Renewable and Sustainable Energy Reviews 65 (2016) 175–182

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Does environmental degradation shackle economic growth? A panel data investigation on 11 Asian countries

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ARTICLE INFO

Article history:
Received 22 December 2015
Received in revised form
13 March 2016
Accepted 28 June 2016
Available online 16 July 2016

JEL classification:
C33
Q50
O40
N55

Keywords:
CO_2 emissions
Economic growth
Panel data
Asia

ABSTRACT

Sustainable economic growth needs to be the primary objective of every government, including developing Asian countries, to improve the social welfare of the people. Therefore, to achieve the desirable level of sustainable economic growth, environmental degradation must be controlled without lowering real growth and the well-being of the society. This study empirically investigates the impact of environmental degradation by CO_2 emissions on the economic growth of 11 Asian countries between 1990 and 2011. Based on the nature of the data, traditional panel estimation techniques encompassing fixed effects and random effects are employed, in which the results of Hausman's test and other tests show that the use of fixed effects is preferable over the random-effect estimator. Empirical results exhibit that environmental degradation has a significantly negative impact on economic growth. Empirical findings also suggest that environmental degradation should be regulated. Therefore, environmentally enlightened management policies for the decrease of CO_2 emissions and fuel consumption by transportation and industries need to be pursued by Asian countries. The adoption of safe carbon emission cutback policies is a promising path to sustainable economic growth.

Contents

1. Introduction

Environmental pollution is a vital issue in the process of sustainable economic development because it has threatening consequences for economic growth and human well-being. Pollution is the cause of various negative effects on health, resource exhaustion, and natural calamities associated with climate change. Environmental pollution occurs when the natural environment is vulnerable to the decomposition of unnaturally produced elements, which humans are not knowledgeable of handling. Focal forms of pollution include atmospheric, water, noise, land dilapidation, and soil. The sources of atmospheric pollution include the burning of fuels to create energy for heating and power production in the domestic and industrial sectors; exhaustion of emissions due to transport automobiles that consume diesel, petrol, and oil, among others; and production of waste gases, dust, and heat from

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http://dx.doi.org/10.1016/j.rser.2016.06.087
1364-0321/

industrial sites comprising chemical manufacturers and electrical power-generating stations. The three key contaminants of ambient air quality are nitrogen dioxide, particulate matter, and sulfur dioxide [11,18,51].

Cutting of trees, soil dilapidation, and loss of biological diversity are important issues for academicians, economists, and policy makers. The predominant causes of air and water pollution and global warming are objectively understood as the consequence of enhanced and unrestrained human activities at distinctive stages of economic growth and development, such as agriculture, industries, transportation, and energy production. Environmental, economic, and social issues are interconnected and must be resolved not only for the development of today's human welfare, but also for that of future generations. Environmental degradation hampers growth and threatens future development in all aspects of human welfare.[1] Pollution has increased considerably because of human activities, mostly through the usage of fossil fuels and the changes in land use directly connected with economic development. The impacts of CO_2 emissions have been shocking, especially global warming, which affects the environment and human well-being. Numerous experts have explicated the need to reduce individual carbon footprints and invest billions to mitigate the risks of change in the earth's environment [30,54].

Auci and Trovato [10] expound that the environment will probably be affected as the economy develops, which will have an unfavorable impact on natural order, society, economy, and infrastructure. The adverse relation between economic growth and environmental degradation requires appropriate environmental policy reactions and strategies locally, regionally, nationally, and internationally. Sebri and Salha [49] state that the main cause of global warming is the increase of CO_2 emissions in Brazil, Russia, India, China, and South Africa (BRICS). Kasman and Duman [40] also mention that industrial revolution not only began a new period of fast economic growth among countries, but simultaneously produced global warming and climate change. The main aspect of industrial development is the conversion of global organic economies based on animal and human power to inorganic economies based on fossil fuel sources. The usage of fossil fuels unambiguously and constantly disorders the carbon levels in the atmosphere and causes the heat to be conserved in the atmosphere. Alexander-Kearns and Cassady [6] suggest that smart policies for controlling CO_2 emissions can provide an impetus to economic growth. Therefore, the correlation between environmental humiliation by CO_2 emissions and economic growth has been a central topic triggered by concerns for the environment and sustainable growth and development.

CO_2 emissions truly play a significant role in present-day debates owing to their detrimental effects on the process of sustainable growth and development. Pollution occurs because CO_2 emissions reduce output by decreasing the productivity of human-made capital, as well as the workforce by affecting human health due to polluted air, water, and so forth. Available literature reveals that prior studies empirically explore the causal linkage between CO_2 emissions, economic growth, and energy use along with some other variables,[2] and some studies are only confined to test the validity of the Environmental Kuznets Curve. Quantitative studies on the effect of CO_2 emissions on growth in the context of developing Asian countries are uncommon. Thus, the current study aims to quantitatively investigate whether there is any adverse effect of environmental degradation by CO_2 emissions[3] on economic growth measured by real GDP per capita in 11 Asian countries between 1990 and 2011. This study also considers other explanatory variables, such as energy consumption, inward foreign direct investment, and human capital. Countries used in this study are low, lower, and middle countries based on income level according to the World Bank classification [Bangladesh (low income); India, Indonesia, Mongolia, Pakistan, Sri Lanka, Vietnam, and the Philippines (lower middle income); and China, Malaysia, and Thailand (upper middle income)].[4] In addition, this study assumes that the sample countries have similar characteristics. The empirical findings are expected to guide policy makers on CO_2 emissions and economic development in order to formulate appropriate sustainable development-oriented policies that are largely environmentally conducive. This study contributes to the literature on the impact of environmental degradation by CO_2 emissions on the economic growth for Asian countries and can be extended to other countries to boost sustainable economic development.

1.1. CO_2 emissions and economic growth in Asia: an overview

Rapid economic and population growth create crucial social results from the environmental problems of air pollution, deforestation, global warming, overfishing, urban overflow, and restricted safe water supplies all over the Asia-Pacific region.[5] According to the United Nations Environment Program (2012), the Asia-Pacific is the fastest flourishing economic region in the world, yet unsustainable economic development, population growth, and enlarged consumption and urbanization threaten its sustainable economic growth and development. The Asian Development Bank [1] noted that the entire Asia-Pacific region has achieved substantial success with the millennium development goals, especially in diminishing income poverty. However, the region still faces numerous constant and evolving threats in rising inequality, demographic shifts, and unplanned urban population growth, along with climate change and environmental burdens. Economic growth, which is motivated by industrialization, has essentially relied on the improper utilization of natural resources, and thereby contributed to environmental problems.

The existing scarce natural resources are under excessive pressure because of the expanding population growth and urbanization. The deleterious impacts of urbanization and industrialization have destroyed ambient air quality, adversely affected proper solid waste disposal, and created unjustifiable consumption pattern and resource inadequacy. The air quality in South Asian countries is affected by the emission of pollutants, such as particulate matters and gaseous emissions, including sulfur oxides and nitrogen oxides. This pollution is apparent in the destruction of ambient air quality in main cities where, in 2010, CO_2 emissions per capita reached 1.4 metric tons. Urban areas are facing the most significant environmental problems because of the nonexistence of proper solid waste disposal and the absence of improved sanitation technology. Poverty elimination and environmental sustainability have been evidently observed as key challenges in attaining sustainable development in the South Asian sub-region [48]. Wang et al. [57] reveal that the fast growth of energy use in China has led to enlarged emissions of air pollutants.

According to the BP Energy Outlook [20], the worldwide

[1] [26].

[2] [24,27].

[3] Due to the non-availability of data on variables include nitrogen dioxide, particulate matter, and sulfur dioxide emissions pollutants, this study uses CO_2 emissions as a proxy variable for environmental degradation.

[4] Countries by Income Group: Classification of Countries is from the World Bank, July 2012, on the basis of 2011 GNI per capita. Retrieved http://www.gfmag.com/global-data/economic-data/pagfgt-countries-by-income-group. Moreover, this study intends to use many developing countries from Asia, but the data (balanced) on the set of incorporated variables are available only on these 11 Asian's countries.

[5] [59].

number of vehicle fleets (commercial vehicles and passenger automobiles) will multiply from approximately 1.2 billion today to 2.4 billion by 2035. The statistics reveal that around 88% growth will occur in developing countries, whereas some OECD markets are already at overload levels. Worldwide CO_2 emissions from energy consumption grow by 25% [1% per annum (p.a.)]. The emissions remain fairly above the level suggested by scientists. Similarly, CO_2 emissions in 2035 will likely be about 18 billion tons above the International Energy Agency's 450 scenario. Fast population growth and rises in per capita income are the vital drivers behind the increasing demand for energy. GDP is predicted to be more than double, with non-OECD Asia providing approximately 60% of that growth. The worldwide GDP per capita in 2035 will likely be 75% higher than today. China and India are the main drivers of the non-OECD growth and are expected to grow by 5.5% p.a. between 2013 and 2035. Data reveal that by 2035, they will respectively be the world's biggest and third biggest economies, both accounting for almost one-third of the world population's and GDP. The statistic indicates that China is the biggest producers of energy-related CO2 emissions in 2015, based on their share of global energy-related CO2 emissions estimated 28.03%, where India and Indonesia ranked 3rd and 11th with 5.81% and 1.32% respectively of global CO2 emissions in the same year [53].

Fig. 1 shows that the global GDP, energy use, and CO_2 emissions trends will persistently grow between 1990 and 2035. The pace of GDP is relatively high compared to that of energy use, and CO_2 emissions are low but constantly increasing. Energy consumption and CO_2 emissions are also parallel from 1990 to 2015, though energy consumption is expected to be higher than CO_2 emissions after 2015. Fig. 2 reveals that the CO_2 emissions of China are persistently increasing, followed by India and Indonesia. Fig. 3 clearly presents that the GDP per capita (constant 2005) of Malaysia among all 11 countries from Asia is high at USD 3147 to USD 6535 from 1990 to 2011, whereas the GDP per capita of Bangladesh is estimated at USD 320 to USD 650 in the same period. Interestingly, the GDP per capita of China displays an increasing trend and is estimated to be USD 3150, almost equaling Thailand's GDP per capita of USD 3158 in 2011.

The improper outputs of CO_2 emissions are detrimental and should be processed to the degree of performance [52]. CO_2 emissions greatly contribute to greenhouse gas emissions and are, therefore, a key source of environmental degradation.[6] Azomahou et al. [15] suggest that the central motive for studying CO_2 emissions is due to their important role in the contemporary debate on environment defense and sustainable economic development. The connection between CO_2 emissions and economic growth has significant implications for environmental and economic policies. Alam et al. [4] reveal that environmental effluence is one of the essential issues in the ubiquitous process of sustainable economic development.

This study is organized as follows. Section 2 provides a pertinent literature review on the relationship between CO_2 emissions and economic growth. Section 3 deals with the empirical methodology, data description, and estimation procedure. Section 4 presents the empirical results and discussions. Finally, Section 5 concludes the study.

2. Literature review

A plethora of prior studies aim to examine the causal relationship between CO_2 emissions and output on different aspects and countries by using broad varieties of methodologies for

[6] [22].

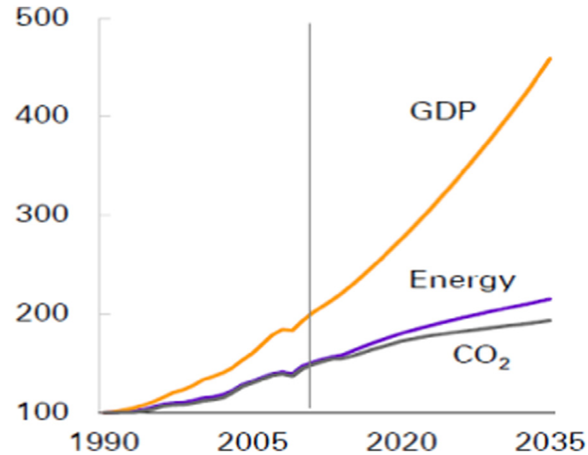

Fig. 1. Gross domestic product (GDP), energy consumption and CO_2 emissions. Source: [20]. - Index: 1990 = 100.

empirical investigation. However, the empirical results are still elusive. For example, Farhani and Rejeb [27] expound that energy plays a vigorous role in the process of sustainable development. However, previous studies have endeavored to analyze the direction of causation among carbon emissions, energy use, and economic growth. The empirical findings of these studies fail to find a causal link between CO_2 emissions, energy use, and short-term growth in 15 Middle East and North African countries over the period of 1973–2008. Papiez [45] investigates the causal associations between CO_2 emissions, energy usage, and economic growth by using panel data for the Visegrad Group countries covering the period of 1992–2010. The empirical results of the panel short-run Granger causality tests show the presence of bidirectional causality between CO_2 emissions and economic growth. Moreover, the short-run dynamics indicate one-way causality from energy use to economic growth in the sample countries.

Alam [5] observes that in the short run, a causality running from carbon emissions to economic growth exists in the case of developed countries. However, joint tests for persuasive causality reveals that economic growth and CO_2 emissions have a bidirectional causal linkage in a panel of 25 countries from 1993 to 2010. Ejuvbekpokpo [25] discovers that CO_2 emissions had significantly negative effects on economic growth in Nigeria during 1980–2010. Leitao [36] examines the relationship among economic growth, renewable energy, carbon emissions, and globalization of the Portuguese economy over the period of 1970–2010. The empirical results indicate that energy consumption had a significantly positive effect on economic growth. Similarly, the impact of CO_2 emissions on economic growth was observed to be significantly positive during the period under study. The empirical results of Dritsaki and Dritsaki [24] reveal that a one-way causality running from carbon emissions to economic growth and energy consumption and economic growth existed in the long-term, in the case of Greece, Spain, and Portugal from 1960 to 2009. Similarly, Bozkurt and Akan [19] discover that CO_2 emissions adversely affected the economic growth of Turkey during the period of 1960–2010, whereas energy consumption positively affected the economic growth. The empirical results are found to be statistically significant.

2.1. Prior empirical studies on Asia

Prior studies on the impact of CO_2 emissions in the context of Asian countries are also very scarce. Pao and Tsai [44] find a unidirectional causality from energy consumption and CO_2 emissions to economic growth for a panel of BRIC countries between 1971

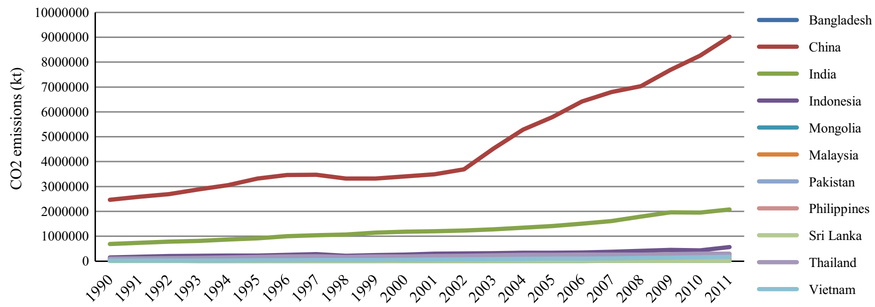

Fig. 2. CO_2 emissions (kt): Asian 11 countries (1990–2011). Data source: World Development Indicators (2015), the World Bank database.

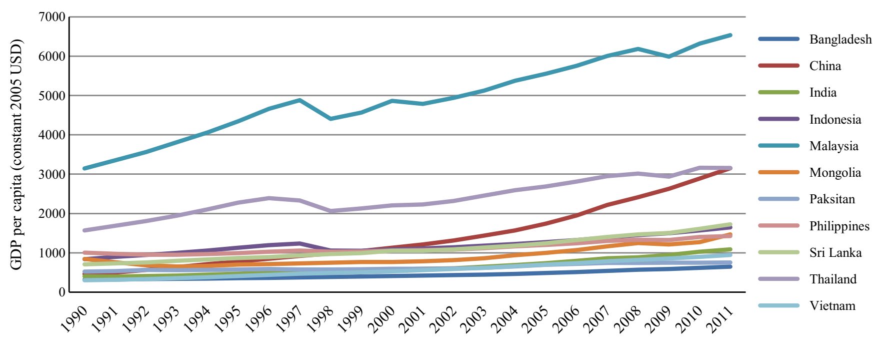

Fig. 3. GDP per capita (constant 2005 USD): Asian 11 countries (1990–2011). Data source: World Development Indicators (2015), the World Bank database.

and 2005, with the exception of Russia (1990–2005). The study suggests mitigating emissions to positively affect economic growth, expanding energy supply investment and energy efficiency, and pursuing energy conservation policies to decrease needless wastage of energy that can be started for energy-dependent BRIC economies. Lean and Smyth [37] observe that Granger causality tests imply a one-way Granger causality running from CO_2 emissions to economic growth in the long run for five ASEAN countries from 1980 to 2006. Ghosh [29] investigates the relationship between CO_2 emissions and economic growth of India over the period 1971–2006. The findings reveal that any effort to diminish CO_2 emissions could undermine the level of national income in the short term. The analysis of IRFs and VDs by Tiwari [55] reveals that CO_2 emissions have negative effects, whereas energy use has a positive effect on the GDP of India. The study also suggests that the decrease in energy use will have an adverse impact on the economic growth of the Indian economy because energy use drives GDP. Similarly, suitable policies need to be devised to deal with CO_2 emissions desirably. Azlina et al. [14] observe a unidirectional causality running from pollutant emissions to economic growth for Malaysia over the period 1970–2010.

Zhai and Song [61] find that in the long and short run, CO_2 emissions have significantly positive effects on the economic growth of China over the period 1990–2011. The findings also reveal that the energy structure has an inverse effect on the economic growth of China. Wahid et al. [56] indicate that causality runs from energy consumption to economic growth in Indonesia and Malaysia from 1975 to 2011. Ghosh et al. [28] investigate the relationship between economic growth, carbon emissions, and energy consumption in Bangladesh over the period 1972–2011. They discover that energy consumption has a significantly positive effect on economic growth, whereas CO_2 emissions have a statistically insignificant negative effect. Lee and Brahmasrene [35] find significantly inverse relationships between CO_2 emissions and economic growth for ASEAN-9 over the period 1991–2009. Yang and Zhao's [60] results indicate that a two-way causality exists between CO_2 emissions and economic growth in India during 1970–2008. Lim et al. [38] observe that a unidirectional causality runs from carbon emissions to economic growth in the Philippines during 1965–2012. Azam et al. [12] probe the relationship between energy use and economic growth in Indonesia, Malaysia, Thailand, Singapore, and the Philippines from 1980 to 2012. The empirical results reveal that energy use has a significantly positive impact on economic growth in the long run for almost all five ASEAN countries during the abovementioned period. In a recent study, Peng et al. [46] examine the Granger causality linkage among economic growth, foreign direct investment (FDI), and CO_2 emissions for 16 provinces from the three main regions of China during 1985–2012. The empirical findings reveal that economic growth is Granger-causing CO_2 emissions in Hubei, Gansu, Guangxi, and Neimenggu. A two-way causality between these two variables in Shanxi is also observed.

Previous studies reveal that investigations on the direct impact of CO_2 emissions on economic growth are insufficient. Most studies either overlook or ignore the impact of environmental degradation on economic growth. Therefore, this study aims to empirically explore the impact of environmental degradation by CO_2 emissions on economic growth.

3. Empirical methodology and data

The econometric model used in this study is derived from a production function,[7] in which the level of a country's output depends on the environmental degradation measured by CO_2 emissions, energy consumption, net foreign investment inflow, and human capital. To analyze the impact of CO_2 emissions along with other regressors, the following basic expressions are specified and written symbolically as

$$G_{it} = \beta_i + \beta_1 EN_{it} + \beta_2 EC_{it} + \beta_3 IN_{it} + \beta_4 GS_{it} + \beta_5 HK_{it} + \varepsilon_{it}, \quad (3.1)$$

$$G_{it} = \beta_i + \beta_1 EN_{it} + \beta_2 EC_{it} + \beta_3 IN_{it} + \beta_4 GS_{it} + \beta_5 HK_{it} + l_i + m_{it}, \quad (3.2)$$

[7] [50].

where $i=1, 2, \ldots, N=11$; $t=1, 2, \ldots, T=22$.

In Eqs. (3.1) and (3.2), β_1, β_2, β_3, β_4, and β_5 are the coefficients, and i and t are the ith country and tth time period respectively. G is the economic growth measured by GDP per capita, EN is the environmental degradation proxied by CO_2 emissions, IN is the net FDI, EC is energy consumption, GS is gross saving, HK is human capital measured by life expectancy, and ε_{it} is error terms. The term β_i in Eq. (3.1) indicates the constant parameter that varies across countries but not over time. Every individual constant controls for country-specific differences, though the error terms (ε_{it}) are supposed to be independent, with the mean zero (0) and constant variance ($\sigma_\varepsilon{}^2$) for all included countries and through the time periods. Similar in Eq. (3.2), l_i is the country-specific random effects that vary across countries. It is supposed to be random and not correlated with the independent built-in variables in the model. Likewise, the m_{it} term is the country-specific error.

A brief justification of the explanatory variables used in this study and in Eqs. (3.1) and (3.2) is as follows. Sustainable development is highly desirable because it exposes the requisite for a meticulous balance between economic growth and environmental conservancy. However, every country is ambitious in achieving global green growth, where the prospective economic and social effects of environmental dilapidation are exceptionally important for developing countries. These developing countries are the most at risk to climate change and have a tendency to be more dependent than developed countries on the utilization of natural resources for economic growth. Moreover, numerous developing countries face risks of premature death due to pollution, poor water quality, and diseases linked with the changing climate; therefore, all of these factors attenuate their development [43]. Borhan et al. [18] also expound that environmental pollution directly dampens output by decreasing the yield of man-made capital and labor. Various studies, including Bianco et al. [17], highlight that even with important drivers of economic growth, such as abundant resources and energy efficiency, investment in infrastructure and improved innovation can also be vital elements for the decrease of greenhouse gas emissions if they are properly performed. Alexander-Kearns and Cassady [6] suggest that smart policies for the control of carbon emissions could incite economic growth.

Numerous policy makers and researchers assert that FDI inflows (IN) can have a substantial constructive impact on the development effort of a host country. In addition, FDI not only supplies direct capital financing but can also be a source of worthy technology and know-how while promoting associations with local firms that can help spur an economy. FDI is often seen as a key catalyst for economic growth in developing countries and is a significant vehicle of technology transfer from developed to developing countries [13,41,7].

Another explanatory variable in this study is energy consumption (EN). Energy clearly plays an imperative role in an economy's performance on both demand and supply. On the demand side, energy is the important product that a consumer chooses to purchase in order to maximize their utility. On the supply side, energy is one of the essential factors of production aside from capital, labor, and materials. Consequently, energy as a valuable input in the process of economic growth and development cannot be overlooked [11,12,21]. Bergasse and Paczynski ([16]:1) indicate that "Energy plays a crucial role as a global commodity and as a cornerstone of socio-economic development." Similarly, HK is usually measured through education and health indicators. Human capital affects the process of economic growth because individuals with longer life expectancies are likely to save more, thus fueling capital accumulation and contributing to economic growth [3]. Therefore, life expectancy is one of the important indicators of human health and economic growth and development of a country. Lorentzen et al. [39] use cross-country variation in geo-climatological conditions to pinpoint the influence of interest and find evidence for higher life expectancy that leads to the promotion of economic growth. Meanwhile, GS is another explanatory variable in this study. The higher the investment and saving rates, the more aggregate capital per labor is produced [50]. One of the important determinants of economic growth identified in literature is the increase in the capital-to-labor ratio (i.e., investment and savings ratio), which is an important source of economic growth [9].

For empirical estimation purposes, the data on all variables are obtained from the World Development Indictors [58] and World Bank database (http://data.worldbank.org/data-catalog/world-development-indicators). Data on all variables are transformed into the natural log form. The logarithm transformation is a fairly standard procedure used in prior studies. Such logarithm transformation in regression analysis helps to deal with a situation where a nonlinear association may exist in data on the response and explanatory variables. Log transformation is also a useful means to convert an otherwise skewed distribution in line with a relatively more nearly normal form. In this way, log transformation significantly helps manage the nonlinearity that exists among the variables and refine data for probable skewedness. Table 1 provides the data definitions and expected signs, and Table 2 reports the descriptive statistics covering all included variables.

3.1. Estimation procedure

The available pertinent economic literature indicates that different methods are used to explore the relationship between environment degradation and economic growth. For example, Rahman and Porna [47] use the panel Granger causality test for Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka on their data from 1970 to 2008. Sebri and Salha [49] employ the autoregressive distributed lag bounds testing approach and vector error correction model on data over the period 1971–2010 for BRICS countries.

Table 1
Definition of variables and expected sign.

Variables	Definition	Sign
Dependent variable:		
GDP per capita (G)	GDP per capita is GDP divided by midyear population and the data are in constant 2005 US dollars.	
Independent variables:		
CO_2 emissions (kt) (EN)	Carbon dioxide emissions generated during uses of solid, liquid, and gas fuels as well as gas flaring.	−
Energy use (kg of oil equivalent per capita) (EC)	Energy consumption is the usage of primary energy before conversion to other end-use fuels.	+
Foreign direct investment (IN)	Net foreign direct investment inflows are the aggregate of equity capital, reinvestment of earnings, other long-term, and short-term capital as exposed in the balance of payments. Data are in US dollars millions.	+
Life expectancy at birth, total (years) (HK)	Life expectancy at birth denotes the span of number of years a newly born child would live.	+
Gross savings (GS)	Gross savings are computed as gross national income excluding aggregate consumption, including net transfers. Data are in US dollars million.	+

Table 2
Descriptive statistics.

	G	GS	EN	EC	IN	HK
Mean	1395.687	135,214.6	622,095.4	797.5026	10,694.74	68.2583
Median	952.1239	29,877.46	103,990.6	512.4889	1637.000	68.6156
Maximum	6535.124	3,644,043.	9,019,518.	2808.030	331,591.7	75.4579
Minimum	301.3124	96.1054	3868.685	114.1886	−4550.355	58.5292
Std. Dev.	1304.693	417,296.2	1,452,672.	593.0644	35,894.04	4.4358
Observations	242	242	242	242	242	242

Dritsaki and Dritsaki [24] use the fully modified ordinary least squares and dynamic OLS approaches on Greece, Spain, and Portugal over the period 1960–2009. Similarly, Gul et al. [32] utilize the maximum entropy bootstrap on Malaysia during 1975–2013. However, the present study uses traditional panel data techniques covering both fixed-effect and random-effect models based on the nature and length of the panel data. Such techniques are relatively appropriate options for investigating the impact of environmental degradation on economic growth for 11 Asian countries from 1990 to 2011.

This study implements Hausman's test [33] to discover whether fixed-effect or random-effect estimators are right for estimation. The guideline for Hausman's test is as follows: If the p-value Prob > chi2 is bigger than 0.05, then it implies insignificance and it is suitable to implement a random-effect estimator; if we obtain a significant p-value, then the fixed-effect estimator is suitable to be employed.[8] In this study, Hausman's test suggests that the fixed-effect estimator is superior to the random-effect estimator.

4. Results and discussions

For the empirical analysis, a balanced panel data set of 22 years is used for the 11 Asian countries. The sample size of the study is 242 ($n = 22 \times 11$). Both fixed-effect and random-effect estimators are used, though Hausman's test and Clark and Linzer's [23] study prefer the use of a fixed-effect estimator. The empirical results of fixed-effect and random-effect estimators are reported in Tables 3 and 4 respectively. The two tables clearly exhibit that the estimation has a predominantly significant explanatory power based on the adj. R^2 value of above 90%. This result means that the coefficient of determination (adj. R^2) explains the above 90% variations by the included regressors, namely, EN, EC, FDI, and HK, in the response variable (real GDP per capita). In addition, the reported F-statistics are fairly large to acknowledge that a joint significance exists among the chosen regressors. All four regressors affect economic growth in 11 Asian countries during the period under the study. Similarly, almost all explanatory variables are individually significant statistically, which endorse and suggest that the model is technically and statistically appropriate.

The empirical result on the impact of environmental degradation on economic growth reveals that CO_2 emissions are negatively related to economic growth, implying that high CO_2 emissions dampen the economic growth in selected Asian countries. The coefficient of the CO_2 variable correctly reflects the theoretical expectations. The estimated coefficients of −0.260 and −0.234 are found for the CO_2 emissions (RE and FE Table 3) variable, which is statistically significant at the 1% level. The results demonstrate that one unit change in the CO_2 emissions will decrease by −0.260 and −0.234 units in the GDP per capita. To further confirm the impact of CO_2 emissions on economic growth, this

[8] ([31]:421)

Table 3
Panel estimates (response variable is GDP per capita).

Variables	Random-effects		Fixed-effects	
	Coefficients	t-ratio	Coefficients	t-ratio
EN	−0.2606* [0.0238]	10.9353	−0.2349* [0.0483]	4.86621
EC	0.8561* [0.0365]	23.4815	0.8515* [0.0662]	12.8479
GS	0.2222* [0.0142]	15.6498	0.2044* [0.0150]	13.6082
IN	0.0107*** [0.0067]	1.6027	0.0140*** [0.0069]	2.0159
HK	1.3560* [0.3404]	3.9832	1.3525* [0.4307]	3.1406
Constant	−3.5645** [1.3376]	2.6649	−3.6647*** [1.6396]	2.2352
R^2	0.9204		0.9886	
Adj. R^2	0.9187		0.9878	
S.E. of regression	0.0846		0.0804	
F-statistic	534.3687		1272.645	
Prob(F-statistic)	0.0000		0.0000	
Correlated Random Effects – Hausman Test				
Test cross-section random effects				
Test Summary		Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random		29.9697	5	0.0000

Standard errors values are in parentheses.
* Statistically significant at 1% levels.
** Statistically significant at 5% levels.
*** Statistically significant at 10% levels.

Table 4
Panel estimates (response variable is GDP per capita).

Variables	Random-effects		Fixed-effects	
	Coefficients	t-ratio	Coefficients	t-ratio
EN	−0.2632* [0.0238]	11.0385	−0.2516* [0.0532]	4.7317
EC	0.7961* [0.0373]	21.3119	0.7762* [0.0747]	10.3872
GS	0.2267* [0.0149]	15.1633	0.2076* [0.0159]	13.0378
IN	0.0091 [0.0071]	1.2784	0.0098 [0.0075]	1.3125
HK	1.8846* [0.3529]	5.3400	2.2178* [0.4659]	4.7601
Constant	5.3732* [1.3885]	3.8698	−6.6023* [1.7697]	3.7307
R^2	0.9097		0.9877	
Adj. R^2	0.9077		0.9867	
S. E. of regression	0.0881		0.0834	
F-statistic	443.7864		1120.287	
Prob(F-statistic)	0.0000		0.0000	
Correlated Random Effects – Hausman Test				
Test cross-section random effects				
Test Summary		Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random		30.6685	5	0.0000

Note: Asterisk * shows statistically significant at 1% level.
Explanatory variables are in one period lagged form (t−1) Standard errors values are in parentheses.

Table 5
Robust Least Squares estimates (response variable is GDP per capita).

Method: Robust Least Squares Robust estimation type: M-estimation M settings: weight=Bisquare, tuning=4.685, scale=Huber Huber Type I Standard Errors & Covariance Variables	Coefficients	z-Statistic
EN	−0.4801* [0.0150]	31.9397
EC	0.9747* [0.0169]	57.3875
GS	0.4443* [0.0138]	32.1638
LE	0.1311* [0.1893]	0.6928
Constant	1.2424*** [0.7600]	1.6347
R-squared	0.7997	
Rw-squared	0.9627	
Adjusted R-squared	0.7963	
Adjust Rw-squared	0.9627	

Note: Asterisks *, and *** shows statistically significant at 1%, and 10% levels respectively.
Standard errors values are in parentheses.

Table 6
Robust Least Squares estimates (response variable is GDP per capita).

Method: Robust Least Squares Robust estimation type: M-estimation M settings: weight=Bisquare, tuning=4.685, scale=Huber Huber Type I Standard Errors & Covariance Variables	Coefficients	z-Statistic
EN	−0.4670* [0.0151]	30.9101
EC	0.9560* [0.0171]	55.9901
GS	0.4413* [0.0139]	31.6591
LE	0.4207* [0.1885]	2.2318
Constant	0.0603* [0.7569]	0.0796
R-squared	0.8033	
Rw-squared	0.9632	
Adjusted R-squared	0.7997	
Adjust Rw-squared	0.9632	

Note: Asterisk * shows statistically significant at 1% level.
Standard errors values are in parentheses.

study uses one period lag of all explanatory variables. Table 4 reports the empirical results and shows that the impact of CO_2 emissions on economic growth is negative. The estimated coefficients size of −0.263 and −0.251 are found to be statistically significant at the 1% level (RE and FE Table 4). The estimated coefficients of CO_2 emissions indicate that one unit change in the CO_2 emissions will restrain by −0.263 and −0.251 units in the GDP per capita. Therefore, the empirical result of this study regarding the impact of CO_2 emissions on economic growth is in accordance with the findings by Tiwari [55], Bozkurt and Akan [19], Lim et al. [38], and Lee and Brahmasrene [35], but contradictory to those of Zhai and Song [61] and Ghosh et al. [28].

In view of the results reported in Tables 3 and 4, energy consumption and human capital by life expectancy have significantly positive impacts on economic growth at the 1% level of significance. Empirical results on inward FDI show that it is positively related to economic growth and statistically significant at the 10% level only where FDI is in current form (Table 3). Similarly, one period lagged GS has a significantly positive impact on economic growth for 11 Asian countries during the period under study. This study also implements the method of robust least squares to further verify the impact of CO_2 emissions along with other explanatory variables, namely, EC, incoming FDI, GS, and HK on economic growth using explanatory variables in current form and one period lagged form. The empirical results of the robust least squares method are presented in Tables 5 and 6, wherein the results found are almost similar to the findings given in Tables 3 and 4. Thus, these results validate that environmental degradation by CO_2 emissions has an adverse impact on economic growth. In the same way, the portfolio of the other explanatory variables has a significantly positive relationship with economic growth as expected. These results are in line with the findings of relevant studies. Therefore, the findings of the study are logically, technically, and statistically plausible for onward policy consideration.

5. Concluding remarks

This study is motivated by the need to evaluate the impact of environmental degradation by EN along with EC, IN, GS, and HK on economic growth measured by real GDP per capita (G) for 11 Asian countries over the period 1990–2011. The empirical results reveal that environmental degradation has a significantly negative impact on economic growth; therefore, the broad objective of this study is investigated empirically. The result confirms the finding of previous studies that environmental degradation discourages economic growth, which is also consistent with theoretical outlooks. The effects of other control variables also encourage both theoretical prospects and prior empirical findings. The expected positive impacts of EC, inward FDI, GS, and HK on economic growth are also verified. As such, environmental degradation in the form of CO_2 emissions is damaging to the economic growth of the 11 Asian countries.

CO_2 emissions consequently condense the level of aggregate output in these economies. Studies on CO_2 emissions and its economic impacts on Asian economies are very essential for generating awareness and offering contextual information for the pursuit of appropriate policies. To boost the level of growth of Asian economies, formulating adequate policies that can constantly decrease CO_2 emissions is required. Given that enlarged concentrations of CO_2 emissions in the atmosphere might lead to global warming, carbon tax, which is a policy instrument for decreasing CO_2 emissions, is often suggested by economists. The carbon tax to be imposed is based on the amount of CO_2 emissions created during combustion; this policy would encourage firms and households to decrease fossil fuel usage and shift the fuel mix toward less-carbon-intensive fuels, like natural gas.[9] Moreover, it will help promote renewable energy. Along with levying carbon tax, governments need to control environmental degradation through an upgraded method of resource exploitation that boosts the use of technology that causes fairly little damage to the environment.[10] Developing Asian countries must adopt safe carbon emissions cut-back and environmentally progressive-oriented policies, which are likely to be more favorable to sustainable economic growth and development. The residential solar producers of silicon-based photovoltaic (PV) systems for decentralized electricity production are now a global truth, both in economically developed and developing countries.[11] The role of low-cost PV solar energy in solving the world's energy and environmentally associated crises seems to be substantial. Along with the rapidly increasing installation of PV power, the two dominant energy technologies of the 19th and 20th centuries, the internal combustion engine and fuel-powered heater, will be substituted by electric motors and electricity-driven heat pumps.[12] Implementing air pollutant emission control modules, multiple end-of-pipe control technologies, and other cleaner and more proficient technologies will certainly decrease air pollution in the near future. These technologies will mitigate final energy use, enlarge the share of electricity in final energy, and enlarge the share of non-fossil fuels in primary energy and electricity use.[13] Aside from the

[9] [34].
[10] [2].
[11] [8,42].
[12] [42].
[13] [57].

abovementioned policies, developing countries will be able to reduce CO_2 emissions if developed countries will help them with various schemes, such as reforestation for debt reduction, in which the former will regrow their forests in return for a reduction in their foreign debt owed to the latter. Another policy can be in the form of FDI in environment-friendly fuel that will help developing countries produce less CO_2 emissions.

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