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Abstract

The paper is an effort to fill the gap in the energy literature with a comprehensive country study for Pakistan. We investigate the relationship between CO_2 emissions, energy consumption, economic growth and trade openness for Pakistan over the period of 1971-2009. Bounds test for cointegration and Granger causality test are employed for the empirical analysis. The result suggests that there exists long-run relationship among the variables and the Environmental Kuznets Curve (EKC) hypothesis is supported. The significant existence of EKC shows the country's effort to condense CO_2 emissions and indicates a reasonable achievement of controlling environmental degradation in Pakistan. Furthermore, we find one-way causal relationship running from income to CO_2 emissions. Energy consumption increases CO_2 emissions both in the short and long runs. Trade openness reduces CO_2 emissions in the long run but it is insignificant in the short run. In addition, the change in CO_2 emissions from short run to the long span of time is corrected by about 10 percent each year.

Keywords: CO_2 emissions, energy consumption, trade openness

1. Introduction

In any economy, sustainable economic development can be achieved by sustainable environment development. The government of Pakistan launched an environmental policy in 2005 to control environmental degradation with sustained level of economic growth. The main objective of the National Environmental Policy (NEP) is to protect, conserve and restore Pakistan's environment in order to improve the quality of life of the citizens through sustainable development. Meanwhile, the economic growth is stimulated by all sectors of economy including agricultural, industrial and services. The rising growth rate in Pakistan is lead by industrial sector generally and manufacturing sector particularly in contributing the national accounts[1]. This industrial-led growth increases energy demand and resulting environmental pollutants increase in the country. In 2002-2003, industrial sector consumed 36% of total energy consumption while 33% is consumed by transportation. Even though total energy consumption is declined to 29% in 2008-2009, but the consumption by industrial sector has increased to 43% over the period[2].

For the case of Pakistan, high usage of petroleum to meet transportation demand is a major reason of CO_2 emissions[3]. A considerable share of CO_2 emissions is coming from natural gas mainly by the electricity production and coal consumption produces more than 50% of CO_2 emissions of natural gas. In 2005, 0.4% of the world total CO_2 emissions were produced by Pakistan and this "contribution" is worsening day by day. While the income per capita has increased from PRS 32,599 to PRS 36,305 over 2006-2009, the usage of energy per capita was increased from 489.36 (kg of oil equivalent) in 2006 to 522.66 (kg of oil equivalent) in 2009. This has led CO2 emissions per capita rise from 0.7657 metric tons to 1.026 metric tons over the period of 2006-2009.

Kuznets [1] postulated that income inequality first rises and then falls with economic growth. Name after him, the Environmental Kuznets Curve (EKC) is a hypothesized relationship between environmental degradation and income per capita. The basic idea is simple and intuitive. In the early stages of economic growth, environmental degradation and pollution tend to increase. After certain level of income has been achieved, economic growth declines environmental degradation and pollution. Hence, the model is specified in quadratic form of income. Environmental degradation under this approach is a monotonically rising function in income with an "income elasticity" less than unity.

Time effect can reduce the environmental impacts regardless of income level. Generally, the scale effect dominates in the fast growing and middle income economies. As such, increases in pollution and other degradations tend to overwhelm the time effect. In the developed economies, growth rate is slower and pollution reduction efforts can overcome the scale effect. This argument provides the foundation of EKC effect. As the recent evidences suggested, many developing economies are addressing and even remedying the pollution problems **(Dasgupta et al. [2]).**

On the other hand, globalization leads to greater integration of economies and societies **(Agenor, [3])**. Thus, new trade routes have been discovered and technology of transport has been improved to obtain benefits from openness. The Hecksher-Ohlin **(Hecksher, [4] and Ohlin, [5])** model posits that differences in labour productivity lead to produce different goods in different economies. Trade is a main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently[1]. Trade openness also provides a way for mobilizing factors of production freely between the

[1] See Barro and Sala-i-Martin, [6] for more details

countries. However, movement of factors of production may also move dirty industries from home countries to developing economies where laws and regulations about environment is just formality. For example, Feridun et al. [7] documented that trade openness harms the environmental quality in less developed economies like Nigeria.

Antweiler et al. [8] examined effect of trade on environmental quality. They introduced composition, scale and technological effects by decomposing the trade model. Their study concluded that trade openness is beneficial for environment if the technological effect is greater than the composition effect and scale effect. This shows that increasing trade will improve the income level of developing nations which induce them to import less polluting techniques to enhance the production. Copeland and Taylor [9] supported that international trade is beneficial to environmental quality through environmental regulations and capital-labor channels. The authors documented that free trade declines CO_2 emissions. The main reason is international trade will shift the production of pollution-intensive goods from developing countries to the developed nations and hence declines CO_2 emissions of the world. Managi et al. [10] found that quality of environment is improved if environmental regulation effect is stronger than capital labour effect. Similarly, McCarney and Adamowicz [11] suggested that trade openness improves environmental quality depending on government policies. The local government can reduce CO_2 emissions through the environmental policies.

The present study is an effort to fill the gap in the energy literature because there is lack of comprehensive study for Pakistan. Single country study helps policy making authorities in making comprehensive policy to control environmental degradation. This study contributes to energy literature with a case study of Pakistan using time series data for the period of 1971-2009. Moreover, an important variable, trade openness is taken into account for its impact on environmental pollution. Technically, we apply the ARDL bounds approach to cointegration and Gregory-Hansen [12] structural break cointegration test to examine the long-run relationship of the variables. The rest of the paper is organized as following: Literature review is explained in section 2. Section 3 describes theoretical and estimable model. The empirical results are reported in section 4 and finally, conclusion and policy implication are drawn in section 5.

2. Literature review

The relevant literature shows two strands of link between energy consumption and CO_2 emissions i.e. economic growth and CO_2 emissions and, economic growth and energy consumption. The dominating relationship between economic growth and CO_2 emissions has been achieved great attention of researchers. The relationship between CO_2 emissions and economic growth is termed as EKC[4]. The association between economic growth and CO_2 emissions reveals that economic growth is linked with high CO_2 emissions initially and CO_2 emissions tends to decrease as an economy achieves turning point or threshold level of economic growth.

The empirical studies of EKC started by Grossman and Krueger [13] and followed by Lucas et al. [14], Wyckoff and Roop [15] Suri and Chapman [16], Heil and Selden [17], Friedl and Getzner [18], Stern [19], Nohman and Antrobus [20], Dinda and Coondoo [21] and Coondoo and Dinda [22]. Existing studies seem to present mixed empirical evidences on the validity of EKC. Song et al. [23], Dhakal [24], Jalil and Mahmud [25] and, Zhang and Cheng [26] supported the existence of EKC in China. The findings of Fodha and Zaghdoud [27] revealed the existence of EKC between the SO2 emissions and economic growth but not for the CO_2 emissions in Tunisia. In contrast, Akbostanci et al. [28] (2009) did not support the existence of EKC in Turkey. They argued that CO_2 emissions are automatically reduced due to the rapid pace of economic growth.

The relationship of energy consumption and economic growth has been investigated extensively as well. For example, Kraft and Kraft [29] for USA, Masih and Masih [30] for Taiwan and Korea, Aqeel and Butt [31] for Pakistan, Wolde-Rufael [32] for African, Narayan and Singh [33] for Fiji, Reynolds and Kolodzieji [34] for Soviet Union, Chandran et al. [35] for Malaysia, Narayan and Smyth [36] for Middle Eastern and Yoo and Kwak [37] for South American concluded that energy consumption causes economic growth. Opposite causality is also found running from economic growth to energy consumption by Altinay and Karagol [38] and Halicioglu [40] for Turkey, Squalli [41] for OPEC, Yuan et al. [42] for China and Odhiambo [43] for Tanzania. Bivariate causality between energy consumption and economic growth is also documented by Asafu-Adjaye [44] for Thailand and Philippines.

Recent literature documented alliance of economic growth with energy consumption and environmental pollution to investigate the validity of EKC. The relationship between economic growth, energy consumption and CO_2 emissions have also been researched extensively both in the country case and panel studies. Ang [45] found stable long run relationship between economic growth, energy consumption and CO_2 emissions for French economy while Ang [46] also got similar result for Malaysia. Ang [45] showed that causality is running from economic growth to energy consumption and CO_2 emissions in the long run but energy consumption causes economic growth in short run. In the case of Malaysia, Ang [46] reported that output increases CO_2 emissions and energy consumption. Ghosh [47] documented that no long run causality between economic growth and CO_2 emissions and bivariate short run causality in India.

For the panel studies, Apergis and Payne [48] investigated the relationship between CO_2 emissions and economic growth for six Central American economies using panel VECM. Their empirical evidence showed that energy consumption is positively linked with CO_2 emissions and EKC hypothesis has been confirmed. Lean and Smyth [49] and Apergis and Payne [50] reached the same conclusion for the case of ASEAN countries and Commonwealth of Independent States respectively. Narayan and Narayan's [51] empirical evidence also validated the EKC hypothesis for 43 low income countries. In addition, Lean and Smyth [49] noted long run causality running from energy consumption and CO_2 emissions to economic growth but in the short span of time, energy consumption causes CO_2 emissions. On the other hand, Apergis and Payne [50] found that energy consumption and economic growth Granger causes CO_2 emissions while bivariate causality is found between energy consumption and economic growth; and between energy consumption and CO_2 emissions.

The relationship between international trade and environment has also been investigated empirically. Grossman and Krueger [13] argued that environmental effect of international trade depends on the policies implemented in an economy. There are two schools of thought about the impact of international trade on CO_2 emissions. First school of though argued that trade openness provides an offer to each country to have access to international market which enhances the market share among countries. This leads the competition among the countries and increases the efficiency of using scarce resources and encourages importing cleaner technologies to decline CO_2 emissions (e.g. Runge, [52] and

Helpman, [53]). Other group probed that natural resources are depleted due to international trade. This depletion of natural resources raises CO_2 emissions and causes environment quality worsened (e.g. Schmalensee et al. [54]; Copeland and Taylor, [55]; Chaudhuri and Pfaff, [56]).

In country case studies, Machado [57] indicated positive link between foreign trade and CO_2 emissions in Brazil. Mongelli et al. [58] concluded that pollution haven hypothesis is existed in Italy[2]. Halicioglu [40] added trade openness to explore the relationship between economic growth, CO_2 emissions and energy consumption for Turkey. The result showed that trade openness is one of main contributor to economic growth while income raises the levels of CO_2 emissions. Shiyi [59] explored this issue to Chinese provinces and documented industrial sector's development is linked with increase of CO_2 emissions due to energy consumption[5]. Ozturk and Acaravci [60] indicated that EKC is valid in Turkey.

Nasir and Rehman [61] also supported EKC in Pakistan. Nasir and Rehman [61] used ADF unit root test and Johansen-Juselius [62] approach to cointegration which may provide inappropriate results when there occurs a structural break in the series.

3. Theoretical and modeling framework

Different approaches have been used to investigate the relationship between economic growth, CO_2 emissions and natural resources. Jorgenson and Wilcoxen [63] and Xepapadeas [64] model the links between energy consumption, environment pollutants and economic growth in equilibrium framework with aggregate growth model. A recent strand of research

[2] The *pollution haven_hypothesis* reveals that in order to attract foreign investment, the governments of developing countries have a tendency to undermine environment concerns through relaxed or non-enforced regulation reported by Haffmann et al. [65].

has explored link between economic growth and CO_2 emissions, and energy consumption and CO_2 emissions in single equation model (Ang, [45], [46] and Soytas et al. [66]. The present study follows the methodology applied by Ang [45, 46], Soytas et al. [66], Halicioglu [40] and Jalil and Mahmud [25][6].

The relationship between CO_2 emissions and energy consumption, economic growth and trade openness is specified as follow:

$$CO_{2t} = f(ENC_t, GDP_t, GDP_t^2, TR_t) \qquad (1)$$

where CO_2 is CO_2 emissions per capita, ENC is energy consumption per capita, GDP (GDP^2) is real GDP (squared) per capita and TR is trade openness (exports + imports) per capita. The linear model is converted into log-linear specification as it provides more appropriate and efficient results compare to the simple linear functional form of model (see Cameron, [67]; Ehrlich, [68, 69]). Hence, the estimable equation is re-written as follow:

$$\ln CO_{2t} = \beta_1 + \beta_{ENC}\ln ENC_t + \beta_{GDP}\ln GDP_t + \beta_{GDP^2}\ln GDP_t^2 + \beta_{TR}\ln TR_t + \mu_t \qquad (2)$$

μ_t is stand for residual or error term.

It is expected that economic activity is stimulated with an increase in energy consumption that in resulting increase of CO_2 emissions. This leads us to expect $\beta_{ENC} > 0$. The EKC hypothesis reveals that $\beta_{GDP} > 0$ while sign of GDP^2 should be negative or $\beta_{GDP^2} < 0$. The expected sign of trade openness is negative, $\beta_{TR} < 0$ if production of pollutant intensive items is reduced due to the environment protection laws and imports such items from the other countries where environmental laws are flexible. However, Grossman and Krueger [70] and Halicioglu [40] argued that sign of β_{TR} is positive if dirty industries of developing economies are busy to produce heavy share of CO_2 emissions with production.

Pesaran et al. [71] established an advanced approach to examine cointegration among variables. This approach is termed as Autoregressive Distributive Lag (ARDL) bounds test. The ARDL model can be applied without investigating the order of integration (Pesaran and Pesaran, [72]). Most macroeconomic variables are integrated at I(0) or I(1). Haug [73] argued that ARDL approach for cointegration presents better results for small sample data set as compared to other techniques for cointegration such as Engle and Granger [74], Johansen-Juselius [62] and Philips and Hansen [75].

Furthermore, the unrestricted error correction model (UECM) seems to take satisfactory lags that captures the data generating process in a general-to-specific framework of specification (**Laurenceson and Chai, [76]**). However, Pesaran and Shin [77] contented that "*appropriate modification of the orders of the ARDL model is sufficient to simultaneously correct for residual serial correlation and the problem of endogenous variables*". The UECM is being constructed to examine the long run and short run relationships among the variables.

$$\begin{aligned}\Delta \ln CO_{2t} &= \alpha_0 + \alpha_1 T + \sum_{i=1}^{p} \beta_i \ln CO_{2,t-i} + \sum_{i=0}^{q} \delta_i \ln ENC_{t-i} + \sum_{i=0}^{r} \varepsilon_i \ln GDP_{t-i} \\ &+ \sum_{i=0}^{s} \sigma_i \ln GDP_{t-i}^2 + \sum_{i=0}^{t} \omega_i \ln TR_{t-i} + \lambda_{CO_{2,t}} \ln CO_{2,t} + \lambda_{ENC} \ln ENC_t \\ &+ \lambda_{GDP} \ln GDP_t + \lambda_{GDP^2} \ln GDP_t^2 + \lambda_{TR} \ln TR_t + \mu_t \end{aligned} \quad (3)$$

Equation (3) presents two segments of results. The first part indicates the short run parameters such as $\beta, \delta, \varepsilon, \sigma$ and ω while λs $\left(\lambda_{CO2}, \lambda_{ENC}, \lambda_{GDP}, \lambda_{GDP^2}, \lambda_{TR}\right)$ explore the long run associations between variables of interest. The hypothesis of no cointegration i.e. $\lambda_{CO2} = \lambda_{ENC} = \lambda_{GDP} = \lambda_{GDP^2} = \lambda_{TR} = 0$ is examined. The decision about cointegration is based on the computed F-statistic. The critical bounds to compare with the F-statistic have been tabulated by Pesaran et al. [71][7]. The upper critical bound (UCB) is based on the assumption that all variables are integrated at I(1) and the lower critical bounds (LCB) variables should be integrated at level. If UCB is lower than the F-statistic, then the decision is in favor of cointegration among the variables. It indicates the existence of long run relationship among the variables. If the F-statistic is less than LCB, then it favors no cointegration among the variables. The decision about cointegration will be inconclusive if the F-statistic falls between UCB and LCB. In such situation, we will have to rely on the finding of lagged error correction term (ECT) for cointegration to investigate the long run relationship. If there is long run relationship between variables, the short run behavior of variables is investigated by the following VECM model:

$$\Delta \ln CO_{2,t} = \delta_0 + \sum_{j=0}^{p} \delta_1 \Delta \ln ENC_{t-j} + \sum_{j=0}^{q} \delta_2 \Delta \ln GDP_{t-j} + \sum_{j=0}^{r} \delta_3 \Delta \ln GDP^2_{t-j} + \sum_{j=0}^{s} \delta_4 \Delta \ln TR_{t-j} + \eta ECT_{t-1} + \mu_t \quad (4)$$

It is documented that if the value of lagged ECT is between 0 and -1, then adjustment to the dependent variable in current period is the ratio of error in the previous period. In such situation, ECT causes the dependent variable to converge to long span of time stable equilibrium due to variations in the independent variables. The goodness of fit for ARDL model is checked through stability tests such as cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ). Finally, sensitivity analysis is also conducted.

4. Empirical Results

The annual data on CO_2 emissions and energy consumption are obtained from the World Development Indicators (WDI CD-ROM, [78]). The Economic Survey of Pakistan

(2008-09) is used to comb the data for real GDP and trade openness. The sample period starts from 1971 to 2009.

Results by traditional unit root tests such as Dickey and Fuller [79], Philip and Perron [80], Elliot et al. [81], Kwiatkowski et al. [82] and Ng and Perron [83] are biased and unreliable when a series has structural break (Baum, [84]). To overcome this problem, we apply Clemente et al. [85] two breaks test. The main advantage of this test is that it has information about two possible structural break points in the series by offering two models i.e. an additive outliers (AO) model informing about a sudden change in the mean of a series and an innovational outliers (IO) model indicates about the gradual shift in the mean of the series. The AO model is more suitable for variables having sudden structural changes.

The results of Clemente et al. [85] unit root test are detailed in Table 1 reveal that all the series are not found to be integrated at I(0). This implies that series are stationary at I(1).

Table 1: Clemente-Montanes-Reyes Detrended Structural Break Unit Root Test

Variable	Innovative Outliers				Additive Outlier			
	t-statistic	TB1	TB2	Decision	t-statistic	TB1	TB2	Decision
$\ln CO_{2,t}$	-3.627(3)	1978	2002	I(0)	-11.493(3)*	1978	1989	I(1)
$\ln ENC_t$	-3.768 (4)	1978	1985	I(0)	-6.805 (3)**	1986	2006	I(1)
$\ln GDP_t$	-4.921 (1)	1978	2002	I(0)	-6.768(4)**	1991	2003	I(1)
$\ln GDP_t^2$	-4.445 (4)	1978	2002	I(0)	-6.650 (3)**	1991	2003	I(1)
$\ln TR_t$	-4.192 (3)	1977	1990	I(0)	-5.842 (4)**	1994	2001	I(1)

Note: * and ** indicates significant at 1 and 5 per cent level of significance. Lag order is shown in parenthesis

The two step procedure of ARDL bound test requires lag length of variables. Based on the minimum value of Akaike Information Criteria (AIC), the optimum lag order is (1, 1, 1, 0, 1). The results are reported in Table 2. The F-statistic is greater than UCB infers that there is cointegration among the variables. The diagnostic tests show the validity of the estimation in the model.

Table 2: Bounds test for cointegration

Estimated equation	$CO_{2,t} = f(ENC_t, GDP_t, GDP_t^2, TR_t)$	
F-statistics	10.0062[a]	
Optimum lag order	(1, 1, 1, 0, 1)	
Significant level	Critical values (T = 39)[b]	
	Lower bounds, $I(0)$	Upper bounds, $I(1)$
1 per cent	7.763	8.922
5 per cent	5.264	6.198
10 per cent	4.214	5.039
Diagnostic tests	Statistics	
R^2	0.8137	
Adjusted- R^2	0.6952	
J-B Normality	0.9537 (0.6207)	
Breusch-Godfrey LM	0.5885 (0.4515)	
ARCH LM	0.0094 (0.9232)	
Ramsey RESET	0.3780 (0.5452)	

Note: [a] Significant at 1 per cent level.

[b] Critical values bounds are computed by surface response procedure by Turner [86].

We also employ Gregory-Hansen [12] structural break cointegration test to examine the robustness of long-run relationship between the variables of interest. The Gregory-Hansen cointegration test is powerful over residual based cointegration tests and allows the presence of one structural break in the series. The results are reported in Table 3. The results show that cointegration exists between energy consumption, economic growth, trade openness and CO_2 emissions after allowing break in 1995[3]. The break point in trade series is due to the implementation of trade reform in removing trade deficit under the umbrella of structural adjustment program forced by IMF.

Table 3: Gregory-Hansen structural break cointegration test

Estimated Model	$CO_{2,t} = f(ENC_t, GDP_t, GDP_t^2, TR_t, DUM_t)$
ADF T-statistics	-7.4842*
Prob. values	0.0000
Note: * shows significance at 10% level of significance. The ADF test statistics show the Gregory-Hansen tests of cointegration with an endogenous break in the intercept. Critical values for the ADF test at 1%, 5% and 10% are -5.13, -4.61 and -4.34 respectively.	

The long run marginal impact of economic growth, energy consumption and trade openness on CO_2 emissions is reported in Table 4. The results reveal that increase in energy consumption will increase CO_2 emissions. It is documented that 1 percent rise in energy consumption raises CO_2 emissions by 0.86 percent. The findings are in line with the literature such as Hamilton and Turton [87], Friedl and Getzner [18], Liu [88], Ang and Liu [89], Say and Yücel [90], Ang [46], Halicioglu [40], Jalil and Mehmud [25].

Both linear and non-linear terms of real GDP provide evidence in support of inverted-U relationship between economic growth and CO_2 emissions. The results indicate that 1 percent rise in real GDP will rise CO_2 emissions by 3.75 percent while negative sign of squared term seems to corroborate the delinking of CO_2 emissions and real GDP at higher level of income in the country.

[3] The results of FMOLS regression are available from authors upon request.

Table 4: Long run relationship

Dependent Variable = $\ln CO_{2,t}$			
Variable	Coefficient	T-Statistic	Probability
Constant	-59.5359	-4.4192	0.0001
$\ln ENC_t$	0.8644	4.6376	0.0001
$\ln GDP_t$	3.7483	3.9443	0.0004
$\ln GDP_t^2$	-0.0506	-3.0698	0.0044
$\ln TR_t$	-0.0855	-1.7927	0.0828
R-Squared = 0.9987 Adjusted R-Squared = 0.9985 Akaike info Criterion = -4.4858 Schwarz Criterion = -4.2659 F-Statistic = 6007.3990 Prob(F-Statistic) = 0.0000 Durbin-Watson = 1.9820			
<u>Sensitivity Analysis</u> Serial Correlation LM = 0.3033 (0.7406) ARCH Test = 0.3210 (0.5747) Normality Test = 2.0552(0.3578) Heteroscedisticity Test = 0.4458 (0.8118) Ramsey Reset Test = 1.9746 (0.1570)			

This evidence provides support for EKC revealing that CO_2 emissions increase at initial stage of economic growth and decline after a threshold point. These findings are consistent with the empirical evidence of He [91], Song et al. [23], Halicioglu [40], Fodha and Zaghdoud [27] and Lean and Smyth [49].

The coefficient of TR shows inverse impact on CO_2 emissions. It indicates that 0.09 percent of CO_2 emissions are declined with a 1 percent increase in international trade. Our finding supports the view by Antweiler et al. [8], Copeland and Taylor [9], McCarney and Adamowicz [11] and Managi et al. [10] that foreign trade reduces CO_2 emissions through technological effects in the country. However, this finding is contrary to Khalil and Inam [39] who probed that international trade is harmful to environmental quality in Pakistan and Halicioglu [40] who posited that foreign trade increases CO_2 emissions in Turkey.

The high value of R-squared and a battery of diagnostic tests confirm goodness fit of the estimated model and the stability of long run results. The unique order of integration leads a support to examine the direction of causality between economic growth and CO_2 emissions through Granger causality test. The same approach is applied for short run causality without the level feedback. The results reported in Table 5 indicate that real GDP (real GDP squared) Granger causes CO_2 emissions in long run as well as in short span of time at 5% level of significance. The causality result also confirms the existence of EKC in long run and short run (see for example, Coondoo and Dinda, [22]; Dinda and Coondoo, [21]; Akbostanci et al., [28] and Lee and Lee, [92]. This empirical evidence is same with the finding of Maddison and Rehdanz [93] for North America, Zhang and Cheng [26] and Jalil and Mahmud [25] for China and Ghosh [47] for India.

Table 5: Granger causality test

Long Run Causality Results	F-Statistic	Prob. Value
$\ln GDP_t$ does not Granger cause $\ln CO_{2,t}$	4.0537	0.0160
$\ln CO_{2,t}$ does not Granger cause $\ln GDP_t$	0.9634	0.4232
$\ln GDP_t^2$ does not Granger cause $\ln CO_{2,t}$	3.8977	0.0186
$\ln CO_{2,t}$ does not Granger cause $\ln GDP_t^2$	0.9183	0.4442
Short Run Causality Results		
$\Delta \ln GDP_t$ does not Granger cause $\Delta \ln CO_{2,t}$	4.9524	0.0136
$\Delta \ln CO_{2,t}$ does not Granger cause $\Delta \ln GDP_t$	0.2798	0.7577
$\Delta \ln GDP_t^2$ does not Granger cause $\Delta \ln CO_{2,t}$	4.3145	0.0222
$\Delta \ln CO_{2,t}$ does not Granger cause $\Delta \ln GDP_t^2$	0.2811	0.7567

The short run dynamics results are reported in Table 6. Empirical evidence indicates that energy consumption leads to increase of CO_2 emissions. It is noted that 1 percent rise in energy consumption will increase CO_2 emissions by 0.6 percent. The sign of coefficients of GDP and GDP^2 are again according to our expectation and significant at 5% and 10% level of significance respectively. This validates the existence of inverted-U Kuznets curve in short run. It is noted that the long run income elasticities for CO_2 emissions are less than the short run elasticities for CO_2 emissions. This further proves the existence of EKC[8]. The short run effect of international trade is also negative but insignificant.

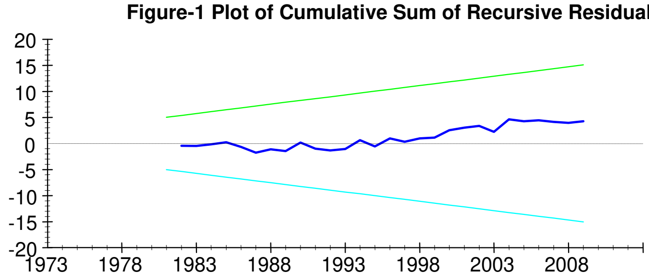
Table 6: Short run results

Dependent Variable = $\Delta \ln CO_{2,t}$			
Variable	Coefficient	T-Statistic	Probability
Constant	0.0303	7.3531	0.0000
$\Delta \ln ENC_t$	0.6077	2.2670	0.0308
$\Delta \ln GDP_t$	11.3108	2.0736	0.0468
$\Delta \ln GDP_t^2$	-0.5283	-1.9280	0.0634
$\Delta \ln TR_t$	-0.0582	-1.4275	0.1637
ECM_{t-1}	-0.1021	-6.1286	0.0000
R-Squared = 0.6605 Adjusted R-Squared = 0.6039 Akaike info Criterion = -4.4690 Schwarz Criterion = -4.2050 F-Statistic = 11.6730 Prob(F-statistic) = 0.0000 Durbin-Watson = 2.1142			
Sensitivity Analysis Serial Correlation LM = 0.8992 (0.4596) ARCH Test = 0.0216 (0.8839) Normality Test = 0.4129(0.8134) Heteroscedisticity Test = 0.6739 (0.7377) Ramsey Reset Test = 0.1405 (0.7104)			

The sign of coefficient of lagged ECM term is negative and significant at 1% level of significance. This corroborates the established long run relationship among the variables. Furthermore, the value of lagged ECM term entails that change in CO_2 emissions from short run to long span of time is corrected by almost 10 percent over each year with high significance.

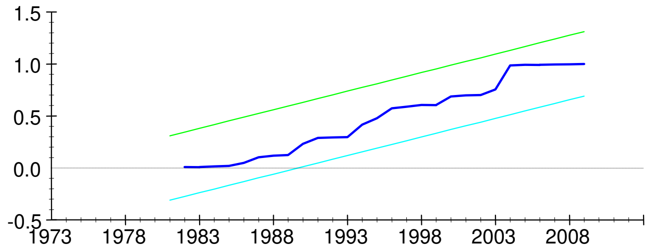
The diagnostic tests such as LM test for serial correlation, ARCH test, normality test of residual term, White heteroskedasticity and model specification test for short run model have also been conducted. The results are reported in Table 7. The empirical findings show that the short run model passes all diagnostic tests successfully. The evidence indicates no serial correlation, the residual term is normally distributed and the functional form of the model is well specified. There is no evidence of autoregressive conditional heteroskedasticity and White heteroskedasticity.

Figure-1 Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure-2 Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests have been employed to investigate the stability of long and short run parameters. Pesaran et al. [71] suggested estimating the stability of long and short run estimate through CUSUM and CUSUMSQ tests. Figures 1 and 2 specify that plots for CUSUM and CUSUMSQ are between the critical boundaries at 5 % level of significance. This confirms the accuracy of long and short run parameters in the model.

5. Conclusion and policy implications

The aim of this paper is to investigate the relationship between CO_2 emissions, energy consumption, economic growth and trade openness for Pakistan over the period of 1971-2009. The EKC hypothesis has been tested by applying ARDL model for cointegration. The result suggests that there exists long run relationship among the variables. The positive sign of linear and negative sign of non-linear GDP indicate that EKC hypothesis is supported in the country. The results of Granger causality tests show one-way causal relationship running from income to CO_2 emissions. Energy consumption increases CO_2 emissions both in short and long run. Openness to trade reduces CO_2 emissions in long run but it is insignificant in short run.

The significant existence of EKC shows the country's effort to condense CO_2 emissions. This indicates the reasonable achievement of controlling environmental degradation in Pakistan. However, this empirical evidence which is in aggregate data may not able to show the pattern of four provinces of Pakistan individually. The implementation of NEP itself is not enough. Effective enforcement of environmental laws and regulation is necessary not only at the federal level but also at the provincial level. Furthermore, research and development activities regarding environmental degradation which are important to attain sustainable development are still remaining unattainable in Pakistan. Therefore, to curb CO_2 emissions, there is a need to implement environment taxes such as green tax.

Moreover, trade openness has beneficial effect on environmental quality in Pakistan. This supports the view by Antweiler et al. [8] that international trade does not harm environment if the country uses cleaner technology for production after achieving a sustainable level of development. Our finding suggests that Pakistan must give her attention to import cleaner technology to develop her industrial sector. This not only enhances the production level but also becomes a safety valve against environmental degradation. The import of advance technology lowers environmental cost and develops the industrial sector. Keeping the composition effect constant, scale effect stimulates economic growth which raises production that increases industrial pollution. Industrial pollution can be reduced if government checks on scale effect by importing cleaner technology for industrial sector to attain maximum gains from international trade in the country.

The limitation of our study is the growth pattern of four provinces of Pakistan is different. For future, study can be focus on the provincial level to attain comprehensive impact of economic growth on CO_2 emissions which will provide new insights for policy making authorities for controlling environmental degradation at provincial level.

References

[1]. Kuznets, S. Economic growth and income inequality. The American Economic Review 1955; 45: 1-28.

[2]. Dasgupta, S., Hong, J. H., Laplante, B and Mamingi, N. Disclosure of environmental violations and stock market in the Republic of Korea. Ecological Economics 2004; 58: 759-777.

[3]. Agenor, P. R. Does globalization hurt the poor? World Bank Policy Research 2003, Working Paper, No. 2922, Washington.

[4]. Heckscher, E., *The effect of foreign trade on the distribution of income*. *Ekonomisk Tidskriff* 1919, 497-512. Translated as chapter 13 in American Economic Association.

[5]. Ohlin, B. *Interregional and International Trade*. Cambridge University Press 1933, Mass: Harvard.

[6]. Barro, R. J and Sala-i-Martin, X. Technological diffusion, convergence, and growth. Journal of Economic Growth 1997; 2: 1-26.

[7]. Feridun, M., Ayadi, F. S and Balouga, J. Impact of trade liberalization on the environment in developing countries: The case of Nigeria. Journal of Developing Societies 2006; 22: 39-56.

[8]. Antweiler, W., Copeland, R. B and Taylor, M. S. Is free trade good for the emissions: 1950-2050. The Review of Economics and Statistics 2001; 80: 15-27.

[9]. Copeland, B. R and Taylor, M. S. Free trade and global warming: a trade theory view of the Kyoto Protocol. Journal of Environmental Economics and Management 2005; 49: 205-234.

[10]. Managi, S., Hibiki, A., Tetsuya, T., Does trade liberalization reduce pollution emissions? Discussion papers 08013/2008, Research Institute of Economy, Trade and Industry (RIETI).

[11]. McCarney, G and Adamowicz, V. The effects of trade liberalization of the environment: an empirical study. International Association of Agricultural Economists, 2006 Annual Meeting, August 12-18, 2006, Queensland, Australia.

[12]. Gregory, A.W and Hansen, B. E. Residual-based tests for cointegration in models with regime shifts. RCER Working Papers 335/1996, University of Rochester - Center for Economic Research (RCER).

[13]. Grossman, G. M and Krueger, A. B. Environmental impacts of a North American Free Trade Agreement, NBER Working Paper, No. 3914/1991, Washington.

[14]. Lucas, G., Wheeler, N and Hettige, R. The Inflexion Point of Manufacture Industries: International trade and environment, World Bank Discussion Paper, No. 148/1992, Washington.

[15]. Wyckoff, A. W and Roop, J. M. The embodiment of carbon in imports of manufactured products: implications for international agreements on greenhouse gas emissions. Energy Policy 1994; 22: 187-194.

[16]. Suri, V and Chapman, D. Economic growth, trade and the energy: implications for the environmental Kuznets curve. Ecological Economics 1998; 25: 195-208.

[17]. Heil, M. T and Selden, T. M. Panel stationarity with structural breaks: carbon emissions and GDP. Applied Economics Letters 1999; 6: 223-225.

[18]. Friedl, B and Getzner, M. Determinants of CO2 emissions in a small open economy. Ecological Economics 2003; 45: 133-148.

[19]. Stern, D. I. The rise and fall of the environmental Kuznets curve. World Development 2004; 32: 1419-1439.

[20]. Nohman, A and Antrobus, G. Trade and the environmental Kuznets curve: is Southern Africa a pollution heaven? South African Journal of Economics 2005; 73: 803-814.

[21]. Dinda, S and Coondoo, D. Income and emission: a panel data-based cointegration analysis. Ecological Economics 2006; 57: 167-181.

[22]. Coondoo, D and Dinda, S. The carbon dioxide emission and income: a temporal analysis of cross-country distributional patterns. Ecological Economics 2008; 65: 375-385.

[23]. Song, T., Zheng, T and Tong, L. An empirical test of the environmental Kuznets curve in China: a panel cointegration approach. China Economic Review 2008; 19: 381-392.

[24]. Dhakal, S. Urban energy use and carbon emissions from cities in China and policy implications. Energy Policy 2009; 37: 4208-4219.

[25]. Jalil, A and Mahmud, S. Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. Energy Policy 2009; 37: 5167-5172.

[26]. Zhang, X. P and Cheng, X-M. Energy consumption, carbon emissions and economic growth in China. Ecological Economics 2009; 68: 2706-2712.

[27]. Fodha, M and Zaghdoud, O. Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energy Policy 2010; 38: 1150-1156.

[28]. AkbostancI, E., Türüt-AsIk, S and Ipek., T. G. The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Policy 2009; 37: 861-867.

[29]. Kraft, J and Kraft, A. On the relationship between energy and GNP. Journal of Energy Development 1978; 3: 401-403.

[30]. Masih, A. M. M and Masih, R. On temporal causal relationship between energy consumption, real income and prices: some new evidence from Asian energy dependent NICs based on a multivariate cointegration vector error correction approach. Journal of Policy Modeling 1997; 19: 417-440.

[31]. Aqeel, A and Butt, M. S. The relationship between energy consumption and economic growth in Pakistan. Asia Pacific Development Journal 2001; 8: 101-110.

[32]. Wolde-Rufael, Y. Electricity consumption and economic growth: a time series experience for 17 African countries, Energy Policy 2006; 34: 1106-1114.

[33]. Narayan, P. K and Singh, B. The electricity consumption and GDP nexus for the Fiji islands. Energy Economics 2007; 29: 1141-1150.

[34]. Reynolds, D. B., Kolodziej, M. Former Soviet Union oil production and GDP decline: granger causality and the multi-cycle Hubbert curve. Energy Economics 2008; 30: 271-289.

[35]. Chandran, V. G. R., Sharma, S., Madhavan, K. Electricity consumption–growth nexus: The case of Malaysia. Energy Policy 2009; 38: 606-612.

[36]. Narayan, P. K and Smyth, R. Multivariate granger causality between electricity consumption, exports and GDP: evidence from a panel of Middle Eastern countries. Energy Policy 2009; 37: 229-236.

[37]. Yoo, S-H and Kwak, S-Y. Electricity consumption and economic growth in seven South American countries. Energy Policy 2010; 38: 181-188.

[38]. Altinay, G and Karagol, G. Structural break, unit root and causality between energy consumption and GDP in Turkey. Energy Economics 2004; 26: 985-994.

[39]. Khalil, S and Inam, Z. Is trade good for environment? a unit root cointegration analysis? The Pakistan Development Review 2006; 45: 1187-1196.

[40]. Halicioglu, F. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 2009; 37: 1156-1164.

[41]. Sqauli, J. Electricity consumption and economic growth: bounds and causality analyses of OPEC members. Energy Economics 2006; 29: 1192-1205.

[42]. Yuan, J., Zhao, C.., Yu, S and Hu, Z. Electricity consumption and economic growth in China: cointegration and co-feature collection. Energy Economics 2007; 29: 1179-1191.

[43]. Odhiambo, N. M. Energy consumption and economic growth nexus in Tanzania: an ARDL bounds testing approach. Energy Policy 2009; 37: 617-622.

[44]. Asafu-Adjaye, J. The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian Developing Countries. Energy Economics 2000; 22: 615-625.

[45]. Ang, J. B. CO2 emissions, energy consumption, and output in France. Energy Policy 2007; 35: 4772-4778.

[46]. Ang, J. B. Economic development, pollutant emissions and energy consumption in Malaysia. Journal of Policy Modeling 2008; 30: 271-278.

[47]. Ghosh, S. Examining carbon emissions-economic growth nexus for India: a multivariate cointegration approach. Energy Policy 2010; 38: 2613-3130.

[48]. Apergis, N., Payne, J. E. CO2 emissions, energy usage, and output in Central America. Energy Policy 2009; 37: 3282-3286.

[49]. Lean, H. H., Smyth, R. CO2 emissions, electricity consumption and output in ASEAN. Applied Energy 2010; 87: 1858-1864.

[50]. Apergis, N., Payne, J. E. The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy Policy 2010; 38: 650-655.

[51]. Narayan, P. K., Narayan, S., 2010. Carbon dioxide emissions and economic growth: panel data evidence from developing countries. Energy Policy 2010; 38: 661-666.

[52]. Runge, C. F. 1994. *Freer trade, protected environment: balancing trade liberalization with environmental interests*. Council on Foreign Relations Books.

[53]. Helpman, E. Explaining the structure of foreign trade: where do we stand? Review of World Economics 1998; 134: 573-589.

[54]. Schmalensee, R., Stoker, T. M and Judson, R. A., World carbon dioxide emissions: 1950-2050. The Review of Economics and Statistics 1998; 80: 15-27.

[55]. Copeland, B and Taylor, M. S. International trade and the environment: a framework for analysis, NBER Working Paper 2001, No. 8540, Washington.

[56]. Chaudhuri, S and Pfaff, A. Economic Growth and the Environment: What Can We Learn from Household Data? Working Paper 2002, Columbia University, USA.

[57]. Machado, G. V., Energy use, CO2 emissions and foreign trade: an IO approach applied to the Brazilian case. Thirteenth International Conference on Input–Output Techniques, Macerata, Italy (2000) 21-25 Aug.

[58]. Mongelli, I., Tassielli, G and Notarnicola, B. Global warming agreements, international trade and energy/carbon embodiments: an input-output approach to the Italian case. Energy Policy 2006; 34: 88–100.

[59]. Shiyi, C. Energy consumption, CO2 emission and sustainable development in Chinese industry. Economic Research Journal 2009; 4: 1-5.

[60]. Ozturk, I., Acaravci, A. CO2 emissions, energy consumption and economic growth in Turkey. Renewable and Sustainable Energy Reviews 2010; 14: 3220-3225.

[61]. Nasir, M., Rehman, F-U. 2011. Environmental Kuznets curve for carbon emissions in Pakistan: An empirical investigation. Energy Policy 2011; 39: 1857-1864.

[62]. Johansen, S., Juselius, K. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxford Bulletin of Economics and Statistics 1990; 52: 169-210.

[63]. Jorgenson, D. W and Wilcoxen, P. J. Reducing U.S. carbon dioxide emissions: an assessment of different instruments. Journal of Policy Modeling 1993; 15: 491-520.

[64]. Xepapadeas, A., Regulation and evolution of compliance in common pool resources. Scandinavian Journal of Economics 2005; 107: 583-599.

[65]. Hoffmann R., Lee, C.-G., Ramasamy, B and Yeung, B. FDI and pollution: a granger causality test using panel data. Journal of International Development 2005; 17: 311-317.

[66]. Soytas, U., Sari, U and Ewing, B. T. Energy consumption, income and carbon emissions in the United States. Ecological Economics 2007; 62: 482-489.

[67]. Cameron, S. A review of the econometric evidence on the effects of capital punishment. Journal of Socio-economics 1994; 23: 197-214.

[68]. Ehrlich, I. The deterrent effect of capital punishment – a question of life and death. American Economic Review 1975; 65: 397-417.

[69]. Ehrlich, I. Crime, punishment and the market for offences. Journal of Economic Perspectives 1996; 10: 43-67.

[70].Grossman, G. M., Helpman, E. The politics of free-trade agreements. American Economic Review 1995; 85: 667-690.

[71]. Pesaran, M. H., Shin, Y., Smith, R. J. Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics 2001; 16: 289-326.

[72]. Pesaran, M. H and Pesaran, B., Working with Microfit 4.0: Interactive Econometric Analysis, Oxford University Press 1997. Chapter 7, "Multiple Equation Options".

[73]. Haug, A. Temporal aggregation and the power of cointegration tests: a monte carlo study. Oxford Bulletin of Economics and Statistics 2002; 64: 399-412.

[74]. Engle, R. F and Granger, C. W. J. Cointegration and error correction representation: estimation and testing. Econometrica 1987; 55: 251-276.

[75]. Phillips, P. C. B and Hansen, B. E. Statistical inference in instrumental variables regression with I(1) processes. Review of Economic Studies 1990; 57: 99-125.

[76]. Laurenceson, J and Chai, J. C. H. Financial reforms and economic development in China. Cheltenham 2003, UK, Edward Elgar.

[77]. Pesaran, M. H and Shin, Y. *An autoregressive distributed lag modeling approach to cointegration analysis*. Chapter 11 in Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium, Strom S (ed.) 1999. Cambridge University Press: Cambridge.

[78]. World Development Indicators, World Bank 2010.

[79]. Dickey, D. A and Fuller, W. A. Distribution of the estimators or autoregressive time series with a unit root. Journal of the American Statistical Association 1979; 74: 427-31.

[80]. Phillips, P.C.B and Perron, P. Testing for a unit root in time series regression. Biometrika 1988; 75: 335-346.

[81]. Elliott, G., Rothenberg, T. J and Stock, J. H. Efficient tests for an autoregressive unit root. Econometrica 1996; 64: 813-836.

[82]. Kwiatkowski, D., Phillips, P., Schmidt, P and Shin, Y., Testing the null hypothesis of stationary against the alternative of a unit root: how sure are we that economic time series have a unit root? Journal of Econometrics 1992; 54: 159-178.

[83]. Ng, S and Perron, P. Lag selection and the construction of unit root tests with good size and power. Econometrica 2001; 69: 1519-1554.

[84]. Baum, C. F. A review of Stata 8.1 and its time series capabilities. International Journal of Forecasting 2004; 20: 151-161.

[85]. Clemente, K., Marx, R., Guzman, R., Ikeda, S and Katz, M. *Prevalence of HIV infection in transgendered individuals in San Francisco*. Poster session presented at the XII International Conference on AIDS 1998, Geneva Switzerland.

[86]. Turner, P. Response surfaces for an F-test for cointegration. Applied Economics Letters 2006; 13: 479-482.

[87]. Hamilton, C and Turton, H. 2002. Determinants of emissions growth in OECD countries. Energy Policy 2002; 30: 63-71.

[88]. Liu, Q. Impacts of oil price fluctuation to China economy. Quantitative and Technical Economics 2005; 3: 17-28.

[89]. Ang, B. W and Liu, F. L. A new energy decomposition method: perfect in decomposition and consistent in Aggregation. Energy 2001; 26: 537-548.

[90]. Say, N.P and Yucel, M. Energy consumption and CO_2 emissions in Turkey: empirical analysis and future projection based on an economic growth. Energy Policy 2006; 34: 3870-3876.

[91]. He, J. China's industrial SO_2 emissions and its economic determinants: EKC's reduced vs. structural model and the role of international trade. Environment and Development Economics 2008; 14: 227-262.

[92]. Lee, C-Cand Lee, J-D. Income and CO2 emissions: evidence from panel unit root and cointegration tests. Energy Policy 2009; 37: 413-423.

[93]. Maddison, D., Rehdanz, K. Carbon emissions and economic growth: homogeneous causality in heterogeneous panels. Kiel Working Papers 2008, No: 1437, Kiel Institute for the World Economy.

[94]. Narayan, P. K. The saving and investment nexus for China: evidence from co-integration tests. Applied Economics 2005; 37: 1979-1990.

[1] In 2009, economic growth rate is 2% due to poor performance of the industrial and manufacturing sectors (Economic Survey of Pakistan, 2008-2009).

[2] Economic Survey of Pakistan, 2008-2009, p. 226.

[3] The nature of transportation has been converted to compressed gas consumption after hike in petroleum prices.

[4] The relationship is described by the linear and non-linear terms of GDP per capita in the model.

[5] Zhang and Cheng [36] concluded that GDP growth causes the energy consumption while energy consumption causes CO2 emissions.

[6] Halicioglu [40] and Jalil and Mahmud [25] included foreign trade as an independent factor in their models to examine the impact of foreign trade on environmental pollutants.

[7] We use Tuner's [86] critical values instead of Pesaran et al. [71] and Narayan [94] because the lower and upper bounds by Turner [86] are more suited for small sample data sets.

[8] For more details, please refer to Narayan and Narayan [51].