln*ENERGY*) in kilowatt per oil equivalent, real gross domestic product of the agricultural sector (ln*AGR*) in constant 2005 U.S. dollars, real gross domestic product of the manufacturing sector (ln*MAN*) in constant 2005 U.S. dollars and real gross domestic product of the service sector (ln*SER*) in constant 2005 U.S. dollars.

4. Results and Discussion

4.1 Panel unit root results

The panel unit root test results are presented in Table 2 and Table 3. 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, all 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 could be concluded that the variables are integrated of order one, suggesting a possible long-run cointegrating relation among the variables, such as ln*ENERGY*, ln*AGR*, ln*MAN* and ln*SER*. Therefore, the next step of the empirical analysis is to investigate the presence of cointegration between the variables under consideration.

Table 2. Results of panel unit root LLC tests and Breitung tests

Variables and in 1st differences	LLC test			Breitung test		
	None	Constant	Constant and Trend	None	Constant	Constant and Trend
ln*ENERGY*	22.93 (1.00)	-1.18 (0.12)	1.72 (0.96)	12.44 (1.00)	10.67 (1.00)	-1.88 (0.03)
ln*AGR*	17.56 (1.00)	-1.78 (0.04)	0.34 (0.63)	12.52 (1.00)	9.59 (1.00)	-3.52 (0.00)
ln*MAN*	13.15 (1.00)	-1.89 (0.03)	1.08 (0.86)	9.85 (1.00)	9.26 (1.00)	-2.76 (0.00)
ln*SER*	13.95 (1.00)	0.21 (0.58)	1.22 (0.89)	10.53 (1.00)	6.54 (1.00)	-3.29 (0.00)
Δln*ENERGY*	-4.89 (0.00)	-13.19(0.00)	-11.16 (0.00)	-4.29 (0.00)	-12.04(0.00)	-12.09 (0.00)
Δln*AGR*	-5.84 (0.00)	-14.75(0.00)	-9.09 (0.00)	-5.17 (0.00)	-7.35 (0.00)	-11.21 (0.00)
Δln*MAN*	-6.87 (0.00)	-4.35 (0.00)	-2.15 (0.02)	-5.23 (0.00)	-4.19 (0.00)	-9.26 (0.00)
Δln*SER*	-2.85 (0.00)	-4.07 (0.00)	-5.49 (0.00)	-3.05 (0.00)	-6.21 (0.00)	-8.86 (0.00)

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

Table 3. Results of panel unit root HT tests and IPS tests

Variables and in 1st differences	HT test			IPS test	
	None	Constant	Constant and Trend	Constant	Constant and Trend
ln*ENERGY*	0.42 (0.66)	1.95 (0.97)	-1.052 (0.15)	2.64 (0.99)	1.16 (0.88)
ln*AGR*	0.13 (0.55)	3.34 (1.00)	0.62 (0.73)	3.70 (1.00)	-0.62 (0.26)
ln*MAN*	0.28 (0.61)	2.99 (0.99)	3.09 (1.00)	2.77 (0.99)	0.88 (0.81)
ln*SER*	0.26 (0.60)	2.99 (0.99)	2.94 (0.99)	4.16 (1.00)	0.87 (0.81)
Δln*ENERGY*	-75.31 (0.00)	-40.32 (0.00)	-23.84 (0.00)	-10.32(0.00)	-8.82 (0.00)
Δln*AGR*	-75.67 (0.00)	-48.01 (0.00)	-28.66 (0.00)	-11.02(0.00)	-9.16 (0.00)
Δln*MAN*	-64.18 (0.00)	-42.32 (0.00)	-25.76 (0.00)	-7.11 (0.00)	-6.27 (0.00)
Δln*SER*	-48.04 (0.00)	-39.75 (0.00)	-23.87 (0.00)	-6.88 (0.00)	-5.44 (0.00)

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 4 are obtained with and without the inclusion of time dummies. Most of the test statistics reject the null hypothesis of no cointegration between energy consumption, agricultural sector output, manufacturing sector output and service sectoroutput at the conventional level of significance. In particular, four test statistics (panel *PP*-statistic, panel *ADF*-statistic, group *PP*-statistic and group *ADF*-statistic) out of seven reject the null hypothesis of no cointegration between the variables under consideration when time dummies are included. On the other hand, five test statistics (panel *v*-statistic, panel *PP*-statistic, panel *ADF*-statistic, group *PP*-statistic and group *ADF*-statistic) out of seven reject the null hypothesis of no cointegration between the variables under consideration when time dummies are not included. These results indicate the existence of long-run co-movement among the variables.

Table 4. Panel cointegration test

Variables	Panel (Within dimension)				Group (Between dimension)		
	v-statistic	*ρ*-statistic	*PP*-statistic	*ADF*-statistic	*ρ*-statistic	*PP*-statistic	*ADF*-statistic
Cointegration Test-With time dummies							
ln*ENERGY*, ln*AGR*, ln*MAN*, ln*SER*, *cons, trend*	0.93	-0.32	-2.15**	-2.17**	0.88	-1.50*	-2.24**
Cointegration Test-Without time dummies							
ln*ENERGY*, ln*AGR*, ln*MAN*, ln*SER*, *cons, trend*	1.45*	-0.51	-1.95**	-2.04**	0.60	-1.44*	-2.03**

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

4.3 Long-run equilibrium relationship

The long-run elasticity results of the panel *FMOLS* and *DOLS* estimators are presented in Table 5 below.

Table 5. Panel cointegration coefficients of thirteen South and Southeast Asian countries

Variables	Panel FMOLS				Panel DOLS			
	Intercept	ln*AGR*	ln*MAN*	ln*SER*	Intercept	ln*AGR*	ln*MAN*	ln*SER*
ln*ENERGY* (full panel)	-5.82*** (13.95)	0.08** (2.11)	0.19*** (8.99)	0.55*** (16.54)	-5.83*** (14.45)	0.10** (2.50)	0.23*** (12.01)	0.45*** (14.36)
ln*ENERGY* (Bangladesh)	-7.95*** (8.61)	-0.26** (2.96)	0.16*** (5.08)	0.84*** (19.6)	-10.69*** (14.07)	-0.03 (0.49)	0.13*** (5.01)	0.76*** (33.40)
ln*ENERGY* (India)	-2.71* (1.83)	-0.01 (0.10)	0.00 (0.00)	0.63*** (3.91)	2.75 (0.34)	-0.39 (0.71)	-0.14 (0.49)	0.94* (1.79)
ln*ENERGY* (Nepal)	-4.87*** (6.62)	0.22** (2.61)	0.03 (1.23)	0.39*** (6.29)	-7.54*** (10.72)	0.51*** (5.90)	0.02 (1.25)	0.24*** (3.60)
ln*ENERGY* (Pakistan)	-12.78*** (10.92)	0.48*** (3.66)	-0.17 (1.33)	0.66*** (3.99)	-14.27*** (10.06)	0.47*** (3.49)	-0.44** (2.6)	0.98*** (4.45)
ln*ENERGY* (Sri Lanka)	3.53 (1.61)	-0.49** (2.60)	0.18** (2.25)	0.53*** (3.89)	6.55** (2.04)	-0.77** (2.87)	0.10 (1.33)	0.73*** (4.28)
ln*ENERGY* (Indonesia)	-23.35*** (4.74)	1.69*** (3.91)	0.26*** (3.24)	-0.48* (1.86)	-13.69 (1.30)	0.95 (1.15)	0.24* (1.96)	-0.13 (0.31)
ln*ENERGY* (Malaysia)	-13.78*** (7.92)	0.24** (2.11)	0.49*** (7.17)	0.28*** (3.21)	-16.79*** (11.15)	0.61*** (4.96)	0.8*** (6.23)	-0.25 (1.33)
ln*ENERGY* (Philippines)	3.36 (0.47)	-0.50 (0.63)	-0.25 (0.53)	1.00** (2.51)	19.74* (1.87)	-2.87** (2.65)	0.41 (0.76)	1.94*** (3.63)
ln*ENERGY* (Thailand)	-5.48 (1.12)	0.51 (1.44)	1.73*** (4.43)	-1.50*** (3.26)	10.14*** (3.48)	-0.02 (0.10)	3.13*** (15.02)	-2.30*** (13.86)
ln*ENERGY* (Singapore)	-9.05 (1.47)	-0.12 (0.64)	-0.19 (0.40)	1.04** (2.10)	-9.43 (0.55)	-0.07 (0.13)	0.25 (0.13)	0.58 (0.28)
ln*ENERGY* (Brunei)	-20.32*** (8.22)	-0.21** (2.14)	0.43*** (4.35)	1.06*** (15.85)	-17.13*** (8.86)	-0.11 (1.43)	0.46*** (4.48)	0.81*** (10.96)
ln*ENERGY* (Myanmar)	-2.33** (2.80)	0.56*** (6.38)	-0.43*** (4.09)	0.38* (1.99)	-2.72** (2.53)	0.45*** (6.04)	-0.51*** (4.5)	0.58** (2.82)
ln*ENERGY* (Vietnam)	1.38* (1.83)	-0.40*** (3.43)	0.63*** (11.01)	0.17 (1.33)	-0.26 (0.61)	-0.34*** (4.13)	0.59*** (14.73)	0.22** (2.08)

Heterogeneity Test (χ^2_{12} -test) for the estimated coefficients

	Panel FMOLS	Panel DOLS
Intercept	232.52 [0.00]	388.37 [0.00]
ln*AGR*	111.37 [0.00]	128.71 [0.00]
ln*MAN*	189.65 [0.00]	462.64 [0.00]
ln*SER*	152.12 [0.00]	405.29 [0.00]

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

In particular, Table 5 presents the panel cointegration coefficients for energy consumption (*ENERGY*) as a group as well as for each specific country i (i = 1,…,13). The results of the heterogeneity tests χ^2-tests 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$_i$, lnAGR_i, lnMAN_i, lnSER_i) are also reported in Table 5. The null hypothesis of the heterogeneity test is that each individual coefficient is equal to the average of the group.

A primary inspection of the empirical results reported in Table 5 indicates that the *FMOLS* and *DOLS* estimators produce very similar results in terms of the sign, magnitude and statistical significance of the parameter estimates for the full panel and slightly different results for the individual countries.

The third row of Table 5 presents the estimated parameters of the cointegration vector corresponding to the full panel, that is, the whole group of 13 South and Southeast Asian countries. All the coefficients of the full panel are positive and statistically significant at the 5% level of significance. The estimates of the full-panel *FMOLS* indicate that a 1% increase in agricultural sector output increases energy consumption by 0.08%; a 1% increase in manufacturing sector output increases energy consumption by 0.19%; and a 1% increase in service sector output increases energy consumption by 0.55%. The estimates of the full-panel *DOLS* indicate that a 1% increase in agricultural sector output increases energy consumption by 0.10%; a 1% increase in manufacturing sector output increases energy consumption by 0.23%; and a 1% increase in service sector output increases energy consumption by 0.45%. Note that energy consumption shows a higher response to service sector output followed by manufacturing sector output and agricultural sector output for both *FMOLS* and *DOLS* models. The *FMOLS* and *DOLS* estimates of individual countries indicate that the effect of agricultural sector output on energy consumption is positive and statistically significant in about 5 out of 13 countries in the *FMOLS* model and 4 out of 13 countries in the *DOLS* model, while it is negative and statistically significant in about 4 out of 13 countries in the *FMOLS* model and 3 out of 13 countries in the *DOLS* model. The negative and significant responses of energy consumption to the agricultural sector output of these countries might be a reason why farmers in the particular countries do not use energy as a modernized tool to enhance agricultural productivity efficiently and effectively. With regard to the manufacturing sector output and service sector output, most of the effects on energy consumption are positive. The heterogeneity tests for the estimated coefficients presented in the last five rows of Table 5 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

Table 6 presents the results of the short- and long-run causality tests for the panel data set under consideration. Based on Table 6, the short-run dynamics in Eq. (2.1) indicate that agricultural sector output (*AGR*), manufacturing sector output (*MAN*) and service sector output (*SER*) have an impact on energy consumption (*ENERGY*),since their *F*-statistics are statistically significant at the 10% level of significance. The results of Eq. (2.2) provide evidence that energy consumption (*ENERGY*) has predictive power to forecast agricultural sector output (*AGR*). On the other hand, manufacturing sector output (*MAN*) and service sector output (*SER*) do not have any predictive power to forecast agricultural sector output since their *F*-statistics are statistically insignificant. In terms of Eq. (2.3), it appears that energy consumption and service sector output have a causal effect on manufacturing sector output, while agricultural sector output does not have any causal effect on manufacturing sector output. The results of Eq. (2.4) show that manufacturing sector output has an impact on service sector output. However, energy consumption and agricultural sector output do not have any impact on service sector output. Therefore, it is implied that the short-run causality relationships between energy consumption and agricultural sector output and between energy consumption and manufacturing sector output in thirteen South and Southeast Asian countries are bidirectional, which supports the feedback hypothesis. These relationships indicate that energy consumption, agricultural sector output and manufacturing sector output are interconnected and may very well serve as complements to each other, also indicating that the agricultural sector output and manufacturing sector output of the thirteen South and Southeast Asian countries are energy dependent.

Table 6. Panel causality test results of thirteen South and Southeast Asian countries

Dependent Variable	**Sources of causation (independent variables)**				
	Short-run				**Long-run**
	Δln*ENERGY*	Δln*AGR*	Δln*MAN*	Δln*SER*	*ECT*
(2.1) Δln*ENERGY*	N.A.	2.492* (0.08) ←	2.887* (0.06) ←	2.501* (0.08) ←	-8.221*** (0.00) ←
(2.2) Δln*AGR*	5.235*** (0.01) ←	N.A.	1.754 (0.17) ▬	1.965 (0.14) ▬	2.539*** (0.01) ←
(2.3) Δln*MAN*	2.563* (0.08) ←	1.104 (0.33) ▬	N.A.	3.165** (0.04) ←	2.402** (0.02) ←
(2.4) Δln*SER*	0.025 (0.98) ▬	0.878 (0.42) ▬	11.426*** (0.00) ←	N.A.	1.930** (0.05) ←
Auto correlation					
Multivariate Q[1] = 11.34327		Significance level as χ^2_{16} = (0.78782)			
Multivariate Q[2] = 22.36837		Significance level as χ^2_{32} = (0.89724)			

Notes: *ECT* represents the error correction term; N.A. means Not Applicable. Numbers of short-run causality are *F*-statistics and numbers of long-run causality are *t*-statistics, while numbers in parentheses are *p*-values. ***, **, and * 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.

In contrast, the causal relationship between energy consumption and service sector output is unidirectional, running from service sector output to energy consumption, which supports the conservation hypothesis, indicating that service sector output is less energy dependent in the short run. With regard to the long-run causality, the results from Eq. (2.1) to Eq. (2.4) indicate that all the error correction terms (*ECT*s) are statistically significant at the conventional level of significance, implying that the causal relationships between energy consumption and agricultural sector output, manufacturing sector output and service sector output in the thirteen South and Southeast Asian countries are bidirectional, which supports the feedback hypothesis justifying that the aforementioned sectors are energy dependent. The results of the short-run and long-run causality tests suggest that an increase in energy consumption may contribute to the agricultural sector, manufacturing sector and service sector, while a reduction in energy consumption may adversely affect these three sectors' outputs in the thirteen South and Southeast Asian countries, with the exception of service sector output, which is not energy dependent in the short run. Finally, it can be concluded that, in the short and the long run, energy is an important component of economic development in the thirteen South and Southeast Asian countries. Thus, the policy regarding energy conservation in South and Southeast Asian countries should be considered carefully.

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, such as energy consumption (*ENERGY*), agricultural sector output (*AGR*), manufacturing sector output (*MAN*) and service sector output (*SER*). Figure 1 shows the panel *IRFs* for the four variables of the thirteen South and Southeast Asian countries. The variable shocked is presented in the column, while the target variable is in the row. From Figure 1it is observed that most of the shocks of all the variables reach the equilibrium level within three to seven years.

The first row of Figure 1 shows the impulse responses of the variables to a one-unit shock in energy consumption. From the graph it is apparent that a one-unit shock in energy consumption negatively affects the remaining variables (i.e. agricultural sector output, manufacturing sector output and service sector output) for all the countries. This graph also shows that the highest responses of agricultural sector output and service sector output occur in the first two years and that of manufacturing sector output is in the first year from the initial shock and they require about seven years to return to their long-run equilibrium level.

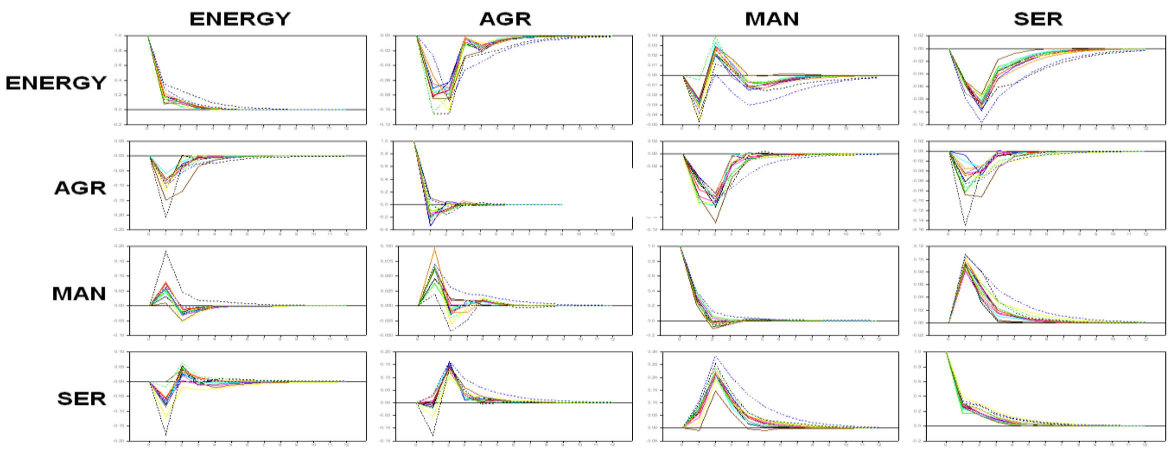

Figure 1. Panel *IRFs* comparison of thirteen South and Southeast Asian countries

The second row of Figure 1 shows the impulse responses of the variables to a one-unit shock in agricultural sector output. From the graph it is evident that a one-unit shock in agricultural sector output negatively affects energy consumption, manufacturing sector output and service sector output. This graph also reveals that the highest responses of energy consumption and service sector output for most of the individual countries are in the first year from the initial shock and they require about four years to return to their long-run equilibrium level. Meanwhile, the highest response of manufacturing sector output for most of the individual countries occurs in the first two years from the initial shock and about five years are required for it to return to its long-run equilibrium level.

The third row of Figure 1 shows the impulse responses of the variables to a one-unit shock in manufacturing sector output. The graph indicates that a one-unit shock in manufacturing sector output positively affects energy consumption, agricultural sector output and service sector output. It is also found that the highest responses of all the variables of most of the countries are in the first year from the initial shock. The response of the service sector output requires about seven years to return to its long-run equilibrium level. The responses of energy consumption and agricultural sector output are different in this case; in the first year from the initial shock they show a positive response, but from the second year they respond negatively and require about four years to come back to their long-run equilibrium level.

The fourth row of Figure 1 shows the impulse responses of the variables to a one-unit shock in service sector output. From the graph it is found that a one-unit shock in service sector output negatively affects the energy consumption and it needs about three years to return to its long-run equilibrium level. Furthermore, it positively affects agricultural sector output and manufacturing sector output, which are the highest in the first two years from the initial shock and require about five years to come back to their long-run equilibrium level.

5. Conclusions and Policy Implications

This study examines the relationship between energy consumption and the three major sectoral outputs (agricultural, manufacturing and service) in thirteen South and Southeast Asian countries using the panel data approach. It uses panel cointegration analysis to estimate the dynamic relationships, the PVECM to detect the direction of short-run and long-run causality and panel *IRFs* to examine the effect of shocks between energy consumption and the three sectoral outputs under consideration.

The panel cointegration analysis reveals that the long-run equilibrium relationship between energy consumption, agricultural sector, manufacturing sector and service sector are positive and statistically significant, indicating the existence of long-run co-movement among the variables. The panel short-run causality results evidence bidirectional causality between energy consumption and agricultural sector and between energy consumption and manufacturing sector, supporting the feedback hypothesis, while the causal relationship between energy consumption and service sector is unidirectional, running from service sector to energy consumption, which supports the conservation hypothesis. These results indicate that the agricultural sector and manufacturing sector of the thirteen South and Southeast Asian countries are energy dependent, but the service sector is less energy dependent. The panel long-run causality results provide evidence that the causal relationship between energy consumption and the three sectoral outputs (agricultural, manufacturing and service) are bidirectional, which supports the feedback hypothesis, indicating that energy consumption and agricultural sector, manufacturing sector and service sector are interconnected and may very well serve as complements to each other, which also suggests that in the long run, the agricultural sector, manufacturing sector and service sector of the thirteen South and Southeast Asian countries are energy dependent. The results of the short-run and long-run causality tests suggest that an increase in energy consumption may contribute to the agricultural sector, manufacturing sector and service sector outputs, while a reduction in energy consumption may adversely affect these three sectors' output in the thirteen South and Southeast Asian countries, with the exception of service sector, which is not energy dependent in the short run. The panel multivariate impulse response functions indicate that: (i) the responses to shocks of all the variables reach the equilibrium level within three to seven years in the time period, (ii) a one-unit shock in energy consumption negatively affects agricultural sector, manufacturing sector and service sector, (iii) a one-unit shock in agricultural sector negatively affects energy consumption, manufacturing sector and service sector, (iv) a one-unit shock in manufacturing sector positively affects energy consumption, agricultural sector and service sector and (v) a one-unit shock in service sector negatively affects energy consumption but positively affects agricultural sector and manufacturing sector.

Finally, the empirical results of the present study might give policymakers a better understanding of the relationship between energy consumption and the three economic sectoral outputs (agricultural, manufacturing and service) to formulate energy policies in the thirteen South and Southeast Asian countries. The dynamic relationships between energy consumption and economic sectoral outputs in the present study clearly indicate that energy consumption has a significant impact on the three economic sectoral outputs. This means that continuous energy consumption may contribute to a continuous increase in agricultural sector, manufacturing sector and service sector outputs and a continuous reduction in energy consumption may compromise the development of agricultural sector, manufacturing sector and service sector outputs, indicating that sectoral outputs are 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 the economic development in the thirteen South and Southeast Asian countries, the policymakers should formulate well-planned short-term and long-term energy conservation policies taking into consideration the sector-specific links with energy consumption and the possible long-run environmental impacts.

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