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Emission intensive growth and trade in the era of the Association of Southeast Asian Nations (ASEAN) integration: An empirical investigation from ASEAN-8

Khalid Ahmed [b], Mita Bhattacharya [a, *], Zahid Shaikh [b], Muhammad Ramzan [b], Ilhan Ozturk [c]

[a] Department of Economics, Monash University, Caulfield, 3145, Australia
[b] Sukkur Institute of Business Administration, Sukkur, Sindh, Pakistan
[c] Faculty of Economics and Administrative Sciences, Cag University, Mersin, Turkey

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A B S T R A C T

This paper attempts to shed some light on the energy consumption and associated emissions linking recent trade integration for eight economies in the ASEAN region: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. Considering the heterogeneity across the panel of countries, a long-run relationship is established between output, energy, trade, and emissions over a period of three decades. The role of transportation is considered in this respect. The overall findings indicate that the environmental consequences of economic growth are alarming for most of the countries in the panel, and non-renewable energy consumption is the key contributing factor towards environmental deterioration in the ASEAN region. Of the eight, it is further established that five economies from the region (Cambodia, Indonesia, Malaysia, Thailand and Vietnam) predominantly engage in emission-intensive trade and an increase in future energy demand and environmental degradation is projected for these countries. We suggest that the implementation of economic and trade policies in future should align with the energy sector. In this respect, renewable energy sources will play a greater role in sustainable growth and development across the countries.

1. Introduction

The Association of Southeast Asian Nations (ASEAN) region, along with China and India, are centre stage in the global energy arena. The energy demand in Southeast Asia will increase by 80% between 2013 and 2035, as reported by the International Energy Agency (IEA, 2013). In 2012, the region had a combined GDP of US$2.31 trillion (1 trillion = 1000,000,000,000) and a population of 600 million (1 million = 1000,000) people (ASEAN Briefing, 2014). For the past three decades, the annual rate of increase of gross domestic product (GDP) in the region has been 5.5%. In this environment of increasing energy demand and trade integration, the region requires effective energy policies.

The ASEAN member countries have significantly reduced intra-regional tariffs through the Common Effective Preferential Tariff (CEPT) Scheme under the Asian free trade agreement (AFTA). The establishment of the ASEAN economic community (AEC) is further expected to create a business environment, conducive to the expansion of trade and investment opportunities. Energy cooperation is considered to be complementary to regional economic integration. For this purpose, the Plan of Action on Energy Cooperation (PAEC) was initiated in 1995. Currently, the ASEAN Centre for Energy (ACE) is responsible for implementing environmental and energy strategies with regional governments.

There is sufficient scientific evidence to conclude that the burning of fossil fuel is a major cause of global climate change (Stern, 2007). Environmental degradation can be associated with recent frequent occurrences of natural disasters within the region.[1] Until recently, most of the countries (except Singapore) have neglected the climate change problem while implementing growth

* Corresponding author.
E-mail address: Mita.Bhattacharya@monash.edu (M. Bhattacharya).

[1] This has been in high agenda around the globe. For some discussion, see Giddens (2009) and Rosenzweig et al. (2010).

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intensive economic policies (Helm et al., 2012). Heavy dependence on fossil fuels, low investment in energy technology, and a lack of use of renewable energy sources have resulted in this region being the third largest emitter in the world.

The developing economies in the ASEAN region now face an increasing energy security problem due to rising energy demand and heavy reliance on conventional energy sources with diminishing supply (Asif and Muneer, 2007). Soytas and Sari (2003) reported that developing economies already outweigh developed economies in terms of energy consumption. This has been corroborated by the U.S. Energy Information Administration (EIA), who predict that the share of energy consumption of developing countries will increase from 54% of total world energy use in 2010 to 64% by 2040 (EIA, 2013a,b). The ASEAN region must strike a balance between sustainable environmental practice and continued economic growth in formulating energy policies. A combination of alternative and conventional energy sources, combined with implementation of modern energy technologies, are amongst numerous solutions to this conundrum. An empirical investigation of the long-run emission-growth-energy nexus is necessary in the current era of trade integration and in the increasing energy demand environment across the selected member states.

The existing literature on the growth-environment nexus suggests that increasing energy consumption is closely linked to increasing emissions. In this context, carbon dioxide (CO_2) accounts for more than 90% of total energy-led atmospheric pollution (Olivier, 2012). A positive association has been established between economic growth and energy consumption; however, the effect becomes negative in the long run due to the parallel increase in CO_2 emissions (Grossman and Krueger, 1991, 1994; Soytas and Sari, 2009; Ahmed et al., 2015). The theoretical justification for this phenomenon is based on the process of economic transformation of a country from an agrarian to an industrial economic base. The process of economic development leads to higher energy consumption and which may cause higher CO_2 emissions. The existing literature contains extensive discussions regarding the environmental repercussions of economic growth and increased energy consumption in developing and emerging economies. For example, a comprehensive review has been conducted by Smyth and Narayan (2015).

The studies establishing the negative environmental impact of economic growth may be critically analysed using the Environmental Kuznets Curve (EKC) hypothesis, based on research by Kuznets (1955). The EKC was first hypothesised by Grossman and Krueger (1991), who showed that environmental quality declines in the initial stages of economic growth, then gradually improves as the economy attains a certain threshold income level (see also Grossman and Krueger, 1994; Cole et al., 1997). The study by Suri and Chapman (1998) identified energy consumption as one of the major sources of environmental problems in developing countries. However, increased energy consumption may improve environmental quality when an economy relies heavily on imports and invests in energy efficient technologies (Bhattacharya et al., 2015). This explains a potential downward trend in the EKC of a developing country. The effect of energy use, however, contributes to an upward trend in the EKC for industrialised countries that import manufactured goods (see the empirical findings of Machado et al., 2001; Harbaugh et al., 2002; Knutsson et al., 2006; Soytas et al., 2007). Higher economic growth necessitates higher energy consumption and results in higher CO_2 emissions. In a recent study, Itkonen (2012) identifies that the carbon Kuznets curve (CKC) model is based on an inappropriate econometric method, with emissions dependence between energy use and output. The causal misspecification overstates the relationship between climate and development policy. Apergis (2016) uses time-varying cointegration and quantile cointegration approaches; the results indicate that the EKC hypothesis holds for the majority of countries in his sample.

In a recent study, Wang et al. (2016) establish a link between carbon emission and urbanisation for the ASEAN region. Their study does not consider heterogeneity across the panel. Our research integrates the effects of economic and trade integration on CO_2 emissions across the region considering heterogeneity across the panel.

Against this backdrop, we aim to analyse the long-run dynamics between energy consumption, economic growth and trade, and the effect of these on CO_2 emissions by focusing on a panel of eight major member countries within the ASEAN region: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. We incorporate the criticisms by Itkonen (2012) in this study and depart from the standard EKC literature by introducing supply-demand models with a simplified version of the endogenous growth framework. Our primary objective here is not to analyse the EKC hypothesis, as the stages of development are different for our selected countries. Rather, we try to identify the drivers of CO_2 emissions in the era of economic and trade integration.

Secondly, Itkonen (2012) reports that the recent literature based on vector autoregression (VAR) models lacks integrity of the estimators in non-linear form. Sadorsky (2012) reports the advantages of panel estimation over time series techniques in increasing efficiency. To overcome the criticism by Itkonen (2012), we employ panel cointegration techniques with heterogeneity and cross-sectional dependence in establishing long-run dynamics across the panel.

Following a review of the history of economic development and trade integration within the region from various sources, we find significant heterogeneity across countries within the region (Secretariat, ASEAN, 2013; Karki et al., 2005). This heterogeneity and cross-sectional dependence is not captured in the existing literature in the ASEAN context. These countries are in various stages of development during the integration process and the energy sector plays a key role. To capture this heterogeneity across the selected sample countries, long-term panel and country-specific elasticities are analysed in the current research. We believe, these econometric steps cover complete robustness checks for our analysis.

Our findings suggest that economic growth is emission intensive for Cambodia, Philippines, Singapore and Vietnam, while it changes over time with the stages of development. Trade is emission intensive for Cambodia, Indonesia, Malaysia, Thailand and Vietnam. Unique within the region, economic growth and trade have a negative significant effect on CO_2 emissions for Singapore. This is due to the reliance of Singapore on natural gas imports, which results in lower emissions than those for countries using other fossil fuel energy sources. It is suggested that, during the process of trade and economic integration, greater cooperation is needed across countries in formulating energy policies to enhance economic and trading activities in the long term. This implies that policy advisers within the region exercise caution in the implementation of energy policies to maintain growth and trade development across the region. Energy and trade-mix play a significant role in reducing CO_2 emissions. Transportation will play a greater role in the region.

In recent times, there has been an increasing acknowledgement amongst policy advisers in the region of the role of the energy sector in economic and trade integrations. To our knowledge, this is the first comprehensive study investigating the link between trade, output, and energy consumption for major countries in the region.

The policy relevance of the study is timely in this respect.

The structure of the paper is as follows: Section 2 provides a brief overview of the literature; Section 3 contains the model, data and econometric methods employed; Section 4 discusses the empirical results; and Section 5 offers concluding remarks and policy implications.

2. A brief literature review

A comprehensive review on the growth-emissions nexus is available (Stern, 2011). The findings are somewhat controversial. The seminal studies by Grossman and Krueger (1991, 1995) identified the issue and established an inverted-U shaped relationship between economic growth and environmental degradation, validating the EKC hypothesis. Beckerman (1992) argued that a high level of income lessens the environmental degradation. Bhagwati (1993) indicated that economic growth might be required for environmental quality. Economic growth is essential for environmental improvement in developing countries, as reported by Dornbusch (1992) and Panayotou (1993). The empirical investigation of Grossman and Krueger (1994) suggested a gross income of $8000 per capita per annum as the turning point at which environmental quality begins to improve following initial deterioration in most of the countries. Induced policy responses through changes in trade, technology, and energy will establish the relationship with the stages of development for any country.

More recent research regarding the relationship between economic growth and environmental degradation adopts both strands in the literature. The first highlights trade liberalisation as the main contributing factor to environmental improvement and the second considers energy consumption, as discussed in Bhattacharya et al. (2015). The literature predominantly focuses on the validity of the EKC hypothesis using the scale and technique effect, and is subsequently linked with the existence of the EKC. For example, in the presence of the EKC, the environmental consequences of growth have less impact on the relevant country because the trend of initial environmental degradation is reversed as economic development progresses (Ahmed et al., 2015). Numerous studies have been conducted for both developed and developing countries in this context. Castaneda (1999) found economic growth and trade liberalisation to be negatively associated with environmental quality in developing countries. Kleemann and Abdulai (2013) employed cross-country panel data to investigate the growth-trade-environment nexus to validate the EKC hypothesis and established a negative relationship for both developing and developed countries. Their findings suggest that the environmental consequences of trade liberalisation may be favourable for advanced economies. An empirical study by Zhang and Cheng (2009) for China established that economic growth and energy consumption increase CO_2 emissions, however, trade liberalisation decreases CO_2 emissions.

Al Mamun et al. (2014) examine the relationship between CO_2 emissions per capita and economic growth across the world between 1980 and 2009. Empirical results suggest that (i) except for high-income-countries, the Environmental Kuznets Curve (EKC) is a general phenomenon across the world, and (ii) the transformation of different economies towards a service economy has produced more pollution in high income countries and less pollution in low and middle income countries. Apergis and Ozturk (2015) test the Environmental Kuznets Curve (EKC) hypothesis for 14 Asian countries spanning the period between 1990 and 2011. Their empirical results support the presence of an Environmental Kuznets Curve hypothesis.

Suri and Chapman (1998) analysed the EKC in conjunction with energy consumption and established energy use as the key indicator behind the inverted-U curve relationship between growth and environmental quality. It was further reported that rising income alters the orientation of trade in terms of exports and imports and that this change in the ratio of exports to imports changes the slope of the EKC, as discussed in the introduction to this work.

The Suri and Chapman (1998) study also prompted a change in direction in the growth-environment literature and several new individual and cross-country studies were subsequently conducted. Harbaugh et al. (2002) re-examined the EKC hypothesis and found weak evidence. Energy had been identified as the major development indicator, as reported by Soytas et al. (2007), Zhang and Cheng (2009), and Omri et al. (2015). The literature predominantly emphasises the use of panel data as countries are dependent on each other via regional trade integration. However, the results and methodology adopted in past studies vary significantly (Ozturk, 2010). Further details regarding economic growth-exports, economic growth-imports and the energy consumption-trade nexus can be found in Awokuse (2008), Sadorsky (2012) and Ozturk and Al-Mulali (2015).

Literature, particularly from the ASEAN region, is scarce to date. In a single country study, Tan et al. (2014) emphasised the importance of anti-pollution and environmental protection acts in maintaining sustainable growth for Singapore. Saboori and Sulaiman (2013) considered Indonesia, Malaysia, Philippines, Singapore and Thailand from the ASEAN region. Their findings suggest that an increase in energy consumption tends to increase carbon emissions for the selected countries. The absence of trade integration in the models is noticeable for both studies. In addition, neither of these studies considers heterogeneity and cross-sectional dependence across the panel for estimation purposes.

3. Empirical model, data and econometric methodology

3.1. Empirical model and data

The ASEAN region has oil reserves of more than 28,000 billion (1 billion = 1000,000,000) barrels, as well as other natural resources, such as natural gas and coal. However, these resources are quickly being depleted due to the rapid economic growth in this region. In this study, a supply-demand model is employed, considering energy as the major source of input in the production process. On the supply side, a simple version of the endogenous growth model is specified:

$$Y_{it} = A_{it} f_1(EN_{it}) \tag{1}$$

and

$$A_{it} = f_2(TR_{it}) \tag{2}$$

where GDP (Y) and EN are gross domestic product and energy consumption, and A denotes technological progress. The symbols i and t are country and time period. In equation (2), technological progress is assumed to be captured by trade (TR) openness. Following the pioneering research by Eaton and Kortum (2002), trade spreads the benefit of technology. This has been supported by recent work by Caliendo and Parro (2015) and Alam et al. (2016).[2]

[2] There is a wide disparity between research and development (R&D) across the ASEAN nations. Among ASEAN countries, only Singapore spent on average 2.04 per cent of its GDP on R&D. Malaysia spent 0.50 per cent, Thailand 0.22 per cent, Vietnam 0.19 per cent and Brunei spent 0.02 per cent of their GDP on R&D (ADB, 2014). This is the primary reason for not considering R&D as a source of trade for this region.

Export market participation allows industries to have increasing contact with international best practice (Kapstein, 1998) and facilitates their learning from international experience (Burpitt and Rondinelli, 2000) as buyers of exports may offer technical assistance to improve technology (Evenson and Westphal, 1995) in the export sector. Imports may enhance technology by importing better quality products, services and intermediates input, as reported in Acharya and Keller (2009) and Sadorsky (2012). Trade-related activities may increase (through export-led growth) or reduce (through import substitution policies or outsourcing) emissions.

The primary focus of this approach is to establish the role of energy in economic and trade integration in the ASEAN region. The roles of capital and labour are assumed to be implicit and follow diminishing returns to scale. Any improvement in technology will be reflected through trade in this model. Trade integration within and outside the region opened up opportunities for foreign investment, foreign technology and international trade (Secretariat, ASEAN, 2013). This has increased output, productivity and growth through diversification, foreign investment and imported technology in the export and import sectors within and outside the region.

Combining (1) and (2) a simple version of the supply side model is defined as:

$$Y_{it} = f_3(EN_{it}, TR_{it}) \tag{3}$$

The main drivers of economic growth are assumed to be from energy and trade.

On the demand side, we define CO_2 emissions as a by-product of energy consumption relating economic growth, trade, and transporation (T).[3] In the literature, trade is significantly deterred by higher transportation costs, as suggested by Bougheas et al. (1999).

$$CO_{2it} = f_4(Y_{it}, TR_{it}, T_{it}) \tag{4}$$

Combining (3) and (4) we get

$$CO_{2it} = f_5(EN_{it}, Y_{it}, TR_{it}, T_{it}) \tag{5}$$

The log-linear version of Equation (5) is used to investigate the relationship between CO_2 emissions, energy consumption, economic growth, trade openness and transporation. The CO_2 emissions are measured in metric tonnes per capita, economic growth is measured in real GDP per capita in constant 2010 US$.[4] Trade openness (TR) is measured as (exports + imports scaled by GDP). Total energy consumption in transportation (T) of goods from air, rail and road is used to measure T. A square term for Y is used to check the validity of the EKC hypothesis, which may or may not be present. Under energy consumption, we consider two major types of energy viz. renewable sources (RE) and non-renewables (NRE), measured as the percent of total final energy consumption.

$$\ln CO_{2it} = \beta_1 + \beta_Y \ln Y_{it} + \beta_{Y^2} \ln Y_{it}^2 + \beta_{RE} \ln RE_{it} + \beta_{NRE} \ln NRE_{it} + \beta_{TR} \ln TR_{it} + \beta_T \ln T_{it} + \mu_t \tag{6}$$

μ_t is the disturbance term and β_s are elasticities. The annual series for these variables are taken from the World Development Indicators data series maintained by the World Bank. Brunei Darussalam, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam were selected from the ASEAN region due to data availability for all series between 1985 and 2015.[5]

3.2. Estimation approaches

The major empirical steps taken to establish the short- and long-term dynamics and elasticities for the panel of countries are discussed in the following sub-sections.

3.2.1. Panel unit root tests

The test for unit root has become a standard practice in applied time series econometrics literature (Ozturk and Acaravci, 2013). However, Maddala and Wu (1999) indicated that individual unit root tests might have limited power to maintain the persistence of individual regression errors across the cross-sections. Levin et al. (2002) developed the Levin-Lin-Chu (LLC) panel unit root test by pooling the cross-section, allowing trend and intercept coefficients to freely move across the cross-sections and generated pooled t-statistics. The LLC test is a panel-based augmented Dickey–Fuller (ADF) test assuming homogeneity in the dynamics of the autoregessive coefficients across a panel, incorporating cross-sectional independence. The test provides better approximations in comparison to common panel unit root tests, as suggested in Bildirici and Kayıkçı (2012). Im et al (2003) developed the IPS test allowing heterogeneity across the panel; we consider this test as an alternative approach.

Following Maddala and Wu (1999), we consider two additional tests based on the nonparametric method. These are the Fisher-ADF test and Fisher-PP (Philips Perron) test, which allow heterogeneity across panels. For all these tests, the null hypothesis represents the presence of a unit root. The Fisher tests use p-values from unit root tests for each cross-section i.

From the second generation group of tests for unit root, we conduct a series of alternative tests. During panel data estimation, it is generally assumed that disturbances in panel data models are cross-sectionally independent, particularly when the cross-section dimension (N) is large. There is, however, considerable evidence that cross-sectional dependence is often present in panel regression settings. Ignoring cross-sectional dependence in estimation can have serious consequences, with unaccounted residual dependence resulting in estimator efficiency loss and invalid test statistics. We apply four different tests to check cross-section dependence for robustness purposes. These are the Breusch and Pagan (1980) LM test, the Pesaran (2004) scaled LM test, the Baltagi et al. (2012) bias-corrected scaled LM test, and the Pesaran (2004) CD test. Table 2a and 2b presents the results of the panel unit root tests and cross-sectional dependence tests.

The findings for the unit root are reported in Table 2a. Findings establish non-stationarity under the null hypothesis.[6] Table 2b presents the results of cross-sectional dependence. We confirm the cross-sectional independence across our panel of countries and the findings are statistically significant.[7]

3.2.2. Panel cointegration test

In the presence of panel unit roots in various series, Pedroni (2004) proposed seven tests for cointegration in panel data

[3] Trade volume determines the cost of transportation. Following the suggestion from a reviewer, we consider total energy consumption in transportation as a driver of CO_2 emissions.

[4] Following Itkonen (2012), we measure all variables in per capita terms, not in levels.

[5] For the selected countries, the major energy sources are listed here in brackets. Brunei Darussalam (oil and gas), Cambodia (oil and hydro), Indonesia (oil, gas, coal, hydro, geo-thermal), Malaysia (oil, gas and coal), Philippines (oil, gas, coal, hydro, geo-thermal), Singapore (no natural energy resources), Thailand (oil, gas and coal), and Vietnam (oil, gas, coal, hydro and bio-mass).

[6] See Levin et al. (2002), Im et al. (2003), and Maddala and Wu (1999) for further details of the panel unit root and stationarity tests.

[7] Bhattacharya et al. (2015) discussed in detail various tests on panel data with heterogeneity and cross-sectional dependence.

models that allow for considerable heterogeneity within the panel. In all tests, Pedroni considers the null hypothesis as no cointegration. The proposed panel regression model has the following form:

$$Y_{i,t} = \propto_i + \partial t + \sum_{L=1}^{pi} B_{mi} X_{mi,t} + u_{it} \tag{7}$$

where i = 1, …, N represents each country in the panel and t = 1, …, T represents the time period. The parameters $\propto_i$ and ∂_t capture country specific fixed effects and deterministic trends. u_{it} denotes the estimated residuals representing the deviation from long-run equilibrium. Panel tests are based on the within-dimension approach and the between-dimension approaches. The first group of four test statistics represents the within-dimension results based on the pooling of autoregression coefficients and considering common time factors across countries. The second group of three test statistics represents the averages of the individual autoregressive coefficients associated with the unit root tests of the residuals of each country in the panel. The statistics related to these tests are given below:

The panel v-statistic

$$T^2 N^{3/2} Z_{\hat{v}NT} = \frac{T^2 N^{3/2}}{\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2} \hat{u}_{it}^2} \tag{8}$$

The panel ρ-statistic

$$T\sqrt{N} Z_{\hat{\rho}NT} = \frac{T\sqrt{N}\left(\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2}\left(\hat{u}_{it-1}^2 \Delta \hat{u}_{it}^2 - \hat{\pi}_i\right)\right)}{\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2} \hat{u}_{it}^2} \tag{9}$$

The panel t-statistic (non-parametric)

$$Z_{tNT} = \sqrt{\hat{\sigma}^2 \sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2} \hat{u}_{it-1}^2} \left(\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2}\left(\hat{u}_{it-1}^2 \Delta \hat{u}_{it}^2 - \hat{\pi}_i\right)\right) \tag{10}$$

The panel t-statistic (parametric)

$$Z_{tNT} = \sqrt{\hat{\sigma}^{*2} \sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2} \hat{u}_{it-1}^{*2}} \left(\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{L}_{11i}^{-2}\left(\hat{u}_{it-1}^{*2} \Delta \hat{u}_{it}^{*2} - \hat{\pi}_i\right)\right) \tag{11}$$

In the second group, between-test statistics are given below:

The group ρ-statistic (parametric)

$$T\sqrt{N} \hat{Z}_{\hat{\rho}NT} = \frac{T\sqrt{N}\left(\sum_{t=1}^{T}\left(\hat{u}_{it-1}^2 \Delta \hat{u}_{it}^2 - \hat{\pi}_i\right)\right)}{\sum_{i=1}^{N}\left(\sum_{t=1}^{T} \hat{u}_{it-1}^2\right)} \tag{12}$$

The group t-statistic (non-parametric)

$$\sqrt{N} \hat{Z}_{tNT-1} = \sqrt{N} \sum_{i=1}^{N}\left(\sqrt{\hat{\sigma}_i^2 \sum_{t=1}^{T} \hat{u}_{it-1}^2}\right) \sum_{t=1}^{T}\left(\hat{u}_{it-1}^2 \Delta \hat{u}_{it}^2 - \hat{\pi}_i\right) \tag{13}$$

The group t-statistic (parametric)

$$\sqrt{N} \hat{Z}_{tNT-1}^{*} = \sqrt{N} \sum_{i=1}^{N}\left(\sqrt{\hat{s}_i^{*2} \sum_{t=1}^{T} \hat{u}_{it-1}^{*2}}\right) \sum_{t=1}^{T}\left(\hat{u}_{it-1}^{*2} \Delta \hat{u}_{it}^{*2}\right) \tag{14}$$

The results of these tests are reported in Table 3.[8]

3.2.3. Long-run elasticities: individual country and full panel

The Fully Modified Ordinary Least Squares estimator (FMOLS) developed by Pedroni (2000) considers heterogeneous cointegrated panel data. This method incorporates both the problems of non-stationary regressors and simultaneity bias. Extending the methodology of Phillips and Hansen (1990), Pedroni developed a semi-parametric correction to the OLS estimator to eliminate the second order bias introduced by the endogeneity of the regressors. With the purpose of removing the nuisance parameters, the FMOLS estimator corrects the dependent variable using the long-run covariance matrices, then applies a simple OLS estimation method to the variables corrected for endogeneity. The long-run elasticity values for each country and for the full panel are presented in Table 4a and 4b.

3.2.4. Forecast: innovative accounting approach (IAA)

In the next step, the Forecast Error Variance Decomposition Method (FEVDM) and the Impulse Response Function (IRF) are employed in their generalised forms. The method is superior to the traditional Granger causality approach, as this captures the relative strength of the causal relation between the variables beyond the selected time period due to some exogeneous shocks. Following Shahbaz et al. (2012), we provide the FEVDM test and IRF plots in Table 5 and Fig. 1 for the forecasting purposes.

4. Empirical findings and discussions

Table 1 displays the descriptive statistics of data series representing different trends. Here, we need to check the stationarity of all variables in the first instance. The results of the four alternative unit root tests confirm the presence of a unit root. The findings from the LLC, IPS, Fisher-ADF and Fisher-PP tests for each series are reported in Table 2a. Each series is stationary at their first difference when considering the trend with and without intercepts. The results further imply that the variables are integrated in first order, i.e. I(1).

From the cross-sectional dependence group, we conduct four different tests, viz. the Breusch and Pagan (1980) LM, the Pesaran (2004) scaled LM, the Baltagi et al. (2012) bias-corrected scaled LM and the Pesaran (2004) CD test, and the results are reported in Table 2b. The results confirm that the series are cross-sectionally independent and appropriate for panel estimation.

In the next step, the Pedroni (2004) approach was used to assess cointegration and establish the long-run association between the variables in each panel. The results of the tests are presented in Table 3. Pedroni uses a total of seven test statistics – four within-dimension (panel) test statistics and three between-dimension (group) statistics – to determine whether or not the selected panel data are cointegrated. Considering the null hypothesis of no cointegration, we reject the null hypothesis for four tests at a significance level of 1%. The results reflect the presence of

[8] There are a variety of panel cointegration tests, the past literature suggests that there have been contrasting results for panel cointegration analysis on the same data sample, as one panel cointegration test may reject the null hypothesis and the other may not. For this reason, we apply the Johansen Fisher panel cointegration test and Kao residual-based cointegration test to validate the results of the Pedroni panel cointegration test. All the tests reject the null hypothesis and confirm the cointegration. The results of applying the Johansen Fisher panel cointegration test and Kao residual-based cointegration test are available on request from the authors.

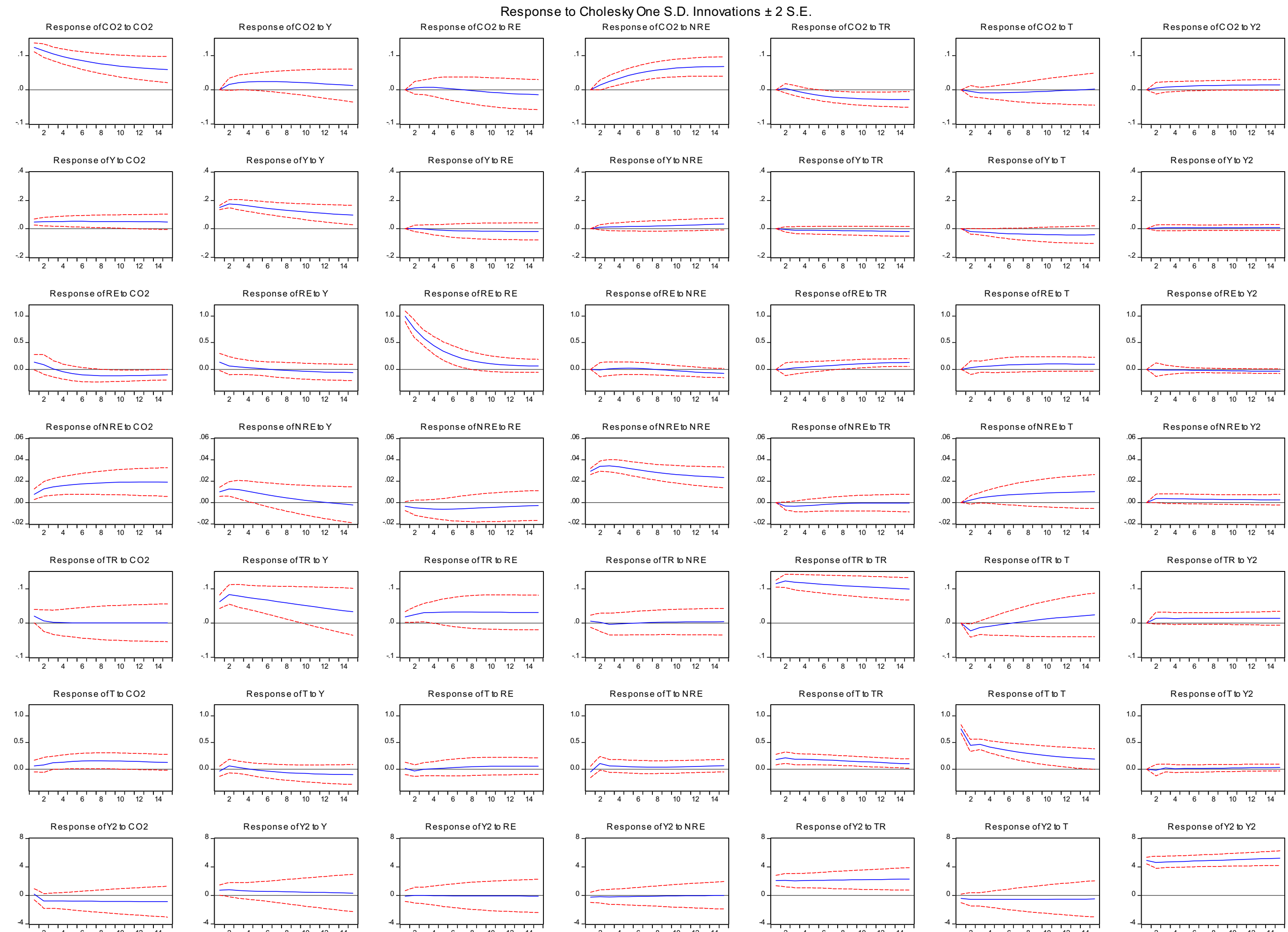

Fig. 1. Impulse response function.

Table 1
Descriptive statistics.

	$\ln CO_{2it}$	$\ln Y_{it}$	$\ln Y_{it}^2$	$\ln RE_{it}$	$\ln NRE_{it}$	$\ln TR_{it}$	$\ln T_{it}$
Mean	0.735	7.772	115.226	1.986	4.124	24.714	6.645
Median	0.574	7.627	48.733	3.441	4.193	25.576	7.916
Maximum	3.235	10.933	525.839	4.475	4.605	28.336	9.446
Minimum	−2.962	0.000	3.944	−9.630	2.790	0.000	−3.787
Std. Dev.	1.504	1.710	145.532	3.177	0.508	4.314	2.583
Skewness	−0.212	−0.353	1.531	−1.996	−1.131	−4.573	−1.295
Kurtosis	2.271	3.988	4.113	6.695	3.392	26.463	4.523
Jarque-Bera	7.310	15.156	109.227	304.629	54.233	6526.684	92.919
Probability	0.026	0.001	0.000	0.000	0.000	0.000	0.000
Sum	181.514	1919.578	28460.883	490.537	1018.724	6104.260	1641.273
Sum Sq. Dev.	556.276	719.359	5210193.248	2483.738	63.554	4578.179	1641.757
Observations	248	248	248	248	248	248	248

Notes: Variables are expressed in log. CO_2: CO_2 emissions, Y: Real GDP per capita, Y^2: (Real GDP per capita) ^{2}, RE: Renewable energy, NRE:Non-renewable energy, TR: Trade and T: Transport Cost.

cointegration in most of the considered series. The empirical findings suggest that, in the case of this panel of ASEAN countries, the variables of CO_2 emission, energy consumption (both renewable and non-renewable), economic growth, trade openness and transport have long-run association as suggested in Bhattacharya et al. (2015).

The long-run output elasticities were estimated using the FMOLS model for each country separately and for the panel. Table 4a presents the empirical results of the country-specific long-run elasticities for each variable. With the exception of Philippines, we could not establish the EKC relationship in the long run. Renewable energy sources are reducing CO_2 emissions for Brunei, Indonesia, Philippines and Vietnam. On the other hand, non-renewable sources of energy are detrimental for CO_2 emissions in Brunei, Cambodia, Indonesia, Malaysia, Phillippines and Vietnam. TR has no significant effect on CO_2 emissions for Brunei

Table 2a
Findings from the unit root tests.

Variables	Level		First difference	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend
LLC test				
ln CO_{2it}	−3.770***	0.473	−10.296***	−10.793***
ln Y_{it}	−3.455***	−3.456	−15.447***	−13.223
ln Y_{it}^2	−3.676***	2.085	−14.308***	−12.273***
ln RE_{it}	−4.477***	−0.208	−11.349***	−11.355***
ln NRE_{it}	0.352	−0.287	−5.063***	−1.162
ln TR_{it}	−4.080***	−4.963***	−11.352***	−9.686***
ln T_{it}	−4.325***	−2.803***	−13.609***	−12.152***
IPS test				
ln CO_{2it}	−1.461*	0.692	−9.475***	−9.534***
ln Y_{it}	−0.445	−6.080***	−13.968***	−11.506***
ln Y_{it}^2	0.442	−0.504	−14.523***	−12.825***
ln RE_{it}	−3.353***	1.443	−10.976***	−10.908***
ln NRE_{it}	−2.730***	−1.110	−9.666***	−8.463***
ln TR_{it}	−1.138	−3.718***	−11.410***	−10.124***
ln T_{it}	−4.867***	−3.150***	−14.095***	−13.006***
Fisher-ADF test				
ln CO_{2it}	23.627*	10.369	109.253***	101.195***
ln Y_{it}	34.428***	280.730***	120.635***	330.718***
ln Y_{it}^2	32.331***	16.073***	169.436***	171.429***
ln RE_{it}	47.567***	20.919	126.637***	117.196***
ln NRE_{it}	40.457***	30.999**	113.849***	101.961***
ln TR_{it}	25.766*	69.948***	129.913***	104.262***
ln T_{it}	52.890***	39.029***	167.224***	141.161***
Fisher-PP test				
ln CO_{2it}	22.983	7.738	119.857***	105.463***
ln Y_{it}	20.606	82.926***	128.758***	248.670***
ln Y_{it}^2	4.097	17.410	170.259***	146.966***
ln RE_{it}	56.296***	39.764***	127.996***	120.578***
ln NRE_{it}	60.234***	10.005	131.723***	421.610***
ln TR_{it}	21.896	61.827***	136.798***	115.429***
ln T_{it}	43.492***	27.718**	213.293***	663.404***

Note: ***, **, * represent 1%, 5% and 10% level of significance. All variables are measured in natural logarithm. The *p*-values are the probabilities of rejecting the null of no unit root. The Im-Pesaran-Shin test assume cross-sectional independence.

Table 3
Cointegration Tests.

Pedroni Panel Cointegration Test Results		
Alternative hypothesis: common AR coefs. (within-dimension)		
Tests	Statistics	Weighted Statistics
Panel *v*-statistic	−0.443	−1.442
panel *ρ*-statistic	0.568	2.600
Panel *t*-statistic (non-parametric)	−2.829***	−1.396*
Panel *t*-statistic (parametric)	−3.170***	−2.517***
Alternative hypothesis: individual AR coefs. (between-dimension)		
Tests	**Statistics**	
Group *ρ*-statistic	3.161	
Group *t*-statistic (non-parametric)	−3.531***	
Group *t*-statistic (parametric)	−3.931***	

Note: ***, * indicate rejection of null hypothesis of no cointegration at the 1% and 10% level of significance. The critical value at 1% level of significance for panel *v*-statistic = 2.33.

Darussalam, and positive and significant effects for Cambodia, Indonesia, Malaysia and Vietnam. In the case of Philippines and Singapore, trade is reducing CO_2 emissions in the long run. Transportation is increasing CO_2 emissions only in the case of Cambodia, out of all eight countries. These findings are significant. With continued economic growth, Singapore is concentrating on developing the services sector, which reduces environmental degradation. Singapore, being at the frontier of clean power growth in Asia, is already positioned to drive further environmental growth and assist companies in implementing such initiatives across the region.

In six of the eight countries selected for this study (Brunei, Cambodia, Indonesia, Malaysia, Philippines and Vietnam), non-renewable energy is a long-run source of environmental degradation. These countries individually and as a group should act together to reduce CO_2 emissions. In a slightly different subset (Cambodia, Philippines, Singapore and Vietnam), economic growth has a positive significant effect on CO_2 emissions. This finding deserves some attention. Singapore relies predominantly on natural gas, rather than coal, as its major energy source. This is a major reason for the lower CO_2 emissions caused by the growth process in this country. Also, Singapore is more proactive in building infrastructure and cleaner technologies, compared to the other countries in the region. It is suggested that other countries should follow the major economic and energy policies of Singapore, and cooperate with each other in reducing CO_2 emissions.

Of the eight countries under investigation, trade is emission-intensive in Cambodia, Indonesia, Malaysia and Vietnam, where the export sector is based predominantly on agriculture and manufacturing, which requires the use of extensive heat and electricity. Conversely, increased trade reduces CO_2 emissions in Singapore and Philippines, which is reflective of the less emission-intensive services sector.

For the full panel, long-run elasticities are significant and positive for all series, as shown in Table 4b. The results indicate that within the ASEAN region, for the selected countries, the significant sources of emissions are non-renewable energy sources, economic growth, and trading activities. We establish the EKC hypothesis for the full panel.

The simulation results of the FEVDM are reported in Table 5. The findings are presented over ten different time horizons between 1985 and 2015. This accounts for changes in a variable due to self-contribution via innovative shock (endogenous) and other explanatory variables (exogenous). For example, between 1985 and

Table 2b
Cross-sectional dependence tests.

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
	Test Stats	Test Stats	Test Stats	Test Stats
ln CO_{2it}	400.060***	49.719***	49.585***	11.665***
ln Y_{it}	693.541***	88.937***	88.803***	26.195***
ln Y_{it}^2	780.464***	100.552***	100.419***	27.847***
ln RE_{it}	452.575***	56.736***	56.603***	10.122***
ln NRE_{it}	580.683***	73.855***	73.722***	13.735***
ln TR_{it}	783.814***	101.000***	100.867***	27.896***
ln T_{it}	193.976***	22.180***	22.046***	5.242***

Note: *** indicates 1% level of significance.

Table 4a
Findings from the FMOLS technique: Country specific long-run elasticities.

Dependent Variable = ln CO_{2ti}			
Country/Variables	Coefficient	Std. Error	t-Statistic
Brunei Darussalam			
ln Y_{it}	1.021	0.738	0.184
ln Y_{it}^2	0.107	0.167	0.639
ln RE_{it}	−0.160***	0.019	−8.187
ln NRE_{it}	6.187***	0.008	6.512
ln TR_{it}	−0.289	0.548	−0.528
ln T_{it}	0.995	0.798	1.245
Constant	−2.369***	0.419	-6.58
Cambodia			
ln Y_{it}	0.941***	0.010	90.432
ln Y_{it}^2	0.470***	0.005	90.43
ln RE_{it}	3.581***	0.109	32.970
ln NRE_{it}	0.443***	0.027	16.585
ln TR_{it}	0.029***	0.005	6.378
ln T_{it}	0.008***	0.001	10.813
Constant	−9.954***	2.488	−4.000
Indonesia			
ln Y_{it}	−0.294	0.197	−1.492
ln Y_{it}^2	−0.146	0.098	−1.491
ln RE_{it}	−1.926*	1.015	1.897
ln NRE_{it}	2.792**	1.403	1.990
ln TR_{it}	0.737**	0.330	2.231
ln T_{it}	−0.043	0.036	−1.203
Constant	−35.085***	11.489	−3.054
Malaysia			
ln Y_{it}	0.146	0.088	1.658
ln Y_{it}^2	0.073	0.044	1.658
ln RE_{it}	0.400***	0.137	2.923
ln NRE_{it}	7.150***	1.588	4.503
ln TR_{it}	0.220**	0.106	2.077
ln T_{it}	0.027	0.101	0.269
Constant	−38.689***	6.185	−6.255
Philippines			
ln Y_{it}	0.042***	0.005	8.415
ln Y_{it}^2	−0.021***	0.002	−8.415
ln RE_{it}	−0.271***	0.016	−17.294
ln NRE_{it}	2.014***	0.016	126.787
ln TR_{it}	−0.369***	0.008	−48.730
ln T_{it}	0.155***	0.003	59.039
Constant	1.240***	0.192	6.452
Singapore			
ln Y_{it}	1.289***	0.248	5.201
ln Y_{it}^2	−2.577***	0.496	5.201
ln RE_{it}	0.185	0.125	1.480
ln NRE_{it}	3.167	9.856	0.321
ln TR_{it}	−1.922***	0.420	−4.582
ln T_{it}	−0.190	0.166	−1.143
Constant	14.640	48.905	0.299
Thailand			
ln Y_{it}	−0.061	0.050	−1.219
ln Y_{it}^2	−0.031	0.025	−1.219
ln RE_{it}	−0.274	0.209	−1.311
ln NRE_{it}	0.817	0.522	1.566
ln TR_{it}	0.373***	0.046	8.145
ln T_{it}	0.031	0.022	1.436
Constant	−11.017***	2.335	−4.719
Vietnam			
ln Y_{it}	0.035***	0.004	9.067
ln Y_{it}^2	0.071***	0.008	9.067
ln RE_{it}	−0.672***	0.055	−12.228
ln NRE_{it}	1.142***	0.032	35.372
ln TR_{it}	0.097***	0.013	7.686
ln T_{it}	−0.217***	0.021	−10.232
Constant	−3.139***	0.505	−6.216

Note: ***, **, and * show significance at 1%, 5% and 10% level of significance.

Table 4b
Findings from the FMOLS technique: Full Panel.

Dependent Variable = ln CO_{2ti}			
Variable	Coefficient	Std. Error	t-Statistic
ln Y_{it}	0.105***	0.025	4.197
ln Y_{it}^2	−0.004***	0.001	−4.325
ln RE_{it}	−0.002	0.006	−0.258
ln NRE_{it}	1.675**	0.065	25.768
ln TR_{it}	0.039***	0.017	2.236
ln T_{it}	−0.029***	0.010	−2.873

Note: ***, ** represent 1% and 5% level of significance.

2015, 74.9% of the variation in CO_2 emissions is contributed endogenously due to innovative shock, and 17.3%, 3.7%, 2.5% and 0.3% of the variation is contributed by renewables, non-renewables, economic growth and trade openness. This reflects that, in this panel of countries, CO_2 emissions are predominantly attributable to energy use (both renewables and non-renewables). These findings are further consistent with the regression results. In the case of economic growth, 83.8% is self-contributed, and 10%, 3.8% and 1% of the variation is contributed by CO_2 emissions, trade openness and renewables. In the case of renewables, 91% is contributed by transport, and 3.9%, 2%, 1.5% and 1% is contributed by CO_2 emissions, trade, non-renewables and economic growth. In the case of non-renewables, 68.9% is contributed by renewables, 19.4%, 5.1%, 3.1% and 2.2% is contributed by CO_2 emissions, economic growth, trade openness, and transport. In the case of trade, 69.2% is contributed by non-renewables, and 24.1% and 4.8% is contributed by economic growth and transport. Finally, in the case of transport, 80% of variation is self-contributed, and 15.4%, 2%, 1.2% and 1% is contributed by non-renewables, CO_2 emissions, economic growth, and trade openness.

The overall findings from the FEVDM suggest that trade openness boosts renewable energy consumption and non-renewables spur trade openness. This is a significant finding as the ASEAN nations move towards trade integration, this will boost the use of renewable sources. In future, we expect to see other key services enabling and facilitating trade within and across borders. This will encourage alternative energy-mix.

On the other hand, predominant use of non-renewable energy resources enhanced the trading base of these economies. As the primary energy resources in this region are fossil fuels, economic and energy policies are expected to play a key role in long-term sustainable energy development in the region. Improving energy efficiency, both in the supply and demand side, and energy diversification through the development of non-fossil fuel resources (i.e., hydropower, solar, bio-mass and geo-thermal) are needed.

There is a positive feedback effect between CO_2 emissions and non-renewables energy consumption, and between economic growth and trade openness. This notion translates that the increasing use of non-renewables not only adds to CO_2 emissions, but this phenomenon in return further stimulates the demand for non-renewables in the economy. This could happen where sustainable development policies do not carry enough incentives to cover the initial cost of adopting the renewable energy technology in the production processes (Burritt et al., 2009). While examining the role of policy instrument and renewable technology development, Mickwitz et al. (2008) suggest that the role of environmental regulations, environmental taxation, and funding of research and development is crucial for the non-renewable to renewable energy consumption transition. We recommend in the light of the above findings that opportunities towards low cost credit, subsidies, and liberal import policy on renewable energy technologies will create better environment both for businesses and households in adopting renewable energy sources. Furthermore, it is also recommended that the ASEAN region requires further policy reforms in terms of environmental policy stringency in order to achieve

Table 5
Findings from forecast-error variance decomposition.

Period	S.E.	ln CO_{2ti}	ln Y_{it}	ln Y_{it}^2	ln RE_{it}	ln NRE_{it}	ln TR_{it}	ln T_{it}
Variance Decomposition of ln CO_{2ti}:								
1	0.124	100	0.000	0.000	0.000	0.000	0.000	0.000
2	0.170	98.208	0.837	0.076	0.653	0.066	0.06	0.100
3	0.203	95.699	1.686	0.201	1.932	0.064	0.219	0.200
4	0.230	92.938	2.311	0.319	3.663	0.208	0.31	0.252
5	0.253	89.899	2.794	0.428	5.773	0.48	0.374	0.252
6	0.273	86.735	3.161	0.535	8.089	0.842	0.409	0.228
7	0.292	83.575	3.428	0.637	10.484	1.253	0.423	0.200
8	0.309	80.515	3.606	0.734	12.859	1.682	0.421	0.183
9	0.325	77.619	3.710	0.823	15.146	2.108	0.406	0.186
10	0.341	74.923	3.752	0.907	17.304	2.516	0.386	0.212
Variance Decomposition of ln Y_{it}:								
1	0.158	9.192	90.802	0.000	0.000	0.000	0.000	0.000
2	0.243	8.017	91.081	0.057	0.187	0.049	0.599	0.009
3	0.302	8.032	90.547	0.097	0.276	0.134	0.903	0.011
4	0.347	8.269	89.735	0.114	0.371	0.193	1.267	0.051
5	0.384	8.571	88.813	0.128	0.460	0.239	1.666	0.122
6	0.416	8.881	87.844	0.14	0.553	0.282	2.092	0.208
7	0.443	9.187	86.854	0.151	0.655	0.325	2.529	0.299
8	0.467	9.481	85.859	0.163	0.769	0.371	2.969	0.389
9	0.489	9.761	84.87	0.173	0.898	0.421	3.400	0.476
10	0.509	10.026	83.895	0.184	1.045	0.475	3.816	0.558
Variance Decomposition of ln Y_{it}^2:								
1	5.399	0.082	1.849	82.331	0.227	14.901	0.578	0.032
2	7.537	1.107	2.09	80.212	0.17	15.554	0.85	0.017
3	9.204	1.430	1.970	79.996	0.168	15.468	0.955	0.011
4	10.624	1.615	1.836	79.918	0.161	15.465	0.994	0.010
5	11.897	1.736	1.719	79.895	0.149	15.469	1.023	0.009
6	13.064	1.823	1.615	79.908	0.137	15.469	1.038	0.010
7	14.153	1.890	1.520	79.940	0.125	15.469	1.046	0.011
8	15.18	1.943	1.433	79.982	0.114	15.469	1.048	0.012
9	16.157	1.986	1.352	80.029	0.103	15.471	1.044	0.013
10	17.094	2.022	1.278	80.079	0.094	15.475	1.037	0.014
Variance Decomposition of ln RE_{it}:								
1	1.009	1.754	1.756	0.000	0.000	0.000	0.000	0.000
2	1.265	1.601	1.382	0.007	0.006	0.000	0.050	96.953
3	1.394	1.323	1.244	0.019	0.008	0.028	0.154	97.223
4	1.466	1.292	1.169	0.029	0.023	0.088	0.297	97.102
5	1.51	1.504	1.113	0.041	0.038	0.188	0.5	96.615
6	1.54	1.892	1.071	0.057	0.046	0.342	0.753	95.839
7	1.562	2.387	1.045	0.076	0.046	0.557	1.046	94.843
8	1.58	2.928	1.039	0.099	0.046	0.835	1.366	93.686
9	1.596	3.471	1.056	0.126	0.057	1.175	1.7	92.415
10	1.611	3.987	1.096	0.157	0.089	1.568	2.037	91.067
Variance Decomposition of ln NRE_{it}:								
1	0.032	5.755	9.831	0.000	83.231	0.000	0.000	1.200
2	0.05	8.558	10.221	0.536	78.584	0.42	0.202	1.480
3	0.064	10.275	9.646	0.635	76.571	0.587	0.575	1.710
4	0.076	11.828	8.89	0.670	75.142	0.608	0.934	1.929
5	0.085	13.274	8.127	0.683	73.942	0.575	1.303	2.096
6	0.093	14.645	7.408	0.686	72.854	0.527	1.673	2.208
7	0.099	15.949	6.751	0.684	71.826	0.479	2.042	2.270
8	0.105	17.183	6.162	0.680	70.842	0.436	2.407	2.292
9	0.111	18.341	5.641	0.675	69.897	0.399	2.766	2.281
10	0.116	19.418	5.187	0.669	68.992	0.368	3.117	2.248
Variance Decomposition of ln TR_{it}:								
1	0.134	2.292	21.588	0.000	0.173	74.181	0.000	1.765
2	0.204	1.101	26.12	0.467	0.084	68.762	1.215	2.251
3	0.252	0.728	27.028	0.636	0.074	67.523	1.074	2.937
4	0.29	0.55	27.064	0.687	0.062	67.325	0.923	3.389
5	0.322	0.447	26.804	0.731	0.051	67.449	0.776	3.742
6	0.35	0.379	26.405	0.766	0.043	67.717	0.659	4.030
7	0.375	0.331	25.919	0.799	0.039	68.06	0.58	4.272
8	0.396	0.296	25.372	0.829	0.037	68.446	0.54	4.481
9	0.416	0.268	24.781	0.857	0.038	68.856	0.538	4.663
10	0.434	0.247	24.16	0.884	0.040	69.273	0.572	4.824
Variance Decomposition of ln T_{it}:								
1	0.778	0.082	1.849	0.032	0.227	14.901	0.578	82.331
2	0.932	1.107	2.090	0.017	0.170	15.554	0.850	80.212
3	1.065	1.430	1.970	0.011	0.168	15.468	0.955	79.996
4	1.165	1.615	1.836	0.010	0.161	15.465	0.994	79.918
5	1.247	1.736	1.719	0.009	0.149	15.469	1.023	79.895
6	1.316	1.823	1.615	0.010	0.137	15.469	1.038	79.908
7	1.375	1.890	1.520	0.011	0.125	15.469	1.046	79.940
8	1.426	1.943	1.433	0.012	0.114	15.469	1.048	79.982
9	1.470	1.986	1.352	0.013	0.103	15.471	1.044	80.029
10	1.509	2.022	1.278	0.014	0.094	15.475	1.037	80.079

Notes: Figures in the first column refer to horizon (i.e., number of years). All other figures are estimates rounded to three decimal places, rounding error may prevent perfect percentage decomposition in some cases.

sustainable development goals. Some of these options are capital-intensive, we recommend there is urgent need for cooperation and development in building appropriate institutional structures and decision mechanisms across the region.

Transport seems to be a key sector where renewable energy is being consumed. The trade liberalisation policies improve economic growth and also increase the use of renewables in the ASEAN-8 region.

For robustness checks, the findings were verified using the IRF. The graphs are presented in Fig. 1 and confirm the previous results. Each sub-figure reflects the response function and supports the findings from the FEVDM test results.

5. Conclusions and policy recommendation

In enhancing the growth and trade integration of ASEAN member countries, cooperation within the energy sectors has become critical. Due to the current uneven distribution of energy sources and increasing demand in the region, there is a huge gap between demand and supply. As the region moves towards a 'single market and production base', most of the energy planning scenarios are based on CO_2 emissions reduction. In the long run, economic growth, trade and the energy sector need to be aligned to face the energy challenges and environmental degradation of the region. In this respect, transportation will play a greater role in this region.

In this research, the effects of energy consumption (considering both renewables and non-renewables), economic growth, and trade openness on CO_2 emissions were investigated over the period from 1985 to 2015, considering a selection of eight ASEAN countries. We incorporate the major criticisms identified in the literature into our model, and in our estimation strategies.

In establishing the long-run dynamics, panel estimation techniques were applied. The panel estimation results show that energy consumption, economic growth, and trade openness significantly contribute towards CO_2 emissions in the ASEAN region. The FEVDM was used to assess causality, and validates the cointegration and panel estimation, suggesting a feedback effect between energy use and economic growth. Energy consumption is a direct cause of CO_2 emissions and there is also uni-directional causality from economic growth to both trade openness and CO_2 emissions. There is significant long-run heterogeneity across these countries. The implementation of economic and trade policies aligning with the energy sector remains a major challenge for long-run integration purposes.

The overall findings indicate that the environmental consequences of economic growth are significant for most of the countries in this panel, and that energy consumption is the key contributing factor towards environmental deterioration in the ASEAN region. We establish heterogeneity and cross-sectional dependence across the panel.

Of the eight selected countries, Cambodia, Indonesia, Malaysia, Thailand and Vietnam follow predominantly emission-intensive trade and project a further increase in future energy demand and environmental degradation.

From a policy perspective, this research strongly suggests that regional economies revisit policies leading to sustainable economic growth and trade, and the reduction of environmental degradation. The increasing environmental cost associated with economic growth and trade integration cannot be ignored. In this respect, the role of transportation should be factored into the emission process.

The inclusion of energy efficient technologies and a gradual shift to renewable sources will provide a better balance between sustainable economic growth and environmental degradation in the region. The enhancement of policy coordination in both the economic and energy sectors and the reduction of barriers will further improve energy efficiency and reduce environmental degradation. In addition, expansion of the services sector in the region will create a less carbon intensive industry base for an area which remains underdeveloped in the region, except in Singapore.

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