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## Nexus between Economy, Agriculture, Population, Renewable Energy and CO2 Emissions: Evidence from Asia-Pacific Countries

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This study uses panel co-integration methods and Granger causality examines to scrutinize the dynamic causal relationship between carbon dioxide (CO<sub>2</sub>) emissions, gross domestic product (GDP), renewable energy (RE), agriculture value added (AVA) and population for the thirteen developed and developing Asia Pacific countries (APCs) covering the period 2005-2017. The results evaluate in two ways: in the short-run, Granger causality test (GCT) is operating from AVA to GDP and express bidirectional causation among GDP and agriculture. In the distant future, there is causality from RE and Population to CO<sub>2</sub> emissions. The short-run causality is important due to the agriculture sector which causes in boosting GDP while economic development, population and clean energy (including waste and combustible) raise CO<sub>2</sub> emissions causes in the reduction of production and services. The research finds out that reduction in AVA, GDP increase, uncontrolled population and lack of attention on clean energy are interrelated in creating emissions. Policy recommendation insights that Asian Pacific establishments should control the population, less use of fossil fuel, encourage clean energy technologies such as solar and wind to fight with global warming.



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## 1. Introduction

Over the previous few epochs, industrialized and new emerging countries have adopted much fossil fuel for energy development in approximately all segments like agriculture, construction, tourism, mining, building and tertiary industries. This coerces to carbon productions in the region of Asia Pacific countries (APCs). Clean energy by globally in 2017, the investment in APCs was 187 \$bn including solar, wind, smart energy technologies and bioenergy. According to WDI in 2017, the world agriculture value added is 3341.792 \$USbn. According to Pachauri, Allen et al. (2014), 25% of GHG emissions occur due to heat and electricity and 24% of GHG emitted due to agriculture, forests and extra land which has become second biggest emitter. The agricultural division commits between 14% - 30% of the global greenhouse gases (GHGs) emanations due to its rigorous use of fossil energy (Reynolds and Wenzlau 2012). Therefore, we believe that greenery is a carbon sink that can help us in reducing CO<sub>2</sub> emissions from the environment. However, agriculture and green plantation contribute to decreasing CO<sub>2</sub> emissions in many ways. Currently, by using modern farm equipment, pumping water, indoor livestock and using dangerous drugs for agriculture contribute to higher GHG emissions (Jebli and Youssef 2017). United Nations, Food and Agriculture Organization (FAO) forecasts 30% improvement in agriculture's GHG emissions by 2050 (FAO, 2014). However, they believe that the agricultural division has considerable potential to diminution its emanations. Actually, many agriculture fields are irrigated via tube wells could be electrified by renewable resources.

The Asia Pacific countries (APCs) have become expeditiously growing economy but at the similar period population, poverty and resources have produced pressure on the countries which needs sustainable consumption and production (SCP) long-lasting strategies in many countries. As such, APCs need to concentrate on human desires and well-being through the least conceivable environmental cost. By 3.897 billion populations, the APCs need more cultural values, traditions, cleaner, and usual prosperity for their well-being (UNESCAP, 2017). For this, APCs have endorsed unprecedented economic expansion cheers to its hasty mechanization and urbanization. In 2017, the total GDP per capita of APCs was 0.000367 billion US dollars (US\$) which are increasing every year (World Bank, 1960-2017). According to Statistical Review of World Energy (2018), the total prime power ingesting in the APCs in 2017 was counted 5743.6 (Mtoe) calculating for about 42.5% of the earth's total energy ingestion. Although, rapid economic war has left many contests linked to the environment in the Asia Pacific countries. The CO<sub>2</sub> emissions in this region in 2017 was 16330.4 (Mtoe) and the growth rate was noted as 2.3 per cent (Statistical Review of World Energy, 2018). Therefore, to lessen the CO<sub>2</sub> emissions, the renewable energy resources arose as an adequate substitute to further fuels (e.g., oil, coal, gas) in many countries of the Asia Pacific region. The European Union (EU) directed to see by 2020 an objective of 20 per cent clean energy assets in power source and 10 per cent in the transport sector to lessen carbon strength in the European Union marketplace (Union, 2009). Moreover, in 2017, the APCs as the whole contribute around 24.7 per cent of the entire world utilization of renewable energy and have become the second major ingesting region in the world (Statistical Review of World Energy, 2018).

Above background inspects the causal associations among carbon emissions, renewable energy consumption, and economic development, agriculture and population in a sample of thirteen APCs. All the countries have diverse peculiarity; few are ironic in natural assets in gas, coal, water, oil and sunlight (for example, Australia, China, India, Indonesia, Malaysia, New Zealand, Pakistan, Philippines and Vietnam) whereas further have insufficient natural resources. Additionally, the Asia Pacific region is contemplated as the hub of the global economy (Le and Quah, 2018). Generally, the Asia Pacific economy is rising quicker than the other regions. Specifically, the development of industrialization in the emerging economies instigated the whole magnitude of these economies (ADB, 2013). This linkage between GDP, Population, Renewable energy and agriculture and their aspect in CO<sub>2</sub> emissions needs to be conscientiously taken for policy makers and businessmen to achieve the real economic targets.

Existing research adds to the literature in three facets. First, the linkage between renewable energy

consumption, agriculture added values, GDP, population and their role in carbon emissions. We also estimate the long-run influence of clean energy utilization, AVA, and economic development and population growth on CO<sub>2</sub> emissions. Secondly, the focus of this study is on a group of thirteen APCs without any comparison of their different developments. Thirdly, for the empirical long-term results, we have used the log-linear equation, panel unit root tests, Co-integration tests for long-run association amongst factors and GCT and the VECM(vector error correction model) to estimate both short run as well as long-run liaison between the factors. Generally, the innovation of our research is based on five factors model. Literature has provided many examples related to our study but no one has examined with respect to this idea either. The study of developing economies is imperative because of the boost in economic growth which is powered typically by the conventional power system, whereas renewable energy is under the grooming process and has not steadied to a definite volume. Lastly, the applied econometric model is original and updated. It is, therefore, the paper syndicates a unique influence with all these novel features: title, sample size and method.

The remaining part of the paper systematized as follows: [Section 2](#) is related to literature, [Section 3](#) gives descriptive statistics. [Section 4](#) is based on results. [Section 5](#) covers the conclusion and policy suggestions.

## 2. Literature Review

Presently, worldwide warming has become a necessary ecological issue that is mostly credited to carbon dioxide emissions and GHGs (Liu and Hao, 2018). CO<sub>2</sub> emission is closely related to power utilization and financial development. There are many studies about CO<sub>2</sub> emissions but there is consensus on the relationship among energy use and CO<sub>2</sub> emissions. Although, previous studies have numerous outcomes related to economic growth and CO<sub>2</sub> emissions (e.g., Ang, 2007; Apergis and Pyne, 2009; Soytas and Sari, 2009; Salahuddin and Gow, 2014; Begum et al., 2015). For China, Zhang and Cheng (2009) showed the deficiency of causation between economic growth and carbon emissions. Chang (2010) and Wang et al. (2011) implied that the traditional policies of lessening carbon emanations are harmful to the economic development of China. As for multiple countries, (e.g., Hanif, 2018; Abbas et al., 2018; Gozgor et al., 2018; Wu et al., 2018; Zhang and Cheng, 2009; Le and Quah, 2018) showed interaction among economic growth and carbon emissions. The recent research focuses on the impact of economic growth, clean power, agriculture and population on carbon dioxide emissions. Number of studies have inspected the causal associations of carbon emissions and inference the different references linked to pollution from the developed and under developing countries (Ben Jebli and Ben Youssef, 2015; Dogan and Seker, 2016; Shahbaz et al., 2014; Lin and Ahmad, 2017; Dogan and Seker, 2016). However, rare researches clarify the CO<sub>2</sub> emissions reduction with renewable energy, population, agriculture value added and GDP, particularly for the Asia Pacific region. The decisions show that these researches based on the selection of countries, variables, time interval and methodology. Some variables affect positively while some contribute to CO<sub>2</sub> reduction. The growing literature presents the effects of selected variables which causes energy consumption. According to Halicioglu (2009), energy consumption is the primary indicator of any country's development. Many studies have been done in regional perspective to check the causal relationship with CO<sub>2</sub>; such as Halicioglu (2009) uses ARDL method and co-integration methods to check the association among CO<sub>2</sub> emanations, energy utilization, trade and output in Turkey's circumstance. The outcomes show that CO<sub>2</sub> emissions are contingent by energy use, foreign trade, and revenue generation. Dong, Sun et al. (2018) inspect the causal association between CO<sub>2</sub> emissions, monetary development, and natural gas ingesting for the case of 14 APCs. The outcomes reject the null hypothesis due to no-correlation and disclose carbon releases, economic development, and natural gas ingestion that contain long-run association during 1970-2016 in the pane of APCs.

Falavigna et al. (2013) applied the DEA model for the Italian agriculture industry to approximate the ecological efficiency and found a significant change in environmental achievements. They also cleared that product estimation is different when emissions are taken into consideration in the Italian region. Sadorsky (2009) uses panel co-integration methods to evaluate the clean energy consumptions of the UK,

USA, Germany, France, Italy, Canada and Japan. In the long run, the results express that GDP and CO<sub>2</sub> emissions are the main factors of energy consumption. [Jebli and Youssef \(2017\)](#) apply two tests (panel co-integration and Granger causality) for the five North African countries to find out the causality between RE consumption, CO<sub>2</sub> emissions, AVA and real GDP. The results presented in both the short and long-run period. In the short-run, the Granger causality test shows a two-way relationship between agriculture and carbon emissions and unidirectional with remaining variables. In long run, CO<sub>2</sub> emissions will increase due to growth in GDP or renewable energy consumption while agriculture added values decrease CO<sub>2</sub> emissions. These variables and research are comparable to our research because they target on clean energy, GDP and agriculture but in Asia Pacific region we have also included population as a variable which affects CO<sub>2</sub> emissions. Additionally, pollutant releases significantly affect renewable energy in China, India, Brazil and Indonesia ([Lin and Omoju, 2017](#)). [Chang et al. \(2009\)](#) investigated the association between GDP, clean power and prices in OECD countries. They found a country whose GDP is higher can easily adopt renewable energy if the prices are high. Another study analyzed and compared relationship among income, energy production and CO<sub>2</sub> emissions in India and China by applying a multivariate vector error correction model (VECM) ([Rafiq et al., 2014](#)). [Apergis and Ozturk \(2015\)](#) apply the GMM (generalized method of moments) for fourteen Asian countries to search the EKC hypothesis. This framework caps CO<sub>2</sub> emission, economic growth, a share of industrial growth, population, land, and remaining four factors representing the institutions' quality. In this era, the impact of population on CO<sub>2</sub> emission has also become a notable issue ([Shi, 2003](#); [Zhang, Yu et al., 2017](#); [Kwon, 2005](#); [Kerr and Mellon, 2012](#); [Yao et al., 2015](#)). There are also certain additional demographic variables excluding population size were also taken such as age etc. ([Liddle and Lund, 2010](#)).

The study is concerned by the association amongst renewable energy use, economic growth, population and agriculture. A study by [Karkacier et al. \(2006\)](#) on agriculture production in turkey showed the excess use of energy increases agriculture production. Even politicians also supported the use of energy in agriculture production. According to [Mushtaq et al. \(2007\)](#); [Turkekul and Unakitan \(2011\)](#) showed unidirectional causality running from (oil and power consumption) has proved in both Turkey and Pakistan. The authors recommend that the Government should support in rural areas and especially subsidize electricity to agriculturists in Pakistan for the better output. [Rafiq et al. \(2016\)](#), examine the results of 53 countries of which 23 high-income and 30 low-medium income. They checked the impact of wealth, population and technology by using STIRPAR and EKC methods to check the CO<sub>2</sub> emissions in these republics. They illustrate that agriculture added values and service sector have an important role in pollution reduction whereas pollution increases by industrialization. They suggested that there should be coordination with the industrial sector and climate sector to decrease the CO<sub>2</sub> emissions.

According to our investigation, [Ben Jebli and Ben Youssef \(2015\)](#) introduced their first econometric study based on agriculture and clean energy consumption by utilizing GCT and co-integration tests. They investigated long-run and short-run associations between CO<sub>2</sub> emanations; GDP, clean and fossil fuel power ingesting, agriculture value added and trade openness in Tunisia. Short-run results related to GCT demonstrate the bidirectional causations among AVA and CO<sub>2</sub> releases, also AVA and trade directness. In the long-term, non-renewable energy, AVA and trade increases CO<sub>2</sub> emissions whereas clean power use decrease carbon emissions. They recommended that subsidies in renewable energy should be given especially in the agriculture sector. [Jebli and Youssef \(2017\)](#) did their econometric study related to renewable energy and agriculture value added and GDP in reducing carbon emissions from the North African countries. They also investigated the relationships between renewable power and agriculture. They measured the bidirectional causality among CO<sub>2</sub> emissions and farming in short-run and found the unidirectional causation between agriculture and GDP. GDP RE and RE utilization and agriculture. Bidirectional causality was found in the long-run among CO<sub>2</sub> emissions and agriculture and unidirectional causality was also found between clean energy and agriculture, and renewable energy consumption and agriculture. For the long-run, they estimated an increase in GDP or clean power utilization boosting CO<sub>2</sub> emissions while the rise in AVA lessens CO<sub>2</sub> releases. They also suggested for North African management should encourage renewable energy to improve agriculture production and help to fight with

global warming. The latest econometric researches related to factors are: [Lin and Xu \(2018\)](#) examine the relationship between population, energy productivity, urbanization, industrialization and financial capacity on CO<sub>2</sub> emissions of China's thirty provinces by using quantile regression method during 2000-2014. They show economic development has a greater impact on CO<sub>2</sub> emissions due to different fixed investments and AVA in the upper of 75<sup>th</sup> -90<sup>th</sup> percentiles. Similarly, urbanization has also maximum influence due to agriculture processing and human capital growth. Econometric research is conducted by [Hanif \(2018\)](#) on power utilization, economic development and urbanization on carbon releases in twelve East APCs from 1990-2014. They applied a GMM that resulted in energy consumption; economic growth and urbanization have an important effect on carbon emissions. They also measured the impact of non-renewable energy in the same countries and found insignificant results. Their policies suggest that renewables can improve economic growth and control over carbon emissions. The existing research is different from that of ([Lin and Xu, 2018](#); [Hanif, 2018](#); [Jebli and Youssef, 2017](#); [Waheed et al., 2018](#); [Ben Jebli and Ben Youssef, 2015](#)) primarily we cogitate panel co-integration technique with renewable energy consumption and population. Furthermore, the model is important in practical applications of energy consumption, agriculture and economic growth.

### 3. Descriptive Statistics

#### 3.1. Data sources

We use panel data from 2005 to 2017 from a sample of five variables including CO<sub>2</sub> emissions, GDP per capita, population, agriculture value added, and renewable energy. Information is based on the panel of thirteen APCs while the remaining countries are not included in this study due to lack of data. [Table 1](#) shows the number of the variables, the data sources, units mean and standard deviation. In this paper, we study the factors that influence carbon dioxide emissions. The data used in this study were collected from the following sources: the [World Development Indicators \(WDI\)](#); and the [Statistics from IMF 1980-2023](#).

**Table 1**  
Descriptions of variables<sup>1</sup>

Variables	Unit	Sources	Mean	Standard deviation
CO2 Emission	Mt	<a href="#">WDI (world development indicators)</a>	8.6318	2914.203246
GDP per capita	Current \$US	<a href="#">World development indicators</a> ; statistics from IMF 1980-2023. survey of Pakistan 1980; 2017	8.6318	6258.60971
Renewable energy	Mtoe	(WDI) World development indicators	-0.3655	11.2203606
Agriculture value added	\$US	The World Bank OECD national accounts. ( <a href="https://data.worldbank.org/indicator/tm.val.tran.zs.wt">https://data.worldbank.org/indicator/tm.val.tran.zs.wt</a> ).	3.3979	969.8157938
Population	Million	<a href="https://data.worldbank.org/indicator/SP.POP.TOT">https://data.worldbank.org/indicator/SP.POP.TOT</a> L, WDI.	4.6258	1797.421689

Notes: Mt, million tons; Mtoe, Million tons of oil equivalents. Mean and standard deviations of all factors are based on the log.

#### 3.2. Graphical description in combination with causal factors

Many countries (China, Pakistan, Japan, India, other Asia Pacific countries and North African countries) explore the causal relationship between CO<sub>2</sub> emissions, economic growth, agriculture, energy consumption, combustion of fossil fuel and renewable development over the periods 1980 to 2014. The analysis includes GDP per capita in current US dollars, overall population in million, clean energy consumption in (Mtoe), and agriculture value added in billion US dollars. Renewable energy includes entirely kinds of renewable power consumption and comprising (wind, solar, biomass and geothermal). The yearly statistics of CO<sub>2</sub> emissions, renewable energy consumption, agriculture, GDP and population

<sup>1</sup> This research is concerns with the thirteen Asia Pacific countries on the availability of data. Data of each country has been taken separately. Each variable contains accurate data based on five different variables (CO<sub>2</sub> emissions, GDP, RE, AGR and Population). The authentic sources have been used to collect data (given in table 1).

have been collected from given sources in Table 1. Fig. 1 indicates the trend of CO<sub>2</sub> emissions, measured in Mtoe, for the defined time period of thirteen APCs. The explained curve shows that China is the highest polluting state throughout the period of 2005-2017 and touched 9224.1 million tons of CO<sub>2</sub> emissions in 2014. India and Japan are ordered equal in 2006 and reached at the level of 1257.3, 1252.2 million tons. After 2006, India ranked in second and reached 2300.5 million tons of CO<sub>2</sub> emissions in 2017 while Japan declined and reached 1203.3 million tons in 2017 with third ranking. Bangladesh is at the endless level with the maximum emissions of 82.5 million tons of CO<sub>2</sub> emissions touched in 2017. Fig. 2 illustrates per capita GDP development, taken in \$US, for the APCs, are rising with the different series in the given period. Singapore has reached the highest level of GDP per capita with 57713.3 \$US while Australia was at the peak point in 2012 with GDP of 68281.8 US dollars. The current position is that Singapore, China, and Australia are growing in a straight direction. Pakistan has the lowest per capita GDP in APCs of 1541.1 \$US. Fig. 3 shows the representation of renewable energy consumption in million tons of oil equivalents, for the selected countries. This graph clears that the procedure acts in an unbalanced way for the whole sample period. China has the biggest portion of clean energy consumption (of 94.5 Mtoe in 2017) during the last 10 years, while Vietnam, Pakistan, and Bangladesh are the smallest consumer (of 0.20, 0.50 and 0.05 Mtoe in 2017). Japan and India have comprehended an important rise throughout the previous four years while Australia is experiencing a continuous increase of 6.2 Mtoe in 2017 according to their need. Malaysia, Pakistan, Singapore and Vietnam, the levels of clean power utilization is very small and have also accomplished to increase their renewable energy projects to control pollution, climate clean and agriculture promotion. Fig. 4 clears the development of agriculture value added (AVA) in \$US, for all countries during the time interval. The statistics show that China growth level is inspiring and is considered by a constant long-run propensity. The variations in AVA for India and Indonesia are competing at the second and third number. Singapore and Malaysia have a serious decrease in AVA and has been observed from 2005-2017. Malaysia, Pakistan, Korea, Thailand and Vietnam have continuous progress is observed in adding values in agriculture. Fig. 5 shows the population of each country. The population of China is the largest population (1386.395 million) while India has the second largest population (1339.180 million) in this region. Singapore has the smallest population of 5.612253 million. Pakistan, Bangladesh and Japan have the third, fourth and fifth largest population in the esteemed countries. Most of the countries are growing their population which may cause pollution, energy consumption, agriculture product use and CO<sub>2</sub> emissions. The smaller population of countries has greater GDP and low CO<sub>2</sub> emissions.

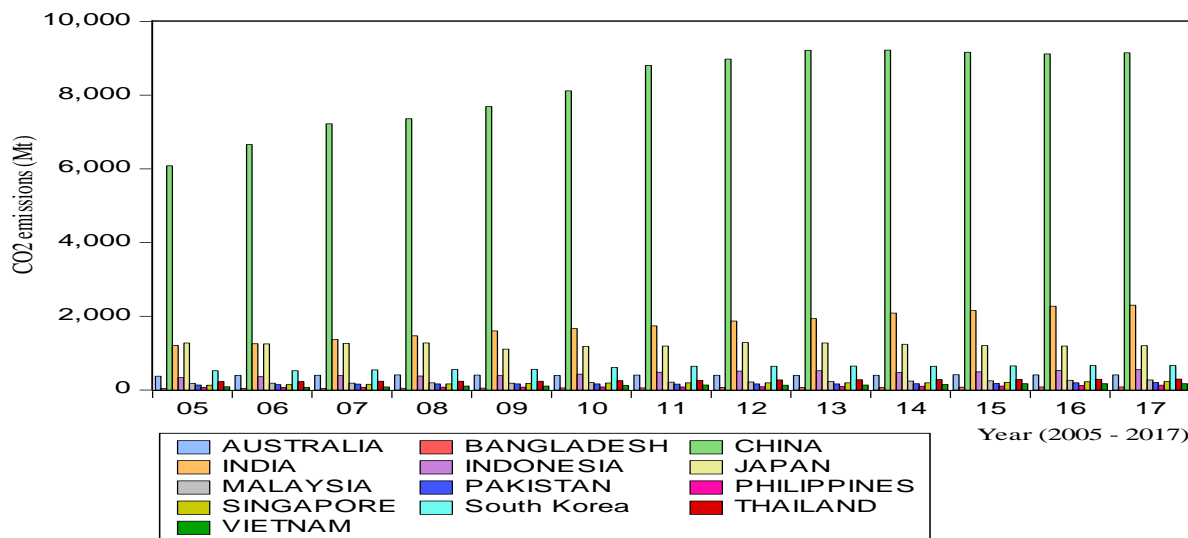


Fig. 1. CO<sub>2</sub> emission plots (in Million tons.).

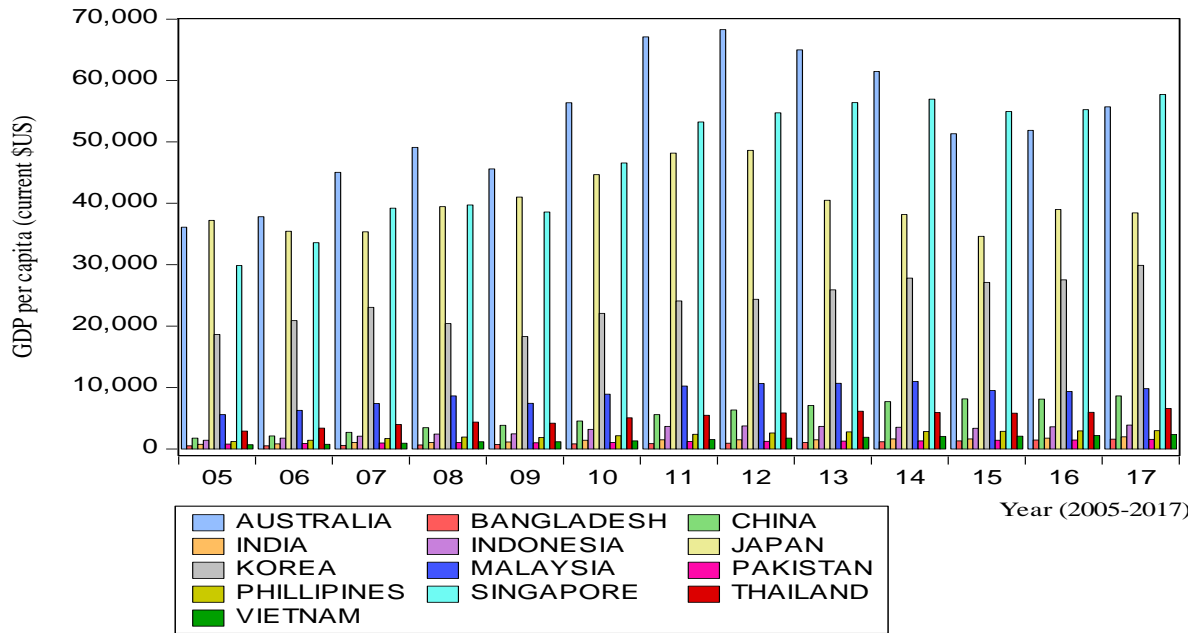


Fig. 2. GDP per capita plots (in current US dollars)

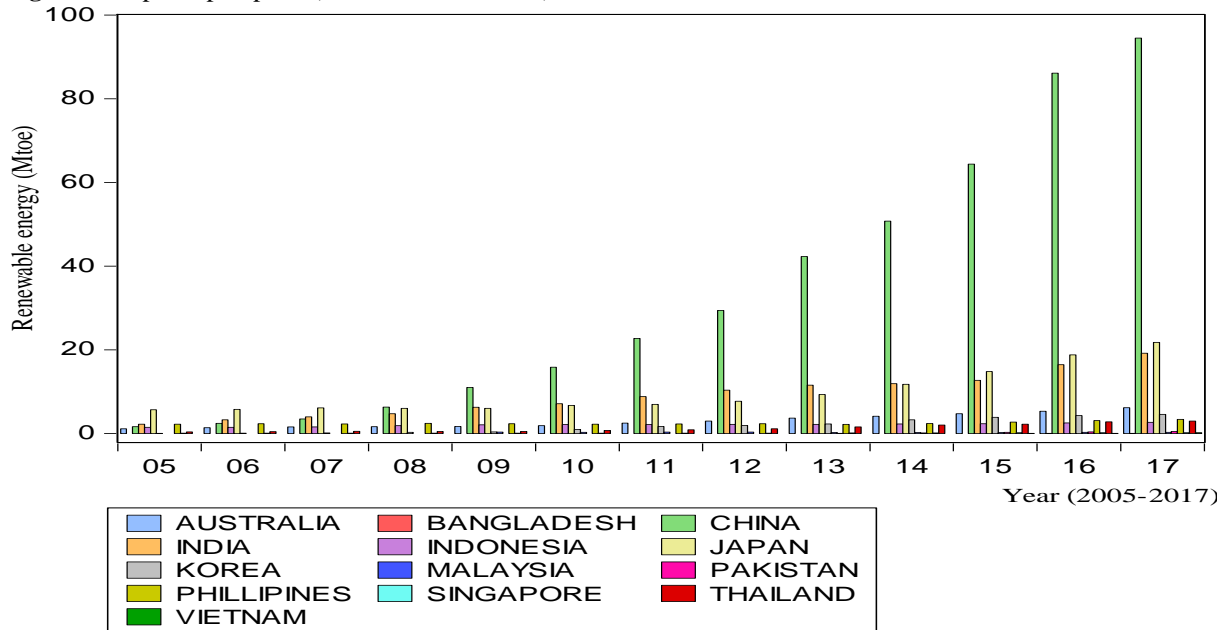


Fig. 3. Renewable energy consumption plots (Mtoe)

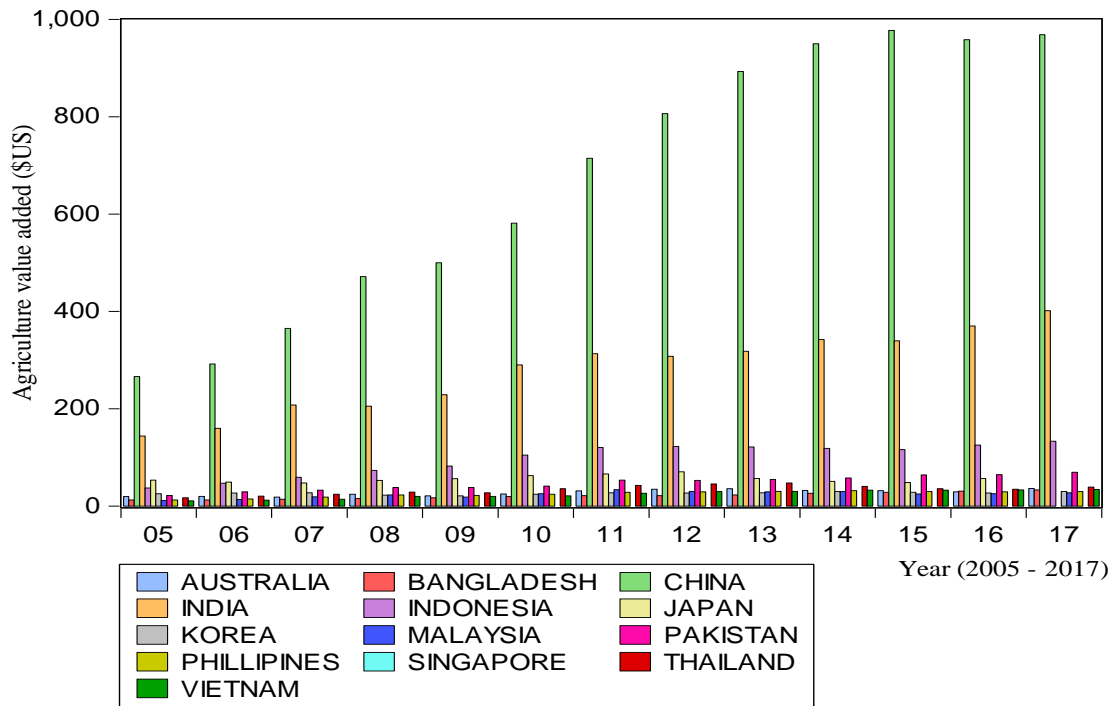


Fig. 4. Agricultural value-added plots (billion US dollars)

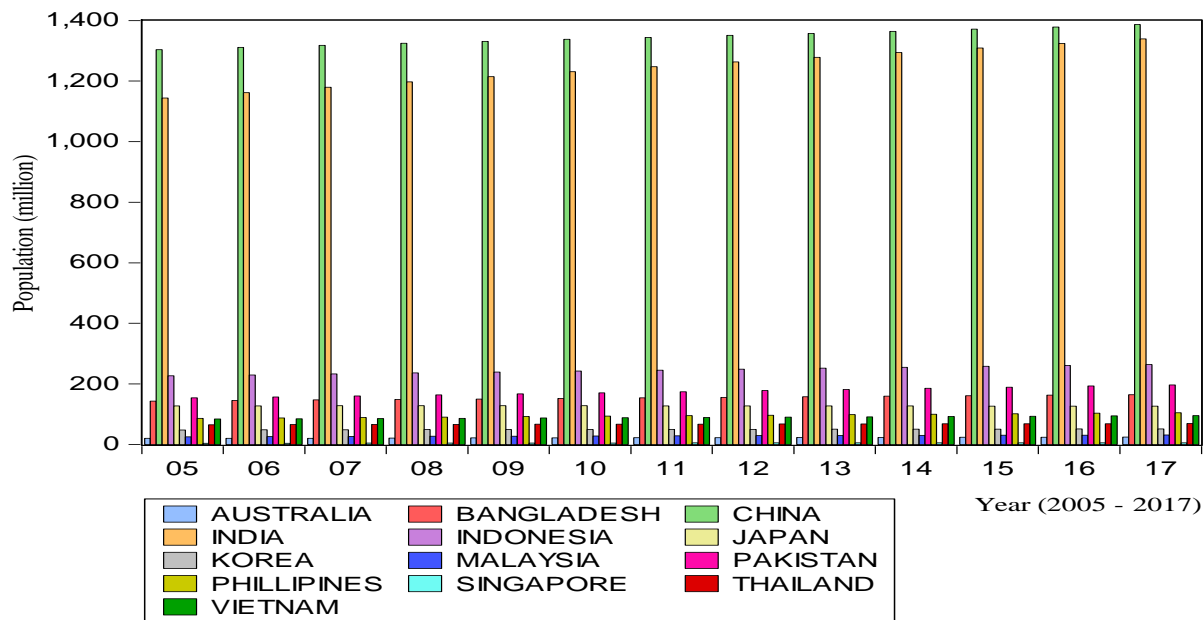


Fig. 5. Population plots (million).

#### 4. Empirical results

The main findings of the study are existing in this section. This section instigates with some econometric tests. Firstly, we conducted the graphical description of all variables given in the previous section (Figures 1-5). Secondly, we examine the stationary test, panel co-integration test, Pedroni co-integration tests, Granger causality test and VECM tests with short-run and long-run estimation. Thirdly, we applied a regression test for the long run estimation by using OLS, FMOLS and DOLS tests. The mathematical models are utilized in the empirical application of the research enlightened below.

##### 4.1. Model description

The subsequent log-linear equations are based on different variables that show the long-run relationship among the factors:

$$CO_{2it} = f(GDP_{it}, RE_{it}, AGR_{it}, POP_{it}) \tag{1}$$



$$\text{LNCO}_{2it} = \alpha_i + \theta_{it} + \beta_i \text{LNGDP}_{it} + \delta_i \text{LNRE}_{it} + \lambda_i \text{LNAGR}_{it} + \mu_i \text{LNPOP}_{it} + \varepsilon_{it} \quad (2)$$

Where, ( $i= 1, \dots, 13$ ) stands for number of states;  $t$  is 2005, ..., 2017 denotes the time duration;  $\varepsilon_{it}$  shows the estimated residual which describe deviations from the long-run association;  $\alpha_i$  and  $\theta_i$  permit for the possibility of a definite country fixed effect and show tendency, correspondingly; LN designate the natural logarithm alteration;  $\beta_i$ ,  $\delta_i$ ,  $\lambda_i$ ,  $\mu_i$  denotes the elasticity of emissions w.r.t. renewable energy, GDP, agriculture value added and population, respectively.

## 4.2. Stationary test

To measure the stationary of each factor we applied panel unit-root tests. LLC test undertakes a mutual unit root across the cross-section (Levin et al., 2002); IPS (Im et al., 2003), Fisher-ADF (Dickey and Fuller, 1979) and Fisher-PP (Phillips and Perron, 1988) accept an individual unit root process. The null hypothesis ( $H_0$ ) claims that there is a unit root whereas the alternative hypothesis ( $H_a$ ) proposes that the variables are stationary. Tests are practiced at the level and first difference. All the variables are log based and comprise a unit root at level but after the first variation, they become stationary at 1% level of significance. All the factors and their outcomes are described in Table 2.

**Table 2**

*Unit root tests of individual variables*

Unit root Method	LLC	IPS	Fisher-ADF	Fisher-PP
$\text{LNCO}_2$	-2.83249 (0.0023)	1.45869 (0.9277)	22.9552 (0.6355)	37.0995 (0.0732)
$\Delta \text{LNCO}_2$	-3.24244 (0.0006)***	-2.37510 (0.0088)***	43.5910 (0.0167)***	96.2881 (0.0000)***
$\text{LNGDP}$	-4.01868 (0.0000)	-1.42465 (0.0771)	36.1015 (0.0898)	118.719 (0.0000)
$\Delta \text{LNGDP}$	-7.01382 (0.0000)***	-3.79530 (0.0001)***	58.6958 (0.0003)***	66.9120 (0.0000)***
$\text{LNRE}$	-24.4698 (0.0000)	-19.7297 (0.0000)	35.8062 (0.0953)	72.3346 (0.0000)
$\Delta \text{LNRE}$	-61.0691 (0.0000)***	-11.8975 (0.0000)***	47.3818 (0.0064)***	49.2367 (0.0039)***
$\text{LNAGR}$	-5.93949 (0.0000)	-2.26321 (0.0118)	42.4682 (0.0220)	93.3751 (0.0000)
$\Delta \text{LNAGR}$	-5.61799 (0.0000)***	-2.82210 (0.0024)***	48.7589 (0.0044)***	69.7637 (0.0000)***
$\text{LNPOP}$	-2.62172 0.0044	2.21159 (0.9865)	28.2437 (0.3466)	102.587 (0.0000)
$\Delta \text{LNPOP}$	-5.31979 (0.0000)***	-5.02488 (0.0000)***	82.5042 (0.0000)***	32.3325 (0.1824)

$H_0$ : There is unit root.

$\Delta$  is the first difference.

\*\*\*significant at the 1% level.

All variables are stationary at first difference as shown in table

## 4.3. Cointegration test

Pedroni, P., (1999); Pedroni, P., (2001); Pedroni, P., (2004) proposed co-integration tests to check out the long-run relationship among the variables. The tests are taken into two parts. The first part covers four-panel statistics  $v$ -Statistic, rho-statistics, PP statistics, and ADF-statistics. This part accepts common within-dimension autoregressive coefficients. The second part is based on three set statistics rho-statistics, PP statistics, and ADF-statistics and undertakes distinct link between dimensions autoregressive

coefficients. In these examinations, the  $H_0$  contains no co-integration amongst the variables while the  $H_a$  recommends that factors are co-integrated. We have applied the intercept and deterministic trend to test the co-integration.  $\varepsilon_{it}$  are the deviations from the long-run equilibrium relationship. No co-integration is calculated by  $(\delta_i \dots 1)$  is verified by the subsequent unit root test.

$$\varepsilon_{it} = \delta_{it}\varepsilon_{it-1} + \omega_{it} \tag{3}$$

Where  $\omega_{it}$  is the error term. Table 3 shows the outcomes of Pedroni co-integration tests and clarifies the long-term association between CO<sub>2</sub> emissions, GDP, RE, AGR and Population. Four statistics for the within dimension reject  $H_0$  of no co-integration and accept the  $H_a$  among factors. For the between dimensions, the two statistics reject the  $H_0$  of no co-integration confirming the long-run relationship between variables. Consequently, six statistics support the long-run co-integration when a CO<sub>2</sub> emission is the outcome variable.

**Table 3** Pedroni co-integration tests

$H_a$ : common autoregressive coefficients (within-dimension)

	Statistic	Prob.	Weighted Statistics	
			Statistic	Prob.
Panel v-Statistic	-3.197449	0.9993	-4.057377	1.0000
Panel rho-Statistic	2.491384	0.9936	2.733569	0.9969
Panel PP-Statistic	-7.927289	0.0000***	-16.35943	0.0000***
Panel ADF-Statistic	-6.477598	0.0000***	-9.824281	0.0000***

$H_a$ : individual autoregressive coefficients (between-dimension)

	Statistic	Prob.
Group rho-Statistic	4.169804	1.0000
Group PP-Statistic	-16.78045	0.0000***
Group ADF-Statistic	-9.303292	0.0000***

$H_0$ : There is no cointegration. \*\*\* means significant at the 1%, correspondingly.

#### 4.4. Granger Causality Test (GCT)

GCT and VECM are applied to measure the short-run and long-run relationship between variables. Engle and Granger (1987) measured the two-way association: firstly, measurement of residual from Eq. (2), secondly the measurement of the coefficients linked to short-run adjustment. Estimation of the VECM model is given as:

$$\begin{bmatrix} \Delta LNCO_{2it} \\ \Delta LNGDP_{it} \\ \Delta LNRE_{it} \\ \Delta LNAGR_{it} \\ \Delta LNPOP_{it} \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix} + \sum_{p=1}^q \begin{bmatrix} \theta_{11P} & \theta_{12P} & \theta_{13P} & \theta_{14P} & \theta_{15P} \\ \theta_{21P} & \theta_{22P} & \theta_{23P} & \theta_{24P} & \theta_{25P} \\ \theta_{31P} & \theta_{32P} & \theta_{33P} & \theta_{34P} & \theta_{35P} \\ \theta_{41P} & \theta_{42P} & \theta_{43P} & \theta_{44P} & \theta_{45P} \\ \theta_{51P} & \theta_{52P} & \theta_{53P} & \theta_{54P} & \theta_{55P} \end{bmatrix} X \begin{bmatrix} \Delta LNCO_{2it-1} \\ \Delta LNGDP_{it-1} \\ \Delta LNRE_{it-1} \\ \Delta LNAGR_{it-1} \\ \Delta LNPOP_{it-1} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} ect_{it-1} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \end{bmatrix} \tag{4}$$

The estimated VECM with CO<sub>2</sub> as a target variable which is our concern.

$$\Delta LNCO_{2t} = ect_{t-1} + \Delta LNCO_{2t-1} + \Delta LNGDP_{t-1} + \Delta LNRE_{it-1} + \Delta LNAGR_{t-1} + \Delta LNPOP_{t-1} + \varepsilon_t \tag{5}$$

The co-integration long-run model can be solved as:

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2  **$H_0, H_a$  is the hypothesis development to measure the relationships between two teachings method.**

$$ect_{t-1} = 1.0000 CO_{2t-1} + LNGDP_{t-1} + LNRE_{it-1} + LNAGR_{t-1} + LNPOP_{t-1} + \varepsilon_t \quad (6)$$

$\Delta$  is the first difference operator. Schwarz information criterion (SIC), Akaike information criterion (AIC) and Hannan-Quinn (HQ) criterion determined the lag length,  $p$ , and set equal to one; error correction term (ect) resulting from Eq. (2);  $\varepsilon$  is the random error term.

The outcomes of Granger causality are described in Table 4. This shows that ‘ect’ is statistically significant at a level of 1% only for carbon dioxide emissions model, Agriculture and Population. Population and GDP at both global and national levels positively and significantly affect the CO<sub>2</sub> emissions which are in line with Hashmi and Alam (2019); Hang and Yuan-Sheng (2011); Dong et al. (2018); Lin and Raza (2019). CO<sub>2</sub> releases and AVA have short and long-run significance at 5% level. The outcomes show that there is short-run and long-run bidirectional causality between CO<sub>2</sub> emissions and AVA. Therefore, a minute adjustment in agriculture production has an instant influence on carbon emissions because of the intensive use of fossil energy in the agriculture sector. The comparable results have been found by Zhangwei and Xungang (2011); Jebli and Youssef (2017); Waheed et al. (2018); for short-run effects in USA Galinato and Galinato (2016); used local weighted least squares method to estimate CO<sub>2</sub> emissions in the agriculture sector of China Xu and Lin (2017) and by using Environmental Kuznets Curve (EKC) carbon emissions generated by agriculture in European Union results having conflicts in short-run (Zafeiriou and Azam, 2017). Unidirectional short run causality is found between clean energy ingestion and agriculture. It means that AVA increases as renewable energy rises short-run. This result is contrary to Jebli and Ben Youssef (2016) in case of short-run but in long-run, they found bidirectional causality among these factors. A panel investigation of East Asia and Pacific developing countries during 1990-2014 has been analyzed by (Hanif, 2018). The results show that energy consumption, economic development, and urbanization all significantly raise carbon emissions. Fang and Chang (2016) measured unit root, co-integration, FMOLS and the fundamental association between energy use and financial development in 16 APCs during 1970–2011. They found that relationship varies for individual countries.

Additionally, a SR causality is found between AVA and GDP and bidirectional causation between GDP and agriculture. This shows that upsurge in agriculture production has an influence on economic development. The long-run growth can support the agriculture sector by increasing investments. The long-run causality from RE and Population to CO<sub>2</sub> emissions for these selected Asian Pacific countries may affect CO<sub>2</sub> emissions in long-run. In the end, we find a short-run causality coming from RE which can cause in the production of goods and services.

**Table 4** GCTs

Dependent variable	$\Delta LNCO_2$	$\Delta LNGDP$	$\Delta LNRE$	$\Delta LNAGR$	$\Delta LNPOP$	Long-run ECT
$\Delta LNCO_2$	-	0.6443 (-0.524)***	0.1572 (-1.3919)***	0.3182 (-0.9990)***	0.8740 (0.2139)***	-0.186584 (0.0258)**
$\Delta LNGDP$	0.4417 (0.96837)	-	0.3739 (-0.8907)***	0.0006 (3.4510)	0.0001 (4.0012)	-0.010053 (0.0011)***
$\Delta LNRE$	0.5627 (0.55986)	0.0341 (2.1750)	-	0.0005 (3.5038)	0.3383 (1.0034)	-0.047322 (0.0000)***
$\Delta LNAGR$	0.1908 (-)	0.0320 (-0.1035)***	0.8381 (0.17828)	-	0.0090 (-)	-0.40095 (0.0239)**

	1.3270)***			2.5163)***	
$\Delta$ LNPOP	0.4100		0.8169	0.2716	-0.012820
	(-	-0.011685	(-	(-	(0.0090)***
	2.1121)***	(0.00364)***	0.1383)***	1.1005)***	-

Notes:  $\Delta$  is the difference operator.

\*\*\*, \*\*, and \* means significant at 1%, 5%, and 10% levels respectively. *t*-statistics are given in parenthesis brackets. ECT (error correction term) based on the coefficients (given in brackets) and probability. ECT long-run is taken by comparing coefficients with probabilities.

#### 4.5. Long-run estimation

To compute long-run estimation by using Eq. (2), Ordinary least square (OLS), fully modified ordinary least square (FMOLS) and dynamics ordinary least square (DOLS) are used. Pedroni (2001); Pedroni (2004) established FMOLS and DOLS, are better than the OLS because these are beneficial in measuring serial correlation problems and endogeneity. Table 5 provides long-run inferences taken from OLS, FMOLS and DOLS. The maximum estimated coefficients are significant at 1% and only one variable is significant at 10% in DOLS. All techniques give close results in sign, scale and in statistical significance. In DOLS method, one percent change in GDP increases co2 emissions by 0.6723%, one percent increase in RE upsurgs emissions by 0.0060%, a 1% increase in AVA decreases co2 emissions by 0.3049%, and 1% per cent increase in population increases emissions by 0.6581%. This is because rising output raises CO<sub>2</sub> emissions in both long-run and short-run. Thus, present study showing that outputs of all the factors are increasing carbon emissions in the long-run because GDP and population still need a concentration of fossil fuel power in producing goods and services. Though, the output of OLS, DOLS is the best fit which can be used for future information. For this, we have discussed many panel studies in literature associated to CO<sub>2</sub> emissions, RE and GDP in the long-run. Similar results have been discussed by (Apergis and Ozturk, 2015; Ben Jebli et al., 2015) that increasing in RE increases CO<sub>2</sub> emissions over a long period. Khan and Jamil (2016) resulted in a unidirectional study among CO<sub>2</sub> emissions and RE while Wang et al. (2018) provide a bidirectional study among CO<sub>2</sub> emissions and RE. Similarly, Ma and Stern (2008) also estimated a causal association between population and CO<sub>2</sub> emissions. Additionally, an increase in AVA reduces emissions in long-run. In fact, in panel countries, the results might be different than individual countries in value addition. The agriculture sector and renewable energy sectors are less polluting in developed and developing countries in the Asia Pacific region. For this, Asia and Pacific request to efforts on human needs and improve welfare with the lesser environmental cost because of rapidly growing economies, consumption and poverty.

**Table 5** Long run estimation

OLS, FMOLS and DOLS estimation results when the logarithmic CO<sub>2</sub> emission is utilized as the dependent variable

Variables	LNGDP	LNRE	LNAGR	LNPOP
OLS	0.392655 (0.0000)***	0.152210 (0.0000)***	0.032172 (0.5118)	0.538059 (0.0000)***
FMOLS	-0.069389 (0.5657)	0.125352 (0.0000)***	0.139046 (0.1258)	1.384607 (0.0000)***
DOLS	0.672299 (0.0000)***	0.006018 (0.3480)	-0.304929 (0.0088)***	0.658183 (0.0756)*

Notes: \*\*\*, \*\*, and \* indicates statistical at 1%, 5% and 10% levels.

P-values are listed in parentheses.

#### 5. Conclusion and Policy Implications

The study shows a causal relationship among CO<sub>2</sub> emissions, GDP per capita, RE consumption, AVA and Population for a panel data of thirteen APCs (Australia, China, India, Bangladesh, Indonesia, Japan, Malaysia, Pakistan, Philippines, Singapore, Korea, Thailand and Vietnam) covering the duration of 2005-2017. We apply panel co-integration techniques (PCTs), GCTs for causalities and long-run association among the variables. Regression techniques such as OLS, FMOLS and DOLS are applied to evaluate the

long-run parameters when a carbon dioxide discharge is taken as an outcome variable. GCT output shows a short-run causality running from AVA to GDP and bidirectional causality among GDP and agriculture; long-run causality from RE and Population to CO<sub>2</sub> emissions. The short-run causality illuminates the significant role played by the agriculture division in increasing economic growth in this region. Except it, GDP boost also has an effect on AVA in the long-run by agriculture investments. Thus, renewable energy and population have an impact on CO<sub>2</sub> emissions in the long-run. The long-run parameters show economic growth, population and RE increases CO<sub>2</sub> emissions which may effect on the production and services. Renewable energy consumption is the only one parameter influences on long-run releases in because the RE sources include wind, geothermal, solar, biomass and waste. This study also clears that the agriculture sector and renewable energy sectors are fewer polluting than the other divisions such as transport and industry. The findings of this study are interesting because this study is the first in examining the linkages between emissions, AVA to GDP, GDP to AVA and RE, Population to CO<sub>2</sub> emissions in the selected APCs but are less polluted than fossil fuel energy.

The results of this study highlight significant policy implications for the individual under developing countries such as Pakistan, Bangladesh, and Indonesia, Thailand and Vietnam and developed countries. According to our econometric results, we encourage clean energy sources such as wind and solar in this specific region because these clean sources can motivate agriculture value additions and production. Through this, we can add a great share and fight with global warming in reducing CO<sub>2</sub> emissions. The policy implications can summarize as follows: Firstly, due to CO<sub>2</sub> emissions economies of APCs are not efficient. This can be achieved by mitigating the air pollution specially coming from industries, energy consumption and fuel supply. Secondly, the government should encourage clean energy sources, as well as environment friendly technologies.. Thirdly, reewable energy should be used in agriculture s, automobiles, manufacturing and construction sector instead of fossil fuels such as oil, coal and gas. Application of this study allows the researchers in the renewable energy performance of the countries under the different energy regimes. The relative analysis of the research would provide significant insights for the policymakers including industries, transport, and agriculture, fossil fuel consuming sectors, academia, and energy security policies for the limited countries. In the end, this study can be extended the proposed methodology to different economies by applying more explanatory variables in the regression model to perform environmental changes over a long period.

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