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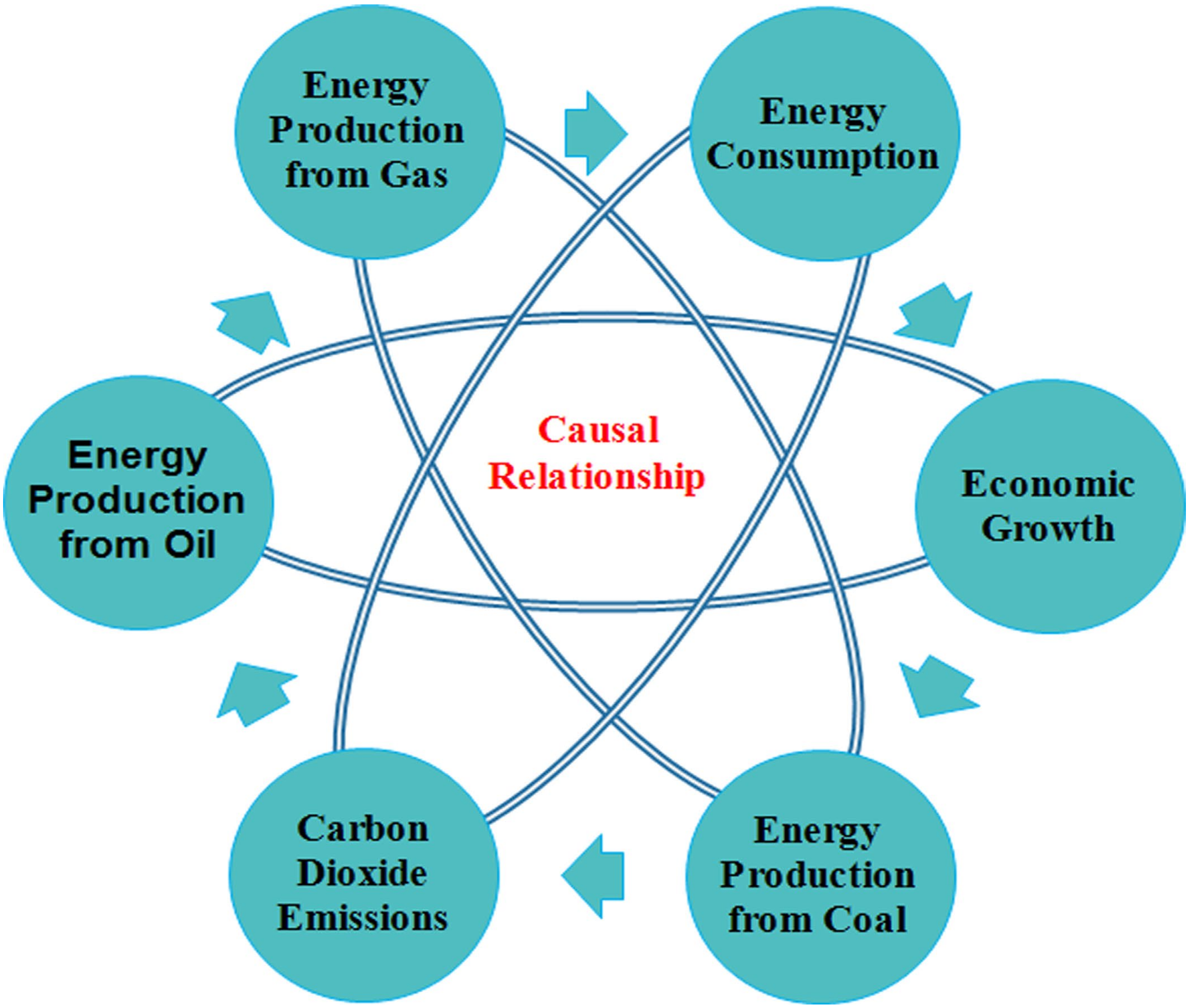

CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

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The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan

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Abstract: In this study an attempt was made to investigate carbon dioxide emissions, energy consumption (EC), GDP, and electricity production from oil, coal and natural gas, a recent evidence from Pakistan by employing a time series data spanning from 1971 to 2013. The study employed the vector error correction model to estimate the long-run equilibrium relationship. There was evidence of long-run equilibrium relationship running from EC, electricity production from coal, electricity production from natural gas, electricity production from oil and GDP to carbon dioxide emissions. The policy implication of the VEC model means that a 1% increase in energy production from oil in Pakistan will increase carbon dioxide emissions by 13.7% in the long-run. There was evidence of a unidirectional causality running from EC to carbon dioxide emissions, electricity production from natural gas to EC, EC to electricity production from oil, electricity production from natural gas to GDP and GDP to electricity production from oil. Evidence from the generalized impulse-response analysis shows that three components contribute to carbon dioxide emissions in Pakistan, which include EC, energy production from gas and GDP.

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PUBLIC INTEREST STATEMENT

Climate change has become the most critical issue of the world within the past decades as the amount of carbon dioxide emission is increasing significantly. As a result, there is a global effort towards mitigating climate change and its impact through multidisciplinary research that increases the global debate and bring to light new evidence to create awareness and provide information for national policy and planning in climate change. This study brings new evidence from Pakistan by investigating the carbon dioxide emissions, energy consumption, electricity production from sources and GDP using the econometric approach. Evidence from the study shows that a 1% increase in energy production of oil in Pakistan will increase carbon dioxide emissions by 13.7% in the long-run. In this way, the exploration of other renewable energy resources will reduce the carbon footprint in Pakistan.

Subjects: Economics; Energy Policy; Energy Policy and Economics; Environmental Change & Pollution; Environmental Studies & Management; Pollution

Keywords: carbon dioxide emission; energy consumption; economic growth; GDP; Pakistan; environmental sustainability engineering

JEL Codes: R41; Q51; Q54; Q56; Q31

1. Introduction

The Intergovernmental Panel on Climate Change has reported that global warming and climate change have become the most critical issue of the world in the past decades since the amount of carbon dioxide emission is increasing significantly (Metz, Davidson, Bosch, Dave, & Meyer, 2007; Owusu & Asumadu-Sarkodie, 2016; Owusu, Asumadu-Sarkodie, & Ameyo, 2016). Organizations worldwide have been struggling to decrease the adverse effect of global warming through binding agreements such as the Kyoto Protocol (Halicioglu, 2009). Several countries have signed the Kyoto Protocol in order to reduce their GHG emission levels, but the United States refused to ratify the treaty. However, US is the largest emitter per capita in the world so that without the United States treaty could not be successful (Kutney, 2014). According to the World Bank Report (2007), among the other pollutants resulting climate change, carbon dioxide (CO_2) is the main pollutant responsible for 58.8% of the GHG emission. The policy makers have realized the requirement for highly resolved CO_2 emissions owing to the emerging needs of recommended carbon trading system (Gurney et al., 2009). According to the current research the major portion of carbon dioxide emissions originates from developing countries caused by rapidly growing economy (Asumadu-Sarkodie & Owusu, 2016f, 2016g, 2016i). In developed, developing and least developing countries, the Sustainable Development Goal 13 emphasizes that the policies, planning and strategies for measures of climate change should be included in the national policies (Asumadu-Sarkodie, Sevinç, & Jayaweera, 2016). Environmental degradation has a direct and significant effect on human health that causes social problems (Asumadu-Sarkodie & Owusu, 2016a, 2016d). Evidence has shown the severe effect of pollution on health, biodegradation which significantly affect the intensity and the occurrence of natural disasters leading to a decline in economic growth (Azam, Khan, Abdullah, & Qureshi, 2016).

In order to achieve a sustainable environment, countries need to develop a robust and sustainable economy. Being a developing country, Pakistan's government has established an environmental policy since 2005 with constant levels of economic development to control the environmental degradation (Mohiuddin, Mohiuddin, Obaidullah, Ahmed, & Asumadu-Sarkodie, 2016). The basic purpose of the national environmental policy (NEP) is to secure, sustain and re-establish the environmental conditions of Pakistan to improve the quality of nature. Furthermore, economic development is simulated by all subdivisions of the economy with agriculture, industrialized and service regions (Shahbaz, Lean, & Shabbir, 2012). The dynamic progress level in Pakistan is controlled by an industrial division, which mostly produces a huge amount of waste and contamination, causing degradation of natural resources and increase in energy demand. Pakistan's energy sector is the major contributor of GHG production accounting for 51% of these emissions (Mohiuddin et al., 2016). According statistics, per capita energy consumption (EC) has increased by 40% during 2001–2007, while the energy consumed by industrial sector has increased to 43% between 2008 and 2009 (Ahmed & Long, 2012). These effects are more drastic when associated with demographic growth since it increases the energy use resulting in more pollution (Alam, Fatima, & Butt, 2007). More than 50% of CO_2 emissions in Pakistan comes from natural gas primarily utilized for electricity generation. Although Pakistan's contribution to greenhouse gasses (GHG) is smaller as compared to international standards. For example, in 2008, Pakistan's GHG emission was about 310 million tons of CO_2 equivalent nevertheless, conditions worsen on a daily basis. Energy supply has increased from 28 million tons of oil in 1991 to 66.8 million tons of oil in 2014 leading to increased rates of CO_2 emissions (Mohiuddin et al., 2016). According to the Energy International Administration report, worldwide coal consumption for energy production has increased significantly in the past decades. It is essential for the modern economy to produce enough energy to meet the growing demand nevertheless, unclean energy technologies are harmful to the environment due to the emission of greenhouse gases (Asumadu-Sarkodie & Owusu, 2016b; Asumadu-Sarkodie et al., 2016).

There are two different perspectives on how to solve the global emission challenge. The first perspective proposes a decrease in EC, meaning that developed countries have to drop their revenue growth while developing countries control their expansions (Dinda & Coondoo, 2006). In contrast, the second perspective proposes the environmental kuznets curve (EKC) theory, as income per capita increases, the environmental degradation and pollution increases in the initial phases of economic growth. However, at a certain level of income, economic growth declines along with reduction in environmental degradation and pollution. EKC theory indicates that economic growth is the solution to the challenges with environmental degradation (Peng & Sun, 2010). Environmental degradation and pollution have become a global concern, therefore a contribution of each country towards climate change mitigation is essential. Against the backdrop, the study makes an attempt to investigate the carbon dioxide emissions, EC, electricity production from different energy sources and GDP from Pakistan. Even though a handful of studies has been done in Pakistan nevertheless, literature is still limited in the scope of analyzing the random innovations from the variables which is essential for future energy and climate change mitigation policy and planning. As a contribution to literature, the study examines the individual contributions of the electricity production from the different fossil fuels (oil, coal and natural gas) towards climate change which is absent in existing literature for Pakistan. The study employs the vector error correction model, Granger-causality and the generalized impulse-response analysis to increase the global debate on climate change from the Pakistan case with some subsequent policy recommendations for Pakistan.

The remainder of this study is organized into “Literature Review”, “Methodology”, “Descriptive Statistical Analysis”, “Results and discussion”, “Diagnostic Test”, “Generalized Impulse Response”, “Conclusion” and “Policy Recommendation”.

2. Literature review

There is a wide range of hypothetical and experimental studies directing on the relation between EC and economic growth in both developed and developing economies. Some of the earlier investigations on this topic discovered Granger-causality, unit root, and co-integration test to establish the relation between economic growth and EC using several structures (Asumadu-Sarkodie & Owusu, 2016c, 2016e, 2016h). Ahmed and Long (2012) evaluated the effect of growth in population, economy, energy intensity and urbanization on the environmental degradation in Pakistan with sustainable economy using co-integrating vector normalized technique. They concluded the significant amount of CO_2 emission caused by economic development relies on the amount of energy utilization and the subsequent of this used energy in Pakistan. Moreover, urbanization and population growth positively influence environmental degradation, whereas economic development is adversely affected in the long run. Nasir and Rehman (2011) employed Johansen co-integration technique to find the link between carbon emission, EC, and foreign trade in Pakistan from 1972 to 2008. They observed long run quadratic relation among carbon emission and income, confirming the validity of the EKC hypothesis for Pakistan. Magazzino (2014), (2015) examined the relationship between economic growth, carbon emission emissions and energy use in Israel and Italy and found bidirectional causality between carbon emission emissions and economic growth as well as carbon emission emissions and energy use.

Asumadu-Sarkodie and Owusu (2016c) employed multivariate co-integration analysis, ARDL and vector error correction modeling techniques to investigate the relationship between carbon dioxide emissions, GDP, EC and population in Ghana for the period of 1971–2013. Their study found evidence of the existence of mutual causality between Ghana’s EC and GDP. Another study by Asumadu-Sarkodie and Owusu (2016e) concluded that the continuous increase in population growth within the last decades has led to a huge increase in energy demand which increases CO_2 emissions in Ghana.

Chang (2010) studied the multivariate co-integration Granger-causality test to examine the relationship between CO_2 emission and EC associated with increased GDP in China while accounting for variables electricity generations; oil, gas, and coal to measure the level of EC. Halicioglu (2009) applied the bound testing co-integration technique in a multivariate model to investigate the dynamic linkage between CO_2 emission, energy utilization, income and foreign trade. Their study found evidence of a bi-directional Granger-causality between carbon emission and income in Turkey.

Decomposition of CO_2 released from the EC in China was investigated by Zhang and Cheng (2009) over the period of 1991–2006. Evidence from their study showed that economic activity is the largest

Table 1. Summary of existing literature

Author(s)	Country	Period	Techniques	Dependent Variable	Environmental variable determinants
Asumadu-Sarkodie and Owusu (2016e)	Ghana	1980–2012	VECM and OLS	CO_2 emission	EC, Population and GDP
Halicioglu (2009)	Turkey	1960–2005	Granger-causality based on VECM	CO_2 emission	EC, GDP & trade openness (TO)
Zhang and Cheng (2009)	China	1960–2007	Granger-causality, GIR	CO_2 emission	EC, P, capital formation & GDP
Chang (2010)	China	1982–2004	Multivariate cointegration & VECM	CO_2 emission	EC and GDP
Lean and Smyth (2010)	ASEAN	1980–2006	Panel vector Error Correction model	CO_2 emission	EC and GDP
Nasir and Rehman (2011)	Pakistan	1972–2008	Johansen method of cointegration	CO_2 emission	EC, income & foreign trade
Ahmed, Shahbaz, Qasim, and Long (2015)	Pakistan	1971–2008	ARDL	CO_2 emission	EC, GDP, TO & P
Saboori and Sulaiman (2013)	Malaysia	1980–2009	ARDL and VECM	CO_2 emission	EC and GDP
Asumadu-Sarkodie and Owusu (2016h)	Ghana	1961–2012	ARDL and VECM	CO_2 emission	Agriculture
Ozturk and Acaravci (2013)	Turkey	1960–2007	Bound *F*-test	CO_2 emission	EC, GDP, trade & financial development
Shahbaz, Uddin, Rehman, and Imran (2014)	Bangladesh	1975–2010	ARDL	CO_2 emission	EC, GDP, FD & TO
Shahbaz, Khraief, and Jemaa (2015)	Tunisia	1971–2010	VECM and ARDL	CO_2 emission	EC and GDP
Asumadu-Sarkodie and Owusu (2016c)	Ghana	1971–2013	VECM and ARDL	CO_2 emission	EC, population and GDP
Al-Mulali and Ozturk (2015)	Middle East	1996–2012	Pedroni cointegration	Environ. degradation	EC, TO, P, industrial output, & political stability
Long, Naminse, Du, and Zhuang (2015)	China	1952–2012	Unit root and cointegration and Granger-causality	CO_2 emission	EC and EG

contributor of carbon dioxide emission and GDP growth, which is in-dissociable because of the increase in both variables. The majority of the aforementioned literature assured the existence of a closed-form relationship between economic growth with EC and CO_2 emission throughout the world. In the existing literature, mostly casualty with less than three variables have been studied. Table 1 shows a summary of existing literature on environmental degradation and pollution, EC, agriculture and macroeconomic variables. As a contribution to literature, an attempt is made to investigate carbon dioxide emissions, EC, electricity production from sources and GDP: a recent evidence from Pakistan. It is noteworthy that the world's sixth largest verified coal reserves are in Pakistan Ministry of Finance (2013) nevertheless, there is no empirical evidence in the existing literature that attempts to examine the relationship it has with carbon dioxide emissions in Pakistan. As a contribution to literature, the study adds a recent evidence to the existing literature by examining the three most trending electricity production contributors of global carbon dioxide emissions namely; coal, oil and gas. In addition, policy recommendations that emanates from the study will provide information for future policy planning and strategies for climate change mitigation.

3. Methodology

The study makes an attempt is made to investigate carbon dioxide emissions, EC, GDP and electricity production from oil, coal and gas: a recent evidence from Pakistan by employing a time series data spanning from 1971 to 2013 from the World Bank (2014) database (World Development Indicators). The study variables include carbon dioxide emission (CO_2) measured in million metric tons, EC measured in GWh, real GDP expressed in current US$, energy production from coal (EPC) measured in GWh, energy production from oil (EPL) measured in GWh, and energy production from gas (EPG) measured in GWh.

The relationship between carbon dioxide emissions, EC, electricity production from sources and GDP can be expressed in a linear relationship as shown in Equation (1):

$$CO_{2_t} = f(EC_t, EPC_t, EPL_t, EPG_t, GDP_t) \tag{1}$$

The VEC model for this study is expressed as:

$$\begin{bmatrix} \Delta LCO_{2t} \\ \Delta LEC_t \\ \Delta LEPC_t \\ \Delta LEPG_t \\ \Delta LEPL_t \\ \Delta LGDP_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{i=1}^{k} \Delta \begin{bmatrix} \beta_{11i}\beta_{12i}\beta_{13i}\beta_{14i}\beta_{15i}\beta_{16i} \\ \beta_{21i}\beta_{22i}\beta_{23i}\beta_{24i}\beta_{25i}\beta_{26i} \\ \beta_{31i}\beta_{32i}\beta_{33i}\beta_{34i}\beta_{35i}\beta_{36i} \\ \beta_{41i}\beta_{42i}\beta_{43i}\beta_{44i}\beta_{45i}\beta_{46i} \\ \beta_{51i}\beta_{52i}\beta_{53i}\beta_{54i}\beta_{55i}\beta_{56i} \\ \beta_{61i}\beta_{62i}\beta_{63i}\beta_{64i}\beta_{65i}\beta_{66i} \end{bmatrix} \times \begin{bmatrix} LCO_{2_{t-i}} \\ LEC_{t-i} \\ LEPC_{t-i} \\ LEPG_{t-i} \\ LEPL_{t-i} \\ LGDP_{t-i} \end{bmatrix} + \begin{bmatrix} \partial_1 \\ \partial_2 \\ \partial_3 \\ \partial_4 \\ \partial_5 \\ \partial_6 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix} \tag{2}$$

where LCO_2 is the logarithmic transformation of carbon dioxide emissions LEC, the logarithmic transformation of EC, LEPC is the logarithmic transformation of electricity consumption from coal, LEPG is the logarithmic transformation of electricity production from natural gas, LEPL is the logarithmic transformation of oil and LGDP is the logarithmic transformation of GDP, in year t, Δ is the difference operator, ECT_{t-1} is the error correction term from the long-run cointegration relationship, ∂ , α and β are the parameters to be estimated, k is the number of lags and ε_t's are serially independjent error terms.

4. Descriptive statistical analysis

Table 2 presents the descriptive statistical analysis of the study variables prior to logarithmic transformation. Evidence of the mean value in Table 2 shows that the bulk of Pakistan's electricity production comes from natural gas, followed by oil and coal, meaning that Pakistan's economy is dependent on natural gas consumption. Evidence from Table 2 shows that all the variables a positively skewed thus increasing over time.

Table 2. Summary of the descriptive statistic for all the variables

Descriptive statistics	Variables					
	CO_2	EPC	EPG	EPL	EC	GDP
Mean	81.69	123	15,933	13,202	38,141	68,931
Median	72.79	90.58	13,838	11,808	37,979	48,635
Min.	18.93	3.36	4,620	42.47	5,584	6,325
Max.	170.5	459	41,194	34,509	81,845	232,286
1st Quar.	35.9	40.9	6,001	1,551	12,604	28,396
3rd Quar.	116.5	132	25,214	24,049	58,096	78,598
SE Mean	7.67	17.67	1,637	1,811	4,005	9,518
Var.	2,527	13,429	115×10^6	$1{,}401 \times 10^6$	691×10^6	$3{,}895 \times 10^6$
St. dev.	50.27	115.8	10,737	11,872	26,269	62,414
Skew.	0.39	1.448	0.76	0.407	0.294	1.264
Kurt.	−1.25	1.084	−0.59	−1.36	−1.38	0.479

Figure 1. The trend of data variables.

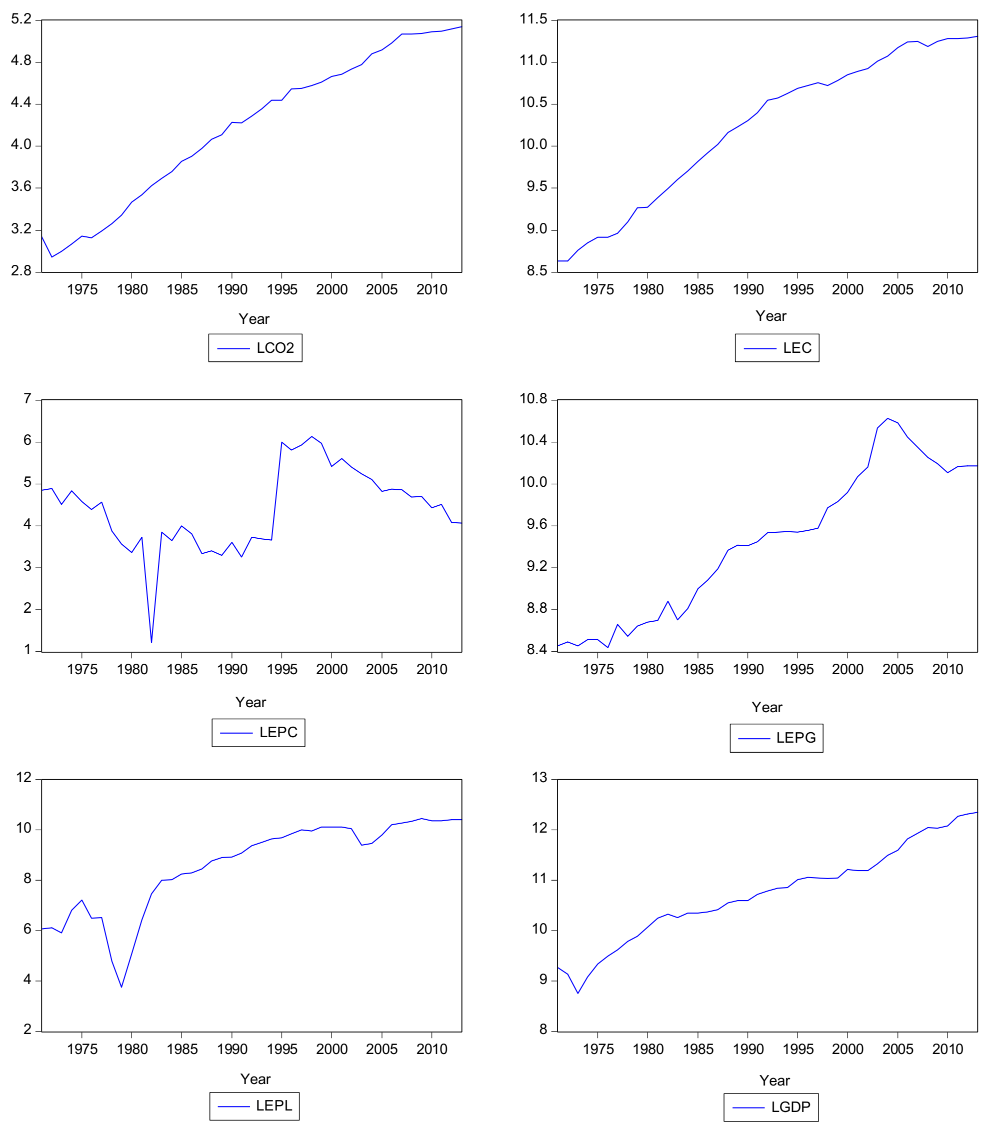


Table 3. Unit root test

	ADF level		ADF 1st diff.		PP level		PP 1st diff.	
	t-stat.	*p*-val.	*t*-stat.	*p*-val.	*t*-stat.	*p*-val.	*t*-stat.	*p*-val.
None								
CO_2	1.5134	0.9656	−1.1431	0.2260	4.8869	1.0000	−4.5821	0.0000
EC	3.2873	0.9996	−2.4317	0.0162	5.1525	1.0000	−2.1058	0.0353
EPC	−0.5866	0.4571	−9.9515	0.0000	−0.6764	0.4180	−9.9501	0.0000
EPG	2.3897	0.9952	−5.0344	0.0000	1.9710	0.9870	−5.2370	0.0000
EPL	0.8490	0.8900	−4.2338	0.0001	0.8188	0.8849	−4.1858	0.0001
GDP	4.0837	1.0000	−4.1780	0.0001	4.0993	1.0000	−4.1832	0.0001
Intercept								
CO_2	−2.6641	0.0890	−4.4850	0.0009	−0.5981	0.8602	−8.5176	0.0000
EC	−2.8875	0.0553	−4.6934	0.0005	−2.7102	0.0807	−4.7406	0.0004
EPC	−1.6424	0.4523	−9.8387	0.0000	−2.4670	0.1306	−9.8388	0.0000
EPG	−0.9595	0.7589	−5.5838	0.0000	−0.9775	0.7526	−5.6888	0.0000
EPL	−0.9653	0.7560	−4.3014	0.0015	−1.2956	0.6229	−4.0658	0.0029
GDP	−0.0688	0.9462	−5.6837	0.0000	−0.0497	0.9482	−5.7075	0.0000
Intercept and trend								
CO_2	0.1786	0.9971	−10.2636	0.0000	−1.5699	0.7880	−10.3637	0.0000
EC	0.5157	0.9990	−6.0520	0.0001	0.4429	0.9988	−6.0563	0.0001
EPC	−2.7347	0.2287	−9.7132	0.0000	−2.6796	0.2498	−9.7140	0.0000
EPG	−1.1792	0.9019	−5.5730	0.0002	−1.7795	0.6968	−5.6695	0.0002
EPL	−3.0777	0.1250	−4.2606	0.0085	−2.2176	0.4679	−4.0141	0.0159
GDP	−2.2098	0.4720	−5.5856	0.0002	−2.4052	0.3717	−5.5933	0.0002

Figure 1 shows the time series plots of the study variables. Evidence from Figure 1 shows that CO_2 emissions, EC and GDP increases periodically from 1971 to 2013. In order to fulfill the electricity demand, Pakistan relies more on natural gas, oil and Coal as showed in Figure 1.

4.1. Unit root test

The study employed the Augmented Dickey–Fuller and Phillips–Perron unit root tests prior to testing Johansen's method of co-integration. The addition of PP unit root test is due to its robustness for a variety of serial correlation and time dependent heteroscedasticities.

Table 3 shows the outcome of ADF and PP unit root tests at level and first difference. Both test results reject the null hypothesis of a unit root at level, but accepts the alternative hypothesis of no unit root at their first differences, implying a first order integration. Thus, confirms the implementation of Johansen's method of cointegration.

5. Results and discussion

5.1. Cointegration

Co-integration techniques are mainly used to test the validity of long-run equilibrium relationship between study variables. The concept of cointegration can be defined as a common stochastic trend between two or more variables over a long-run. Johansen and Juselius cointegration technique is applicable only variables that are integrated at I(1). Evidence from ADF and PP test results in Table 3 shows that all series are integrated at first order which meets the condition of Johansen cointegration to test. Prior to estimating the cointegration, the study selects an optimal lag using the LR, FPE, AIC, SC and HQ selection criteria as shown in Table 4. Two test statistics are involved in the Johansen

Table 4. Lag selection criteria

Lag	Log L	LR	FPE	AIC	SC	HQ
0	−36.7523	NA	3.42E−07	2.137614	2.390946	2.229211
1	211.7417	410.0151	8.49E−12	−8.48709	−6.713763*	−7.845908*
2	246.1418	46.44005	1.04E−11	−8.40709	−5.11377	−7.21633
3	296.6765	53.06149*	7.16E−12*	−9.133826*	−4.32052	−7.39349

*Indicates lag order selected by the criterion.

Table 5. Johansen's method of cointegration results

Hypothesized No. of CE(s)	Eigen value	Trace statistic	5% Critical value	Prob.**	Max-Eigen statistic	5% Critical value	Prob.**
None*	0.8877	254.6603	117.7082	0.0000	85.2613	44.4972	0.0000
At most 1*	0.8129	169.3990	88.8038	0.0000	65.3781	38.3310	0.0000
At most 2*	0.5987	104.0209	63.8761	0.0000	35.6081	32.1183	0.0179
At most 3*	0.5760	68.4128	42.9153	0.0000	33.4656	25.8232	0.0040
At most 4*	0.4380	34.9472	25.8721	0.0028	22.4705	19.3870	0.0172
At most 5	0.2738	12.4766	12.5180	0.0508	12.4766	12.5180	0.0508

*Denotes rejection of the hypothesis at the 5% level.

**MacKinnon–Haug–Michelis (1999) *p*-values.

Table 6. Long run equilibrium relationship based on VECM

Error correction	$LDCO_2$	LDEC	LDEPC	LDEPG	LDEPL	LDGDP
ECT(−1)	−0.9614	0.1011	−1.9921	0.2684	13.7117	−0.255
SE	−0.2421	−0.4169	−10.4072	−1.4296	−4.7928	−0.722
t-stat.	−3.9714	0.2426	−0.1914	0.1878	2.8609	−0.354
Prob.	0.0001*	0.8087	0.8485	0.8513	0.0049*	0.7239
ECT(−2)	0.4328	−0.1391	−0.2200	0.0355	−3.7398	0.0456
SE	−0.0994	−0.1712	−4.2735	−0.5870	−1.9681	−0.296
t-stat.	4.3543	−0.8128	−0.0515	0.0605	−1.9003	0.1536
Prob.	0.0000*	0.4178	0.9590	0.9519	0.0596	0.8782
ECT(−3)	0.0178	−0.0193	−0.0150	0.0110	−0.1599	−0.049
SE	−0.0062	−0.0107	−0.2660	−0.0366	−0.1225	−0.018
t-stat.	2.8691	−1.8149	−0.0565	0.2997	−1.3055	−2.681
Prob.	0.0048*	0.0718	0.9551	0.7649	0.1940	0.008*
ECT(−4)	0.1674	0.1476	0.6969	−0.3510	−1.3476	0.047
SE	−0.0320	−0.0551	−1.3759	−0.1890	−0.6336	−0.095
t-stat.	5.2318	2.6781	0.5065	−1.8571	−2.1268	0.4996
Prob.	0.0000*	0.0083*	0.6134	0.0655	0.0353*	0.6182
ECT(−5)	−0.0057	0.0076	0.4746	−0.0554	−0.9844	−0.032
SE	−0.0090	−0.0155	−0.3859	−0.0530	−0.1777	−0.026
t-stat.	−0.6294	0.4912	1.2300	−1.0455	−5.5395	−1.189
Prob.	0.5302	0.6241	0.2209	0.2977	0.0000*	0.2367

*Significance at 5% level.

cointegration testing; trace and eigenvalue statistics, which are presented in Table 5. Evidence from the trace and max-eigenvalue test shows 5 cointegration equations significant at 5% level, which rejects the null hypothesis of no cointegrating relationship. In other words, there is a cointegrating relationship between LCO_2, LEC, LEPC, LEPG, LEPL and LGDP.

5.2. VEC model analysis

The Vector error correction model was first proposed by Sargan (1964), forwarded by Engle and Granger (1987) and later modified by Hendry and Juselius (2000) which highlighted the significance of error correction in a multivariate causality analysis. As proposed by Granger, when non-stationary variables turn out to be stationary after their first difference and are cointegrated, then it is essential to examine the vector error correction model for multivariate causality. Table 6 shows the result of long-run based on vector error correction model. Evidence from Table 6 shows that the error correction term [ECT(−1) = −0.96] is negative and significant at 5% level, which means a long-run

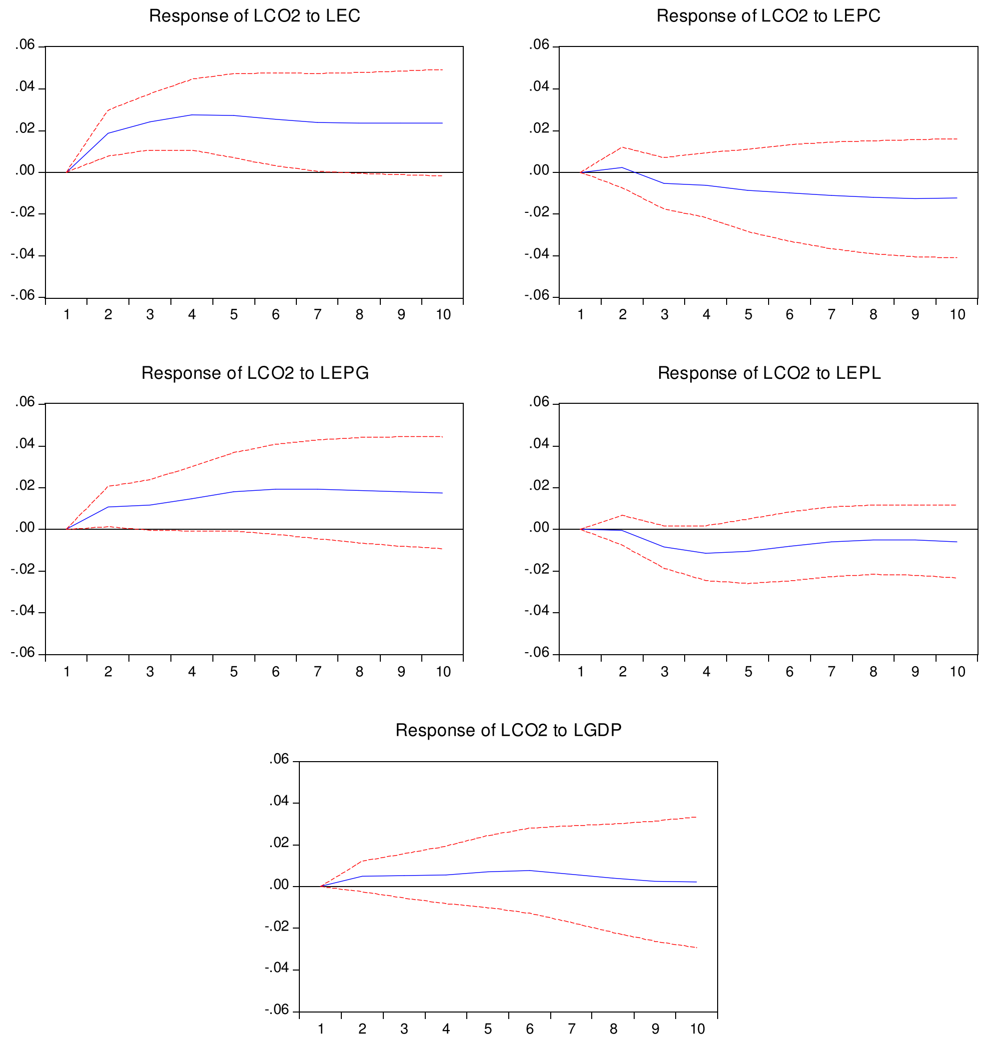
Table 7. Granger-causality relationship

Null hypothesis	*F*-stat.	Prob.
LEC does not Granger Cause LCO_2	6.2368	0.0018*
LCO_2 does not Granger Cause LEC	0.4516	0.7179
LEPC does not Granger Cause LCO_2	0.3839	0.7653
LCO_2 does not Granger Cause LEPC	0.4620	0.7107
LEPG does not Granger Cause LCO_2	1.8722	0.1535
LCO_2 does not Granger Cause LEPG	2.3537	0.0900**
LEPL does not Granger Cause LCO_2	1.1672	0.3370
LCO_2 does not Granger Cause LEPL	2.5132	0.0755**
LGDP does not Granger Cause LCO_2	0.7129	0.5513
LCO_2 does not Granger Cause LGDP	1.8638	0.1549
LEPC does not Granger Cause LEC	1.3087	0.2880
LEC does not Granger Cause LEPC	0.9866	0.4110
LEPG does not Granger Cause LEC	3.2413	0.0344*
LEC does not Granger Cause LEPG	1.7060	0.1848
LEPL does not Granger Cause LEC	0.0288	0.9933
LEC does not Granger Cause LEPL	4.2644	0.0119*
LGDP does not Granger Cause LEC	0.5627	0.6434
LEC does not Granger Cause LGDP	0.8499	0.4766
LEPG does not Granger Cause LEPC	0.3098	0.8182
LEPC does not Granger Cause LEPG	1.3967	0.2611
LEPL does not Granger Cause LEPC	1.1818	0.3316
LEPC does not Granger Cause LEPL	0.2643	0.8506
LGDP does not Granger Cause LEPC	0.8713	0.4658
LEPC does not Granger Cause LGDP	2.0086	0.1318
LEPL does not Granger Cause LEPG	1.7970	0.1669
LEPG does not Granger Cause LEPL	1.1573	0.3407
LGDP does not Granger Cause LEPG	1.8370	0.1596
LEPG does not Granger Cause LGDP	5.1683	0.0049*
LGDP does not Granger Cause LEPL	3.6230	0.0230*
LEPL does not Granger Cause LGDP	1.8609	0.1554

*Rejection of the null hypothesis at 5%.

**10% significance level.

Figure 2. Response of carbon dioxide to other variables.

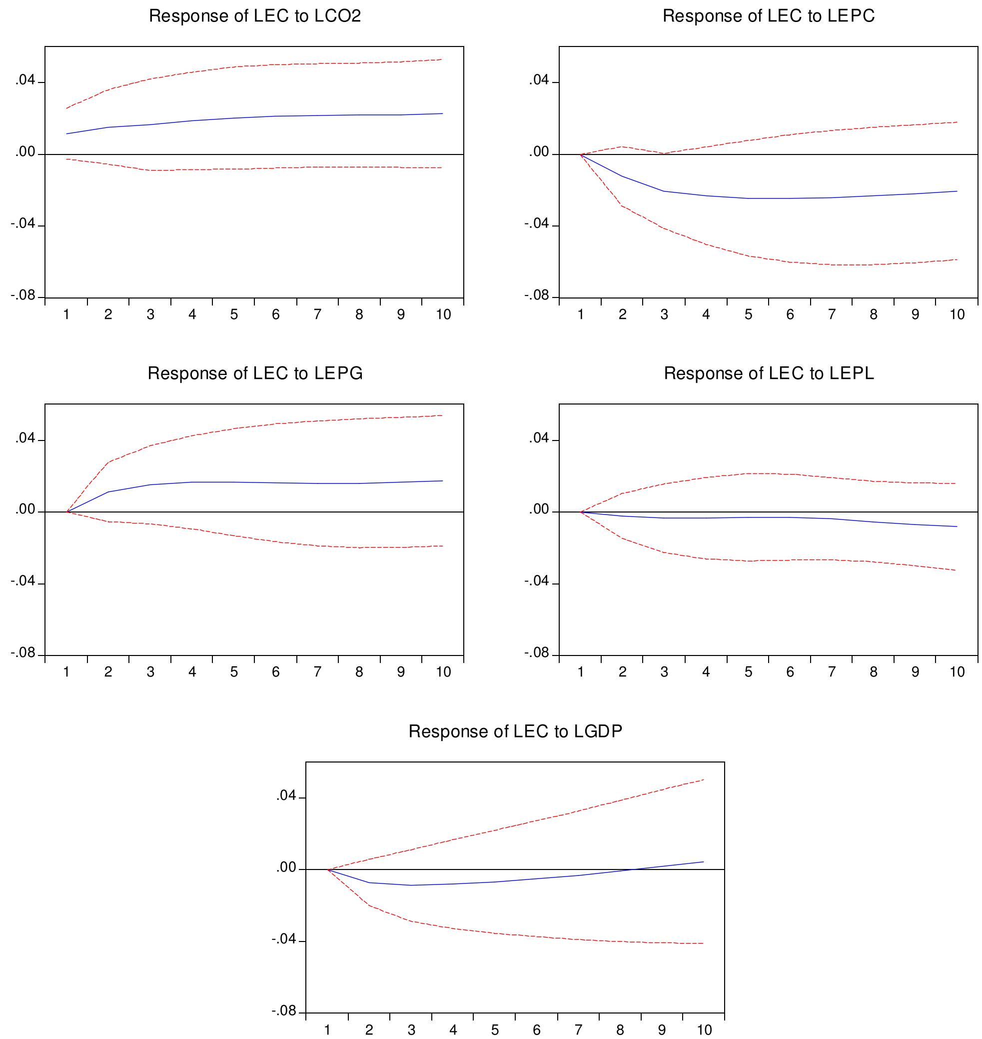


equilibrium relationship running from LEC, LEPC, LEPG, LEPL and LGDP to LCO_2. Moreover, evidence from Table 6 shows that only LDEPL [ECT (−1) = 13.71] is significant at 5% level, which means a long-run equilibrium relationship running from LEPL to LCO_2. The policy implication of the VEC model means that a 1% increase in energy production of oil in Pakistan will increase carbon dioxide emissions by 13.7% in the long-run.

5.3. Granger-causality analysis

To test the direction of causality between two different variables, the study employs the Granger causality test based on VECM. The Granger-causality analysis is presented in Table 7. Evidence from Table shows that the null hypothesis that LEC does not Granger Cause LCO_2, LEPG does not Granger Cause LEC, LEC does not Granger Cause LEPL, LEPG does not Granger Cause LGDP and LGDP does not Granger Cause LEPL is rejected at 5% significance level. In addition, the null hypothesis that LCO_2 does not Granger Cause LEPG and LCO_2 does not Granger Cause LEPL is rejected at 10% significance

Figure 3. Response of energy consumption to other variables.



level. Meaning that there is evidence of a unidirectional causality running from LEC → LCO_2, LEPG → LEC, LEC → LEPL, LEPG → LGDP and LGDP → LEPL. However, there is a weak unidirectional causality running from LCO_2 → LEPG and LCO_2 → LEPL.

6. Diagnostic test

The study employs VEC residual serial correlation LM, VEC residual heteroskedasticity and VEC residual normality tests to examine the independence of the residuals in the VEC model. Evidence from Table 8 shows that the null hypothesis of no serial correlation at lag order by the Breusch–Godfrey test cannot be rejected at 5% significance level. Moreover, the null hypothesis of constant variance in the residual by the Breusch–Pagan–Godfrey test cannot be rejected at 5% significance level. The null hypothesis of normal distribution of the Jarque–Bera test in the residual cannot be rejected at 5% significance level. Meaning that the residuals are normally distributed, there is no evidence of serial correlation and heteroskedasticity among the residuals which indicates a robust model to make unbiased statistical inferences.

Table 8. Diagnostic test

VECM diagnostics test		
Serial correlation LM tests		
Lags	LM-stat.	Prob.
1	48.37912	0.0814
2	40.49364	0.2786
3	27.30689	0.8510
Heteroskedasticity tests		
χ^2	df	Prob.
708.6561	714	0.5494
Jarque–Bera tests		
Component	Jarque–Bera	Prob.
1	1.7066	0.4260
2	2.5686	0.2768
3	2.2874	0.3186
4	3.4345	0.1796
5	0.0494	0.9756
6	5.8738	0.0590
Joint	15.9203	0.1949

7. Generalized impulse response

The Granger-causality is capable of testing the direction of causality among variables, but do not consider how variables response to innovations in other variables. The study employs the generalized impulse-response analysis (Cholesky one S.D. innovation ± S.E.) by Koop, Pesaran, and Potter (1996) which overcomes the problem of orthogonality in out-of-sample Granger-causality tests. Figures 2–3 shows the generalized impulse-response analysis based on Cholesky one standard deviation (S.D.) innovation ± S.E (standard error).

Evidence from Figure 2 shows that the response of LCO_2 to LEPL and LCO_2 to LEPC are insignificant within the 10-period horizon. In contrast, the response of LCO_2 to LGDP is significant, but gradually decreasing within the 10-period horizon. Moreover, the response of LCO_2 to LEC and LCO_2 to LEPG is significant and has a constant trend within the 10-period horizon. Hence, the evidence from the impulse-response analysis confirms the outcome of the Granger-causality that EC Granger Causes carbon dioxide emissions. It is noteworthy that three components are attributed to carbon dioxide emissions in Pakistan as per the impulse-response analysis; EC, EPG and GDP. It is worth mentioning that two components have a negative impact on carbon dioxide emissions in Pakistan; EPL and EPC.

Evidence from Figure 3 shows that the response of LEC to LEPC and LEC to LEPL are insignificant within the 10-period horizon. In contrast, the response of LGDP to LEC is insignificant, but gradually rises over the 8th-period horizon. Moreover, the response of LEC to LCO_2 and LEC to LEPG is positive, significant and has a constant trend within the 10-period horizon. Hence, the evidence from the impulse-response analysis shows that three components are positively attributed to EC in Pakistan as per the impulse-response analysis; carbon dioxide emissions, EPG and GDP. It is noteworthy that two components have a negative impact on EC in Pakistan, which in tend affect carbon dioxide emissions; EPL and EPC.

8. Conclusion

In this study an attempt was made to investigate carbon dioxide emissions, EC, GDP and electricity production from oil, coal and natural gas in Pakistan by employing a time series data spanning from 1971 to 2013. The study employed the vector error correction model to estimate the long-run equilibrium relationship between study variables. Prior to testing Johansen's method of cointegration, the study employed the Augmented Dickey–Fuller and Phillips–Perron unit root tests. The study further employed the Granger-causality test to estimate the direction of causality and the generalized impulse-response analysis, which examines the response of variables to random innovations in other variables.

There was evidence of long-run equilibrium relationship running from EC, electricity production from coal, electricity production from natural gas, electricity production from oil and GDP to carbon dioxide emissions. The policy implication of the VEC model means that a 1% increase in energy production of oil in Pakistan will increase carbon dioxide emissions by 13.7% in the long-run.

Contrary to the work by Shahbaz et al. (2012), there was evidence of a unidirectional causality running from EC to carbon dioxide emissions, electricity production from natural gas to EC, EC to electricity production from oil, electricity production from natural gas to GDP and GDP to electricity production from oil. However, there was a weak unidirectional causality running from carbon dioxide emissions to electricity production from natural gas and carbon dioxide emissions to electricity production from oil.

Moreover, evidence from the generalized impulse-response analysis shows that three components are attributed to carbon dioxide emissions in Pakistan, which include EC, EPG and GDP. It is worth mentioning that two components have a negative impact on carbon dioxide emissions in Pakistan, which include EPL and EPC.

Finally, evidence from the impulse-response analysis shows that three components are positively attributed to EC in Pakistan as per the impulse-response analysis; carbon dioxide emissions, EPG and GDP. It is noteworthy that two components have a negative impact on EC in Pakistan, which in tend affect carbon dioxide emissions; EPL and EPC.

9. Policy recommendations

Environmental degradation has an adverse effect on social life, leading to extreme events such as heavy rainfall, extreme temperature and extreme floods with an increase in the occurrence within the same time period. The Environmental Protection Act of 1997 from the national assembly was updated after 17 years to an Environmental Protection Ordinance which still have some shortfalls. It is believed that the study can help provide policies that can be incorporated into the already existing policy document. The directional relationship between the carbon dioxide emission, EC, economic growth, and EPL, gas and coal will offer assistance in declaring inclusive policies for economic growth by utilization of energy efficient technologies that will reduce environmental degradation. The following are policy recommendations emanating from the study:

Evidence from the generalized impulse-response shows that two components, namely; EPL and EPC have a negative impact on EC in Pakistan which in tend increase carbon dioxide emissions. As a policy implication, the exploration of other renewable energy resources for reducing the carbon footprint is worthwhile. These renewable resources may include biomass, and solar energy. Pakistan's richness in biomass (agricultural waste and animal waste like dung) can be utilized for electricity generation, for heating and cooling purposes.

Since the utilization of the solar resources will further improve the environment and air quality, the Government of Pakistan should subsidize renewable energy systems like solar panels and encourage households to install them in order to reduce the electricity load as a way of mitigating climate change.

For residential purposes, the Government of Pakistan should encourage a shift from the current use of natural gas to the investment of clean energy technologies that are economical to residential users in order to reduce the emissions from natural gas.

Forestation will also help the nature to balance itself from extreme events, therefore, the Government of Pakistan should initiate tree planting projects that will protect the country from extreme events while providing aesthetical environment. It is believed that the utilization of these renewable resources will reduce the amount of fossil-fuel based electricity generation, thereby reducing the rate of carbon dioxide emissions in Pakistan.

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