Do Economic and Financial Development Increase Carbon Emission in Pakistan: Empirical Analysis through ARDL Cointegration and VECM Causality

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Abstract

This empirical study is an effort to establish cointegration and causality between carbon emissions, economic growth, energy consumption, financial development and trade openness in Pakistan. Lack of environmental protection laws, energy crises and resulting lower economic growth make Pakistan a unique setting to study the country specific reactions among the variables. The annual data after the separation of Bangladesh from 1973 to 2011 is used for the empirical work. The stationarity of the variables with structural breaks is analyzed. The Auto-regressive Bound Testing (ARDL) approach to cointegration is used to determine the cointegration relation. Fully Modified Ordinary Least Square (FMOLS) and Dynamic OLS (DLOS) cointegration equations are applied to estimate long run co-efficients. Short run relationship is determined through Vector Error Correction (VEC) based Granger causality, Variance Decomposition Analysis (VDA) and Impulse Response Function (IRF). After confirmation of cointegration between the variables, long term estimations confirm that economic growth and energy consumption increase the carbon emissions. Economic growth, energy consumption and trade openness Granger cause carbon emission in short run. There is unidirectional causality running from financial development and energy consumption to economic growth. Financial development is caused by carbon emissions and trade openness. Trade openness also Granger causes energy consumption. There is a bi-directional causality between financial development and energy consumption in Pakistan. Hence, the efforts to overcome energy crises and foster the economic growth require considerable attention to the carbon emissions; the best policy is to improve the situation through alternate energy resources i.e. Coal, Liquefied Petroleum Gas (LPG) and Liquefied Natural Gas (LNG). There is a need to introduce conservation policies so that wastage and spillovers of energy resources can be minimize. Efficient use of scarce energy resources will not only reduce the environment degradation but will also help to foster the economic growth. The environmental protection laws require proper enforcement.

Key words: Carbon emission, economic growth, financial development, Pakistan

1. Introduction

When we talk about environment then there are many concerns and issues which turn researchers and policy makers to think about environmental degradation. Among Green House Gas emissions, Carbon Dioxide is the most important which contributes about 58% of the total GHG emissions of the world. In the fourth assessment report of international panel on climate change (IPCC's) by Bacon (2007), increase in the carbon emission intensity per unit of gross domestic has been reported which indicates that global co2 emissions are increasing at a higher rate since 1970's.

The relationship between environment and growth has been studied and discussed in Environmental Kuznets curve (EKC). In 1955, Kuznets studied the income inequality nexus under Kuznets curve and Environmental Kuznets Curve (EKC) was originated from this. EKC postulated that the relationship between environment and growth is inverted and U-shaped nature. At the start of development, Green House Gas emissions increases but after reaching certain turning point, emissions decreases with the increase in growth. Hence countries adopt three types of strategies to control GHG emissions. They can reduce their production (Scale effect), move to cleaner/greener technologies (Technique effect), and swapping to cleaner sectors of production (Composition effect). Kyoto Protocol was signed in December 1977 under Nations Framework Convention on Climate change (UNFCC to decrease global GHG emissions. It came into force in 2005. The major objective of Kyoto protocol was to set targets of GHG reduction for 37 industrialized and European countries.

In 2005, the controls on environmental degradation were implemented through an environment policy by Pakistan's Government. The main objective of National Environmental Policy (NEP) is to protect the environment and take immediate actions to decease environmental degradation in Pakistan. There is a strong link between environment and growth of a country. In case of Pakistan the growth rate is most dependent on industrial sector. This Industrial-led growth increases energy demand which in turn increases the pollutant level of Pakistan. 36% of the total energy is consumed by the industrial sector during 2002-2003 and transportation sector consumed 33% of the total.

Rising Carbon dioxide emissions in Pakistan are due to the heavy use of petroleum in transportation sector of Pakistan. Pakistan contributes 0.4% of the world's total carbon emissions and this percentage has been increasing very quickly. During the time period 2006-2009 , the income per capita has been increased from PKR 32,599 to PKR36, 305 and energy consumption per capita has been increased from 489.36 (Kg of oil equivalent) to 522.66 (Kg of Oil equivalent). This shows that CO_2 emissions per capita has already increased from 0.7657 metric tons to 1.0226 metric tons for case of Pakistan.

It is widely written and believed that relationship between energy consumption, economic growth and emissions exist. This relationship has been studied and formulated in four types of hypothesis. The first one is growth hypothesis which postulates that there is a unidirectional causality moving from energy consumption to growth. This hypothesis explains that shocks or sudden increase/decrease in energy supply will have adverse on the growth of the country. The second hypothesis is conversation hypothesis which posits that economic growth Granger cause energy consumption. The Third namely feed-back hypothesis states that economic growth and energy consumption posit a bidirectional causality. So the higher energy consumption increases the economic growth and vice versa. And finally according to Neutrality hypothesis, there is no causality relationship between economic growth and energy consumption.

Therefore it is very much important to study energy consumption in this nexus because energy related GHG emissions has a major contribution in total GHG emissions (61.4 % of Global GHG emissions come from energy sector – world's resource institute). Along with energy consumption other variables are also included as studied and mentioned by Karanfil (2009). Karanfil suggests that there are other variables like financial variables which could impact the demand for energy in any economy.

Financial development is very important to study. It is basically a country's decision to allow and promote such activities which increases economic growth. Foreign Direct Investment, increase in Banking sector and stock market activities are the part of financial development. It is important to study banking sector and stock market because a country's financial system is based on them which in turn is associated with growth. Financial development give more access to the financial capital and cutting edge technologies. It can also increase the demand for energy by many ways. It will be easier for consumers to buy big ticket items like refrigerators, Ac's, automobiles which in turn increases the energy consumption. On the same way businesses also get benefits from high financial development as they gain huge financial capital much easier and less costly. Businesses then expand their operations by installing more plants, machinery and equipment or create new ones. Businesses can get extra source of funding (equity financing) from stock market development as well. Increase in stock market activity boosts consumer and business confidence which in turn increases economic activities and hence it will affect the environment by increasing more pollutants.

There is also a contribution of trade on economic activity of a country. Hecksher-Ohlin Proposed a trade theory which describes the relationship between trade and environment. This theory posits that when there is a free trade then developing countries produce such goods whose resources are readily available to them. Whereas developed countries focus on the capital intensive activities. Trade is linked with the increase in pollution as goods are transferred from one country to the other country. Trade has three types of effect on environment as mentioned by Antweiler, Copeland et al. (2001). The first is technology effect in which increase in income has direct impact on consumption of environmental goods. With the rise of income and lifestyle people become more aware of environmental issues and pollution control and management policies. The next is the scale effect in which free trade increases the trade volume in a country which deteriorates the environment when outputs are increased. The last is Composition effect where developing countries tend to attract pollution intensive industries which increases the pollution level in these countries.

In sum up there is a relationship between energy consumption-Growth-Carbon emissions framework especially for the case of developing county like Pakistan. This study is the first empirical effort to evaluate the energy-growth-emissions nexus by incorporating trade openness and financial development indicators for the case of Pakistan where there are lack of comprehensive studies. Single county study will help in policy making decisions regarding environmental degradation. Summaries of the previous work is presented in Table 1.

Table 1: Summaries of the previous empirical work.

Authors	Time-Period	Country/Sample	Methodology	Findings
Panel based studies				
Huang el al (2008)	1960-2001	82 Low, Middle and High Income countries	Panel VAR, GMM Model	GDP → EN (Middle and High Income countries) EN----GDP (Low Income Countries)
Artur Tamazian et al (2009)	1992 - 2004	BRICS	Panel Analysis	FD ← − CO_2
Lean and Smith (2010)	1980-2006	ASEAN	PC & PGC	EC & GDP −→ CO2 EC → GDP EC ↔ CO_2
Perry (2010)	1996 - 2006	9 Central and Eastern European frontier economies	FEM Systematic GMM	FD −→ ED
Pao & Tsai (2011)	1971-2005	BRIC	PC & PGC	GDP, EN −→ CO_2 EN ↔ CO_2 EN ↔ GDP CO_2 → GDP
Hossain (2011)	1970-2007	NIC	PC & PGC	GDP, EN , UR & TD −→ CO_2 GDP ↔ CO_2 TD → CO_2 GDP → EN
Usama (2011)	1980 - 2009	MENA countries	PCT & PGC	OC ↔ CO_2 OC ↔ GDP CO_2 ↔ GDP
Usama and Che (2012)	1980 - 2008	19 selected countries	PC & PGC	EC & CO_2 −→ FD & GDP EC & CO_2 → FD &

				GDP
Usama (2012)	1990 - 2009	12 Middle Eastern countries	PC FMOLS PGC	GDP ↔ FDI FDI ↔ EN EN ↔ CO_2 CO_2 ↔ TO
Usama and Che (2012)	1980 - 2008	Sub Saharan African countries	PCT & PGC	EN ↔ CO_2 GDP ↔ FD FD ↔ CO_2
Country Specific studies				
Jumbe (2004)	1970-1999	Malawi	JC & ECM GC	EC ↔ GDP NGDP → GDP
Wang et al (2005)	1995-2007	China	PC & PGC	GDP, EN −→ CO_2 CO_2 ↔ EN EN ↔ GDP GDP → CO_2
Gaolu and Chau (2006)	1953 - 2002	China	JC & GC	EN → GDP
Jalil & Mahmud (2009)	1975-2005	China	ARDL Model and Granger Causality	GDP −→ CO_2
Odhiambo (2009)	1971-2006	Tanzania	ARDL Bounds Tests	EN → GDP
Abdul Jalil and, Mete Feridun (2010)	1953 - 2006	China	ARDL	FD ← − CO_2 GDP, EC & TO −→ CO_2
Hatzigeorgou et al (2011)	1977-2007	Greece	JC & VECM GC	EN & GDP, −→ CO2 GDP → CO_2 EN ↔ CO_2
Pao & Tsai (2011)	1980-2007	Brazil	JC & VECM GC	GDP, EN −→ CO_2 CO_2 ↔ EN EN ↔ GDP GDP ↔ CO_2
Pao et al (2011)	1990 - 2007	Russia	JC & VCEM GC	GDP ↔ EN
Shahbaz and Hooi (2012)	1971 - 2008	Tunisia	ARDL & VECM GC	FD ↔ EN FD ↔ IND EN ↔ IND
Jayanthakumaran & Liu (2012)	1971-2007	China & India	ARDL	GDP, TD & EN −→ CO_2
Shahbaz et al (2012)	1971-2009	Pakistan	ARDL & VECM	GDP → CO_2 EN ↔ CO_2 TO----- CO_2
Shahbaz et al (2013)	1965 - 2008	South Africa	ARDL & VECM GC	GDP → CO_2 EN → CO_2

Shahbaz et al (2013)	1971 - 2011	China	ARDL & VECM	FD ← − CO_2 TO ← − CO_2 EC → GDP EC ↔ FD EC ↔ IT FD ↔ IT EC ↔ C FD ↔ GDP GDP ↔ IT
Ozturk and Ali (2013)	1960 - 2007	Turkey	ARDL & VECM	FD → EC & GDP
Shahbaz (2013)	1975Q1–2011Q4	Indonesia	ARDL VECM	GDP & EC −→ CO_2 FD & TO −→ GDP EC ↔ CO_2
Khalid et al (2014)	1980 - 2013	Pakistan	ARDL & VECM	GDP ↔ CO_2 FD → CO_2 GDP & TO −→ EC GDP ↔ EC
Rashid Sbia et al (2014)	1975Q1 - 2011Q4	UAE	ARDL & VECM	FDI ↔ EN FDI ↔ CO_2 FDI ↔ GE GDP ↔ CO_2 GDP ↔ EN EN ↔ CO_2
Sakiru and Shahbaz (2014)	1971-2012	Malaysia	ARDL & VECM	NGC, FDI, C & TO −→ GDP NGC ↔ GDP FDI ↔ GDP NGC ↔ FDI

Note: ----, → & ↔ indicate no, unidirectional and bidirectional Granger causality, respectively. −→ & ← − represent positive and negative long run relationship. Abbreviations are as follow: ARDL=Autoregressive Distributed Lags; BMI=Broad Money Investments; C=Capital; CO_2 =Carbon Emissions; EN=Energy Consumptions; ED=Energy Demand; FD=Financial Development; FDI=Foreign Direct Investments; FEM=Fixed Effect Model; FMOLS=Fully Modified Ordinary Least Square; GDP=Gross Domestic Product; GE=Green Energy; GMM=Generalized Method of Movement; GC=Granger Causality; IT=International Trade; IND=Industrialization; JC=Johanson Cointegration; NGC=Natural Gas Consumption; OC=Oil Consumption; PC=Panel Cointegration; PGC=Panel Granger Causality; TO=Trade Openness; TD=Trade Development; UR=Urbanization; VAR=Vector Auto-regressor; VECM=Vector Error Correction Model.

2. Econometric Methodology

2.1. Unit Root Testing

Various unit root test proposed in the literature e.g. ADF by Dickey and Fuller (1979), DF-GLS by Elliot et al. (1996) and Ng–Perron by Ng and Perron (2001) have a potential weakness that they are unable to take into account structural breaks, and hence may provide the biased results (Baum, 2004). These traditional unit root test normally encounter a type II error i.e. failure to reject the null hypothesis of unit root when it's false, when the time series haveone or more structural breaks. The structural break unit root test developed by Clemente *et al.* (1998) considers the presence of structural breaks and have therefore been applied in this paper. Clemente *et al.* is appropriate when a time series has one or two structural breaks. The presence of two structural breaks are tested based on the following null and alternative hypothesis:

$$H_0:\ y_t = y_{t-1} + \delta_1 DTB_{1t} + \delta_2 DTB_{2t} + u_t \qquad (1)$$

$$H_1:\ y_t = u\ + d_1 DU_{1t} + d_2 DTB_{2t} + e_t \qquad (2)$$

Where, DTB_{it} is a pulse variable that takes the value 1 if $t = TB_1$+1 (i =1, 2) and 0 otherwise. Further, DU_{it} =1 if $t > TB_i$ (i =1, 2) and 0 otherwise. TB and TB are the time periods when the mean is being modified (Clemente *et al.,* 1998). If the two breaks belong to the innovational outlier, unit root hypothesis can be first estimated using the following model:

$$y_t = \mu + \rho y_{t-1} + \delta_1 DTB_{1t} + \delta_2 DTB_{2t} + d_1 DU_{1t} + d_2 DU_{2t} + \sum_{i=1}^{N} c_i \Delta y_{t-i} + e_t \qquad (3)$$

If the shifts in mean are considered as additive outliers, then the unit root null hypothesis can be tested through the following two-step procedure. First, the deterministic part of the variable is removed by estimating the following model:

$$y_t = \mu + d_1 DU_{1t} + d_2 DU_{2t} + \tilde{y}_t \qquad (4)$$

And, test of unit root is applied by searching for the minimal t-ratio for the r 51 hypothesis in the following model:

$$\tilde{y}_t = \sum_{i=1}^{N} \omega_{1i} DTB_{1t-1} + \sum_{i=1}^{N} \omega_{2i} DTB_{2t-1} + \rho \tilde{y}_{t-1} + \sum_{i=1}^{N} c_i \Delta \tilde{y}_{t-i} +\ e_t \qquad (5)$$

2.2. ARDL Bound Testing for Cointegration

The Autoregressive Distributed Lag (ARDL) approach introduced by Pesaran and Smith (1995) and modified by Pesaran *et al.* (2001) has several econometric advantages in comparison to the traditional cointegration models. The approach can be applied regardless of the order of integration i.e. the variables may be stationary at levels or first difference. Traditional cointegration tests require all the variables to be integrated of order one. The ARDL bound testing approach also assumes that all the variables are endogenous.[1] Thus, we can apply ARDL

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[1] Variables have been tested by applying ADF, DF-GLS and Ng–Perron unit root tests to make sure that none of the variable is integrated at *I* (2) as the so-called ARDL bound testing can't be applied in the presence of a variable that is *I* (2).

model to check cointegration among the variables of CO2 emission, economic growth, energy consumption, financial development and trade openness. An ARDL representation of Co_2 Omission (C), economic growth (G), energy consumption (EN), financial development (FD), and trade openness (OP) can be formulated as follows:

$$C_t = \alpha_0 + \alpha_1 G_t + \alpha_2 FD_t + \alpha_3 EN_t + \alpha_4 OP_t + \mu_t \quad (6)$$

The ARDL bound procedure to check the existence of cointegration is as under:

$$\Delta C_t = \alpha_0 + \alpha_1 C_{t-1} + \alpha_2 G_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 EN_{t-1} + \alpha_5 OP_{t-1} + \sum_{i=1}^{p} \theta_i \Delta C_{t-i} + \sum_{j=1}^{q} \theta_j \Delta G_{t-j} + \sum_{K=1}^{r} \theta_k \Delta FD_{t-k} + \sum_{l=1}^{s} \theta_l \Delta EN_{t-l} + \sum_{m=1}^{T} \theta_l \Delta OP_{t-l} + \mu_t \quad (7)$$

$$\Delta G_t = \alpha_0 + \alpha_1 C_{t-1} + \alpha_2 G_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 EN_{t-1} + \alpha_5 OP_{t-1} + \sum_{i=1}^{p} \theta_i \Delta G_{t-i} + \sum_{j=1}^{q} \theta_j \Delta C_{t-j} + \sum_{K=1}^{r} \theta_k \Delta FD_{t-k} + \sum_{l=1}^{s} \theta_l \Delta EN_{t-l} + \sum_{m=1}^{T} \theta_l \Delta OP_{t-l} + \mu_t \quad (8)$$

$$\Delta FD_t = \alpha_0 + \alpha_1 C_{t-1} + \alpha_2 G_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 EN_{t-1} + \alpha_5 OP_{t-1} + \sum_{i=1}^{p} \theta_i \Delta FD_{t-i} + \sum_{j=1}^{q} \theta_j \Delta C_{t-j} + \sum_{K=1}^{r} \theta_k \Delta G_{t-k} + \sum_{l=1}^{s} \theta_l \Delta EN_{t-l} + \sum_{m=1}^{T} \theta_l \Delta OP_{t-l} + \mu_t \quad (9)$$

$$\Delta EN_t = \alpha_0 + \alpha_1 C_{t-1} + \alpha_2 G_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 EN_{t-1} + \alpha_5 OP_{t-1} + \sum_{i=1}^{p} \theta_i \Delta EN_{t-i} + \sum_{j=1}^{q} \theta_j \Delta C_{t-j} + \sum_{K=1}^{r} \theta_k \Delta G_{t-k} + \sum_{l=1}^{s} \theta_l \Delta FD_{t-l} + \sum_{m=1}^{T} \theta_l \Delta OP_{t-l} + \mu_t \quad (10)$$

$$\Delta OP_t = \alpha_0 + \alpha_1 C_{t-1} + \alpha_2 G_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 EN_{t-1} + \alpha_5 OP_{t-1} + \sum_{i=1}^{p} \theta_i \Delta OP_{t-i} + \sum_{j=1}^{q} \theta_j \Delta C_{t-j} + \sum_{K=1}^{r} \theta_k \Delta G_{t-k} + \sum_{l=1}^{s} \theta_l \Delta FD_{t-l} + \sum_{m=1}^{T} \theta_l \Delta EN_{t-l} + \mu_t \quad (11)$$

Cointegration procedure of Narayan (2005) has been adopted to verify the long run cointegration relationship between the variables; F or Wald-statistics are used for the bound testing. The test statistics is a joint significance test that test the null hypothesis of no cointegration against an alternative hypothesis that there is cointegration for equations (7) to 11) i.e.

$H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ (No cointegration)

The respective alternative hypotheses are:

H_1 : $atleast\ one\ of\ the\ \alpha's\ is\ not\ equal\ to\ Zero$ (Cointegration exists)

Narayan (2005) computed the critical values for a given significance level. The null hypothesis i.e. no cointegration exists, can be rejected if the calculated F-statistic is higher than the upper critical bound. The critical values proposed by Narayan (2005) are considered appropriate when the sample size is small, therefore this paper used these values. After confirmation of the cointegration between the variables, next step is to estimate the long term coefficients. Several models have been proposed in the literature for long-run coefficient estimation i.e. OLS, Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS). The relative strength and weakness of different OLS estimators have been examined by Chen et al. (1999). They suggest that later techniques can be promising to obtain the coefficients of cointegrated variables. The present study applies FMOLS and DOLS models to get the long run parameters for carbon emission, economic growth, energy consumption, financial development and trade openness.

2.3.1. The Fully Modified OLS (FMOLS) estimator

Due to biasness and inconsistency of the OLS estimates in a panel of cointegrated variables, we have utilized the "group-mean" panel FMOLS developed by Pedroni [1999; 2001]. The coefficient estimates obtained through FMOLS model are consistent in relatively small sample and also control the possible endogeneity issue between the regressors. It also deal with the problem of serial correlation. Following FMOLS estimator for the i-th panel member is utilized in this study:

$$\beta_i^* = (X_i' X_i)^{-1}(X_i' y_i^* - T\delta), \qquad (12)$$

Where y* presents the transformed endogenous variable, T is the number of time periods and δ is a parameter for autocorrelation adjustment.

2.3.2. The Dynamic OLS (DOLS) estimator

To check the consistency of the FMOLS estimates, we have also analyzed the relationship between the variables by further applying DOLS technique. Similar to FMOLS, DOLS model also provide unbiased and estimators while correcting the potential endogeneity issue. DOLS achieves the previously mentioned estimates through parametric adjustment of error terms by adding both past and the future differenced I(1) values of the regressors. Following equation is used to obtain the Dynamic OLS estimator in present setting:

$$Y_{it} = \alpha_i + X_{it}'\beta + \sum_{j=-q_1}^{j=q_2} C_{ij}\, \Delta X_{it+j} + v_{it}, \qquad (13)$$

In the above mentioned equation X indicates all the independent variables i.e. G, FD, EN, and OP. C_{ij} indicates the coefficients for the lead or lag of first differenced independent variables. Hence, the estimated coefficients using DOLS can be obtained through the following equation:

$$\hat{\beta}_{DOLS} = \sum_{i=1}^{N} (\sum_{t=1}^{T} z_{it} z_{it}^{'})^{-1} \left(\sum_{t=1}^{T} z_{ij}\, \hat{y}_{it}^{+} \right), \qquad (14)$$

Where z_{it}= $[X_{it}$- $\bar{X}_i,\ \Delta X_{i,t-q}, \dots \dots . \Delta X_{i,t+q}]$ is vector of regressors, and $\hat{y}_{it}^{+}$ ($\hat{y}_{it}^{+}$= $y_{it} - \bar{y}_i$) is the carbon emmision variable.

2.2. Causality Analysis

The cointegration analysis can only reveal whether the causality is present or not; however, the direction of causality cannot be determined through ARDL procedure. If the variables are cointegrated then the direction of causality in bot short-run and long-run can be ascertained through the Granger causality approach. The Vector Error Correction (VECM) based Granger causality test applied is presented below:

$$\Delta C_t = \alpha_{01} + \sum_{i=1}^{n} \alpha_{11} \Delta C_{t-i} + \sum_{j=1}^{p} \alpha_{22} \Delta G_{t-j} + \sum_{k=1}^{q} \alpha_{33} \Delta FD_{t-k} + \sum_{l=1}^{r} \alpha_{44} \Delta EN_{t-l} + \sum_{m=1}^{s} \alpha_{55} \Delta OP_{t-m} + \eta_1 ECM_{t-1} + \mu_{1t} \quad (15)$$

$$\Delta G_t = \beta_{01} + \sum_{i=1}^{n} \beta_{11} \Delta C_{t-i} + \sum_{j=1}^{p} \beta_{22} \Delta G_{t-j} + \sum_{k=1}^{q} \beta_{33} \Delta FD_{t-k} + \sum_{l=1}^{r} \beta_{44} \Delta EN_{t-l} + \sum_{m=1}^{s} \beta_{55} \Delta OP_{t-m} + \eta_1 ECM_{t-1} + \mu_{1t} \quad (16)$$

$$\Delta FD_t = \gamma_{01} + \sum_{i=1}^{n} \gamma_{11} \Delta C_{t-i} + \sum_{j=1}^{p} \gamma_{22} \Delta G_{t-j} + \sum_{k=1}^{q} \gamma_{33} \Delta FD_{t-k} + \sum_{l=1}^{r} \gamma_{44} \Delta EN_{t-l} + \sum_{m=1}^{s} \gamma_{55} \Delta OP_{t-m} + \eta_1 ECM_{t-1} + \mu_{1t} \quad (17)$$

$$\Delta EN_t = \delta_{01} + \sum_{i=1}^{n} \delta_{11} \Delta C_{t-i} + \sum_{j=1}^{p} \delta_{22} \Delta G_{t-j} + \sum_{k=1}^{q} \delta_{33} \Delta FD_{t-k} + \sum_{l=1}^{r} \delta_{44} \Delta EN_{t-l} + \sum_{m=1}^{s} \delta_{55} \Delta OP_{t-m} + \eta_1 ECM_{t-1} + \mu_{1t} \quad (18)$$

$$\Delta OP_t = \theta_{01} + \sum_{i=1}^{n} \theta_{11} \Delta C_{t-i} + \sum_{j=1}^{p} \theta_{22} \Delta G_{t-j} + \sum_{k=1}^{q} \theta_{33} \Delta FD_{t-k} + \sum_{l=1}^{r} \theta_{44} \Delta EN_{t-l} + \sum_{m=1}^{s} \theta_{55} \Delta OP_{t-m} + \eta_1 ECM_{t-1} + \mu_{1t} \quad (19)$$

In eq. 15 to 19, ECT indicates the error correction term, μ's present the error terms assumed to be uncorrelated. The coefficient of the error correction term is denoted by η's, which indicates the speed of adjustment of ΔC_t, ΔG_t, ΔFD_t, ΔEN_t, and ΔOP_t, towards long run equilibrium. In fact, the addition of EC term in the traditional Granger causality framework allows the emergences of causality and re-establishes the equilibrium relationship between the variables, in the event of a shock. Hence, by adding the ECT term, VECM can opens up new channels for Granger causality to emerge. Short term causality is captured through the estimated coefficients of ΔC_{t-1}, ΔG_{t-1}, ΔFD_{t-1}, ΔEN_{t-1}, and ΔOP_{t-1}. The positive and significant coefficients of the lagged error term(s) indicates the presence of the long run relationship as it is obtained through the long run cointegrating relationship(s).

3. Data and Findings

Annual time series data from 1973 to 2011 is used for the empirical work. Data on Carbon Emissions (Kilo Tons), Gross Domestic Product - GDP (Current $US) as a proxy for economic growth, Domestic Credit by Financial Sector (Current $US) as a proxy for financial development, Energy Consumption (Kilo tons of Oil equivalent) and trade openness (export plus imports as a percentage of GDP) is taken from World Development Indicators (WDI) – 2014 by the World Bank (WB). All variables are transformed in annual growth form.

Table 2 provides descriptive statistics of the variables along with correlation matrix of the variables. Carbon emissions, financial development and energy consumption growth is positive in Pakistan over the sample period. Economic growth and trade openness have remained negative with a very low percentage growth. All the variables are positively correlated with each other. The result of simplistic correlation analysis is the start of study which calls for a further detailed framework to examine the potential relationship.

Table 2: Descriptive Statistics and Correlation Analysis

	C_t	G_t	FD_t	EN_t	OP_t
Mean	0.0375	-0.003	0.062	0.039	-0.002
Median	0.063	0.019	0.090	0.044	0.005
Maximum	0.135	0.066	0.340	0.098	0.442
Minimum	-0.495	-0.977	-0.770	-0.017	-0.789
Std. Dev.	0.100	0.157	0.192	0.022	0.162
C_t	1				
G_t	0.876	1			
FD_t	0.643	0.713	1		
EN_t	0.132	0.136	0.068	1	
OP_t	0.531	0.754	0.491	0.168	1

Tables 3 reports the results of Clemente–Montanes–Reyes detrended unit root test with two structural breaks[2]. Results indicate presence of two structural breaks. Carbon emission, economic growth and financial development are integrated of order one i.e. I(I) whereas energy consumption and trade openness are stationary at level i.e. it is integrated of order one, $I(0)$. Since all variables do not have same level of integration, we will apply ARDL technique to find long run cointegration relationship among variables.

[2] The results report presence of two structural breaks in the time series data therefore, we have not reported the results obtained through Clemente–Montanes–Reyes detrended unit root test with one structural break

Table 3: Results of Clemente–Montanes–Reyes two structural break unit root test

	Innovation Outlier (IO)			Additive Outlier (AO)			Decision
Series	t-statistic	T_{B1}	T_{B2}	t-statistic	T_{B1}	T_{B2}	
C_t	-3.287	1978	1989	-2.272	1988	2005	I (I)
ΔC_t	-8.867*	1977	2006	-8.945*	1980	2002	
G_t	-4.242	1991	2001	-3.528	1990	2003	I (I)
ΔG_t	-5.345*	2002	2005	-5.545*	2002	2005	
FD_t	-4.585	1981	2001	-2.485	1980	1999	I (I)
ΔFD_t	-6.004*	2003	2008	-7.412*	2002	2006	
EN_t	-6.892*	1985	2005	-6.503*	1993	2004	I (0)
OP_t	-3.929	1979	1999	-6.422*	1977	1998	I (0)

Note: * indicates significance at 5% level.

To ascertain the existence of a long run cointegrating relationship among carbon emission, economic growth, financial development, energy consumption and trade openness, the bounds testing approach is applied. Moreover, the selection of lag length should be performed carefully because an inappropriate lag length may lead to biased results and is not acceptable for policy analysis. Therefore, to ensure that the lag length was selected appropriately. Results of Akaike information criteria (AIC), Schwartz Bayesian criteria (SBC) and Hannan-Quinn information criterion (HQ) are reported in Table 4. Based on Akaike information criterion (AIC), Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ), optimal lag length 1 is selected for causality analysis (Table 4).

Table 4: Lag Order Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	322.212	NA	1.53e-14	-17.622	-17.402	-17.546
1	351.712	49.168*	1.21e-14*	-17.872*	-16.553*	-17.412*
2	376.430	34.329	1.34e-14	-17.857	-15.437	-17.012
3	406.526	33.440	1.27e-14	-18.140	-14.621	-16.912

Note: * indicates lag order selected by the criterion; LR=sequential modified LR test statistic (each test at 5% level); FPE-=Final prediction error; AIC=Akaike information criterion; SC=Schwarz information criterion; HQ=Hannan-Quinn information criterion

After determining the optimal lag length, we have applied F-statistics to check the existence of long run cointegration among variables. Table 5 provides the F-statistic results. The null hypothesis of no cointegration is rejected when the computed F-statistics of the Wald test is higher than the upper critical bounds value. The rejection of null hypothesis concludes that there is a long run cointegrating relationship between the selected variables. F statistics value are 20.887, 7.262 and 8.426 when carbon emission, energy consumption and trade openness are considered as dependent variables (Eq. 7, 10 & 11) respectively. The F statistics are significant at 1% level because it is higher than the upper critical bounds of Narayan (2005). The results for economic growth and financial development (Eq. 8 & 9) are inconclusive.

Table 5: Bound Test for Cointegration (1973 – 2011)

Critical values (lower and upper bound) of the *F* statistics: intercept and no trend		
Tabulated F Statistics (T=40, K=4)		
	I(0)	*I(I)*
90% level	2.660	3.838
95% level	3.202	4.544
99% level	4.428	6.250
Estimated Models		Calculated *F* statistics
$Eq. 2;\ C_t = f(G_t, FD_t, EN_t, OP_t)$		20.887*
$Eq. 3;\ G_t = f(C_t, FD_t, EN_t, OP_t)$		6.154
$Eq. 4;\ FD_t = f(C_t, G_t, EN_t, OP_t)$		3.557
$Eq. 5;\ EN_t = f(C_t, G_t, FD_t, OP_t)$		7.262*
$Eq. 6;\ OP_t = f(C_t, G_t, FD_t, EN_t)$		8.426*

Note: * indicates that F-statistic falls above the 1% upper bound. Reported critical values are from Narayan (2005).

The ARDL bound testing procedure to ascertain a long-run relationship between carbon emission, economic growth, energy consumption, financial development and trade openness in Pakistan show that there are three cointegration vectors. The cointegration exits as the calculated F statistics falls above the upper critical values provided by Narayan (2005). The authenticity of the cointegration equation is made by testing the assumption of Classical Linear Regression Model (CLRM). Results presented below (Table 6) show that different diagnostic tests reject the null hypothesis at 10% level of significance. The tests result in combination confirm that there is no problem of non-normality, serial correlation and conditional heteroskedasticity in the long-run ARDL bound testing equations. The model specification is tested by applying Ramsey RESET test which indicates that models are correctly specified.

Table 6: The Results of Diagnostic Tests

Equation	**2**	**3**	**4**	**5**	**6**
Diagnostic Tests					
R Square	0.863	0.575	0.654	0.610	0.659
F-statistics	18.940	4.059	3.208	4.704	5.815
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
JB Normality Test	0.693	0.729	0.936	4.307	0.457
	(0.706)	(0.694)	(0.625)	(0.116)	(0.795)
Breusch–Godfrey LM test	0.225	0.614	0.354	0.183	1.448
	(0.720)	(0.420)	(0.540)	(0.765)	(0.146)
ARCH (1) test	1.443	0.954	2.146	0.824	2.249

	(0.226)	(0.321)	(0.143)	(0.355)	(0.135)
Ramsey RESET	2.804	0.102	1.839	0.790	7.455
	(0.106)	(0.751)	(0.189)	(0.382)	(0.011)

Note: * , ** and *** indicate that values are significance at 1%, 5% and 10% levels of significance respectively.

The stability of the long and short run parameters in the ARDL bound testing equations is further examined by applying cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) tests (Pesaran and Shin, 1999). Figs. 5 and 6 indicate the graphs of CUSUM and CUSUMsqare, respectively. Both the graphs indicate the CUSUM and CUSUMsqare values are between the critical boundaries at 5% level of significance. As the calculated values shown in the graph are between the critical boundaries, the long and short run parameters which have effect on carbon emission in Pakistan, are assumed to stable. These stability tests further confirm that there are no structural breaks and hence no impact on the ARDL bound testing equations. Based on above mentioned diagnostic and stability tests, we can conclude that the ARDL model seems to be steady and appropriately specified.

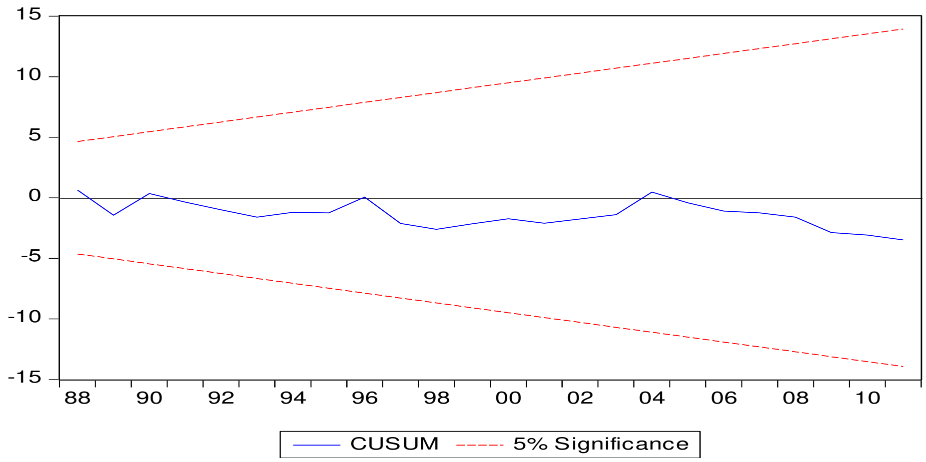


Fig.1. Graph of Cumulative Sum of Recursive Residuals

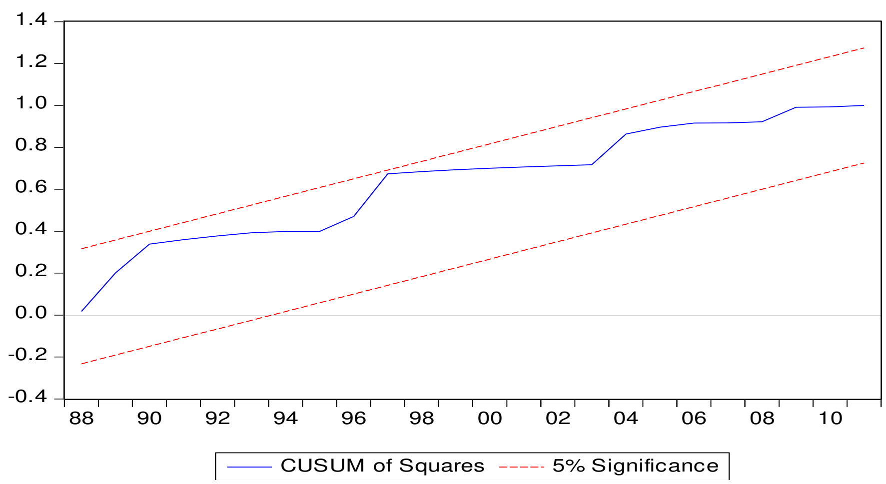


Fig.2. Graph of Cumulative Sum of Squares of Recursive Residuals

Tables 7 display the results of FMOLS and DOLS using carbon emission as the dependent variable. The economic growth and energy consumption coefficients are positive and significant in Pakistan. The positive (+) coefficients suggests that increase in economic growth and energy consumption leads to increase in carbon emission in Pakistan. One percent increase in economic growth and energy consumption lead to 0.97% and 0.42% increase in carbon emission, respectively. The coefficients of financial development and trade openness are insignificant and thus do not impact the carbon emissions in the long run. Results of both FMOLS and DOLS are consistent and almost similar in magnitude.

Table 7: Result of Cointegration Equations

Dependent Variable: C_t		
	FMOLS	DOLS
Variable(s)		
G_t	0.972*	0.943*
	(3.052)	(3.198)
FD_t	-0.032	-0.012
	(-0.655)	(-0.336)
EN_t	0.422***	0.316**
	(1.750)	(0.068)
OP_t	0.053	0.058
	(0.831)	(0.910)
Constant	0.022**	0.036*
	(2.054)	(3.417)
R-squared	0.197	0.229

VECM based Granger Causality approach is applied to examine the direction of causality for carbon emission, economic growth, financial development, energy consumption and trade openness. Zeller (1998) suggest that causality can be interpreted in purely probability sense, not in deterministic terms. Table 8 reports the results of both short and long run causality estimates. The t statists is used to determine the significance of lagged ECT and hence proves the long run relationship. The significance of Wald test on sum of lags of independent variables in Eq. (15) to Eq. (19) is used to determine the existence of short term causality relation. This interpretation is similar to Masih and Masih (1996). Carbon emissions are impacted by economic growth, energy consumption and trade openness in short-run. Financial development and energy consumption Granger cause economic growth in short run. Carbon emissions and trade openness Granger cause financial development. Trade openness also have an impact on the energy consumption in the short term. Bi-directional Granger causality exists between energy consumption and financial development in Pakistan. The convergence to long term equilibrium, as captured through significance of ECT term in VECM model, is -0.527 for carbon emissions. The speed of convergence is highest in case of trade openness i.e. -1.1888 and lowest for financial development. The joint (short and long run causality is almost significant in all five cases except for the economic growth where only energy consumption Granger causes economic growth.

Table 8: Vector Error Correction Model: Causality Analysis

	Short-run Causality					Joint (Short and long run) Causality					Long-run Causality
	C_t	G_t	FD_t	EN_t	OP_t	C_t, ECM_{t-1}	G_t, ECM_{t-1}	FD_t, ECM_{t-1}	EN_t, ECM_{t-1}	OP_t, ECM_{t-1}	ECM_{t-1}
C_t	-	2.751***	0.689	7.473*	11.261*	-	7.229*	4.357*	10.528*	7.507*	-0.527*
		(0.063)	(0.502)	(0.000)	(0.000)		(0.000)	(0.004)	(0.000)	(0.000)	[-3.531]
G_t	0.956	-	2.799***	3.614**	0.182	0.640	-	1.867	2.677**	0.390	-0.027
	(0.384)		(0.060)	(0.026)	(0.832)	(0.588)		(0.132)	(0.045)	(0.760)	[0.796]
FD_t	4.944*	2.090	-	8.203*	2.726***	5.229*	4.736*	-	6.388*	2.626**	-0.196*
	(0.007)	(0.123)		(0.000)	(0.065)	(0.001)	(0.002)		(0.000)	(0.048)	[-2.795]
EN_t	1.843	0.953	2.308***	-	1.214	2.442***	3.080**	2.712**	-	2.242***	-0.389***
	(0.158)	(0.385)	(0.099)		(0.296)	(0.062)	(0.026)	(0.043)		(0.081)	(-1.931)
OP_t	2.161	1.196	2.081	4.724*	-	5.166*	6.065*	6.156*	5.435*	-	-1.188*
	(0.115)	(0.302)	(0.124)	(0.008)		(0.001)	(0.000)	(0.000)	(0.001)		(-3.895)

Summary of Causality Analysis

$G_t \nrightarrow C_t$	$EN_t \nrightarrow C_t$	$OP_t \nrightarrow C_t$
$FD_t \nrightarrow G_t$	$EN_t \nrightarrow G_t$	
$C_t \nrightarrow FD_t$	$EN_t \nrightarrow FD_t$	$OP_t \nrightarrow FD_t$
$FD_t \nrightarrow EN_t$		
$EN_t \nrightarrow OP_t$		

Note: * , ** and *** indicate that values are significance at 1%, 5% and 10% levels of significance respectively. P-values (F-statistics) are in (). Student t-statistics are in [].→ implies Granger cause.

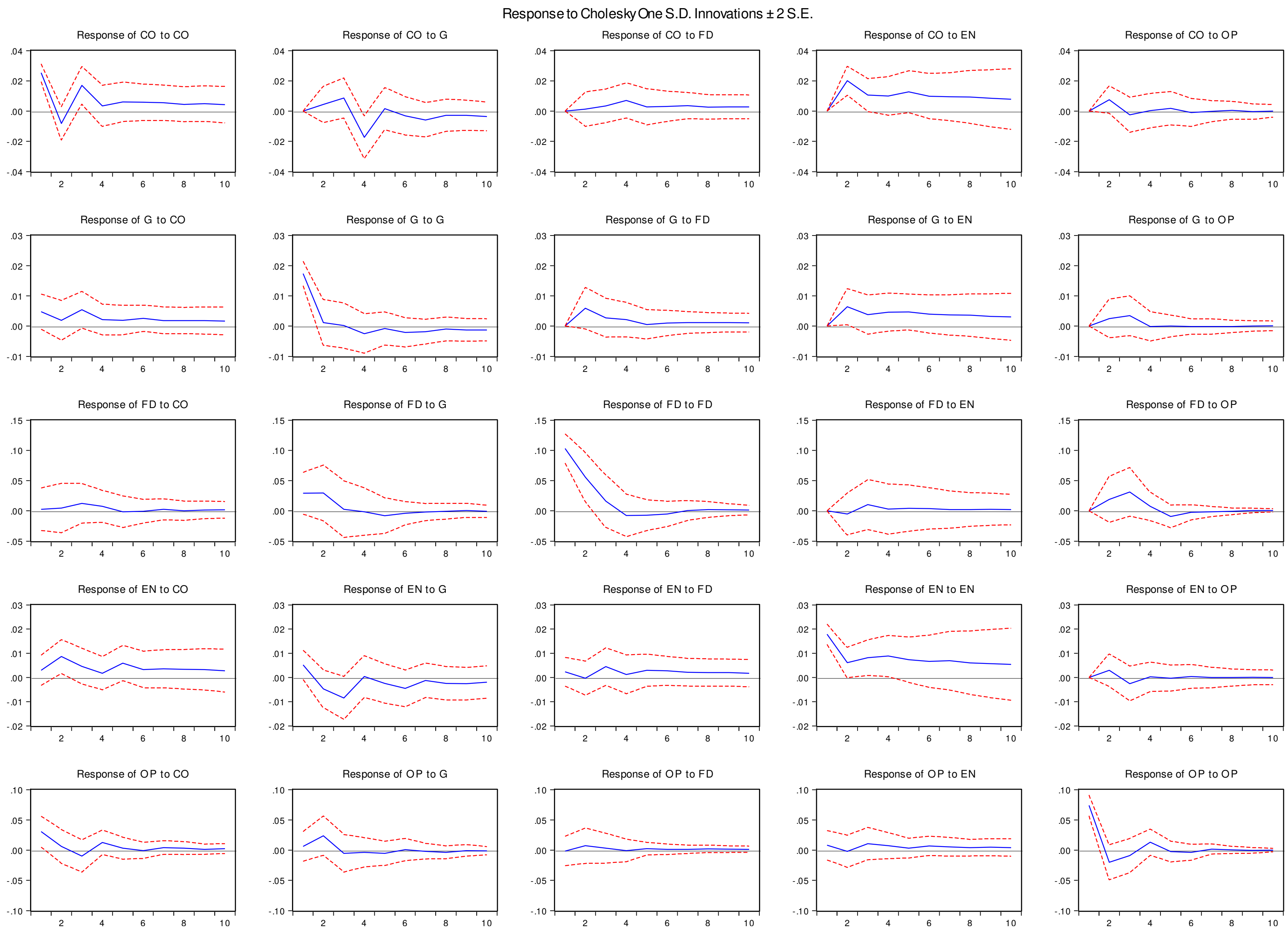
Wolde-Rufael (2009) argues that Granger causality is unable to determine the cause and effect relationship between the variables beyond the observed time period. Thus the reliability of Granger causality to capture the feedback amongst the variables is significantly decreased. Wolde-Rufael (2009) highlights the importance of Variance decomposition analysis (VDA) to establish the direction as well as strength of causality ahead of time. It also helps to examine the feedback effect from one variable to another. This paper applies both VDA and Impulse Response Function (IRF) for such analysis as both techniques are considered alternates to each other. Both the preceding methods help to capture the error variance of dependent variable(s) in response to shock or change occurring in independent variable over future time periods. Results reported in Table 9 indicate the VDA values for all five equations where carbon emission, economic growth, financial development, energy consumption and trade openness as dependent variables are reported from top to down, respectively. 47.12% of carbon emissions are impacted by own innovative shocks in a four year time period. Energy consumption and economic growth explains 28.67% and 18.33% of carbon emissions through their innovative shocks. 60.66% of growth variation is explained through its own innovations. 14.98%, 11.65 and 9.17% of variation in growth is through shocks in energy consumption, carbon emissions and financial development, respectively. 80.10% variation in financial development is explained by its own innovations. Economic growth explains 9.79% variations in financial development through its innovative shocks and trade openness explains 7.95%. Energy consumption and trade openness are majorly impacted by the innovation in economic growth and carbon emissions. The findings of VDA confirm the findings of VECM granger causality analysis. Similar findings are also evident through Impulse response function (figure 1). Finally, there are three cointegration vectors between carbon emissions, economic growth, energy consumption, financial development and trade openness in case of Pakistan using annual data from 1973 to 2011.

Table 9: Variance Decomposition Analysis

Variance Decomposition of C_t:						
Period	S.E.	C_t	G_t	FD_t	EN_t	OP_t
1	0.025	100.0	0.000	0.000	0.000	0.000
2	0.034	59.53	1.592	0.130	33.93	4.805
3	0.040	59.27	5.592	0.818	30.58	3.729
4	0.046	47.12	18.33	2.927	28.67	2.932
Variance Decomposition of G_t:						
1	0.018	6.918	93.08	0.000	0.000	0.000
2	0.020	6.295	73.70	8.439	10.04	1.515
3	0.021	11.57	64.00	8.926	11.70	3.787
4	0.022	11.65	60.66	9.174	14.98	3.519
Variance Decomposition of FD_t:						
1	0.107	0.061	7.323	92.61	0.000	0.000
2	0.125	0.181	10.78	86.60	0.176	2.259
3	0.131	1.030	9.884	80.57	0.782	7.730
4	0.132	1.322	9.795	80.10	0.819	7.956
Variance Decomposition of EN_t:						
1	0.019	2.401	7.575	1.543	88.48	0.000
2	0.022	16.48	9.846	1.121	70.84	1.699
3	0.026	15.13	17.54	3.717	61.43	2.163

4	0.027	13.88	15.67	3.523	64.97	1.939
Variance Decomposition of OP_t:						
1	0.080	14.36	0.566	0.032	0.997	84.04
2	0.086	12.81	7.989	0.735	0.915	77.54
3	0.088	13.50	8.016	0.824	2.324	75.33
4	0.091	14.83	7.800	0.789	2.838	73.73

Figure 3: Impulse Response Function analysis



Different ordering of the independent variables are considered to have significant implications on the results of variance decompositions and impulse response. Change in the order may change the results of both these tests. In the present empirical setting, five variables can have 120 ($5!$) different ordering pairs. The robustness of the results while changing the order of variables for 120 times is almost next to impossible and also cumbersome. Masih and Masih (1996) proposed an alternate to solve this puzzle. They suggest that the covariance matrix of the error term obtained through reduced form VAR can be examined to ensure the consistency of VDA and IRF results. If the covariance matrix of the errors are close to diagonal then we can conclude that different orders of variables will not influence the structural inference. The covariance matrix of the residual is reported in Table 10. Results indicate that covariance matrix is almost diagonal and hence it can be concluded variables' orderings have no impact on the IRF and VDA errors. An alternative method to ensure this conclusion, is to examine the statistical significance of correlation between the error terms. If the correlation between the errors is high and significance (based on traditional t statistics) then it is can be inferred that different identifying restrictions have a potential impact on the results. If no significance relationship between the errors exits then identification restriction cannot influence the results of VDA and IRF. The lower values in the table 10 reports the correlation between the errors. Results indicate that residuals' correlations is weak and statistically insignificant. Both diagnostic tests confirm that results of VDA and IRF are not sensitive to the change in identifying restrictions.

Table 10: Covariance and correlation matrix

	C_t	G_t	FD_t	EN_t	OP_t
	0.000				
C_t	1				
	0.000	0.000			
G_t	0.263	1			
	0.000	0.000	0.011		
FD_t	0.024	0.267	1		
	0.000	0.000	0.000	0.000	
EN_t	0.154	0.306	0.197	1	
	0.000	0.000	0.000	0.000	0.006
OP_t	0.378	0.172	0.012	0.171	1

Note: The upper values are of covariance and lower values show correlation.

4. CONCLUSION

This study is the first effort to establish a short and long run relationship between carbon emissions, economic growth, financial development, energy consumption and trade openness in Pakistan. Lack of environmental protection laws, energy crises and resulting lower economic growth make Pakistan a unique setting to study the country specific reactions among the variables. The annual data after the separation of Bangladesh from 1973 to 2011 is used for the empirical work. The unit properties of selected variables is examined in the presence of structural breaks. The Auto-regressive Bound Testing (ARDL) approach to cointegration is used to determine the cointegration relation. Fully Modified Ordinary Least Square (FMOLS) and Dynamic OLS (DLOS) cointegration equations are applied to estimate long run co-efficients.

Short run relationship is determined through Vector Error Correction (VEC) based Granger causality, Variance Decomposition Analysis (VDA) and Impulse Response Function (IRF). The presence of long run cointegration between the variables is confirmed. We find that carbon emissions increases with the increase in economic growth and energy consumption in long run. The results show that there is a unidirectional causality running from growth, energy consumption and trade openness to carbon emission. Financial development and energy consumption cause economic growth. Carbon emissions and trade openness cause financial development. Trade openness also Granger causes energy consumption. There is a bi-directional causality between financial development and energy consumption in Pakistan. Hence, the efforts to overcome energy crises and foster the economic growth require considerable attention to the carbon emissions; the best policy is to improve the situation through alternate energy resources i.e. coal, LPG and LNG. The formulation as well as enforcement of environmental protection laws is also required. Efficient and conservative use of scarce energy resources can spur the economic growth while limiting the degradation of environment.

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