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Carbon emissions and industrial growth: an ARDL analysis for Pakistan

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Abstract
Purpose – This paper is a direct extension of the work by Hussain *et al.* (2012). They have investigated a long-term relationship between climatic change and economic growth in case of Pakistan. Agricultural sector plays an important role in economic field, whereas industrial sector is the main source of carbon dioxide (CO_2) emission. Therefore, this study aims to replace economic growth variable with industrial growth in case of Pakistan.
Design/methodology/approach – Investigation is made on the basis of the environmental Kuznets curve by using the time series data during the period 1971-2009. The per capital carbon dioxide (CO_2) emission is used as an environmental indicator and per capita industrial income as the economic indicator. Different econometric tools including augmented Dickey–Fuller, autoregressive distributed lag and Granger-causality test are used to verify this relationship.
Findings – The empirical findings will help the policy-makers of Pakistan in developing new standards and monitoring networks for reducing CO_2 emission. It is essential to extend the current research work at provincial and different sectors levels in order to have clear understanding about the impact of current emission rate.
Originality/value – This study replaces economic growth variable with industrial growth in case of Pakistan because the industrial sector is the main source of carbon dioxide (CO_2) emission. This study is to investigate a long-term relationship between climatic change and industrial growth in case of Pakistan.

Keywords Pakistan, ARDL, CO_2 emissions, Environmental Kuznets curve, Industrial growth
Paper type Research paper

1. Introduction
Climatic change and global warming is a hot topic now-a-days[1]. Though global warming generally depends on the emission of greenhouse gases, yet carbon dioxide (CO_2) emission is the major contributor, and, during the recent years, it has been seen increasing legislation to limit CO_2 emissions (Zhang and Cheng, 2009). According to Alcock (2008), the investors will demand reliable information about company's carbon

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foot print in near future and the effort is being made to reduce CO_2 emissions; the company's carbon statement will be taken as important as its financial statement.

The ever-increasing risk of global warming and climatic change has raised awareness about the relationship among economic growth, energy consumption and environmental pollution. Most of the previous empirical studies focus on using the cross-country panel data to estimate the relationship between per capita income and various environmental indicators. However, moving from a cross-country study to an individual country's time series study is a new trend for environmental Kuznets curve (EKC) researchers because the latter can eliminate the problems associated with cross-country data (Fodha and Zaghdoud, 2010). Lindmark (2002) argues that "historical studies of individual countries offer an advantage over cross-section approaches in bringing the analyses closer to the dynamic that causes the Environmental Kuznets Curve (EKC) pattern". Therefore, this study focuses on a single country; i.e. Pakistan.

Industrialized countries have signed Kyoto Protocol Summit in 1997 to reduce their national CO_2 by 5 per cent during the period of 2008-2012. However, the issue of climatic change is very sensitive for the developing world, particularly for Asian countries because of their heavy industry and warm weather. Unlike industrialized nations, developing countries do not have financial and infrastructure resources to adapt and mitigate climatic change (Intergovernmental Panel on Climate Change [IPCC], 2007, c). In case of Pakistan, a large amount of energy is being consumed to run her economic cycle. Almost 54 per cent out of total primary energy consumption depends on oil and gas, which contribute more CO_2 emission after coal in environment. Therefore, energy consumption is the major cause of environmental pollution in Pakistan. The environment is being exposed to additional 167 million tons of CO_2 because of these sources of energy consumption. To bring CO_2 emission to the level of 1995, new policy incentives must have to be introduced (Qudrut Ullah and Karahul, 2007). This paper addresses this issue in Pakistan.

Most of the previous researches have explored the relationship between climatic change, energy consumption and economic growth by using econometric tools (Ang, 2007; Halicioglu, 2009; and Jalil and Mahmud, 2009). According to Stern (2014):

> […] on the theoretical front, there is still scope for developing more complete dynamic models of the evolution of the economy and pollution emissions. On the empirical front, there has still been little explicit testing of alternative theories.

In 1960, the agriculture sector of Pakistan contributed 46 per cent to gross domestic product (GDP) that gradually decreased to 26 per cent in 2000. But, the industrial sector contributed 16 per cent to GDP in 1960 that gradually increased to 23 per cent in 2000 (World Bank, 2013). Hussain *et al.* (2012) also mentioned that the most of the previous researches have explored the relationship between climatic change, energy consumption and economic growth. Pakistan's economy based on agriculture land, and its GDP is heavily dependent on agricultural sector, whereas industrial sector is the major contributor of pollution because of CO_2 emission. Therefore, this work addresses this research gap and investigates climatic change issue by replacing the economic growth variable, i.e. GDP by industrial growth variable.

Pesaran and Shin (1995) and Pesaran *et al.* (2001) introduced a new methodology to determine the long-run relationship called the autoregressive distributed lag (ARDL) approach. In ARDL approach, there is no need for pre-estimating the stationarity of time series because the series are not mandatory to be integrated at the same order. Therefore, it is well appropriated to evaluate the determinants of environmental degradation in Pakistan because ARDL provides more efficient results.

The structure of this paper is as follows. Section 2 introduces brief literature review. Section 3 discusses research methodology and model. Section 4 presents analysis and discussion, whereas Section 5 offers concluding remarks.

2. Literature review

Kuznets (1955) found that an inverted U-shaped curve (bell shaped) defines the relationship between per capita income and income in-equality; this curve is known as Kuznets curve (KC). The inverse U-shaped curve hypothesis states that "As per capita income increases, environmental pollution also increases at first and then starts declining at a turning point". Later, it was found that environmental conditions and per capita income also follow the same bell-shaped curve as found in the KC. As a result, a new relationship was explored between economic growth and environmental quality indicators in the form of inverted U-shaped curve. This has been given the name EKC.

The EKC model that has been promoted by the World Bank (WB), as seen in the World Development Report (IBRD, 1992), stated that the economic activity inevitably hurts the environment but, with the increase in income, the demand for improvements in environmental quality will also increase (pp. 38-39), so the decline reaches a turning point (TP). According to Dietz *et al.* (2012):

> EKC posits an inverted "U" shaped relationship between the affluence of a nation and the stress it places on the biophysical environment, with increases in affluence from low to moderate levels producing increased environmental stress but further increases eventually leading to a tipping point after which further affluence reduces environmental stress.

Draze gave personal comments on the application of econometric tools. According to Saboori *et al.* (2012), "with the improvement of time series econometric techniques, the focus of research has changed to test cointegration and causal relationship on the basis of the EKC hypothesis". Shafik and Bandyyopadhyay (1992) measured the relationship between the pollutants and per capita GDP by using the log linear, log quadratic and log cubic of GDP. The econometric results suggested that trade, debt and the other macroeconomic variables had little effect on the environment. Grossman and Krueger (1993) and Panayotou (1993) tested for relationships between measures of environmental degradation due to presence of SO_2 and NO_2 presence and the rate of deforestation and economic variables such as per capita GDP, trade intensity and population. They did not find any significant relationship between them.

Selden and Song (1994) also measured the quadratic relationship and effect of pollutants such as per capita SO_2, NO_2 and CO_2 on per capita GDP and population density for the case of Turkey. It was found that a significant relationship exists among the variables. Shafik (1994) measured the relationship between environmental quality and per capita income by taking into account other variables such as: endowment; income; technology; and policy. It was found that most of societies, except that of the developing countries, were adopting policies and making investments to reduce the environmental damage. However, Sun (1999) demonstrated that CO_2-EKC exists only in those countries that have got peak energy intensity. The peak theory of energy intensity reveals that the energy intensity follows an inverted U-shaped curve against per capita GDP.

Heil and Selden (1999) analyzed international trade and pollution by applying cross-country econometric tools to carbon emission. They collected the data of 132 countries from all over the world from1950 to 1992. They concluded that an increase in trade intensity raises CO_2 emission in lower-income countries and lowers CO_2 emissions in higher income countries. Cole (2004) investigated the relationship between pollution and trade. The developed countries' data had been analyzed with that of developing countries by using the cubic function. The result stated that the trade openness also had the significantly relationship with pollution. Lee (2006) investigated the relationship between energy consumption and economic growth by taking the panel of 11 major industrialized countries, i.e. USA, UK, Germany, France, Italy, Canada, Japan, Belgium, Netherland, Sweden and Switzerland. The econometric tools that had been used to investigate the relationship were augmented Dickey–Fuller (ADF) unit root test and causality test. The causality results indicate the bidirectional causality relationship between energy consumption and economic growth in the case of the USA. However, a unidirectional relationship exists between economic growth and energy consumption in case of France, Italy and Japan. The causal relationship is missing in the UK, Germany and Sweden.

Ang (2007) investigated a relationship between CO_2 emission, energy consumption and economic growth of France from 1960 to 2000. The econometrics techniques that had been used to investigate the quadratic relationship were ADF unit root test, Phillips–Perron (PP) test, Elliott–Rothenberg–Stock Point-Optimal test to measure the stationarity; Johansen co integration test and ARDL bounds test to measure the long-term relationship; and the Granger-causality test is used to measure the causal relationship. The result found that there is a long run relationship between CO_2 emission, energy consumption and economic growth. The causality results indicate that there is a bi-causal relationship between CO_2 emission, energy consumption and economic growth in long run.

For the case of Turkey, Halicioglu (2009) examined the dynamic causal relationship between CO_2 emissions, energy consumption, income and foreign trade using time series data from 1960 to 2005. The results show that the EKC does not exist for CO_2 emission. He and Sandberg (2012) conducted a similar study for Canada, using time series data from 1948 to 2004. They found that the oil shock of the 1970s had a major impact on Canada's economic growth, although again there was no evidence of the EKC curve. Fodha and Zaghdoud (2010) analyzed the relationship, on the basis of the EKC hypothesis, between pollutant emissions such as CO_2 and SO_2 and economic growth (GDP) for Tunisia for the period 1961-2004. The results show that there is a long run co integration relationship between the per capita of both emissions and GDP. The causality results indicate a unidirectional causality relationship between income and pollution, both in the short and long terms. The results also confirmed the existence of the EKC for SO_2 emission but not for CO_2 emission in Tunisia.

Jalil and Mahmud (2009) analyzed the relationship on the basis of EKC hypothesis between pollutant emission like CO_2, energy consumption, economic growth (GDP) and foreign trade for China during the period of 1975-2005. The techniques that had been used to investigate the quadratic relationship were ADF unit root test to measure the stationarity; the Granger-causality test; ARDL to measure the long run and error correction model (ECM) estimates; and the cumulative sum of recursive residual (CUSUM) and the cumulative sum of squares of recursive residual (CUSUMQ) techniques were used to check the stability of test. The results confirmed the existence of EKC for CO_2 emission for China. There is a long-run relationship between the per capita emission, energy consumption, income and trade. The causality results indicate a unidirectional causality relationship between income and pollution. But, the trade has the positive but insignificant impact on CO_2 emission. The CUSUM and CUMSUMQ techniques showed that the estimated coefficients of the model were stable.

Ghosh (2010) examined the dynamic causal relationship between carbon emission, energy supply, real GDP, real investment and employment using the time series data for the period of 1971-2006 for India. The techniques that had been used to investigate the quadratic relationship were ADF unit root test to measure the stationarity; Johansen co integration test; the Granger-causality test; ARDL bound testing to measure the long run and ECM estimates; generalized variance decomposition analysis; and the CUSUM and the CUSUMQ techniques were used to check the stability of test. The results show that there is a no long-run equilibrium relationship between the per capita emission and per capita GDP. The result of bound testing indicates that there is one form of long-run relationships between the variables. The causality results indicate a bidirectional causality relationship between income and pollution. The CUSUM and CUMSUMQ techniques show that the estimated coefficients of the model are stable.

Fodha and Zaghdoud (2010) analyzed the relationship on the basis of EKC hypothesis between pollutant emission such as CO_2 and SO_2 and economic growth (GDP) for Tunisia during the period of 1961-2004. The techniques that had been used to investigate the quadratic relationship were ADF unit root test, PP test, Kwiatkowiski–Phillips–Schmidt–Shin to measure the stationarity; Johansen co integration test; and the Granger-causality test. The results show that there is a long-run co integration relationship between the per capita for both emission and per capita GDP. The causality results indicate a unidirectional causality relationship both in short- and long-run between income and pollution. The results show the confirmed existence of EKC for SO_2 emission but not for CO_2 emission for Tunisia.

Al-Mulali *et al.* (2013) found the bi-directional long run relationship among energy consumption, CO_2 emission and economic growth in the Latin American and Caribbean countries. It has been found that 60 per cent of these countries show a positive bi-directional long run relationship between energy consumption, CO_2 emission and economic growth, but, for the remaining countries, the results are mixed one. Lee and Brahmasrene (2013) investigated that the tourism influences economic growth and CO_2 emissions for the countries of European Union. Park and Hong (2013) explored the correlations between the economic growth, CO_2 emission and energy consumption in case of South Korea.

Sephton and Mann (2013) has found the non-linearly co integration between growth and CO_2 emissions in Spain and there is existence of EKC. They had described it an asymmetric adjustment between equilibria in the dynamic relationship. Shahbaz *et al.* (2014) suggested that there is long run relationship between economic growth and CO_2 emissions in Tunasia. The co integration and EKC hypothesis exist; it tells that CO_2 emissions rise in the early phase of economic growth and decline after a threshold point.

Farhani *et al.* (2014) studied ten countries of Middle East and North African countries and found that there exist long and short-run causality relationships among the variables for EKC, and all coefficients are statistically significant over the period 1990-2010. Lau *et al.* (2014) had revealed that EKC hypothesis exist in the Malaysia by using ARDL approach. They argue that it is because of only the implementation of national program on the environment. Al-Mulali *et al.* (2015) found that the pollution haven hypothesis exist in Vietnam economy; it is because capital increases pollution. They discuss that labor force cuts the pollution because most of Vietnam's labor force is involved in the agricultural and services sectors which are less energy concentrated than the industrial sector.

Hussain *et al.* (2012) have investigated the relationship among environmental pollution, economic growth and per capita energy consumption in case of Pakistan by using EKC curve. Different econometric tools such as ADF unit root Johansen co-integration VECM and Granger causality tests have been applied. A monotonically increasing curve between GDP and CO_2 emission has been found for the sample period, rejecting the EKC relationship, shows that as per capita GDP increases a linear increase is observed in per capita CO_2 emission. The limitation of their work is that relationship between economic growth and CO_2 emission has been explored, whereas in reality, CO_2 depends on industrial growth (Hussain *et al.*, 2012). Agricultural sector shows a significant part in economic field, whereas industrial sector is the main source of CO_2 emission (Al-Mulali *et al.*, 2015). Therefore, this study replaces economic growth variable with industrial growth in case of Pakistan. This work fulfills this research gap and explores the EKC curve between industrial growth and CO_2 in case of Pakistan.

3. Research methodology and model

The model adopted here to investigate the relationship between per capita CO_2 emission and per capita industrial income has the following function form:

$$c_t = f(ig_t, ig^2{}_t, ig^3{}_t) \tag{1}$$

Where:

- c = CO_2 emission per capita;
- ig = per capita industrial income;
- ig^2 = square of per capita industrial income;
- ig^3 = cube of per capita industrial income; and
- t = time period.

The cubic equation describes the relationship give below:

$$c_t = \alpha_1 + \alpha_2 ig_t + \alpha_3 ig^2{}_t + \alpha_4 ig^3{}_t + \varepsilon_t \tag{2}$$

Where α_1 is one of the constant, which describes change in CO_2 per capita when there is no change in industrial income. α_2, α_3 and α_4 are the slope parameters. ε_t is the regression error term. All the variables are transformed in natural logarithm shown in equation below:

$$lnc_t = \alpha_1 + \alpha_2 lnig_t + \alpha_3 lnig_t^2 + \alpha_4 lnig_t^3 + \varepsilon_t \quad (3)$$

Where *ln* is the natural log transformation for each variable. There are three reasons for transforming the equation (2) in our case, viz:

(1) The time series used in our research shows a healthy exponential trend (i.e. the value moves upward or downward consistently), the natural log of time series effectively linearize the exponential trend.

(2) The nonlinear model is linearized one because our model is cubical.

(3) It allows the coefficients of regression equation (2) to be interpreted as elasticities (Asteriou and Hall, 2007).

According to Ansuategi (2000), that there is multicollinearity between independent variables in cubic regression equation to measure EKC does not create any dispute. While measuring EKC, there should not use and should not check whether or not multicollinearity is present (Leib, 2003). Even a lot of studies had found multicollinearity issue in their data, but they had used quadratic or cubic specifications to estimated EKC like Stern (1998).

Under the EKC hypothesis, the greater output (industrial growth) should generate more CO_2 emission, the sign of $\alpha_2 > 0$ means α_2 is expected to be positive. If $\alpha_3 < 0$ is negative, then it is statistically insignificant; this indicates that there is a monotonic increase in the relationship between per capita CO_2 emissions and per capita GDP. And it is expected that $\alpha_4 > 0$. The above equation (3) allows testing the several forms of environmental economic relationship:

if $\alpha_2 > 0$, $\alpha_3 < 0$, $\alpha_4 > 0$, it gives a N-shaped curve;
if $\alpha_2 < 0$, $\alpha_3 > 0$, $\alpha_4 < 0$, it gives an inverted N-shaped curve;
if $\alpha_2 < 0$, $\alpha_3 > 0$, $\alpha_4 = 0$, it gives a U-shaped curve; and
if $\alpha_2 > 0$, $\alpha_3 < 0$, $\alpha_4 = 0$, it gives an inverted U-shaped curve.

The TP of EKC hypothesis shown by inverted-U shaped curve, if $\alpha_2 > 0$ and $\alpha_4 = \alpha_5 = 0$, which tells a monotonically increasing linear relationship, and, $\alpha_3 < 0$ and $\alpha_4 = \alpha_5 = 0$, which tells a monotonically decreasing linear relationship (Grossman and Krueger, 1995; Friedl and Getzner, 2003; Egli, 2004; Halicioglu, 2009; Jalil and Mahmud, 2009; Annicchiarico *et al.*, 2009; Fodha and Zaghdoud, 2010 and Hussain *et al.*, 2012).

This study investigates the long-run relationship between CO_2 and *IG*. To perform co integration analysis, it is required to determine the order of co integration of each variable. However, as noted in the literature, depending on the power of the unit root tests, different tests yield different results. In view of this problem, Pesaran and Shin (1995) and Pesaran *et al.* (2001) introduce a new method of testing for co integration called the "Autoregressive Distributed Lag" approach. This method has the advantage that there is no need for unit root pre-testing because series are not required to be integrated of the same order. Further, the ARDL approach is very suitable to estimate the determinants of environmental degradation in Pakistan because ARDL provide more efficient results.

ARDL estimates the long-run and short-run components of the model simultaneously, and it can distinguish the dependent and explanatory variables. In the absence of prior information about the direction of the long-run relationship among the variables, the following error correction (EC) version of ARDL model based on variables in equation (3) is given as under:

$$\Delta \ln CO_t = \alpha_0 + \sum_{i=0}^{1} \alpha_{1t} \Delta \ln IG_{t-i} + \sum_{i=0}^{1} \alpha_{2t} \Delta \ln IG^2_{t-i} + \sum_{i=0}^{1} \alpha_{3t} \Delta \ln IG^3_{t-i} + \gamma_1 \ln CO_{t-1} + \gamma_2 IG_{t-1} + \gamma_3 \ln IG^2_{t-1} + \gamma_4 \ln IG^3_{t-1} + \varepsilon_t \tag{4}$$

For testing co integration, incase long-run relationships exist, the *F-test* indicates which variable should be normalized. The null hypothesis of no long-run relationship is defined by *H0*: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ and is tested against its alternative *H1*: $\gamma_1 \neq 0$, $\gamma_2 \neq 0$, $\gamma_3 \neq 0$, $\gamma_4 \neq 0$ by computing the *F*-statistics. If the results support the evidence that a long-run relationship (co integration) equation (3), then ARDL (m, n, p, q) equation is estimated as follows:

$$\ln CO_t = \alpha_0 + \sum_{i=0}^{n} \alpha_1 \ln IG_{t-i} + \sum_{i=0}^{p} \alpha_2 IG^2_{t-i} + \sum_{i=0}^{q} \alpha_3 \ln IG^3_{t-i} + \omega_t \tag{5}$$

The orders of the lags in the ARDL model above are selected by the *Schwartz Bayesian criterion*, and the selected model is estimated by the *Ordinary Least Squares* (OLS) technique. In the presence of co integration, short-run estimates can also be obtained by constructing an ECM:

$$\Delta \ln CO_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta \ln CO_{t-i} + \sum_{i=0}^{n} \beta_2 \Delta \ln IG_{t-i} + \sum_{i=0}^{n} \beta_3 \Delta \ln IG^2{}_{t-i} + \sum_{i=0}^{n} \beta_4 \Delta \ln IG^3_{t-i} + \psi EC_t + \theta_t \tag{6}$$

Where EC_t is the EC term, which is defined as:

$$EC_t = LnCO_t - \alpha_0 + \sum_{i=1}^{m} \alpha_1 LnCO_{t-i} - \sum_{i=0}^{n} \alpha_2 IG_{t-i} - \sum_{i=0}^{n} \alpha_2 \ln IG^2 - \sum_{i=0}^{n} \alpha_3 \ln IG^3{}_{t-i} \tag{7}$$

Here, Δ is the first difference operator; αs are the coefficients relating to the short-run dynamics of the model's convergence to equilibrium and ψ measures the speed of adjustment. The robustness of ARDL bound test of co integration is checked by the *Likelihood Ratio* (LR) Tests to determine the number of co integrating relationships proposed by Johansen (1995). The *Wiener Granger Causality Test* popularly known as *Granger Causality Test* put forward by Granger (1969) is used to measure the two ways causality means the cause and effect relationship between two or more variables.

To check the performance of the estimated model, the diagnostic tests associated with the model are presented that examine the serial correlation and functional form. *Breusch–Godfery Langrage Multiplier* (LM) test are used to test the presence of serial correlation. The linear function form is measured by using *Ramsey Reset Test*.

Additionally, in this study the stability tests, namely, *CUSUM* (Cumulative Sum) and *CUSUMSQ* (CUSUM of Squares) of recursive residuals are also conducted.

The variable of CO_2 emission per capita (C) is measured in metric tons per capita. The variable of per capita industrial income (IG) is measured in local monetary unit (Rs.). The data for the CO_2 emission and per capita industrial income have been taken from World Bank's (2013), Cole (2004), Halicioglu (2009), Jalil and Mahmud (2009).

4. Analysis and discussion

The first step is to check the stationarity of variables for which *ADF Unit Root Test* and *Phillips Perron Unit Root Test* have been used. The ADF test includes constant with no trend at level *I(0)* and first difference *I(1)* of variables. The lag differences (*k*) are chosen according to *Schwarz Info Criterion*. ADF unit root test is commonly applied to measure the existence of stationarity, but it is not very powerful tool for infinite samples. Therefore, Phillips and Peron (1997) have introduced "Phillips-Peron (PP) Unit Root Test". The PP test includes constant with no trend at level *I(0),* and first difference *I(1)* of variables. The bandwidth (*t*) is chosen according to Bartlett Kernel.

The test result shown in Table I indicates that the time series data at level *I(0)* is non-stationary at significance level of 1 per cent and at different lags. The deterministic trend reveals that the time series is predictable and variables are stationary in case of Pakistan. This implies that the effects of temporary shocks will be eliminated with the passage of time as the series regress to long term variance. After identifying the economic variables that are integrated at order *I(0)* and order *I(1)*, the next step is to apply *ARDL Co-integration Test* by the selection of the *VAR Optimal Lag Orders*. In the first stage of this step, LogL, sequential modified LR test statistics LR, final prediction error FPE, AIC, SC and LR information criteria are employed to find the optimum lag length of vector autoregressive (VAR). The results of this test have been presented in Table II:

Table I. ADF unit root test and Phillips–Perron unit root test statistics: Pakistan 1971-2009.

	ADF unit root test				Phillips–Perron unit root test			
Variable	*I (0)*	*k*	*I (1)*	*K*	*I (0)*	*T*	*I (1)*	*t*
Lnc	−0.3933	0	−5.2235*	0	−0.3932	0	−5.2096*	2
Lnig	−0.3808	0	−5.9947*	0	−0.3931	2	−5.9906*	3
$lnig^2$	−0.3121	0	−5.8109*	0	−0.3351	2	−5.8191*	2
$lnig^3$	−0.2449	0	−5.6276*	0	−0.2675	1	−5.6408*	2

Note: *denotes MacKinnon critical values for rejection of null hypothesis of a unit root and significance at the 1% level

Table II. Test statistics and VAR lag order selection criterion of model

Order	LL	LR	FPE	AIC	SC	HQ
0	177.0298	NA	1.65e−09	−8.8733	−8.7027	−8.8121
1	349.2773	300.3289*	5.48e−13*	−16.8860*	−16.0329*	−16.5799*

Note: *denotes lag order selected by the criterion

It is important to choose high order lag for the VAR so that optimal lag order may not exceed it. Hence, the four VAR 0, 1, 2, 3 models have been calculated over the time period of 1971-2009. However, SC criteria implied that the order is 1. The log LR statistics, whether adjusted for small sample or not, has rejected order 0 but accepted a VAR of order 1. In the light of above statistics, it has been decided to choose VAR (1) model.

After finalizing the selection of the VAR optimal lag orders, the third step of the ARDL co-integration test is to establish for a long-run relationship (co-integration) among the variables using *Bound Test*. In *Bound Test*, OLS is calculated by equation (4) and OLS is used to calculate F-statistics with the help of *Wald Test*.

Table III shows that F-statistic for order of lag 1 is 7.31 at a 1 per cent significant level. The result implies that there is a strong long-run relationship among the variables of the model. After finding the long relationship among the variables, the fourth step is to estimate the long- and the short-run coefficients. The long run coefficients have been estimated by using the OLS technique with equation (5).

Table IV shows that the coefficient of industrial income per capita is statistically significant. Since the long-run estimates have been calculated, the short-run (ECM) coefficients are estimated in the next stage. The estimated results of ECM allow measuring the speed of the adjustments required to adjust the long-run values after a short-term shock. The short-run results are shown in Table V:

The coefficient of ECM is −0.3119 with the expected sign and significant *t*-value and *p*-value. However, the ECM coefficient is fairly small and which implies that 31.19 per cent of the disequilibria in per capita CO_2 emission of the previous year's shocks adjust back to the long run equilibrium in the current year. And the speed of the adjustment insignificantly fast in the case of any shock to the CO_2 emission equation.

F-statistics	7.3174*	Probability (6,28)	0.0001**
Chi-square	43.9045*	Probability (6)	0.0000**

Notes: *the critical value ranges of *F*-statistics at 1% level of significance; **denotes rejection of hypothesis at the 1% significance level

Table III. Wald test

Dependent variables: CO_2	Coefficients	*t*-values	*p*-values
Lnig	−5.1520	−3.5458	0.0011*
$lnig^2$	1.0405	3.0821	0.0040*
$lnig^3$	−0.0522	−2.6631	0.0116*

Note: *denotes significance at the 1% level

Table IV. ARDL model long run estimates

Dependent variables: CO_2	Coefficients	*t*-values	*p*-values
$\Delta CO_{2\ t-1}$	0.1527	1.2161	0.2321
$\Delta lnig_t$	0.6663	4.8089*	0.0000*
ecm_{t-1}	−0.3119	1.8388*	0.0744*

Note: *denotes significance at the 10% level

Table V. ARDL model ECM estimates

The relationship between environmental pollution and economic growth has been the subject of extensive research over the past of few decades. The previous studies suggested that there was an inverse U-shaped curve relationship between economic activity and environmental pollution. But, this study considers the industrial growth variable instead of economic activity. The fitted values of CO_2 emissions are estimated to draw an inverted U-shaped curve to test the EKC hypothesis with the per capita industrial income. Table IV shows the coefficients of long run estimates by using ARDL model of Pakistan from 1971 to 2009. From the sign of parameters, the results show that there is an inverted N-shaped relationship i.e. $\alpha_3 < 0$, $\alpha_4 > 0$, $\alpha_5 < 0$ between per capita CO_2 and per capita industrial income. The EKC curve is shown in Figure 1:

The fitted values of per capita CO_2 emissions are taken on the y-axis, and the per capita industrial income in terms of local monetary unit rupees (Rs.) on x-axis. The CO_2-IG relation seems to be a monotonically increasing curve. The EKC hypothesis stated that as per capita income increases, the environmental degradation also increases at first and then starts declining at TP. Thus, the findings do not support the hypothesis of an inverted U-shaped EKC for CO_2 emissions in Pakistan.

The robustness of ARDL bound test of co integration is checked by the LR Tests to determine the number of co integrating relationships proposed by Johansen (1995). The test results of trace statistics tests, which is shown in Table VI:

Table VI reported that long-run equilibrium exists between the variables (*lnc, lnig, lnig*^{2} *and lnig*^{3}). Thus, it can be concluded that a long-run relationship between the CO_2

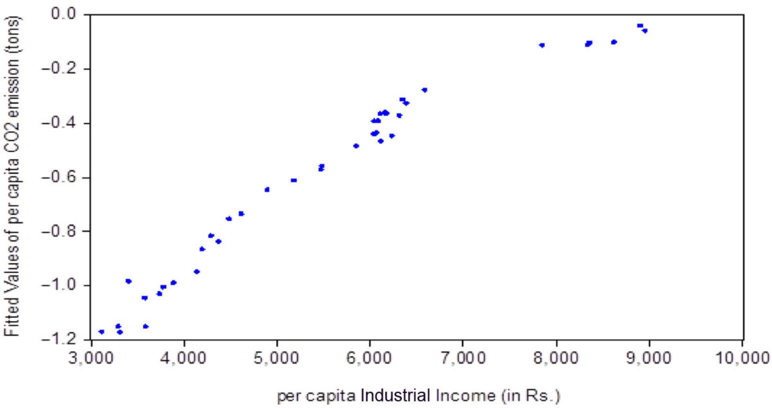

Figure 1.
The EKC-CO_2 relationship: Pakistan 1971-2009

Table VI.
Cointegration rank test with trace statistic for CO_2

Hypothesized no. of CE	$r = 0$ None*	$r \leq 1$ At most 1*	$r \leq 2$ At most 2*	$r \leq 3$ At most 3*
Eigen value	0.5796	0.2589	0.2395	0.0782
Trace statistics	59.3499	25.5477	13.8603	3.1797
Critical value	37.0353	21.7771	10.4745	2.9761
Probability**	0.0002*	0.0344*	0.0274*	0.0883*

Notes: * denotes rejection of hypothesis at the 10% significance level; LR rejects any cointegration at 10% significance level; ** MacKinnon–Haug–Michelis (1999) p-values emissions and industrial income exist in terms of Pakistan. The trace statistics indicates that there are three numbers of co integration equations at the 10 per cent level which confirm the results of the Pesaran *et al.* (2001) co integration approach. The Granger Causality test has been used to verify the direction of causality between the variables of Pakistan. The results are shown in Table VII.

The test results show that there is unidirectional causality between per capita industrial income and per capita CO_2 emission. The model passed through the diagnostic tests such as serial correlation, functional form specification, normality and hetroskedasticity. To investigate the serial correlation, the Breusch–Godfery LM test is applied, and the result has been concluded by allowing for up to two lags in Table VIII.

The results have suggested the acceptance of null hypothesis, i.e. there is no serial correlation; it means that the disturbance term relating to any variable has not been influenced by the disturbance term relating to another variable. The functional form is measured by regression error specification test (RESET), which defines the linearity of the model. If the residuals from a liner model are independent, they should not be correlated with the regressors used in the estimating equation or with the fitted values. Therefore, a regression of the residuals on these values should not be statistically significant (Enders, 2008). Table VIII shows that the regression of the residuals terms on the regressor's value is not statistically significant and model is linear in nature.

The assumption of classical linear regression model is that all disturbance terms have the same variance means homoskedasticity. The presence of hetroskedasticity has been tested through Breusch–Pagan–Godfery. The null hypothesis is homoskedasticity and alternative hypothesis is hetroskedasticity. The p-value is greater than 10 per cent significance level; accept the null hypothesis that there is homoskedasticity means equal variance. Another way to determine the misspecification problems is through observing the regression residual. The assumption of regression model is that the residuals are normally distributed with a zero mean and a constant variance. Jarque–Bera test can be

Null hypothesis	F-statistics	p-value
Industrial income does not granger CO_2 emission	6.2112	0.0050*
CO_2 emission does not granger industrial income	0.3037	0.7400

Note: *indicates the rejection of null hypothesis at 5% significant level

Table VII. Granger causality results F-statistics

Breusch–Godfery serial correlation LM test			
Observation*R^2	0.1693	Probability	0.9188
Ramsey RESET test			
Log likelihood ratio	0.7402	Probability	0.3896
Hetroskedasticity Breusch–Pagan–Godfery test			
Observation*R^2	1.9171	Probability	0.5898
Jarque–Bera normality test			
JB statistics	2.3834	Probability	0.3037

Note: *denotes rejection of hypothesis at the 10% significance level

Table VIII. Breusch–Godfery serial correlation LM test used to test the normality. The null hypothesis is the normality of residuals. The p-value is greater than 10 per cent significance level; accept the null hypothesis that the residuals terms are normally distributed.

Finally, the model has passed through the stability test. The CUSUM and the CUSUMSQ are used as the last stage of ARDL estimation to check whether all coefficients in an ECM are stable or not. The plots of CUSUM and CUSUMSQ statistics are presented in Figure 2:

Figure 2 indicates the plot of CUSUM and the CUSUMSQ that all the coefficients in the estimated ECM are stable over the sample period at the 5 per cent level of significant.

5. Conclusion

Most of the previous researches have explored the relationship between environmental pollution and economic growth. Pakistan has agricultural-based economy and GDP is heavily dependent on agricultural sector, whereas industrial sector is a major contributor of environmental pollution (Hussain *et al.*, 2012). Therefore, this research replaces economic growth variable with industrial income. The data for the CO_2 emission and per capita industrial income from 1971 to 2009 has been taken from World Bank's (2013), and ARDL technique has been used to determine a long-term relationship between these two variables.

At the first step, ADF Unit Root test has been used to check that the economic variables have unit root. The test result indicates that the time series data are stationary. Second, ARDL test has been used to measure the long run and short run estimates. The long-run equilibrium relationship has been measured by applying co integration and the results of test reported that long-run equilibrium exists between the variables.

The different diagnostics tests are used to investigate the autocorrelation, the Breusch–Godfery LM test is applied and the results have suggested that there is no autocorrelation. The functional form is measured by RESET which defines the model is linear in nature. The model has passed through the stability test. The CUSUM and the CUSUMSQ are used at the last stage of ARDL estimation to check that all coefficients in ECM are stable.

The Granger Causality test has been used to verify the direction of causality between the variables of Pakistan. The test results show that there is a unidirectional causality between per capita industrial incomes to per capita CO_2 emission. This implies that

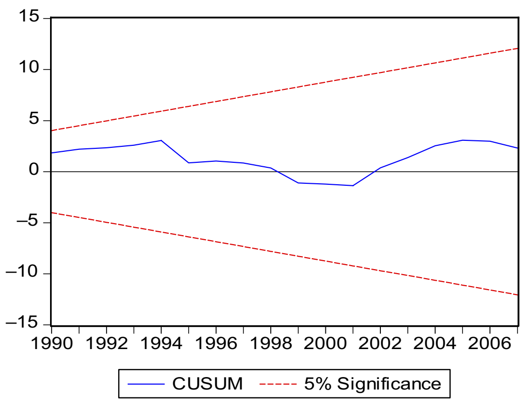

Figure 2.
Plot of cumulative sum of recursive residuals

emission reduction guidelines and policies should be introduced. The logic of more investment in pollution control will not hurt industrial growth and could be a feasible policy tool for Pakistan to achieve its sustainable growth in the long-run. The government of Pakistan should take emergency actions to encourage the corporate social responsibility (CSR) plans for highly polluted industries. The new industry should be commenced by adopting the CSR plans and new technology.

The CO_2-IG relation does not support the hypothesis of an inverted U-shaped EKC for CO_2 emissions in Pakistan. It seems to be monotonically increasing curve. The rejection of inverted U-shaped EKC hypothesis has articulated the two different ways to control pollution:

(1) change of the energy mix with the passage of time; and

(2) deployment of different energy saving programs in the heavy industries that will lower the emission.

According to Stern (2014):

> […] in slower growing economies, emissions-reducing technological change can overcome the scale effect of rising income per capita on emissions. In faster growing middle-income economies the effects of rising income overwhelmed the contribution of technological change in reducing emissions.

More importantly, the international cooperation and mitigation technology transfer from industrialized countries will also help to follow a low-carbon growth path. For future study, it is essential to outspread the current research work at provincial level and different sectors level to develop advance understanding of the impact of current emission.

Note

1. This paper is a direct extension of the work by Hussain *et al.* (2012).

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