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RESEARCH ARTICLE

Agricultural practices and quality of environment: evidence for global perspective

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Abstract
The study emphasizes to examine the causal relationship among CO_2 emission, agricultural value added, industrial production, urbanization, nuclear energy consumption, and economic growth across the panel of 59 countries. The data is collected from World Bank database over the period of 1982–2015. For econometric estimations, we have divided the sample into different income groups: low income, lower middle income, upper middle income, and higher income. In case of higher income countries, empirical results have reported the unidirectional causality from agricultural value added to CO_2 emission, whereas, bidirectional causality between nuclear energy consumption and CO_2 emission. Upper-middle-income countries have confirmed the bidirectional causality between CO_2 emissions and agricultural added; however, unidirectional causality runs from nuclear consumption to CO_2 emission. According to Granger causality estimations, agricultural value added and nuclear energy consumption do not cause the CO_2 emission in low income and lower-middle-income countries. Long-run estimations have mentioned that higher agricultural value added leads to increase the CO2 emission, in upper middle income and higher income countries. On contrary, in case of low-income and lower-middle-income countries, agricultural value added has inverse relationship with CO_2 emission. Higher nuclear energy consumption tends to reduce the CO_2 emission, except the upper-middle-income countries.

Keywords CO_2 emission · Agriculture · Renewable energy · Urbanization, causality

JEL Classification P18 · Q19 · Q20

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Introduction

Global warming is putting the life in danger on this planet as it is deteriorating the ecosystems and disturbing the natural balance of temperature, water, and food (Cai et al., 2016). Sea level is rising and glaciers are retreating on the daily basis (Clark et al., 2016). Many ecological theories elucidates that rising level of CO_2 in the atmosphere is the initial reason of global warming, which is generated by human activities (IPCC, 2006). Currently, the CO_2 emission is reaching on a dangerously high level since last few decades (Pearson & Palmer, 2000). Majority of studies on environment exhibits that increase in concentration of greenhouse gases will add 20 gigatons (G_t) of carbon in the atmosphere (Sims, 2004). Additionally, industries use fossil fuels which are among the major sources of energy; this has remarkably increased the level of CO_2 in atmosphere. So, utilization of fossil fuels as a foundation of energy is considered as a primary contributor in CO_2 emission (Wang et al., 2016). Thirty-seven percent of worldwide greenhouse gas emission comes from industry; out of which, 80% accounts for total energy used (Worrell et al., 2009). It is confessed that excess consumption of these fossil fuels will diminish the reserves of fossil fuels and deteriorate the quality of environment, health, and climate change (Farhad et al., 2008). Taking account of these hazardous effects of fossil fuels, societies are seeking alternate energy sources that are less dangerous for the environment (Sims, 2004). That's why sources of renewable energy, such as solar wind, geothermal energy, and biomass, offer an alternate source of energy for domestic as well as commercial use with negligible emission of greenhouse gases and pollutants in the atmosphere (Zakhidov et al., 2008).

Agriculture takes part in CO_2 emissions by using fossil fuel energy intensively in its production. The agriculture sector contributes 14 to 13% of the emission of greenhouse gases. Majority of machinery used in farming, e.g., pumping for water irrigation, indoor facility for livestock, and utilization of nitrogen-rich fertilizer for higher agriculture productivity, will increase the emission of greenhouse gases. Furthermore, food and agriculture organization (FAO) agriculture sector can contribute positively in reduction of greenhouse gases (Reynolds & Wenzlau, 2012), while Chebbi (2010) investigates the affiliation between consumption of energy and quality of environment. Author included three major sector of economy such as industry, agriculture, and services in his model. Long run results provided by this study reveal the existence of bidirectional causality for energy consumption and economic growth with CO_2 emission. However, short-run results did not exhibit any significant relationship between CO_2 emission, economic growth, and consumption of energy. Taking account of panel data studies for 53 countries, Rafiq et al. (2016) discussed the determinants of emission of CO_2 based on trade openness, energy use, and sectorial production. He included 30 low-income and 33 high-income countries in his sample. The results indicated that agriculture value added and service sectors reduce the CO_2 emissions, while industrial sector increases the pollutants.

Ben Jebli and Ben Youssef (2017) examined the relationship among agriculture value added, consumption of renewable energy, economic activity, and environmental quality among five North African economies such as Tunisia, Morocco, Algeria, Sudan, and Egypt. Renewable energy sources comprise of biomass waste, solar, tide wave, wind, and hydroelectric. Results revealed that rise in the economic activity and consumption of energy from renewable source will lead to deterioration of environmental quality as this set of renewable resources also includes combustible elements and waste which are not clean, while in long-run, increase in agriculture value added will lead to decrease in emission of carbon for this group of countries. Hamilton et al. (2007) investigate the system of Michigan crop and find that the application of lime in agriculture can be a sink for carbon dioxide as it exports loads of drainage water of bicarbonate. However, they claim that nitrification, which is generated through acidity, will decrease the sink. Considering the study of Japan, Koga et al. (2006) investigate the system of farming through "life cycle inventory analysis." Their findings revealed that emission of greenhouse gases, which is arrived from their system of cropping, can be compacted by soil management rehearses. This will further enhance the sequestration in the soil. Also, Searchinger et al. (2008) confirm that gauge CO_2 emanations from land utilization and find that corn-based ethanol as opposed to creating 20% funds, about duplicates ozone depleting substance discharges more than 30 years and expands these gases for a long time. Biofuels from switchgrass, whenever developed on US corn lands, increment outflows by half. This outcome raises worries about extensive biofuel orders and features the benefit of utilizing waste items. While many other aspects of agriculture's impact on CO_2 emission are not explored yet and required to be studied.

Agricultural practices affect the environment in multiple ways: firstly, agriculture is an important contributor of CO_2 emissions due to burning of plant, microbial decay, and soil organic matter (Smith, 2004; Oenema et al., 2005). Secondly, the traditional use of farming in agriculture sector will deteriorate the environmental quality in developing economies due to intensification of farm production in various regions and regional concentration of activities, such as farming of livestock. Thirdly, the uses of non-renewable energy for agricultural practices are also a major contributor of CO_2 emissions. This phenomenon will lead to increasing the level of nutrient surplus, ammonia, and greenhouse gas emissions and further increase the water and air pollutants (OECD). On contrary to above discussion, the use of renewable energy sources, modern farming practices and organic seeds in agriculture sector will decrease the level of CO_2 emission in atmosphere (Fedoroff, & Cohen, 1999; Trewavas, 2002; Huang et al., 2002; Green and Cornell 2005). However, developed countries decrease the usage of pesticide and nitrogen emission by 10% with improvement in the quality of available water and lowering greenhouse gas emission. Soil erosion rate has been declined due to adaptation of new technologies of farming in different areas of USA, Canada, and Europe, which further enhance the environmental quality.

The main involvement of current study is to examine the part of agricultural practices in different income-level regions; upper-middle income, high income, low-middle income, and low income. The motive behind examining the relationship between agriculture values added and emission of CO_2 is that the low-income countries are having fewer resources and knowledge of farming; due to the fewer resources, it is difficult for low-income countries to adopt renewable source of energy for farming and use of latest seeds and pesticides. Similarly, the lack of education creates hurdles for policymakers to teach and convince the farmers to adopt the latest farming machines and methods. However, the case is different for high-income countries, as they have unlimited resources to use carbon-free farming techniques. Some studies such as that of Janzen (2004); Smith (2004); Koga et al. (2006); Searchinger et al. (2008); Ben Jebli and Ben Youssef (2017); and Waheed et al. (2018) investigate the relationship between agricultural practices and environmental quality, but it has not been that extensively studied, keeping in view the different regions of the world. To our best knowledge, almost all the available studies are for some particular country, group of countries, or a region.

A study incorporates (Westerlund, 2005a, 2005b) panel integration to solve the problem of slope heterogeneity and cross-sectional dependency. He outspread the work of Breitung (2002), who explained the univariate variance ratio test to panel data. Westerlund (2005a) proposes the null hypothesis of no cointegration, which depends upon two residual-based panel cointegration tests and these statistics are non-parametric in nature. There are some advantages of non-parametric over parametric statistics. Initially, the effect of dependent data is not necessary to be corrected. This will prevent nuisance parameter problem. Secondly, parametric tests include less amount of calculation in comparison to those utilize in semi-parametric and parametric statistics. In addition, parametric statistics has to face problem for the selection of correct lag length selection for autoregressive process, while Westerlund (2005a) proposes the heterogeneous panel regression equation which is based on the assumption that residuals are independent in each cross section. The long-run relationship between variables are estimated by using dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS), and pool mean group (PMG) which shows the positive and significant relationship between agriculture value added and CO_2 emissions in high- and upper-middle-income countries. However, agriculture value added shows negative and significant relationship with CO_2 emissions in low-middle-income countries. Moreover, the study discourses the policy strategies for different group of countries based on their income. Next, the assessments portray condensed recommendations for the administration of countries to manage the quality of environment by using environmental friendly techniques in agriculture sector.

The study is organized as follows: "Literature review" presents literature review, "Data description and model" debates about the description of data and model, while "Estimation and discussion" incorporates the estimation and its argument and "Conclusion" concludes consequence of the study with policy implications.

Literature review

The relationship between environment and economic growth was primarily initiated by Grossman and Krueger (1995), who discusses the environmental Kuznets curve hypothesis (EKC). EKC hypothesis reveals that increase in economic growth will badly affect the quality of environment at initial stages, later; increase in economic growth will improve the quality of environment. However, Ben Jebli and Ben Youssef (2015) empirically investigated economic growth, consumption of renewable energy, environmental quality, and their interconnection considering the panel of five countries from North African. Findings of his study reveal unidirectional causality running from CO_2 emissions and combustion renewable waste to economic growth in long and short-run. However, combustion renewable waste unidirectional causes CO_2 emissions in short-run. In addition, results of fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) exposes that the relationship between combustion renewable waste and CO_2 emissions is positive and significant. In addition, Chiu and Chang (2009) entitle that renewable energy accounts 8.3% of total energy supply before starting to influence the CO_2 emissions negatively. On the contrary to the above findings, Sadorsky (2009) elucidates that increase in real income will lead to increase in utilization of renewable energy consumption among G-7 countries.

Unlike industrialization, the exploration of relationship between urbanization and environmental quality has not concretely established. All urban environmental theories claim that there is no clear indication regarding the net effect of urbanization on CO_2 emissions (Sadorsky, 2014). From the last 2 decades, the scientists have adopted two parallel approaches to have insight in relationship between urbanization and environmental quality. One is "Environmental Kuznets curve," and the other is "STIRPT" (Perman & Stern, 2003; Shi, 2003; York et al., 2003; Martínez-zarzoso et al., 2007). Furthermore, Martínez-Zarzoso et al. (2011) discuss several channels for the association between urbanization and environmental dilapidation. He elucidates that increase in urban population will increase the number of people work in industry and this will lead to increase output, consumption of energy, and emission of gases. However, there are several studies such as Sharma (2011); Sharif Hossain (2011); Kasman and Duman (2015) which describe the relationship between urbanization, economic growth, trade, consumption of energy, and CO_2 emission. Furthermore, there are numerous studies such as Wolde-Rufael (2005); Narayan and Smyth (2007); Soytas et al. (2007); Ozturk (2010); Shahbaz et al. (2015); Sarwar et al. (2017); and Shahbaz et al. (2017) which evaluated the role of energy consumption as an input on economic growth for different group of economies and regions. It is broadly discussed that real output and environmental quality has inverted U-shaped association. This phenomenon is known as "environmental Kuznets curve." Environmental dilapidation rises with the increase in real output till a certain point and then it starts decreasing (Akbostanci et al. 2009).

In addition, consumption of nuclear energy also plays a significant role to provide alternative source of energy. Nuclear power plants play significant role in reducing the amount of greenhouse gases, which is produced by electricity sector in OECD countries over the past 40 years. However, it is estimated that power plants in OECD countries will emit one-third higher CO_2 emissions if nuclear power did not play their role. It is also elucidated that nuclear power plants save more than 1200 million tons of CO_2 annually. Furthermore, Europe also believes that reducing of CO_2 emissions would not be impossible without taking help from nuclear power plants (Nuclear Energy Agency, 2002; European Union, 2006). Many studies such as Wolde-Rufael (2005) and International Energy agency (IEA, 2008) believes that many developing countries show a keen interest for the usage of nuclear energy as source of diversifying energy supplies because nuclear energy also act as carbon free energy source, which provides a dynamic solution for the security of energy and global warming (Ferguson, 2007; Elliot, 2007; Vaillancourt et al., 2008; Toth & Rogner, 2006).

Furthermore, Chang and Lin (1999) discuss the closest link between production of industries and environmental quality because majority of existing industries in Taiwan are CO_2 intensive. However, Chaitanya (2007) shows that the higher economic growth rates, fast industrialization, and more importantly elevated trade of industrial products add in energy consumption accordingly promotes more environmental issues and devastation. In addition, Tunç et al. (2009) examined the determinants which take part to alter emission level of CO_2 in Turkey by splitting the economy into three broad sectors named as agriculture, industry, and services during 1970–2006. The study revealed that the contribution of industrial sector in discharge of CO_2 kept on rising during the whole time period taken for analysis. So, industrial sector elevates emissions level of carbon dioxide.

In addition, Banerjee and Rahman (2012) threw light on CO_2 emission's determining factors by focusing merely on the economy of Bangladesh for the periods 1972–2008. The empirical evidence highlighted that escalation of industrial production is enhancing factor of CO_2 emissions. The positive link has been found as elucidated by the results of study between industrial growth and environmental pollution (CO_2 emissions). Yao et al. (2012) explored the close connections, employing approach of Grey Relation Degree and taking 18 different industries from China's province Jilin, among industrial development and emissions of carbon but indicated the fact at the same time that the influence of output aspect of every industry is different on carbon discharge. The heavy industries are found as the most prominent industries in Jilin having major impact on carbon emissions.

Ahmad et al. (2013) analyzed the consequences of industrial growth on environmental degrading element (CO_2 emissions). The data of four South Asian countries was utilized from 1980–2008. The results showed that the increase in growth of industries tends to upraise the emission level of carbon dioxide (CO_2) which leads to the conclusion that swift expansion of industrial sector originates environmental decay and causes decline in environmental standards. Industrialization and carbon dioxide emissions nexus was tested by Gazi et al. (2014) for Bangladesh while selecting time period from 1975 to 2010. The findings disclosed that initially, as the industries flourish, the emissions of CO_2 accelerate but then after reaching to a certain level, the further advancement in industrial sector declines CO_2 discharge indicating the existence of environmental Kuznets curve.

Many researchers such as Skaza and Blais (2014); Al-mulali et al. (2015b); Omri et al. (2015); Jamel and Derbali (2016); and Bekhet et al. (2017) discuss the phenomena of "environmental Kuznets Curve" by incorporating panel data of several countries. Skaza and Blais (2014) integrate 190 countries from developed and developing economies, while Al-mulali et al. (2015b) discuss EKC relationship among Asia Pacific, Western Europe, Middle East, sub-Sahara Africa, and North Africa. They made a panel of 189 countries. Taking account of time series data, many studies such as Jalil and Mahmud (2009); Ozturk and Acaravci (2011); Alam et al. (2012); Alkhathlan and Javid (2013); Shahbaz et al. (2013); and Boutabba (2014) empirically investigate the EKC phenomena and discuss the occurrence of "environmental Kuznets Curve" EKC in India, South Africa, China, Turkey, Saudi Arabia, and Bangladesh. However, Al-Mulali et al. (2015a); Farhani and Ozturk (2015) did not find any significance of EKC phenomena in Vietnam and Tunisia. Keeping in view, the above discussion agriculture practices also played a crucial role in emission of CO_2.

Data description and model

The empirical investigation is comprised of 13 High, 23 Upper-middle, 18 Low-middle and 5 Low income economies based on World Bank criteria.[1] The study incorporates panel data from 1982 to 2015, keeping in view the merits of panel data. Most of the variables in the data have been taken out from World Development Indicators. The functional form of environmental quality proxied using CO_2 emissions is modeled as

$$co_2 = f(ava, iva, ub, nec, gdp) \quad (1)$$

[1] List of countries are mentioned in Appendix

Due to linear specification, this study has transformed all variables into natural log because linear specification leads to reliable, efficient, and comparable results with other specification (Shahbaz & Lean, 2012; Shahbaz et al., 2017; Sarwar et al., 2017; Waheed et al., 2018). Further, the estimates become elasticities of homogenous units making it comparable with each other. The transformed empirical equation can be modeled as follows

$$\ln(co_2) = \beta_0 + \beta_1 \ln(ava) + \beta_2 \ln(iva) + \beta_3 \ln(ub) + \beta_4 \ln(nec) + \beta_5 \ln(gdp) + \varepsilon \quad (2)$$

Also,co_2, *ava*, *iva*, *ub*, *nec*, and *gdp*are natural logarithm of CO_2 emission per capita (regarding tones). For *ava*, we use the unit of agriculture value added per capita, industrial value added per capita (constant 2010 US$), urbanization (% of total population), nuclear energy consumption per capita (thousand tones), and GDP per capita (constant 2010 US$).

There is a need of an hour to find the sources of energy alternative to fossil fuels and other polluting sources of energy. However, the use of nuclear energy not only reduce the dependence on imported oil but it also provide us the secure energy which reduce the unpredictability of oil prices associated with imports of oil and further reduce the CO_2 emissions and other greenhouse gases. (Ferguson, 2007; Elliot, 2007; Adamantiades & Kessides, 2009). Further, they do not deplete the natural resources. The main reason to account the agricultural production is the unclear relationship with CO_2 emission; some of the studies have reported agricultural as a source of CO_2 emission (e.g., Waheed et al., 2018; Ben Jebli and Ben Youssef 2016; Holly, 2015; Soni et al., 2013; Reynolds, and Wenzlau, 2012), while others suggested as a measure to control the CO_2 emission (Ben Jebli and Ben Youssef 2017; Rafiq et al., 2016). However, increase in agriculture sector reduces CO_2 emission because mostly agriculture sector is less polluting in comparison with other sector of the economy (Rafiq et al., 2016). Environmental Kuznets curve proposes that upsurge in economic activity leads to an increase in environmental degradation because of industrialization, which further increases the level of CO_2 emission in the atmosphere (Alvarez et al., 2012). Moreover, economic growth causes urbanization because of reallocation of labor from rural agricultural sector to urban manufacturing and services sector, which enhance the rate of CO_2 emission in the atmosphere due to production of more commodities in manufacturing sector (Michaels et al. 2012).

Cross-sectional dependence test

During the last few decades, globalization increases rapidly, due to which cross-sectional dependence prevail among several economies (Koga et al., 2006). However, the simpler versions of panel unit root and cointegration testing (first generation) are sensitive to the presence of cross-sectional dependence. Certainly, panel data models display cross-sectional dependence which exists in the errors, due to unobserved components and common shocks across countries integrated with each other. Residual independence, spatial spillover effects, omitted common factors, and unobserved common factors are the major causes of cross-sectional dependence (Pedroni, 2001, 2004). To resolve this issue, this study has resorted to apply second generation panel unit root test. Second generation unit root tests are superior to first generation unit root tests as they are robust to presence of cross-sectional dependence.

In order to determine the test which is suitable for detection of unit root problem, this study has examined the cross-sectional dependence. Lagrange multiplier test was proposed by Breusch and Pagan (1980), where the cross-sectional dependence is estimated using the average squared pairwise correlation of residuals. The statistics of Lagrange multiplier test is asymptotically distributed under chi-square distribution with $n(n-1)/2$ degree of freedom. However, the mathematical equation of LM cross-sectional dependence test is given below.

$$CD_{lm} = P \sum_{i-1}^{n-1} \sum_{j=i+\gamma_{ij}^2}^{n} \quad (3)$$

where sample estimates of the pairwise correlation of residuals is represented by γ_{ij}, which is defined as

$$\gamma_{ij} = \gamma_{ji} = \frac{\sum_{t-1}^{T} r_{it} r_{jt}}{\left(\sum_{t-1}^{T} r_{it}^2\right)^{1/2} \left(\sum_{t-1}^{T} r_{jt}^2\right)^{1/2}} \quad (4)$$

Residual of ordinary least square (OLS) is represented by r_{jt}, which is defined as

$$r_{jt} = Y_{it} - \alpha_i - \beta_i X_{it} \quad (5)$$

T 1, 2, 3..........T
i 1, 2, 3...........n

where *i* and *T* index the cross-sectional and time series units respectively. However, Breusch and Pagan (1980) elucidates that LM test is only valid for large *n* and small *T*. Taking account of this shortcoming, Pesaran (2004) introduces the cross-sectional dependence test among errors, which is useful for different panel data models. This test incorporates the unit root dynamic heterogeneous panels and stationary with large *n* and small *T*. The results are robust to a multiple or single structural breaks in the error variance of single regression and slope coefficient. Pesaran (2004) proposed the dependence test is based on pairwise correlation coefficients instead of the squares of correlation, as discussed in LM test;

$$CD = \sqrt{\frac{2T}{n(n-1)}}\left(\sum_{i=1}^{n-1}\sum_{j=i+\gamma_{ij}}^{n}\right) \tag{6}$$

Second generation panel unit root test

After examining the dependence, this study has applied second generation panel unit root test introduced by Pesaran (2007). Keeping in view the t ratio of ordinary least square (OLS) estimator $\beta_i(\beta_i)$ in the cross-sectional DF (CADF) regression, Pesaran unit root test constructs the test statistics and utilize the cross section mean to proxy the common factor.

$$dY_{it} = \alpha_i + \beta_i Y_{i,t-1} + \varphi_i dY_t + r_{ij} \tag{7}$$

However, there is one option to consider the augmented version of IPS test by using mathematical formulae given below

$$CIPS(n,T) = t\text{–}bar = n^{-1}\alpha_{i=1}^{n} t_i(n,T) \tag{8}$$

Moreover, $r_{ij}(n, T)$ represents the augmented dickey fuller statistics across the cross section for i^{th}cross section unit, which is set by the t ratio of coefficient $(Y_i, t-1)$ in CADF regression.

Panel cointegration test

When any one of the variable is confirmed to be non-stationary I(1), then the next step is the confirmation of presence of long-run relation using panel cointegration approach. The second generation cointegration test is developed by Westerlund (2007), which utilize the bootstrap approach to generate the sample and employ new sample to construct two panel statistics and two groups mean. This approach evaluates the model, whether, it has converging error terms for the case of full panel or within individual groups.

$$dY_{it} = \nu_i + \alpha_i\left(Y_{i,t-1} - \beta_i X_{i,t-1}\right) + \alpha_{j=1}^{p_i}\alpha_{ij} dY_{i,t-j} + \alpha_{j=0}^{p_i}\delta_{ij} dX_{i,t-j} + r_{it} \tag{9}$$

where speed of adjustment term is represented by α_i. $H_0 : \alpha_i = 0$ shows that variables are not cointegrated and there is no error correction term, while $H_1 : \alpha_i < 0$ concludes the presence of error correction and variables are cointegrated.

Long-run parameter estimation

After ensuring the existence of cointegration among the variable in panel data setup, this study shifts the analysis towards the estimation of long-run coefficients by using dynamic ordinary least square (DOLS) estimator. This approach incorporates parametric adjustment to the errors by using lags and leads of differenced explanatory variables for obtaining unbiased long-run estimators (Kao & Chiang, 2000). The equation of DOLS estimator is modeled as follows

$$U_{it} = \alpha_i + Y'_{it}\beta + \sum_{j=-q1}^{j=q2} v_{ij}\Delta Y_{i,t+j} + e_{it} \tag{10}$$

The coefficient of leads and lags of first differenced regressors is represented by v_{ij}. The coefficient of estimated DOLS is presented as follows

$$\beta_{dols} = \sum_{i=1}^{n}\left(\sum_{i=1}^{T} s_{it}s'_{it}\right)^{-1}\left(\sum_{i=1}^{T} s_{it}U^{+}_{it}\right)$$
$$s_{it} = \left[Y_{it} - \overrightarrow{Y}_i, \Delta Y_{i,t-q}, \ldots\ldots., \Delta Y_{i,t+q}\right] \tag{11}$$

Vector of explanatory variables is denoted by s_{it}, while U^{+}_{it} $\left(U^{+}_{it} = U_{it} - \overrightarrow{U}_i\right)$ is transformed dependent variable.

Pool mean group test

Confirmation for the presence of cointegration and application of DOLS model among the variables moves our analysis towards the application of Pool Mean Group model (PMG) developed by Pesaran et al. (1999). This technique adopts panel data variant of cointegration based on ECM. In this technique, deviation from equilibrium inspired the short-run dynamics. The dynamic panel specification of autoregressive distributed lag model (ARDL) is discussed as follows.

$$X_{it} = \sum_{j=1}^{p}\phi_{ij}X_{i,t-1} + \sum\vartheta_{ij}Y_{i,t-j} + \upsilon_i + r_{it} \tag{12}$$

However, the vector of explanatory variables $(K \times 1)$ for group i is represented by $Y_{i,\ t-1}$, whereas, υ_i shows the fixed effect, while p and q are different among several countries and vector error correction (VECM) model is described as follows.

$$\Delta X_{it} = \theta_i\left(X_{i,t-1} - \alpha'_i X_{i,t-1}\right) + \sum_{j=1}^{p-1}\lambda_{ij}\Delta X_{i,t-j} + \sum_{j=1}^{q-1}\lambda'_{ij}\Delta Y_{i,t-j} + \upsilon_i + r_{it} \tag{13}$$

where long-run parameter and error correction term is presented by α'_i and θ_i. α'_i is utilized by PMG, which is mutual across countries.

$$X_{it} = -\left(\frac{\theta_i}{\alpha_i}\right)X_{it} + \nu_{it} \tag{14}$$

The stationary process is represented by ν_{it}, whereas the results do not exhibit any long-run relationship if $\alpha' = 0$ and long-run relationship exists between the variables if $\alpha' < 0$. Pool mean group

(PMG) approach is an intermediate among mean group (MG) and fixed effect method (FEM). Coefficients and slopes are different among countries in MG estimation, while in FEM, intercept may be different but slopes are the same. In comparison with the above approaches, in short-run, PMG allows coefficients to vary across countries. Also, MG is also a consistent technique for the average coefficients of country specific regression but it is not suitable for small group of countries and period (Hsiao et al., 1999). However, the estimator incorporates the mixture of averaging and pooling of coefficients in PMG technique.

Heterogeneous and panel causality

Keeping in view the simplest version of Granger (1969), this study has incorporated the Dumitrescu and Hurlin (2012) panel causality test. This approach is suitable here where the panels are heterogeneous with fixed coefficients. The linear model is discussed below.

$$Z_{it} = \tau_i + \sum_{m-1}^{M} \lambda_i^{(m)} Z_{i,t-m} + \sum_{m-1}^{M} \alpha_i^{(m)} Y_{i,t-k} + r_{it} \quad (15)$$

Keeping in view the above equation, Y and $Z$are represented as two variables for time period $T$and number of countries n. Taking account of time dimension, we assume intercept τ_{it} and coefficient $\alpha_i = \left(\alpha_i^1, ...\alpha_i^m\right)$ are fixed, while regression coefficient $\alpha_i^{(m)}$ and autoregressive parameter $\lambda_i^{(m)}$ are considered to be different among cross section. The null hypothesis can be discussed as homogeneous non-causality (HNC), which concludes no association for any cross sections among panels and disused below

$H_0 : \alpha_i = 0 \ \forall_i = 1, 2, 3....., n$

The hypothesis is discussed below

$$F_{n,T}^{HNC} = \frac{1}{n} \sum_{i=1}^{n} F_{i,T} \quad (16)$$

The hypothesis is tested using Wald statistics following chi-squared distribution, which have M degree of freedom and $T \to \propto$. The standardize test of $H_{n,T}^{HNC}$, having T, $n \to \propto$ is stated below

$$H_{n,T}^{HNC} = \frac{n}{2M} \left(H_{n,T}^{HNC} - M\right) \to n(0, 1) \quad (17)$$

Dumitrescu and Hurlin (2012) study is useful to estimate the causality among panel data variables while allowing for cross-sectional heterogeneity.

Estimation and discussion

Tables 1 and 2 report the outcomes of cross-sectional dependence test on SURE estimates. Based on the probability values of Pesaran (2007) cross-sectional dependence test, all variables were showing the traits of cross-sectional dependence.

This infers that data are cross-sectionally dependent. Similarly, Table 2 also provides the statistical evidence whereby the study fails to accept of null hypothesis for cross-sectional independence by using Pesaran (2004), Breush-Pagan (LM), and Friedman tests of cross-sectional dependence. Hereby the existence of cross-sectional autocorrelation invalidates the first generation unit root and cointegration tests in panel data. Thus this study have applied CIPS (cross-sectionally augmented IPS test) unit root test introduced by Pesaran (2007).

The implications of human error learning behavior becomes significant if the data has long time periods ($t > 20$) (Pedroni, 2008; Eberhardt and Teal 2011); in such cases, it will violate the assumption of OLS by variables not having constant mean and variance in time. This leads to the problem of autocorrelation in the data (Gujarati, 2009). The presence of this property in panel data can be confirmed by using panel unit root tests. Table 3 discusses the results of CIPS tests. The null hypothesis of these tests is that the mean and variance of the variable is not constant in time such that it is non-stationary while the alternative hypothesis is that variable is stationary, which confirms that all variables are stationary at first difference. However, test was calculated for trend and without trend. Both specifications of CIPS tests confirm that mean and variance of all variables are independent of time at first difference. In addition, stationarity of variables at first difference precedes our analysis towards cointegration test introduced by Westerlund (2007). Panel cointegration test works same as time series cointegration whereby there must be significant evidence that the residuals of the long-run model converge to zero for every random shock.

Table 4 shows the outcomes of Westerlund (2007) cointegration test, which confirms the presence of cointegration among variables. Considering, the robust P value of Westerlund (2007), there is no significant evidence to accept the null hypothesis of no cointegration. This concludes the existence of a valid long-run relationship among CO_2 emission, industrial value added, agricultural value added, economic growth, urbanization and nuclear energy consumption, covering the period of 1982 to 2015 among high-, high-middle-, low-middle-, and low-income countries.

After checking the existence of cointegration, the study has estimated the long-run association among studied variables by using three different techniques such as dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS), and pool mean group (PMG) to ensure the robustness of estimates. Table 5 discusses the consequences of long-run estimates by using dynamic ordinary least square (DOLS). However, the results of fully modified ordinary least square (FMOLS) and pool mean group (PMG) discussed in Table 6 and Table 7. In high- and upper-middle-income countries,

Table 1 Pesaran (2007) cross-sectional dependence

Variables	co_2	*ava*	*iva*	*ub*	*nec*	*gdp*
High income						
CDF	10.01***	21.07***	10.96***	49.42***	0.17***	42.56***
Upper-middle income						
CDF	49.36***	19.56***	14.50***	74.99***	4.41***	60.43***
Low-middle income						
CDF	29.56***	37.05 ***	2.90***	70.19***	1.24*	54.59***
Low income						
CDF	− 1.59*	3.24***	− 1.34	17.76***	− 1.93**	3.42***

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

majority of variables exhibits positive and significant relationship with CO_2 emissions except nuclear energy consumption in high-income countries. These three techniques estimate similar results in terms of sign and statistical significance. However, among low- and low-middle-income countries agriculture value added, nuclear energy consumption shows negative and significant relationship with CO_2 emissions, while industrialization, urbanization, and economic growth will increase the level for CO_2 in the atmosphere.

Study includes the results of heterogeneous panel causality test in order to examine the robustness of pool mean group (PMG). The results of panel causality have reported in Table 8. Taking account of higher income countries confirms that agriculture value added negative and significantly Granger cause CO_2 emissions in short-run. However, nuclear energy consumption exhibits bidirectional (negative and short-run) causality with CO_2 emissions among high-income countries, while nuclear energy consumption negative and significantly Granger causes to CO_2 emissions for upper-middle-income countries in short-run. This shows the prominence for adaptation of nuclear energy for the reduction of CO_2 emissions. However, economic growth exhibits bidirectional (positive & short-run) causality with CO_2 emissions in case of upper-middle- and low-middle-income countries. Also, urbanization positively Granger causes CO_2 emissions for considering low-middle-income countries. Moreover, the coefficient of ecm_{t-1} is negative and significant, which shows the speed of convergence to long-run equilibrium, which occurs due to occurrence of any shock.

Table 2 Cross-sectional dependence

Tests	Pesaran CD (2004)	Breush-Pagan (LM)	Friedman CD
High income			
Statistics	5.674***	394.56**	60.169***
Upper-middle income			
Statistics	6.834***	285.89*	25.380***
Low-middle income			
Statistics	2.652***	453.68**	52.862***
Low income			
Statistics	2.124***	367.58**	27.179***

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

Discussion

Rise in agriculture production leads to upsurge in environmental quality for long-run because agriculture sector is less polluting among developing countries as compared to other sectors such as manufacturing and transport in low-middle-income countries (Rafiq et al., 2016). These results are constant with the findings of Ben Jebli and Ben Youssef (2016); Xu and Lin (2017); and Waheed et al. (2018). Considering agriculture sector of Indian economy, agricultural production has a huge potential to curtail the greenhouse gases. It is estimated that by 2030; agricultural production of India reduces the greenhouse gases by 50% because they substitute the fossil fuel with renewable energy sequestration through crops and soils, while they also emphasize biotechnology and biofuels. However, India also restores the soil organic carbon (SOC) pool in arable land, which reduces the CO_2 emission (Jarecki et al., 2005). On the contrary to the above findings, agriculture production leads to an increase in CO_2 emission among developed countries due to application of chemical fertilizer. Increase in usage of chemical fertilizer causes the discharge of greenhouse gases and increase the level of CO_2 emission in the environment (World Bank, 2007, 2009). Keeping in view, the high-income country; China is the world's main customer of nitrogen fertilizer. Half of the nitrogen fertilizer is used for volatilization and 5 to 10 percent by leaching. Agriculture is also a source of air pollution due to anthropogenic source of ammonia. The projection of livestock implies a 60% increase in ammonia emission from animal excreta. Ammonia gas is the main cause of acid rain, which acidifies soil, damages trees, and contaminates rivers (IPCC, 2006). Moreover, in case of low-income region, the agricultural value added has no noteworthy impact on quality of environment. The reason for this can be the lower contribution of low-income region (around 5%) of global agricultural production. On the contrary, high-income countries contribute around 25% of total

Table 3 Pesaran (2007) unit root test

High income							
Variables		co_2	*ava*	*iva*	*ub*	*nec*	*gdp*
Without trend	Level	− 14.54	− 15.275	− 12.718	1.771	− 13.999	− 7.861
	1st difference	− 9.999***	− 8.858***	− 8.671***	− 0.363***	− 9.769***	− 5.181***
With trend	Level	− 13.689	− 15.167	− 11.703	2.258	− 13.042	− 6.966
	1st difference	− 8.790***	− 8.173***	− 7.585***	0.603***	− 8.924***	− 4.243***
Upper-middle income							
Without trend	Level	− 18.39	− 16.643	− 14.551	− 1.773	− 19.68	− 12.774
	1st difference	− 11.540***	− 9.863***	− 7.722***	− 5.720 ***	− 14.100***	− 8.616***
With trend	Level	− 17.174	− 15.708	− 13.954	− 0.172	− 19.469	− 10.711
	1st difference	− 10.149***	− 9.260***	− 6.693***	− 5.218***	− 13.919***	− 6.600***
Low-middle income							
Without trend	Level	− 17.454	− 16.817	− 15.332	1.235	− 17.384	− 12.792
	1st difference	− 8.910 ***	− 9.936**	− 8.683***	− 4.312**	− 11.002***	− 8.330***
With trend	Level	− 16.466	− 15.874	− 14.722	1.149	− 16.467	− 11.466
	1st difference	− 7.751 ***	− 8.748**	− 7.819***	− 6.110***	− 9.904***	− 5.950***
Low income							
Without trend	Level	− 8.474	− 6.815	− 5.8	0.125	− 9.461	− 6.344
	1st difference	− 5.077***	− 6.821**	− 4.432***	− 2.955**	− 5.596***	− 3.576***
With trend	Level	− 7.702	− 5.955	− 5.4	1.962	− 9.404	− 6.63
	1st difference	− 4.201***	− 5.637 ***	− 5.092***	− 1.032***	− 5.475***	− 4.470***

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

global agricultural production, which indicates that higher agricultural production is a source of higher CO_2 emission (USDA ERS, 2017).

Higher industrial value added has also confirmed the positive relationship with CO_2 emission, which mentions that higher industrial activities are also a source of higher CO_2 emission. There are some factors associated with industries that are responsible for carbon emission. Firstly, the waste that industry produces is one of the aspects increasing the rate of carbon emission. Secondly, the increased demand for power supply leads to the increased burning of coal that ultimately leads to carbon emission in the form of carbon dioxide (CO_2) and carbon monoxide (CO). Thirdly, industrialization also leads to greater transportation which results in air pollution thus increased carbon content in the atmosphere (Lund & Kempton, 2008; Xu & Lin, 2015).

Estimated results have proved the existence of positive association between urbanization and emission of carbon. A

Table 4 Westerlund (2007) cointegration test

Statistics	G_t	G_a	p_a	p_t
High income				
P value	0.51	0.58	0.94	0.67
Robust *P* value	0.06**	0.04***	0.06**	0.08*
Upper-middle income				
P value	0.23	0.98	0.92	0.95
Robust *P* value	0.00***	0.00***	0.00***	0.04***
Low-middle income				
P value	0.62	0.85	0.55	0.99
Robust *P* value	0.00***	0.06**	0.00***	0.05***
Low income				
P value	0.22	0.99	0.45	0.98
Robust *P* value	0.00***	0.08*	0.00***	0.07**

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

Table 5 Long-run estimates (DOLS)

Variables	*ava*	*iva*	*ub*	*nec*	*gdp*
High income					
Coefficient	0.152***	0.506***	0.217	− 0.257***	0.216**
P value	0.02	0.00	0.17	0.00	0.06
Upper-middle income					
Coefficient	0.140***	0.168**	0.588***	0.012*	0.780***
P value	0.00	0.01	0.00	0.06	0.00
Low-middle income					
Coefficient	− 0.350***	0.447***	0.008	− 0.155***	0.669***
P value	0.03	0.00	0.89	0.00	0.00
Low income					
Coefficient	− 0.174	0.429**	0.562***	− 0.136***	1.17***
P value	0.51	0.05	0.00	0.01	0.00

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

Table 6 Long-run estimates (FMOLS)

Variables	*ava*	*iva*	*ub*	*nec*	*gdp*
High income					
Coefficient	0.22***	0.12	0.08***	− 0.16***	− 0.427***
P value	0.00	0.27	0.01	0.00	0.00
Upper-middle income					
Coefficient	0.18**	0.36	0.13***	0.36**	0.42
P value	0.04	0.18	0.00	0.06	0.13
Low-middle income					
Coefficient	− 0.14***	− 0.36	0.31***	− 0.12*	0.278
P value	0.00	0.34	0.00	0.08	0.45
Low income					
Coefficient	− 0.79***	− 0.49***	0.23***	− 0.31***	0.82
P value	0.00	0.00	0.01	0.00	0.58

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

similar finding is commendably proved by Martínez-Zarzoso and Maruotti (2011) and Zhang et al. (2015); they mentioned that some people migrate from rural to urban areas as there are a lot of job opportunities and have higher living standards and ease of life. Moreover, the increase in economic activity will create more wealth, and wealthier residents and these residents will demand high energy intensity products such as air conditioner and automobile. This further increases the urbanization trend and economic activity; however, the higher urbanization boosts the energy consumption, transportation, etc., which increase the intensity of carbon dioxide in atmosphere (Sadorsky, 2014). The empirical findings reassure the previous researches, such as (Wang & Shao, 2014; Shahbaz et al., 2016; He et al., 2016).

Table 7 Long-run estimates (PMG)

Variables	*ava*	*iva*	*ub*	*nec*	*gdp*
High income					
Coefficient	0.28**	0.14	0.08	− 0.17***	− 0.66***
P value	0.05	0.48	0.20	0.00	0.00
Upper-middle income					
Coefficient	0.12***	0.45	0.10**	− 0.60**	0.67
P value	0.00	0.13	0.06	0.07	0.34
Low-middle income					
Coefficient	− 0.31***	− 051	0.32***	0.97	0.98***
P value	0.00	0.47	0.00	0.59	0.00
Low income					
Coefficient	− 0.80***	− 0.42***	0.16	− 0.34***	0.79***
P value	0.00	0.00	0.49	0.00	0.00

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

The estimated results for nuclear energy consumption show the negative and significant relationship with CO_2 emissions among high-, low-, and low-middle-income countries, which shows that leading countries adopted the nuclear energy consumption for generation of carbon-free electricity. Specially, for the case of France and Switzerland, nuclear energy is the major source for low-carbon generation mix. In 2012, there are 450 nuclear reactors, which supply the 10% of world's electricity. This will reduce the 2.5 billion tons of carbon dioxide emission in the atmosphere. In 2016–2017, twelve reactors are under construction, which has a capacity to supply 10 GW of electricity, out of which, eight were built in China and the rest will be built in India, Pakistan, and Russia. Nuclear energy is considered as one of the major sources of energy, which act as carbon-free source of energy. However, policy maker should try to implement this source of energy at large scale but the apprehensions such as safety issues, nuclear energy processing plants, and removal of radioactive waste. Scientists have initiated research and development to curtail above-discussed issues. It is forecasted that consumption of nuclear energy will increase from 2639 billion kilowatt hours in 2005 to 3731 billion kilowatt hours in 2020 and it will further increase to 4916 billion kilowatt hours by 2035 around the world (Alam, 2013; Nuclear Energy Agency, 2002).

Empirical findings have proven that various positive effects and outcomes are associated with the carbon emission; moreover, the studies have also proved that the increasing economic activities are responsible for the carbon emissions rather they play a vigorous role in increasing carbon emission and their outcomes. Use of fossil fuels and transportation are higher in these regions to sustain the economic activities; these findings are similar with Shahbaz et al. (2017), Sarwar et al. (2017), Waheed et al. (2017). However, economic activity causes environmental deterioration because production of more goods and services emits huge amount of fossil energy, which increases the amount of carbon dioxide (CO_2) in the air (Apergis et al., 2010; Waheed et al., 2018).

Conclusion

A study discusses the new empirical understanding for the relationship between agriculture value added and emission of CO_2 for the sample of 13 high-, 23 upper-middle-, 5 low-, and 18 low-middle-income countries from 1982 to 2015. This study has incorporated second generation panel cointegration and heterogeneous Granger causality in order to estimate the causality among non-stationary and cross-sectionally dependent variables for short-run. To ensure the robustness of estimates, the long-run relationship

Table 8 Pool mean group causality

	Δco_2	Δava	Δiva	Δub	Δnec	Δgdp	ecm_{t-1}
High income							
Δco_2		0.139	0.072**	− 0.007	− 1.003***	0.06	− 0.253***
Δava	− 0.057*		0.002	− 0.002	− 0.031	− 0.085	− 0.432***
Δiva	0.247	− 0.955***		0.025	0.649**	0.534***	− 0.167***
Δub	− 1.53**	0.459	− 0.388		− 1.476	− 0.247	− 0.009*
Δnec	− 0.275***	0.018	0.003	− 0.004		0.014	− 0.358***
Δgdp	0.078	0.319	0.530***	− 0.044*	0.251		− 0.032**
Upper-middle income							
Δco_2		− 0.055*	0.017	0.001	− 0.167	0.089**	− 0.353***
Δava	− 0.087*		− 0.068	− 0.006**	0.538**	− 0.141***	− 0.356***
Δiva	0.063	− 0.439**		− 0.001	0.211	0.157**	− 0.311***
Δub	1.072	3.442	− 1.68		− 1.653	− 0.605	− 0.028***
Δnec	− 0.092***	− 0.013	0.034	0.005		0.01	− 0.376***
Δgdp	0.317*	− 0.113	0.234**	0.006	0.547		− 0.125***
Low-middle income							
Δco_2		− 0.021	0.037*	− 0.002	− 0.704***	.049***	− 0.310***
Δava	0.075		− 0.077	− 0.017	0.61	− 0.094	− 0.199***
Δiva	0.145	− 0.624		0.022	0.173	0.097	− 0.124***
Δub	− 3.760***	− 2.071	0.159		− 1.708	0.464	− 0.017***
Δnec	− 0.063	0.037	0.003	0.0007		0.009	− 0.328***
Δgdp	0.524**	0.28	0.210**	− 0.012	1.523		− 0.048**
Low income							
Δco_2		− 0.014	0.065	− 0.003	0.304	0.066***	− 0.371***
Δava	0.248		− 0.758**	− 0.021	0.289	− 0.122	− 0.177***
Δiva	0.197	− 0.180**		− 0.015	− 0.085	− 0.093***	− 0.278***
Δub	− 0.78	− 0.597	− 0.118		− 3.204	0.517	− 0.017**
Δnec	− 0.071	− 0.006	− 0.004	0.006***		0.023	− 0.384**
Δgdp	0.838	− 0.013	− 0.13	0.017**	0.161		− 0.060***

*, **, and *** denote the significance level of 0.10, 0.05, and 0.01

between the variables are estimated using the dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS), and pool mean group (PMG), when as CO_2 emission is dependent variable in the model. The findings are robust to the presence of cross section dependence within the included variables among different economies.

In the long-run process of economics regulates the association between agriculture value added and emission of CO_2. Findings reveal the positive association among value added of agriculture and environmental degradation among high- and upper-middle-income countries, while increase in agriculture value added leads to decrease in emission of CO_2 among low-middle-income countries. Furthermore, it is important that the direction of short-run causality changes for different time horizon. In short-run, agriculture value added exhibits negative and bidirectional causality with emission of CO_2 among upper-middle-income countries. However, agriculture value added negatively Granger cause to CO_2 emission for high-income countries in short-run. Furthermore, nuclear energy consumption exhibits negative bidirectional causality with emission of CO_2 in sort-run.

Our results presented that use of pesticide and nitrogen fertilizer among high-income countries affects the quality of environment. However, developing countries have less polluting agriculture sector as compare to other sectors of the economy that is why increase in agriculture value added will improve the environmental excellence. The results suggest that establishing new techniques in agriculture sector such as fertilizer to meet the excess demand of population has an adverse effect on environment. Based on econometric evidence, we recommend the use of environment friendly agriculture techniques, such as adopt clean water, curtail the greenhouse gases, and use less chemical fertilizer among developed countries. The will increase the agriculture production and combat global warming by reducing CO_2 emission.

Appendix

Table 9 List of countries

Sr. no.	Low-middle income	Low income	Upper-middle income	High income
1	Bangladesh	Congo, Dem. Rep.	Bulgaria	Argentina
2	Bolivia	Ethiopia	Brazil	Venezuela, RB
3	Congo, Rep.	Nepal	Botswana	Australia
4	Egypt, Arab Rep.	Togo	China	Austria
5	Guatemala	Zimbabwe	Colombia	Chile
6	Honduras		Costa Rica	Finland
7	Indonesia		Cuba	France
8	India		Dominican Republic	Japan
9	Kenya		Algeria	Korea, Rep.
10	Sri Lanka		Ecuador	Netherlands
11	Morocco		Gabon	Norway
12	Nigeria		Iran, Islamic Rep.	New Zealand
13	Pakistan		Iraq	Sweden
14	Philippines		Jamaica	
15	Sudan		Jordan	
16	Senegal		Mexico	
17	El Salvador		Mauritius	
18	Zambia		Malaysia	
19			Panama	
20			Peru	
21			Thailand	
22			Tunisia	
23			South Africa	

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