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Cogent Engineering (2016), 3: 1210491
CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

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.
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 (CO₂) is the main pollutant responsible for 58.8% of the GHG emission. The policy makers have realized the requirement for highly resolved CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO2 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 CO2 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

| Author(s) | Country | Period | Techniques | Dependent Variable | Environmental variable determinants |
|-----------|---------|--------|------------|--------------------|-------------------------------------|
| Chang (2010) | China | 1982–2004 | Multivariate co-integration & 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 |
| Saboor and Su-laiman (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 Acaraveci (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 CO₂ 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 (CO₂) 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):

\[
\text{CO}_2 = f(\text{EC}_t, \text{EPC}_t, \text{EPL}_t, \text{EPG}_t, \text{GDP}_t)
\]

The VEC model for this study is expressed as:

\[
\begin{bmatrix}
\Delta \text{LCO}_2 \\
\Delta \text{LEC} \\
\Delta \text{LEPC} \\
\Delta \text{LEPG} \\
\Delta \text{LEPL} \\
\Delta \text{LGDP}
\end{bmatrix}_t =
\begin{bmatrix}
\alpha_1 \\
\alpha_2 \\
\alpha_3 \\
\alpha_4 \\
\alpha_5 \\
\alpha_6
\end{bmatrix}
+ \sum_{i=1}^{k} \Delta
\begin{bmatrix}
\beta_{11} \beta_{12} \beta_{13} \beta_{14} \beta_{15} \beta_{16} \\
\beta_{21} \beta_{22} \beta_{23} \beta_{24} \beta_{25} \beta_{26} \\
\beta_{31} \beta_{32} \beta_{33} \beta_{34} \beta_{35} \beta_{36} \\
\beta_{41} \beta_{42} \beta_{43} \beta_{44} \beta_{45} \beta_{46} \\
\beta_{51} \beta_{52} \beta_{53} \beta_{54} \beta_{55} \beta_{56} \\
\beta_{61} \beta_{62} \beta_{63} \beta_{64} \beta_{65} \beta_{66}
\end{bmatrix}
\times
\begin{bmatrix}
\text{LCO}_2 \\
\text{LEC}_t \\
\text{LEPC}_t \\
\text{LEPG}_t \\
\text{LEPL}_t \\
\text{LGDP}_t
\end{bmatrix}_t - 1 + \begin{bmatrix}
\delta_1 \\
\delta_2 \\
\delta_3 \\
\delta_4 \\
\delta_5 \\
\delta_6
\end{bmatrix}
\begin{bmatrix}
\text{ECT}_{t-1}
\end{bmatrix}
+ \begin{bmatrix}
\varepsilon_{1t} \\
\varepsilon_{2t} \\
\varepsilon_{3t} \\
\varepsilon_{4t} \\
\varepsilon_{5t} \\
\varepsilon_{6t}
\end{bmatrix}
\tag{2}
\]

where LCO₂ 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, ECTₜ₋₁ is the error correction term from the long-run cointegration relationship, α, β and δ are the parameters to be estimated, k is the number of lags and εᵢ’s are serially independent 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  | 150.8 | 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 Quart.             | 35.9   | 40.9 | 6,001 | 1,551 | 12,604 | 28,396 |
| 3rd Quart.             | 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 × 10$^6$ | 691 × 10$^6$ | 3,895 × 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.
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* | −7.84908* |
| 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      | 34.9747         | 25.8721           | 0.0000  | 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 | LDCO₂ | 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 LCO₂, 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 corre-
cction term \( [ECT(-1) = -0.96] \) is negative and significant at 5% level, which means a long-run

| Null hypothesis                                      | F-stat. | Prob.  |
|------------------------------------------------------|---------|--------|
| LEC does not Granger Cause LCO₂                      | 6.2368  | 0.0018*|
| LCO₂ does not Granger Cause LEC                      | 0.4516  | 0.7179 |
| LEPC does not Granger Cause LCO₂                     | 0.3839  | 0.7653 |
| LCO₂ does not Granger Cause LEPC                     | 0.4620  | 0.7107 |
| LEPG does not Granger Cause LCO₂                     | 1.8722  | 0.1535 |
| LCO₂ does not Granger Cause LEPG                     | 2.3537  | 0.0900**|
| LEPL does not Granger Cause LCO₂                     | 1.1672  | 0.3370 |
| LCO₂ does not Granger Cause LEPL                     | 2.5132  | 0.0755**|
| LGDP does not Granger Cause LCO₂                     | 0.7129  | 0.5513 |
| LCO₂ 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 LEPC                     | 0.5627  | 0.6434 |
| LEC does not Granger Cause LGDP                      | 0.8499  | 0.4766 |
| LEPG does not Granger Cause LEC                      | 0.3098  | 0.8182 |
| LEPC does not Granger Cause LEPG                     | 1.3967  | 0.2611 |
| LEPL does not Granger Cause LEPC                     | 1.1818  | 0.3316 |
| LEPG 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 |
| LGDP does not Granger Cause LEPC                     | 1.1573  | 0.3407 |
| LEPG does not Granger Cause LGDP                     | 1.8370  | 0.1596 |
| LEPL does not Granger Cause LEPG                     | 5.1683  | 0.0049*|
| LGDP does not Granger Cause LEPL                     | 3.6230  | 0.0230**|
| LEPC does not Granger Cause LGDP                     | 1.8609  | 0.1554 |

*Rejection of the null hypothesis at 5%.
**10% significance level.
equilibrium relationship running from LEC, LEPC, LEPG, LEPL and LGDP to LCO₂. 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 LCO₂. 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 LCO₂, 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 LCO₂ does not Granger Cause LEPL and LCO₂ does not Granger Cause LEPL is rejected at 10% significance
level. Meaning that there is evidence of a unidirectional causality running from LEC → LCO₂, LEPG → LEC, LEC → LEPL, LEPG → LGDP and LGDP → LEPL. However, there is a weak unidirectional causality running from LCO₂ → LEPG and LCO₂ → 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.
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 LCO₂ to LEPL and LCO₂ to LEPC are insignificant within the 10-period horizon. In contrast, the response of LCO₂ to LGDP is significant, but gradually decreasing within the 10-period horizon. Moreover, the response of LCO₂ to LEC and LCO₂ 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 LCO₂ 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.

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 | χ²  | 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      |
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.

Funding
The authors received no direct funding for this research.

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Citation information
Cite this article as: The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan, Obaidullah Mohiuddin, Samuel Asumadu-Sarkodie & Madina Obaidullah, Cogent Engineering (2016), 3: 1210491.

References
Ahmed, K., & Long, W. (2012). Environmental kuznets curve and Pakistan: An empirical analysis procedia economics and finance, 1, 4–13.
Ahmed, K., Shahbaz, M., Qasim, A., & Long, W. (2015). The linkages between deforestation, energy and growth for environmental degradation in Pakistan, Ecological Indicators, 49, 95–103. doi:10.1016/j.ecolind.2014.09.040
Al-Mulali, U., & Ozturk, I. (2015). The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. Energy, 84, 382–389. http://dx.doi.org/10.1016/j.energy.2015.03.004
Alam, S., Fatima, A., & Butt, M. S. (2007). Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation. Journal of Asian Economics, 18, 825–837.
Asumadu-Sarkodie, S., & Owusu, P. (2016a). The casual nexus between child mortality rate, fertility rate, GDP, household final consumption expenditure, and food production index. Cogent Economics & Finance, 4(1), 1191985. doi:10.1080/23320393.2016.1191985
Asumadu-Sarkodie, S., & Owusu, P. (2016b). A review of Ghana’s energy sector national energy statistics and policy framework. Cogent Engineering, 3(1), 1155274. doi:10.1080/23311916.2016.1155274
Asumadu-Sarkodie, S., & Owusu, P. A. (2016c). Carbon dioxide emissions, GDP, energy use and population growth: A multivariate and causality analysis for Ghana, 1971–2013. Environmental Science and Pollution Research, 23, 13508–13520. doi:10.1007/s11356-016-6511-x
Asumadu-Sarkodie, S., & Owusu, P. A. (2016d). Feasibility of biomass heating system in Middle East Technical University, Northern Cyprus Campus. Cogent Engineering, 3(1), 1134304. doi:10.1080/23311916.2015.1134304
Asumadu-Sarkodie, S., & Owusu, P. A. (2016e). Multivariate co-integration analysis of the Kaya factors in Ghana. Environmental Science and Pollution Research, 23, 9934–9943. doi:10.1007/s11356-016-6245-9
Asumadu-Sarkodie, S., & Owusu, P. A. (2016f). The potential and economic viability of solar photovoltaic power in Ghana Energy Sources, part A, Recovery, Utilization, and Environmental Effects, 38, 709–716. doi:10.1080/15567036.2015.1122682
Asumadu-Sarkodie, S., & Owusu, P. A. (2016g). The potential and economic viability of wind farms in Ghana Energy Sources, part A, Recovery, Utilization, and Environmental Effects, 38, 695–701. doi:10.1080/15567036.2015.1122680
Asumadu-Sarkodie, S., & Owusu, P. A. (2016h). The relationship between carbon dioxide and agriculture in Ghana: A comparison of VECM and ARDL model. Environmental Science and Pollution Research, 23, 10968–10982. doi:10.1007/s11356-016-6252-x
Asumadu-Sarkodie, S., & Owusu, P. A. (2016i). Recent evidence of the relationship between carbon dioxide emissions, energy use, GDP and population in Ghana: A linear regression approach. Energy Sources, Part B: Economics, Planning, and Policy. doi:10.1080/15567249.2016.1208304
Dinda, S., & Coondoo, D. (2006). Income and emission: A panel data-based cointegration analysis. Ecological Economics, 57, 167–181. http://dx.doi.org/10.1016/j.ecolecon.2005.03.028
Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55, 251–276. http://dx.doi.org/10.2307/1913236
Gurney, K. R., Mendoza, D. L., Zhou, Y., Fischer, M. L., Miller, C. C., Geethakumar, S., & de la Rue du Can, S. (2009). High resolution fossil fuel combustion CO2 emission fluxes for the United States. Environmental Science and Technology, 43, 5535–5541. http://dx.doi.org/10.1021/es900806c
Halicioglu, F. (2009). An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy, 37, 1156–1164. http://dx.doi.org/10.1016/j.enpol.2008.11.012

Hendry, D. F., & Juselius, K. (2000). Explaining cointegration analysis: Part 1. The Energy Journal, 21(1), 1–42.

Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. Journal of Econometrics, 74, 119–147. http://dx.doi.org/10.1016/0304-4076(95)01753-4

Kutney, G. (2014). Carbon politics and the failure of the Kyoto protocol. Hoboken, NJ: Taylor and Francis. Retrieved from http://public.eblib.com/choice/publicfullrecord.aspx?p=1613788

Lean, H. H., & Smyth, R. (2010). CO2 emissions, electricity consumption and output in ASEAN. Applied Energy, 87, 1858–1864. http://dx.doi.org/10.1016/j.apenergy.2010.02.003

Long, X., Namisne, E. Y., Du, J., & Zhuang, J. (2015). Nonrenewable energy, renewable energy, carbon dioxide emissions and economic growth in China from 1952 to 2012. Renewable and Sustainable Energy Reviews, 52, 680–688. http://dx.doi.org/10.1016/j.rser.2015.07.176

Magazzino, C. (2014). The relationship between CO2 emissions, energy consumption and economic growth in Italy. International Journal of Sustainable Energy, 1–14.

Magazzino, C. (2015). Economic growth, CO2 emissions and energy use in Israel. International Journal of Sustainable Development & World Ecology, 22, 89–97.

Metz, B., Davidson, O., Bosch, P, Dave, R. & Meyer, L. (2007). Climate change 2007: Mitigation of climate change, contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. New York, NY: Cambridge University Press, ISBN.

Ministry of Finance. (2013). Pakistan Economic Survey. Retrieved from September 15, 2015, http://www.finance.gov.pk/survey_1415.html

Mohiuddin, O., Mohiuddin, A., Obaidullah, M., Ahmed, H., & Asumadu-Sarkodie, S. (2016). Electricity production potential and social benefits from rice husk, a case study in Pakistan. Cogent Engineering, 3(1), 1177156. doi:10.1080/23311916.2016.1177156

Nasir, M., & Rehman, F. U. (2011). Environmental kuznets curve for carbon emissions in Pakistan: An empirical investigation. Energy Policy, 39, 1857–1864. http://dx.doi.org/10.1016/j.enpol.2011.01.025

Owusu, P., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering, 3(1), 1167990. doi:10.1080/23311916.2016.1167990

Owusu, P. A., Asumadu-Sarkodie, S., & Ameyo, P. (2016). A review of Ghana’s water resource management and the future prospect. Cogent Engineering, 3(1), 1164275. doi:10.1080/23311916.2016.1164275

Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Economics, 36, 262–267. http://dx.doi.org/10.1016/j.eneco.2012.08.025

Peng, S., & Sun, Z. (2010). An econometric study of CO2 emissions, energy consumption and economic growth in China. In 2010 International Conference on Mechanic Automation and Control Engineering (MACE) (pp. 1805–1808). IEEE. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5536531

Saboori, B., & Sulaiman, J. (2013). Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. Energy Policy, 60, 892–905. http://dx.doi.org/10.1016/j.enpol.2013.05.099

Sargan, J. D. (1964). Wages and prices in the United Kingdom: A study of econometric methodology. In Econometric analysis for national economic planning (pp. 25–63). London: Butterworth.

Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2012). Environmental Kuznets curve hypothesis in Pakistan: Cointegration and Granger causality. Renewable and Sustainable Energy Reviews, 16, 2947–2953. http://dx.doi.org/10.1016/j.rser.2012.02.015

Shahbaz, M., Uddin, G. S., Rehman, I. U., & Imran, K. (2014). Industrialization, electricity consumption and CO2 emissions in Bangladesh. Renewable and Sustainable Energy Reviews, 31, 575–586. http://dx.doi.org/10.1016/j.rser.2013.12.028

Shahbaz, M., Khinie, N., & Jemaa, M. M. B. (2013). On the causal nexus of road transport CO2 emissions and macroeconomic variables in Tunisia: Evidence from combined cointegration tests. Renewable and Sustainable Energy Reviews, 51, 89–100. doi:10.1016/j.rser.2015.06.014

World Bank. (2014). World development indicators. Retrieved October 24, 2015, from http://data.worldbank.org/country

World Bank Report. (2007). How do different countries. “Growth and CO2 emissions: How do different countries fare?” Retrieved November 6, 2015, from http://www3.imperial.ac.uk/pls/portallive/docs/1/34721711.PDF

Zhang, X.-P., & Cheng, X.-M. (2009). Energy consumption, carbon emissions, and economic growth in China. Ecological Economics, 68, 2170–2172. doi:10.1016/j.ecolecon.2009.05.011