Sustainable Growth-Environment Nexus in the Context of Four Developing Asian Economies: A Panel Analysis

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This paper has used a STIRPAT model to investigate the synergistic effect of CO_2 emission, energy consumption, energy intensity, economic growth, population, urbanization and trade openness to demonstrate growth-environment nexus in four selected developing Asian economies. Taking a panel data set from Bangladesh, China, India and Indonesia this study applies Autoregressive Distributed Lag (ARDL) model and VEC Granger Causality/Block Exogeneity Wald Tests. The empirical results show that energy intensity, urbanization, population, and per capita GDP growth are the raison d'être of CO_2 emissions whereas trade openness is found to be negatively related to CO_2 emissions. Conversely, energy consumption, urbanization, population and trade openness are positively related to per capita GDP. In addition, it also investigates the Environmental Kuznets Curve (EKC) hypothesis and the findings substantiate an inverted U-shaped relationship. Cross-section short-run coefficients of country-level data are inquired into to check the robustness of the panel outcomes.

Key Words: EKC hypothesis, STIRPAT model, CO_2 emission, urbanization, energy consumption
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Introduction

Anthropogenic pollutant emission due to energy consumption is emerging as an awfully challenging trouble in front of the humankind in the 21st century. The implications of human-induced CO_2 emissions to the environment not only change the Earth's eco-system but also change the pattern of technology use, lifestyle, economies, and policy. It is also factual for the four Asian developing economies of this study: Bangladesh, India, China and Indonesia. Rapid economic growth has usual association with augmented energy consumption which is responsible for unforeseen effects on the energy source and the atmosphere. Hence, carbon emissions and energy consumption play a decisive role in the contemporary dispute on the environmental conservation and sustainable development issues. Climate change could spring from many environmental issues (viz. anthropogenic pollutants emission from sulfur dioxide, oxides of nitrogen etc.), but this study focuses on CO_2 emission related predicament that cause global warming. The Paris Climate Conference 2015 (COP21) agreement proclaimed limiting emissions following national level environment policies (Rhodes 2016). COP21 declarations also augment an increase of the study regarding carbon emission, energy consumption, global warming and climate change.

Sustainable development embraces a wide range of social, environmental and economic development issues. This paper strives to address most of them viz. climate change, energy, urbanization and environment. Variables like GDP and trade openness deals with the economic aspect while trade openness exhibits global dimension as well. Energy consumption, CO_2 emission addresses the environmental features whereas urbanization and population demonstrates social development aspects. Urban population growth is a process of social transformation and rejuvenation as well.

The rational for selecting the four economies for analysis is that Bangladesh, Indonesia, China and India are remarkable for being the fastest growing promising developing economies in Asia maintaining exceptionally high growth rates 8.15%, 5.02%, 6.1% and 6.8% respectively with rapid urbanization (see http://data.worldbank.org/). China is the world's second largest economy by nominal GDP and largest by purchasing power parity (PPP) and potentially hailed as new superpower. It is the largest CO_2 emitter and the leading investor in renewable energy as well. India is the third largest economy by purchasing power parity (PPP). Indonesia is the largest economy in the Southeast Asia and seventh largest in terms of PPP. Bangladesh positioned as one of the next eleven promising markets and third largest South Asian economy. The economic background of Bangladesh and Indonesia are roughly similar as emerging economy and China and India are on the verge of being the superpowers in the global economy. Here arises the apprehension of CO_2 emission related global warming with the increase in energy consumption keeping in pace with economic growth.

Against this background, the main objective of this study is to investigate the impact of per capita energy consumption, per capita GDP, urbanization, population and trade openness on per capita CO_2 emission employing a linear STIRPAT model and a non-linear EKC hypothesis in four Asian developing economies from 1980 to 2014. The study will simultaneously analyze another linear model showing the consequence of energy consumption, population, trade openness, urbanization, and CO_2 emission on viable economic growth as well.

The study is distinctive because it inquired into the synergy between energy, economy, and social development along with their contribution and relationship to the CO_2 emission in the four selected developing Asian economies. In addition, this study also included three separate equations including both linear and nonlinear estimation process taking four countries representing three stages of development. Moreover, not many research works have integrated urbanization variable together with trade openness simultaneously like this study. For instance, only Hossain (2011); Kasman and Selman Duman (2015); Rafiq, Salim, and Nielsen (2016) have taken both the variable and only latter used a non-linear estimation. Hence there is a paucity of non-linear estimation process in this regard which this study attempts to deal with. This paper tries to address the sustainable development issues as well, as it concentrates on environmental quality or degradation (in this case CO_2 emission), economic growth and population being the fundamental aspects of sustainable development.

Starting with the introduction in Section 1 above, the remainder of the study is ordered as follows: the existing empirical evidence from the literature is reviewed in Section 2. Section 3 examines the theoretical framework with model specifications; Section 4 represents data sources; Section 5 illustrates econometric methodology. Empirical results are analyzed in Section 6. The final section draws conclusion and policy implications.

Literature Review

Attention concerning the impact of economic growth on environment is on the rise from the last few decades of the previous century. The empirical findings of Hamit-Haggar (2012) posit that energy consumption has a positive and statistically significant impact on greenhouse gas emissions whereas a non-linear relationship is found between greenhouse gas emissions and economic growth, consistent with the environmental Kuznets curve in the long-run. Empirical results for China in the study of Zhang and Cheng (2009) show that neither carbon emissions nor energy consumption leads economic growth. The domino effect from the study of Halicioglu (2009) shows that income is the most significant variable in explaining the carbon emissions in Turkey which is followed by energy consumption and foreign trade and it is further extended into the environmental function of Jalil and Mahmud (2009) and Jayanthakumaran, Verma, and Liu (2012). McGee and York (2018), York (2007) and Cole and Neumayer (2004) have found urbanization encourages CO_2 emissions for a group of economies but Chen, Jia, and Lau (2008) and Liddle (2004) have found that upgradation of urbanization along with urban density increases the efficacy of public transport exploitation.

Ample numbers of pragmatic research works has been accomplished since the emergence of the EKC theory. Grossman and Krueger (1991) have examined the ecological outcome of the NAFTA (North American Free Trade Agreement). The study findings have confirmed the inverted-U type association among SO_2, dark matter (fine smoke), suspended particles (SPM) and per capita GDP and the findings have been contemporaneously established by Shafik and Bandyopadhyay (1992), Panayotou (1993) and Selden and Song (1994). Holtz-Eakin and Selden (1995) have used global panel data and estimate a log-quadratic relationship from 1951 to 1986 and also found EKC. Galeotti and Lanza (1999) estimate EKC using two alternative parametric functional forms and found inverted-U relationships. Friedl and Getzner (2003) have considered the EKC for Austria from 1960 to 1999, and found an N-shaped relationship with evidence of a structural break in the mid-seventies due to the oil price shock. The study of Martínez-Zarzoso and Bengochea-Morancho (2004) on 22 OECD countries spanning from 1975 to 1998 using a PMG (pooled mean group) method have found an N-shaped correlation preponderance for many countries. Study of Sachs, Panayotou, and Peterson (1999) for panel data for 150 countries from 1960 to 1992, have found an inverted-U shaped relationship explainable by structural changes accompanying economic growth: from agriculture, to industry, to services.

Further, Agras and Chapman (1999) have employed a log-quadratic EKC model with a lagged dependent variable and trade variables, in addition to income applying the ARDL to analyze the dynamic process and wrap up that income has the maximum influence. Al-Mulali, Saboori, and Ozturk (2015) also applied ARDL and provide a review of studies that examined EKC theory taking information from particular economies. They have found two types of the EKC corresponding to CO_2 emissions. The work of McConnell (1997) has postulated that for EKC, positive sign of income elasticity of demand is not only optional but also inadequate. Andreoni and Levinson (2001) indicate that economies of scale in pollution abatement are sufficient conditions for the existence of the EKC.

The study of Hossain (2011) has included urbanization, CO_2 emissions, GDP, energy consumption and trade in his study of nine newly industrialized countries. The result indicates that higher energy consumption gives rise to more CO_2 emissions polluting the environment. But in respect of GDP, trade openness and urbanization the environmental quality shows stable association in the long-run. The study of Sharmin (2021) have found 1% increase in non-renewable energy consumption will increase CO_2 emission by on an average more than 0.75%. Pao and Tsai (2010) in their study of BRIC countries have found bidirectional causal relationship between pollutant emissions and energy consumption, and GDP and energy consumption in the long run but unidirectional causal relationship between energy consumption and GDP in the short run. Sharma (2011) has found urbanization has a negative and significant impact on carbon emissions for a panel of 69 countries while this impact was identified insignificant if income-level group is considered. Sadorsky (2014) have employed a STIRPAT model to investigate the effect of urbanization on CO_2 emissions in 7 emerging economies. Using ARDL model he shows that increase in affluence, population, or energy intensity increase CO_2 emissions in the long-run. The study of Sharmin and Tareque (2018) has postulated growth stimulates energy consumption and consequently causes CO_2 emissions. VDC result posits that energy intensity, urbanization, industrialization and growth are responsible for more than 60% of the CO_2 emission in the long run.

In pooling together, from the above existing empirical evidence it can be observed that the idea of the nexus is clear though some researchers are differing. The magnitude and the sign of the association of the studies vary depending upon the data set used, countries considered and estimation techniques applied. This study looks into the different dimensions of growth-environment nexus in the context of four most promising economies of Asia now at different stages of development. Moreover, very few studies took both urbanization and trade openness concomitantly. To address the sustainable development issues this study attempts to analyze the synergism among energy, environment, economy, and social development in the four selected developing Asian economies.

Theoretical Framework

This study employs the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) and EKC model, panel cointegration technique, and dynamic PMG/ARDL (Autoregressive Distributed Lag) estimator (Pesaran, Shin, and Smith 2001) to determine the influence of GDP growth, energy consumption, energy intensity, population, trade openness and urbanization on CO_2 emissions for four Asian developing economies.

STIRPAT which is a stochastic adaptation of the IPAT form is an acknowledged method employed to study the nexus between population and environment (Dietz and Rosa 1997). STIRPAT follows the IPAT equation of Ehrlich and Holdren (1971). IPAT form postulates environmental impacts can be found by multiplying population, affluence and technology. It takes the form:

$$I = P \times A \times T, \tag{1}$$

where I denotes environmental impact, P indicates population, A is affluence or consumption per capita (GDP per capita), and T is technology or impact per unit of consumption. Affluence is typically operationalized as per capita gross domestic product (GDP) so that T is the impact per unit of economic activity. The criticisms of the Ehrlich-Holdren's IPAT framework are that it does not authorize hypothesis testing, and it presumes a stiff proportionality between factors. Dietz and Rosa (1997) addressed those two criticisms by proposing a stochastic version of IPAT:

$$I_{it} = a_i P_{it}^b A_{it}^c T_{it}^d e_{it}, \tag{2}$$

where the subscript i ($i = 1, \ldots, N$) symbolizes countries, and t ($t = 1, \ldots, T$) refers to time period, a is the constant and exponent b, c, and d are to be estimated, and e denotes the residual error term.

The three-way associations among the variables of this study are empirically examined by using the following three simultaneous equations. In model specification, the first model (Model I) investigates the association among CO_2 emissions, GDP growth, energy intensity, population, urbanization and trade openness. The model (I) is expressed as follows:

$$\begin{aligned} Ln(CO_{2it}) = \alpha_0 + \alpha_{1i}(LnY_{it}) + \alpha_{2i}(LnEI_{it}) + \alpha_{3i}(LnP_{it}) \\ + \alpha_{4i}(LnU_{it}) + \alpha_{5i}(LnTO_{it}) + \varepsilon_{it}, \end{aligned} \tag{3}$$

where CO_2 is per capita pollutant emissions, Y is GDP per capita (affluence), EI is energy intensity, P is total population, U is urbanization and

TO is trade openness. Here ε refers to particular error symbol, the subscript i denotes countries and t stands for time. These symbols are synonymously used in equation (5).

Another model (Model II) has looked into the impact of CO_2 emissions, energy consumption, population, urbanization and trade openness on economic growth:

$$Ln(Y_{it}) = \gamma_0 + \gamma_{1i}(LnCO_{2it}) + \gamma_{2i}(LnEC_{it}) + \gamma_{3i}(LnP_{it}) + \gamma_{4i}(LnU_{it}) + \gamma_{5i}(LnTO_{it}) + \varepsilon_{it}, \quad (4)$$

where CO_2 is per capita pollutant emissions, Y is GDP per capita (affluence), EC is per capita energy consumption, P is total population, U is urbanization and TO is trade openness. Here ε refers to idiosyncratic error term, the subscript i denotes countries and t is time.

In EKC model (Model III), a logarithmic form of per capita GDP squared is included to find out the possibility of an EKC assumption for the stipulated four economies. According to the theory, economic growth exhibits no threat but directs to environmental improvement at the higher stage of income intensity. Coefficients of non-linear models with GDP per capita squared directly demonstrate the turning point of income, where emissions are maximum. This study tries to find more precise estimators of the coefficients to observe the presence of an EKC in four Asian economies. The EKC model of this study is formulated as follows:

$$Ln(CO_{2it}) = \beta_0 + \beta_{1i}(LnY_{it}) + \beta_{2i}(LnY_{it}^2) + \beta_{3i}(LnEI_{it}) + \beta_{4i}(LnP_{it}) + \beta_{5i}(LnU_{it}) + \beta_{6i}(LnTO_{it}) + \varepsilon_{it}. \quad (5)$$

Theoretical expectations of the three models are:

Model I, $\alpha_1 > 0; \alpha_2 > 0; \alpha_3 > 0; \alpha_4 > 0; \alpha_5 \gtrless 0$
Model II, $\gamma_1 > 0; \gamma_2 > 0; \gamma_3 > 0; \gamma_4 > 0; \gamma_5 \gtrless 0$
Model III, $\beta_1 > 0; \beta_2 \gtrless 0; \beta_3 > 0; \beta_4 > 0; \beta_5 > 0; \beta_6 \gtrless 0$

The models get insight from some earlier studies and strongly follow some preceding studies for instance, Model I and III are inspired by the studies of York, Rosa, and Dietz (2003), Cole and Neumayer (2004), Halicioglu (2009), Hossain (2011), Sadorsky (2014) and Rafiq, Salim, and Nielsen (2016). This study contributes to the existing literature as the study combines these above mentioned approaches but make pertinent modification employing three simultaneous equations for estimation to capture particular features of the stipulated economies. Equation (3) em-

TABLE 1 Definition and Measurement of the Variables

Variables	Definition	Measurement
CO_2	Per capita carbon emissions	Metric tons per capita
Y	GDP per capita	Constant 2010 US$
Y^2	Quadratic term of Y	US$ per capita squared
EC	Energy use per capita	Kg of oil equivalent per capita
EI	Energy consumption per capita divided by GDP per capita	–
U	Urban population growth	Annual %
P	Total population	–
TO	Share of export import ratio to GDP	Constant 2010 US$

NOTES All data are in natural logarithm.

ploys a STIRPAT model and equation (4) intends to see the impact of CO_2 emissions, energy consumption, population, urbanization and trade openness on economic growth. Equation (5) looks into the EKC hypothesis.

Data Sources and Diagnostic Tests

We have used balanced panel dataset of 4 Asian developing economies (Bangladesh, India, China and Indonesia). Annual data for carbon dioxide emissions (CO_2), energy consumption (EC), energy Intensity (EI), trade openness (TO), per capita real GDP (Y), urbanization (U), and population (P) are taken from the WDI (World Development Indicators) spanning from 1980–2014. The definition and measurement of the variables used in this study are expressed in table 1. Taking natural logarithm, correlation matrix between variables is demonstrated in table 2.

Correlation matrix between variables of the four Asian economies of this study shows the highest CO_2 emissions correlation (98%) with energy consumption followed by trade openness (83%) with per capita GDP and per capita GDP (75%) with CO_2 emission. CO_2 emission correlates negatively with urbanization but has positive correlation with energy consumption, energy intensity, per capita GDP growth, population and trade openness.

Econometric Methodology

Firstly, we have carried out panel unit root test (PURT) as macroeconomic variables exhibit trends. Therefore, test of unit root is a prerequi-

TABLE 2 Correlation Matrix

Item	$lnCO_2$	lnEC	lnEI	lnY	lnU	lnP	lnTO
$lnCO_2$	1						
lnEC	0.986*	1					
lnEI	0.404*	0.344*	1				
lnY	0.759*	0.811*	−0.269*	1			
lnU	−0.374*	−0.320*	−0.094	−0.270*	1		
lnP	0.745*	0.674*	0.762*	0.217*	−0.511*	1	
lnTO	0.495*	0.529*	−0.473*	0.838*	−0.145***	−0.034	1

NOTES *, **, and *** represents statistical significance at the 1%, 5% and 10% point, correspondingly.

site to address whether there are restrictions on the autoregressive procedure across cross-sections or series. PURT primarily consists of (i) First-generation techniques, that presume cross-sectional independence (e.g. Maddala and Wu 1999; Choi 2001; Levin, Lin, and Chu 2002; Im, Pesaran, and Shin 2003) with (ii) Second generation techniques, that clearly permit for several sort of cross-sectional dependence (e.g. Pesaran (2007). This paper employs the Levin, Lin and Chu (LLC), Im, Pesaran, and Shin (IPS), ADF – Fisher Chi-square, PP – Fisher Chi-square and Hadri Z-stat tests to check for panel unit root properties.

Secondly, we have employed panel co-integration techniques. If the indicators used for the study are stationary at first difference, co-integration tests in the panel form are applied to find out the long-run equilibrium association amid the non stationary indicators. The existence of a co-integrated relationship between the series exhibits potential long-run connection between the indicators. As the indicators used in the study are integrated of order 1, this paper uses Kao test (Kao 1999) following Engle-Granger methodology and Johansen test in the context of panel unit roots to examine the possible existence of one or more co-integrated relationships among the variables (i.e. indicators).

Thirdly, we have used PMG/ARDL estimator to calculate long-run as well as short-run dynamics among the indicators. If there exists co-integration between the indicators, PMG estimator (Pesaran, Shin, and Smith 1999) are employed for dynamic heterogeneous panels. PMG is employed to examine the causal path connecting dependent and independent indicators as well. In addition PMG model limits the long-run coefficients to remain unchanged but makes the short-run coefficients and error variances to differ across countries. Another advantage of this model is that it yields consistent estimates of the long-run parameters irrespective of whether the underlying regressors are stationary, non-stationary or mutually co-integrated (Pesaran, Shin, and Smith 1999).

Finally, VEC Granger Causality/Block Exogeneity Wald Tests test in the VECM framework is applied to see the short-run causality and significant t-test on a negative ECT to exhibit long-run causality among the variables.

Analysis of Empirical Results

PANEL UNIT ROOT TEST RESULTS

This paper uses various econometric tests (Im, Pesaran and Shin W-test, Fisher type tests, Levin, Lin and Chu test, and Hadri test) to check for the existence of a unit root in the panel data set. In all the above tests except for Hadri test, the null hypothesis is that of a unit root. The W-test is based on the application of the ADF test to panel data, and allows heterogeneity in both the constant and slope terms of the ADF regression (Christopoulos and Tsionas 2003). The panel unit root check outcomes are expressed in table 3.

Employing pertinent techniques, the study finds that all the indicators used to see the growth environment nexus are stationary at first difference I (1). This paper includes individual intercept, individual intercept and trend, no intercept and no trend in order to minimize the problems arising from cross-sectional dependence. The Schwarz Information Criterion (SIC) is utilized to verify the automatic lag measurement lengthwise. Further, the Bartlett kernel is operated to analyze the long-run variation using LLC technique where Newey-West bandwidth selection algorithm decides the lags.

PANEL CO-INTEGRATION TESTS RESULTS

Panel co-integration techniques have been employed in this study to portray quicker implication. Still, the question of homogeneity arises. In order to investigate the existence of one or more co-integrated vectors two tests are applied. First, Kao test (Kao 1999) based on Engle-Granger methodology and finally a Johansen test in the context of panel unit roots, to estimate residuals from long run relations. Results of Panel Co-Integration Tests are provided in table 4.

Findings suggest that the null hypothesis of no co-integration is rejected at 5% level according to the employed co-integration tests. More

TABLE 3 PURT Results

Variable	Levin, Lin, and Chu t^*		Im, Pesaran, and Shin W-stat		ADF – Fisher Chi-square		PP – Fisher Chi-square		Hadri Z-stat	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
lnY	5.87860	1.35291	9.52927	2.06392	0.10439	5.17402	0.14606	2.19842	7.07131*	5.05052*
$lnCO_2$	0.20351	0.57539	2.61153	−0.09480	1.28860	5.78028	0.72525	10.8356	6.90309*	3.64293*
lnEC	2.88884	0.33692	4.92659	2.52410	1.00792	1.53754	1.04325	1.16433	6.66181*	5.11114*
lnEI	−0.02355	−0.42811	2.50027	1.25140	2.29215	3.02484	3.83616	2.18707	6.76840	5.52917
lnP	−1.28218	8.10526	0.26344	8.89124	4.14848	0.54424	68.4215*	93.7514*	7.06377*	6.65056*
lnU	1.08595	3.79297	1.88234	0.26403	3.12205	3.71956	0.9265*	22.5812*	6.85872*	4.70976*
lnTO	−0.31878	0.29287	0.13787	−0.55671	11.4916	8.41277	11.3597	17.506**	6.26146*	3.17375*
Δ(lnY)	−4.4967*	−6.9139*	−4.8194*	−7.4696*	38.4655*	59.5368*	37.8100*	62.7405*	1.42500	0.52799
Δ($lnCO_2$)	−3.8820*	−1.7389**	−7.6284*	−5.6863*	66.0460*	45.1824*	89.7601*	302.530*	0.15968	0.24058
Δ(lnEC)	−7.4587*	−7.31523*	−8.2506*	−8.2766*	69.7923*	68.1057	70.8926	300.324	1.60338	1.16888
Δ(lnEI)	−9.6169*	−9.77117*	−8.9859*	−8.8705*	76.7467*	71.5106*	79.7026*	305.966*	1.8894**	1.11955
Δ(lnP)	−2.5072*	−6.99896*	−0.60335	−5.0551*	14.5842	49.2008*	11.9112	4.95855	6.39069*	3.56433*
Δ(lnU)	−8.9022*	−8.83222*	−7.4266*	−6.4511*	61.5867*	48.3668*	60.5394*	47.4453*	2.12783*	3.30664*
Δ(lnTO)	−11.115*	−10.3085*	−10.856*	−10.042*	93.3676*	83.2729*	94.6653*	86.2286*	0.81776	0.58885

NOTES Column headings are as follows: (1) intercept, (2) intercept and trend. Δ denotes the first difference. The null hypothesis of LLC and IPS techniques checks non-stationary. * and ** indicates statistical significance respectively at the 1% and 5% point. Lag range choice (automatic) followed Schwarz Information Criteria (SIC).

TABLE 4 Panel Co-Integration Tests

Segment	Fisher (combined Johansen)	Kao Test
Model I	(1) 193.6* [$r = 0$], 100.3*[$r \geq 1$], 55.96*[$r \geq 2$], 25.03*[$r \geq 3$], 13.00[$r \geq 4$]	−2.707493*
	(2) 112.0*[$r = 0$], 53.22*[$r \geq 1$], 38.22*[$r \geq 2$], 19.83**[$r \geq 3$], 9.116[$r \geq 4$]	
Model II	(1) 193.6*[$r = 0$], 100.3*[$r \geq 1$], 55.96*[$r \geq 2$], 25.03*[$r \geq 3$], 13.00[$r \geq 4$]	−2.175668**
	(2) 112.0*[$r = 0$], 53.22*[$r \geq 1$], 38.22*[$r \geq 2$], 19.83**[$r \geq 3$], 9.116[$r \geq 4$]	
Model III	(1) 222.3*[$r = 0$], 149.8*[$r \geq 1$], 86.78*[$r \geq 2$], 48.08*[$r \geq 3$], 24.68*[$r \geq 4$], 12.41[$r \geq 5$]	−2.792482*
	(2) 235.8*[$r = 0$], 76.71*[$r \geq 1$], 45.48*[$r \geq 2$], 29.82*[$r \geq 3$], 19.73**[$r \geq 4$], 8.417[$r \geq 5$]	

NOTES Null hypothesis means lack of co-integration, whilst r designates the figure of co-integrating equations through linear deterministic trend; * and ** shows significance at 1% and 5% level respectively.

specifically, by employing the Fisher test (Johansen 1992 and Maddala and Wu 1999) it is evident that there are four co-integrating vector for Model I, and II and five co-integrating vector for Model III at the 5% level of significance. Kao test (Engle-Granger based) also confirms that there is co-integration among the variables.

ESTIMATION OF LONG-RUN AND SHORT-RUN RELATIONSHIPS USING PMG/ARDL MODEL

As co-integrating relationship is established among the variables the PMG/ARDL technique is applied to estimate both the long and short-run association among CO_2 emission, growth, energy intensity, urbanization, population and trade openness using three models. Table 5 depicts the panel PMG/ARDL estimation results.

The outcomes posit statistically significant negative sign of the coefficient of the ECM in support of all the countries in all the three models. It indicates any short-term fluctuations stuck between CO_2 emission, growth, energy intensity, urbanization, population and trade openness will be corrected to signify a firm long-run correlation involving all the indicators.

Results of the PMG estimation in Model I, demonstrates in the long-run growth, energy intensity, urbanization, population have a positive

TABLE 5 Panel PMG/ARDL Estimation Results

	Model I		Model II		Model III	
	Variables	Coefficient	Variables	Coefficient	Variables	Coefficient
Long-Run	LnY	1.135816*	$LnCO_2$	−2.156686*	LnY	1.482575*
	LnEI	1.123813*	LnEC	3.345926*	LnY^2	−0.020260*
	LnU	0.299722*	LnP	4.327030*	LnEI	1.193408*
	LnP	1.948703*	LnU	0.465658**	LnU	0.323276*
	LnTO	−0.15961*	LnTO	0.465637*	LnP	1.919864*
					LnTO	−0.161750*
Short-Run	COINTEQ01	−1.10835*	COINTEQ01	−0.139377**	COINTEQ01	−1.84179**
	$D(LnCO_2(-1))$	0.364831**	D(LnY(−1))	0.273771**	$D(LnCO_2(-1))$	0.715383
	D(LnY)	0.084848	$D(LnCO_2)$	0.161153	$D(LnCO_2(-2))$	0.234347
	D(LnY(−1))	0.276042	$D(LnCO_2(-1))$	0.249299	D(LnY)	−3.518502
	D(LnY(−2))	0.140655	$D(LnCO_2(-2))$	0.212817**	D(LnY(−1))	−10.55889
	D(LnEI)	−0.298985	$D(LnCO_2(-3))$	0.147800	D(LnY(−2))	0.393871
	D(LnEI(−1))	−0.204336	D(LnEC)	−0.207595	$D(LnY^2)$	−0.066490
	D(LnEI(−2))	0.178209	D(LnEC(−1))	−0.120845	$D(LnY^2(-1))$	0.880279
	D(LnU)	−0.323222*	D(LnEC(−2))	−0.270433	$D(LnY^2(-2))$	0.008849
	D(LnU(−1))	−0.177797*	D(LnEC(−3))	−0.28617**	D(LnEI)	−0.976297
	D(LnU(−2))	−0.032991	D(LnP)	−68.15284	D(LnEI(−1))	−0.477997
	D(LnP)	−22.95059	D(LnP(−1))	355.1662	D(LnEI(−2))	0.120562
	D(LnP(−1))	93.04180	D(LnP(−2))	−491.9675	D(LnU)	−0.65877**
	D(LnP(−2))	−42.55090	D(LnP(−3))	211.4901	D(LnU(−1))	−0.4288**
	D(LnTO)	0.091509**	D(LnU)	−0.124524	D(LnU(−2))	−0.27819**
	D(LnTO(−1))	0.113437**	D(LnU(−1))	−0.086954	D(LnP)	88.36102
	D(LnTO(−2))	−0.029863	D(LnU(−2))	−0.040257	D(LnP(−1))	−52.88338
			D(LnTO)	−0.100464	D(LnTO)	0.216703
			D(LnTO(−1))	−0.085757	D(LnTO(−1))	0.162117**
			D(LnTO(−2))	−0.101428*	D(LnTO(−2))	−0.002942

NOTES *, **, and *** shows statistical significance at the 1%, 5% and 10% level correspondingly.

significant impact but trade openness has negative significant impact on CO_2 emissions. In short-run urbanization seems to have negative impact and trade openness has positive impact on CO_2 emissions. In Model II, energy consumption, urbanization, trade openness and population has statistically significant positive effect but the effect of CO_2 emissions is negative on growth also found by Martínez-Zarzoso and Bengochea-Morancho (2004) and (Liu 2005). Energy consumption, urbanization and trade openness have positive but insignificant association with per capita GDP in the short-run. Model III, estimates all the variables have positive noteworthy effect on CO_2 emissions for except the quadratic form of GDP per capita which in the long-run has negative impact. It shows the presence of EKC hypothesis (Kuznets 1955) which implies that there exists an reversed curved association linking CO_2 emission and other economic variables used in this study. In short-run urbanization shows significant negative association with CO_2 emissions.

Results of Short-run and Long-run Granger Causality Test

To analyze the short-run and long-run causal relationship, Granger Causality in the VECM framework is estimated and table 6 illustrates the outcomes.

The existence of co-integration among the series implies that causality must be present at least in one direction. Granger Causality results in the VECM framework shows: In Model I all the independent variables have unidirectional short-run causal relationship with dependent variable.

Per capita GDP (DLnY) and energy intensity (DLnEI) has bidirectional causal relationship with CO_2 emission ($DLnCO_2$). Model II specifies unidirectional short-run causality from independent to dependent variables. It is evident from Model III, all the independent variables have unidirectional short-run causal relationship with the predicted variable and per capita GDP (DLnY) and squared per capita GDP ($DLnY^2$) and energy intensity (DLnEI) has bidirectional causal relationship with dependent variable. On the other hand, a significant t-test on a negative ECT (error correction term) exhibits long-run causality in all the three equations. This result postulates that per capita GDP (i.e. economic growth) encourages energy intensity in four Asian economies. For that reason, energy conservation actions that do not discourage growth should be promoted. The connection involving CO_2 emissions and energy intensity shows substantiation of bidirectional causality implying that emissions lead to energy use and vice versa. From the result it is discernible that though apparently it seems to be impossible to trim down CO_2 emissions if energy utilization is not reduced but at an advanced plane of growth, per capita GDP is found to be negatively related with CO_2 emission. This phenomenon implies after reaching a certain level of growth emission decreases.

FURTHER ANALYSIS FOR ROBUSTNESS CHECK

Previously in the above panel estimations, the results are estimated taking the panel data as a whole. To examine the country specific impacts

TABLE 6 Granger Causality Result in the VECM Framework

	Model I			Model II			Model III		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Short-run	D(LnCO$_2$)	D(LnY)	22.66165*	D(LnY)	D(LnCO$_2$)	1.568706	D(LnCO$_2$)	D(LnY)	13.36822*
		D(LnEI)	16.22005*		D(LnEC)	0.140969		D(LnY^2)	9.482284*
		D(LnP)	5.443782**		D(LnP)	4.218555**		D(LnEI)	27.65789*
		D(LnU)	9.190636*		D(LnU)	0.154581		D(LnP)	2.079504
		D(LnTO)	4.259522		D(LnTO)	1.549574		D(LnU)	4.773731**
		All	58.60246*		All	11.06733**		D(LnTO)	5.925060**
								All	51.91125*
	D(LnY)	D(LnCO$_2$)	5.106181**	D(LnCO$_2$)	D(LnY)	4.500722**	D(LnY)	D(LnCO$_2$)	5.472495**
	D(LnEI)	D(LnCO$_2$)	6.763017**	D(LnEC)	D(LnY)	0.018799	D(LnY^2)	D(LnCO$_2$)	5.472170**
	D(LnP)	D(LnCO$_2$)	3.901229	D(LnP)	D(LnY)	1.317040	D(LnEI)	D(LnCO$_2$)	7.065111**
	D(LnU)	D(LnCO$_2$)	2.555237	D(LnU)	D(LnY)	2.992580**	D(LnP)	D(LnCO$_2$)	7.932018**
	D(LnTO)	D(LnCO$_2$)	0.942492	D(LnTO)	D(LnY)	5.038584**	D(LnU)	D(LnCO$_2$)	2.325476
							D(LnTO)	D(LnCO$_2$)	0.584908
Long-run (ECT)	Model I	−0.240302*	−0.001088*	0.059993	0.014618	0.065533**	−0.094832**		
		[−3.82060]	[−3.52641]	[0.50622]	[0.32595]	[2.29458]	[−2.46364]		
	Model II	−0.026916*	−0.000122*	0.006720	0.001637	0.007340**			−0.003282
		[−3.82060]	[−3.52641]	[0.50622]	[0.32595]	[2.29458]			[−0.82280]
	Model III	−0.131257*	−0.001271*	−0.062678	−0.002145	0.064652*	−0.093309*	0.846453*	
		[−2.69780]	[−6.08610]	[−0.70538]	[−0.06298]	[3.07368]	[−3.32607]	[2.73908]	

NOTES Column headings are as follows: (1) dependent variable, (2) excluded, (3) chi-square statistics; *, **, and *** denotes statistical significance at the 1%, 5% and 10% level, respectively; figures in brackets shows t-statistic.

TABLE 7 Cross-Section Short-Run ECT of the Three Models

Economies	Model I		Model II		Model III	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
Bangladesh	−1.155122	0.0000	−0.197151	0.0000	−1.519505	0.0001
India	−0.358313	0.0001	−0.260365	0.0000	−0.528018	0.0000
China	−1.625032	0.0000	−0.152188	0.0000	−3.967601	0.0002
Indonesia	−1.294944	0.0004	0.052194	0.0001	−1.352071	0.0012

cross-section short-run ECT of the three models provided in table 7 are observed.

The results divulge that the calculated ECT for all the four economies has statistically significant negative sign for all the three models except for Indonesia in Model II. However, the speeds of adjustments diverge significantly.

As far as cross-section short-run coefficients of the three models are concerned, model I exhibit, in the short-run urbanization shows significant negative effect for all economies except for Indonesia whereas trade openness has positive significant effect on CO_2 emission for all economies. Regarding energy intensity all countries poses negative association except for India which shows positive impact on CO_2 emission. In Model II, the short-run result specifies, CO_2 emission and energy consumption is positively related to GDP per capita except for Indonesia and trade openness is negatively related for all the stipulated economies. Furthermore, in Model III, energy intensity shows negative impact except for India and urbanization and trade openness shows negative and positive impact on CO_2 emission respectively in the short run for all economies.

Conclusion and Policy Implications

The study empirically looks into the interactions among economic growth, population growth energy consumption, urbanization, energy intensity and CO_2 emission addressing the sustainable development stance. Findings postulate that economic growth is determined by energy consumption, as a consequence of this CO_2 emission springs forth. The projected findings show that CO_2 emission is affected by the consumption of energy, economic growth and urbanization within 35 years. Therefore, it is visible that energy use directs GDP growth. The findings from the direction of the causality test also indicate the need for suitable policies to meet increasing energy demand caused by economic growth to support continuous economic growth. The findings will provide valuable policy implications for the four developing Asian countries as well as to other developing countries. Crucial apprehension is that CO_2 emissions cause environmental degradation for instance, global warming and climate change. In the process of economic growth and development, energy consumption, population, urbanization, CO_2 emissions are acting as stimulators. Despite the strong association among the variables there are approaches to avert environmental impact on growth in a sustainable manner. Thus to ease the specter it is imperative to consider the potential harmful impacts they have on the growth process and in initiating the energy preservation strategies.

Economic development, urbanization and population growth is the reason behind energy requirement amplification resulting in CO_2 emission and global warming in the four economies of the study. Hence, Energy consumption, energy intensity, urbanization, population, and trade openness strategies should deem economies' revenue intensity at every phase of advancement. Moreover, long-run as well as short-run consequences need to be considered to ease CO_2 emissions related predicament in environmental management and sustainable development perception. The research focus is on the economic, social and environmental aspect of sustainable development goals and further research should take into consideration the political and governance related institutional issues.

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