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Modeling Energy Consumption, Carbon Emission and Economic Growth: Empirical Analysis for Pakistan

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ABSTRACT

This study examines the short run and long relationship among carbon emission, energy consumption and economic growth in case of Pakistan for the time period 1980-2012. For this purpose we have employed Johansen co-integration approach and the results reveal that there exists long run relationship among energy, growth and environment (E-E-E) in Pakistan. It is found that the environmental Kuznets curve hypothesis is valid in long run but not in short run. Also there exists unidirectional causality between energy consumption to energy emission in Pakistan. Unidirectional causality also found between financial development and economic growth running from financial development to economic growth.

Keywords: Environmental Kuznets Curve, Energy, Growth, Co-integration, Pakistan
JEL Classifications: G00, Q43, Q50

1. INTRODUCTION

Worldwide, increasing energy generation from non-renewable sources is one of a major contributor in the environmental degradation. However, this increased energy consumption is linked to the market mechanism of demand and supply, and because energy is used as an input in the production process. Therefore, the method and source of energy production matter, to assess the environmental degradation.

Energy, economy and environment are closely associated with each other. In Pakistan, the energy sector is the top contributor of greenhouse gas emissions (Economic Survey of Pakistan, 2012-2013). In the recent years, the oil, gas and coal are the major sources of energy consumption, and the global liquid fuel consumption is 88.4 million barrels per day in 2011 and 89.0 million barrels per day in 2012, and hence, the global demand for liquid oil grew by 0.8% (Economic Survey of Pakistan, 2012-2013). International oil prices are affecting by the global demand, and the future oil prices are uncertain are depending by adjusting key factors of the energy demand growth in non-OECD countries, production of OPEC and non-OPEC countries affect the international prices (International Energy Outlook, 2014).

The economists empirically test a short and the long run relationship of energy consumption and economic growth. It is believed, at the outset of economic development the environmental degradation is expected to deteriorate. However, in the long run the environmental improvement is expected to improve. This phenomenon is commonly known as Environmental Kuznet Curve (EKC). This concept is not a new to the economist, and it has been widely empirically tested. The difference in the results of the studies is due to the differences in the methodologies used and data sets. Stern (2004) has identified the proximate factors of EKC. These are the changes in the scale of production, changes in the output mix due to changes in pollution intensities, changes in the input mix due to the substitution to less environmentally damaging inputs from more damaging ones, and the improvements in the state of technology that results in increased production efficiency and emissions reduction.

This paper tests the EKC hypothesis and the model is build up on the previous research studies of Nasir and Rehman (2011), Siddiqui (2004), and Alam (2006). However, we have included financial development and energy consumption as a controlling variable, and the latest datasets available for Pakistan. The main objectives of this paper are:

- To determine the dynamic causal relationship among economic growth, energy consumption and carbon emission (CO_2)
- To check empirically the existence of EKC in short run as well in long run in Pakistan.

2. LITERATURE REVIEW

Song et al., (2013) describe the inflection point of EKC in Mainland China. In China the environmental problems arises day by day which receives the attentions of policy makers. The results of analysis indicates that in few areas of china such as Shanghai, Tibet, Guizhou, Jilin and Beijing have overstepped their inflection point but the Liaoning, Anhui, Fujian, Hainan and Qinghai have no inflection points. So it is important to make some sound mind policies to change the process of reaching inflection point for each and every area of China.

Shahbaz et al., (2013) studied the EKC hypothesis in Romania and significant role of energy consumption. They analyze the dynamic relationship between three variables i.e. economic growth, energy consumption and carbon dioxide emissions. Thus the data consisting on the years from 1980 to 2010 and autoregressive distributive lag (ARDL) testing approach is used to find out the dynamic relationship among the said variables. But the environmental Kuznets hypothesis is found in long run as well as in short run. So their result shows that the democratic regimes put their contribution to reduce the carbon emission by making and implementing effective economic policies.

Tiwari et al., (2013) studied the EKC and the role of coal consumption in India based on co-integration and causality analysis in an open economy to investigate the dynamic relationship between use of coal consumption, economic growth, trade openness and carbon emission. The data are based on the period for 1970-2000 and the structural break unit test is used to test the integration of the variables. The ARDL bounds testing approach is used to investigate the long run relationship between the considered variables and Johansen co-integration is applied to analysis the long run dynamics. So their findings confirm the existence of the long run relationship between the mentioned variables and empirical results shows the presence of EKC in both long run as well as in short run. The coal consumption and trade openness contributes to the carbon emission.

Onuonga (2012) analyzed the causal relationship between economic growth and energy consumption in Kenya by using published data. Granger casualty error correction model is used, which suggest the results that the economic growth caused the energy use in Kenya. The findings of the study show that the energy preservation procedures would not cause negative effect on economic growth of the country. Thus their results have the significant policy implications on Kenya energy and economic growth policy.

Qinga and Yujie (2012) studied the relationship between China's energy consumption and economic development. They launched the energy as a new factor of production into Cobb Douglas production function. Two different levels of periods are taken about the economic development as one is from 1985 to 2000 and the other is 2001-2009 and the time series data are weighted by applying least square analysis. By conducting the comparison of two empirical results the estimation analysis of Granger casualty test on variables of 1985-2009 shows that the energy consumption have role in the economic growth at the different levels of economic development. So, their results show that the energy consumption is not the key factor to derive the economic growth.

Sadeghimojarad and Mehrabirad (2012) made an effort to see a co-integration relationship between energy consumption and economic growth in Iran. For this purpose a co-integration analysis is undertaken. Findings from the analysis indicate that these two variables are co-integrated and there exists a causal relationship between them. So the energy restrictions do not distort the economic growth and they come to the point that energy consumption keeps on rising as long as the economic growth rises.

Alam et al., (2012) analyzed the co-integration and dynamic causality of energy consumption, carbon emission and economic growth nexus in Bangladesh. The co-integration relationship of variables is tested by using the Johansen bivariate co-integration model. This method is used with the implementation of an analysis of ARDL model to examine the results. After that the granger long run and short run causality are investigated by using the vector error correction model (VECM). Their results reveal that there exists a unidirectional causality from energy consumption to economic growth in long run and in short run. On the other hand there exist bidirectional long run causality between electricity consumption and economic growth but in short run there is no relationship between them. So the energy is an important factor for the economic development.

Saboori et al., (2012) explored the economic growth and carbon emission in Malaysia. To check long run causal relationship between economic growth and carbon emission the data are taken for the period of 1980-2009. The EKC hypothesis is tested by applying the ARDL methodology. Their empirical findings suggest that there exist a long run relationship between per capita carbon emission and real per capita gross domestic product (GDP) and the carbon emission is considered as a dependent variable. By supporting EKC an inverted U-shape relationship of these two variables in long run and in short run is indicated. On the other hand the granger causality test which is based on VECM in the study shows the deficiency of causality between carbon emission and economic growth in short run while in long run there is a unidirectional causality from economic growth to carbon emission.

Ahmed and Long (2012) empirically analyzes the EKC in Pakistan. Like other investigations which are based on the relationship between energy consumption, economic growth and carbon emission this review also investigates the relationship by including two other new variables trade liberalization and population density in Pakistan. The yearly data are taken from 1972 to 2008 and co-integration analysis uses the ARDL testing approach to find out the long run relationship among the variable. Results of the study show an inverted U-shape relationship among carbon emission and growth in long run by supporting the hypothesis. Trade supports the environment positively and the energy consumption and economic growth are considered as the major explanatory variables which contribute to environmental pollution.

Jalil and Feridun (2011) examined the impact of energy, financial development and growth on the environment of China. The yearly data are taken from 1953 to 2006 and ARDL bounds testing approach is used. They investigate the long run equilibrium relationship between financial development and environmental pollution. Findings from their analysis reveal that the financial development coefficient has negative sign and it is established that the financial development has caused the decrease in environmental pollution. So they came to the point that the carbon emission is determined by energy consumption, trade openness and income, in the long run and the existence of Kuznets curve is confirmed in the case of Chinese case.

Baranzini et al. (2011) investigated the short run and long run relationship between economic growth and energy consumption in Switzerland. The co-integration and error correction models are used to find out the relationship of variables by taking data based on period from 1950 to 2009. The results confirm that there is a long run relationship from economic growth to energy consumption of heating oil, fuel and electricity. But a significant relationship from energy consumption towards economic growth is not indicated.

3. MODEL SPECIFICATION

In the light of above discussions and following Nasir and Rehman (2011), Siddiqui (2004), and Alam (2006) the relationship between CO_2 emissions, energy consumption, economic growth and financial development is specified below:

$$CO_2 = f(Y, Y^2, EC, M_2) \quad (1)$$

This functional form can be written in the following model

$$LCO_2 = \alpha_0 + \alpha_1 Lgdp_t + \alpha_2 Lgdp^2_t + \alpha_3 Lec_t + \alpha_4 Lm_2 + \mu_t \quad (2)$$

Where:
LCO_2: The log of per capita carbon emission
$Lgdp_t$ and $Lgdp_t^2$: The log of per capita GDP and its square term
Lec_t: The log of per capita energy consumption
Lm_2: The log of financial development (measured by M_2/GDP)
μ_t: The regression error term
The data on all variables have been taken from World Development Indicators, 2013.

4. ESTIMATION TECHNIQUES

4.1. Unit Root Test

Generally time series variables suffer from unit root problem and if we don't care about it, the results will be spurious. In order to check the unit root problem in the data we apply augmented dickey fuller (ADF) (1979) based on the following regression equation.

$$\Delta y_t = \alpha + \delta_t + \beta y_{t-1} + \sum_{i=1}^{k} \gamma \Delta y_{t-1} + \mu_t \quad (3)$$

Where Δy_t represents the first difference of y, u_t shows the serial correlation errors and α, δ, β and γ are parameters of the model to be estimated. The null and alternative hypothesis for a unit root in variables y_t are:

$$H_0 =: \beta = 1$$

$$H_\epsilon =: \beta < 0$$

If the null hypothesis is not rejected then we have the problem of unit root in the series.

4.2. Johansen Co-integration Test

If a time series variable is not stationary at level, then it may be stationary at first difference and hence it is called integrated of order one in such case. Time series variables may be co-integrated if there exists at least one linear combination among the variables that is stationary. In this case there exists a stable long run equilibrium relation among them.

The order of r is determined by using the likelihood ratio (LR) trace test statistic suggested by Johansen (1988).

$$\lambda_{trace}(q,n) = -T \sum_{i=q+1}^{k} \text{In}\left(1 - \hat{\lambda} i\right) \quad (4)$$

In the above equation r=0, 1, 2 …. k−1, T is the number of observation used for estimation, $\hat{\lambda_i}$ is the i[th] largest estimated eigenvalue. The maximum eigenvalue (LR) test statistics as suggested by Johansen is:

$$\lambda_{max}(q, q+1) = -T\text{In}\{1 - \lambda\_(q+1)\} \quad (5)$$

The outlined statistics either rejects the null hypothesis of co-integration among the variables (r=0) or does not rejects the null hypothesis that there is one co-integrating relation between the variables ($r \le 1$).

4.3. VECM

After obtaining the long run estimates, we know check the short run estimates as well. The short run estimates are obtained by applying VECM. In VECM, all variables are taken as endogenous one by one and thus the number of equations in VECM is equal to the number of variables in the chosen system. In this methodology each dependent variable is function of its own lags, explanatory variables lags, error correction term and the random error term. The VECM in our case can be written as follow;

$$\Delta lco2_t = \alpha_1 + \sum_{i=1}^{p}\beta_{1i}\Delta lco2_{t-i} + \sum_{i=1}^{q}\beta_{1i}\Delta lgdp_{t-i} + \sum_{i=1}^{r}\beta_{1i}\Delta lgdp2_{t-i} + \sum_{i=1}^{s}\beta_{1i}\Delta lec_{t-i} + \sum_{i=1}^{t}\beta_{1i}\Delta lm_{2t-i} + \lambda_1 EC_{t-1} + \mu_{1t} \quad (6)$$

$$\Delta lgdp_t = \alpha_2 + \sum_{i=1}^{p}\beta_{2i}\Delta lco2_{t-i} + \sum_{i=1}^{q}\beta_{2i}\Delta lgdp_{t-i} + \sum_{i=1}^{r}\beta_{2i}\Delta lgdp2_{t-i} + \sum_{i=1}^{s}\beta_{2i}\Delta lec_{t-i} + \sum_{i=1}^{t}\beta_{2i}\Delta lm_{2t-i} + \lambda_2 EC_{t-1} + \mu_{2t} \quad (7)$$

$$\Delta lgdp2_t = \alpha_3 + \sum_{i=1}^{p}\beta_{3i}\Delta lco2_{t-i} + \sum_{i=1}^{q}\beta_{3i}\Delta lgdp_{t-i} + \sum_{i=1}^{r}\beta_{3i}\Delta lgdp2_{t-i} + \sum_{i=1}^{s}\beta_{3i}\Delta lec_{t-i} + \sum_{i=1}^{t}\beta_{3i}\Delta lm_{2t-i} + \lambda_3 EC_{t-1} + \mu_{3t} \quad (8)$$

$$\Delta lec_t = \alpha_4 + \sum_{i=1}^{p}\beta_{4i}\Delta lco2_{t-i} + \sum_{i=1}^{q}\beta_{4i}\Delta lgdp_{t-i} + \sum_{i=1}^{r}\beta_{4i}\Delta lgdp2_{t-i} + \sum_{i=1}^{s}\beta_{4i}\Delta lec_{t-i} + \sum_{i=1}^{t}\beta_{4i}\Delta lm_{2t-i} + \lambda_4 EC_{t-1} + \mu_{4t} \quad (9)$$

$$\Delta lm_{2t} = \alpha_5 + \sum_{i=1}^{p}\beta_{5i}\Delta lco2_{t-i} + \sum_{i=1}^{q}\beta_{5i}\Delta lgdp_{t-i} + \sum_{i=1}^{r}\beta_{5i}\Delta lgdp2_{t-i} + \sum_{i=1}^{s}\beta_{5i}\Delta lec_{t-i} + \sum_{i=1}^{t}\beta_{5i}\Delta lm_{2t-i} + \lambda_5 EC_{t-1} + \mu_{5t} \quad (10)$$

Where u_{1i}, u_{2t}, u_{3t}, u_{4t}, and u_{5t} serial uncorrelated error terms in the respective equation and ECTs are presents the co-integrating vectors and λ_1, λ_2, λ_3, λ_4 and λ_5 are coefficients of the speed of adjustment towards equilibrium. The statistical significance of ECTs term is vital due to the fact that it measures how much the error is corrected in each short period to the long period in response to a random shock. Thus the main benefit of VECM is that it identifies causality among the co-integrated variables and helps us in detecting the differences between short run and long run. The data on all variables have been taken from World Development Indicators, 2013.

5. DATA ANALYSIS AND DISCUSSION

5.1. Results of Unit Root Test

Generally time series data require checking the problem of unit root in variables under consideration. This test is mainly a descriptive tool employ to categorize series as stationary and non-stationary. There are two-ways through which the unit root is tested one is ADF test and the other is the Philips Perron test. Both these tests are used to identify the order of integration of the variables. In this study we used the ADF test to identify the presence of unit root. All the variables are tested one by one for the unit root in level, first difference and second difference of the series and accordingly the decision regarding the stationary and non-stationary variables is taken. Figures in Table 1 show the results of ADF test which reveal that all variables under consideration are non-stationary at level but they all are stationary at first difference.

5.2. Vector Autoregressive (VAR) Lag Order Selection

After testing for the stationaity of the variables, the next step is to choose the optimal lag length of underlying VAR. It is crucial to choose an appropriate lag length to conclude the dynamic relationship among the variables. Hannan Quinn, Schwartz information criteria, LR and final prediction error for determining the optimal lag length. Unsuitable lag length choice gives unreliable results. In this study we have applied Akaike information criteria (AIC) and Schwarz Bayesian criterion to select lag order but our decision is based minimum value of AIC. So lag order based on AIC provides consistent and efficient results. Table 2 shows that by using VAR lag order selection criterion it is established that the optimal lag length is 3.

5.3. Results of Johansen Co-integration Test

After the establishment of optimal lag length the next step is to examine the existence of long run relation between the variables. There are three methods for testing co-integration as Engle Granger test, autoregressive deterministic test (ARDL) and Johansen maximum likelihood method. Unlike the Engle-Granger method the Johansen test allows more than one co-integrating relationship so, is more relevant than the Engle Granger method. If a model consists of more than two variables, then there is chance of having more than one co-integrating vectors. In this case it is desirable feature of Johansen co-integration approach to resolve the multiple equations and obtain estimates for both co-integrating vectors, which can't be resolved by Engle Granger single equation approach.

The results of co-integration are shown in Tables 3 and 4 that the maximum eigenvalue test is conducting under the null hypothesis as r0=r against the alternative hypothesis $r_0>r$ but the trace test is conducted under the null hypothesis of $r_0<r$ against alternative hypothesis $r_0>r$. So the trace statistics and the maximum eigenvalue indicates that there exists one co-integrating equation where the *P* values are <0.05 and at this level the null hypothesis of no co-integrating equation is rejected. Therefore, the integration rank test based on the trace statistics and maximum eigenvalue values

Table 1: ADF test statistics

Variables	Level	First difference	Integration order
Lco_2	−2.37	−7.8873	I (1)
Leu	−0.4938	−4.8108	I (1)
Lm_2	0.4085	−4.4085	I (1)
Ly	−1.0197	3.9261	I (1)
Ly^2	−0.747	−3.8855	I (1)

Critical value: 1%=−3.66, 5%=2.96, 10%=−2.61, ADF: Augmented dickey fuller

Table 2: Selection of lag order

Lag	LogL	LR	FPE	AIC	SC	HQ
0	223.7562	NA	3.19e-13	−14.58374	−14.35021	−14.50904
1	421.0585	315.6838*	3.37e-18*	−26.07057	−24.66937	−25.62231
2	446.3522	32.03870	3.84e-18	−26.09015*	−23.52129	−25.26835
3	467.7953	20.01354	7.53e-18	−25.85302*	−22.11649*	−24.65767*

*Selected lag order by the criterion. LR: Likelihood ratio, FPE: Final prediction error, AIC: Akaike information criteria, SC: Schwarz criterion, HQ: Hannan-Quinn

Table 3: Co-integration rank test (trace)

Hypothesized	Trace			
Number of CE (s)	Eigen value	Statistics	Critical value	*P* (0.05)
None*	0.924659	133.2326	69.81889	0.0000
At most 1	0.474116	38.24624	47.85613	0.3039
At most 2	0.380736	22.93040	29.79707	0.2495
At most 3	0.230583	9.032894	15.49471	0.3623
At most 4	0.048158	1.431341	3.841466	0.2315

*Trace statistic indicates one co-integrating education at 0.05 levels

Table 4: Co-integration rank test (maximum eigenvalue)

Hypothesized	Max-Eigen			
Number of CE (s)	Eigen value	Statistic	Critical value	*P* (0.05)
None*	0.924659	74.98634	33.87687	0.0000
At most 1	0.404116	15.31584	27.58434	0.1242
At most 2	0.380736	13.89751	21.13162	0.3735
At most 3	0.230583	7.601554	14.26460	0.4207
At most 4	0.048158	1.431341	3.841466	0.2315

*Max-eigen statistic indicates one co-integrating education at 0.05 levels

both show that there exists long-term relationship (co-integration) among variables of the country. The results from this test are illustrated in Tables 3 and 4.

5.4. Long Run Results

The dependent variable is CO_2 as carbon emission in our model. The positive and negative signs of coefficients show the impact of independent variables on the dependent variable. The coefficient of lec is positive as 0.78 shown in Table 5 and statistically it is significant as its absolute *t*-value is 4.29 (Table 5). Its coefficient value indicates that the energy use does add to carbon emission in long run. Thus the coefficient of energy consumption suggests that a 1% increase in per capita energy will lead to increase the per capita carbon emission by 0.78%.

The financial development (lm_2) has positive coefficient as 0.12 and it is significant which implies that the financial development does contribute to the carbon emission in long run. Due to the positive coefficient of lm_2 it is suggested that a 1% increase in financial development tends to increase the carbon emission by 0.12%. In case of GDP (Y) the coefficient is positive and statistically it is significant as its value is 4.42. It implies that a 1% increase in real GDP will raise per capita carbon emission by 4.42% in the long run. While in case of GDP square as LY^2 the coefficient value is −0.42, which is negative and statistically significant as it's absolute *t*-value is >2. This coefficient value of square term of GDP explains that after a particular level of income a 1% increase in real per capita GDP will decrease the per capita emission by 0.42%. Thus it is confirmed the existence of EKC in Pakistan. Initially the carbon increases with raise in income and goes to its stabilization point but starts to come down when income further increases.

Table 5: Long run results based on Johansen co-integration

Regressors	Coefficients	*t*-values
Lec	0.783766	4.29690
Lm_2	0.120437	8.13603
Ly	4.424260	2.74536
Ly^2	−0.423976	−3.36208

Dependent variable: LCO_2	
Adj R-square	0.35
F-statistics	2.6

Table 6: Results of ECM

Dependent variable: $DLCO_2$		
Regressors	Coefficients	t-statistic
D (LEC(-1))	0.287	0.694
D (LEC(-2))	0.803	2.148
D (LEC(-3))	1.058	2.734
D (LM_2(-1))	−0.173	−1.323
D (LM_2(-2))	0.061	0.55
D (LM_2(-3))	−0.067	−0.519
D (LY(-1))	−13.48	−0.705
D (LY(-2))	−23.3	−1.122
D (LY(-3))	−18.53	−1.117
D (LY^2(-1))	1.083	0.724
D (LY^2(-2))	1.828	1.123
D (LY^2(-3))	1.492	1.142
ECM (-1)	−0.616	−2.39

Diagnostic test statistics

	t-values	*P*-values
Serial correlation	0.75	0.52
Heteroskedasticity	1.9	0.12
ARCH test	1.02	0.39
R^2	0.72	

5.5. Results of ECM

The results of short run analysis are presented in Table 6. Since the optimal lag length was 3, and the short run results are also presented three lags for every variable. At conventional significance levels coefficients of all explanatory variables are statistically insignificant except the coefficient of energy consumption (LEC) which is significant at second and third lag. This means that in short run only the energy consumption contributes significantly to per capita carbon emission while all the other explanatory variables used in study does not contribute significantly to carbon emissions. Thus the results from Table 6 shows that in short run the EKC hypothesis does not hold. The possible reason for this result could be that in Pakistan industrial production is a major source of carbon emission in Pakistan however, its portion in GDP of Pakistan is very small. Thus it does not significantly contribute too environmental pollution in the short run.

It is clear from Table 6 that the ECT is statistically significant and negative sign. The value of coefficient of error correction term is −0.616 showing that when per capita carbon emission is above or below its equilibrium level, it is adjusted almost 62% within the 1st year. This indicates that adjustment speed towards equilibrium is significantly high. Bannerjee et al. (1998) pointed that the statistical significant lagged error term having negative sign is a way to give that the obtained long run relationship is stable. The value of R^2 shows that the model is comparatively good fit and show 72% variation caused by independent variables on dependent variable.

5.6. Results of Causality Test

Results of causality test bases on VECM are presented in Table 7. The F-statistics for short run significance shows that the energy consumption, economic growth and its square are not granger caused by any variable used in the study. While the carbon emissions granger caused by energy consumption which illustrate that there exists a unidirectional causality which runs from energy consumption to carbon emission, because here the energy consumption is not caused by carbon emission. The financial development (lm_2) granger caused by the economic growth Ly and its square term Ly^2. Thus there also exists a unidirectional causality because ly and ly^2 are not caused by lm_2, so the financial development is the only variable which is caused by the economic growth and its growth square.

The ECT (t-stats) in the Table 7 shows the long run causality among the mentioned variables. It is obvious from the results that the deviation from the equilibrium (long run) is corrected by the carbon emission, GDP (ly) and financial development (m_2). While the ly^2 and the energy consumption are come out to be exogenous. It reveals the reality that any alterations in these two variables which distort the long run equilibrium are corrected by balancing the changes in three variables which are significant at 5%. So we conclude that the carbon emission, financial development and GDP are caused by the energy consumption and ly^2 and there exists uni-directional causality between them.

6. CONCLUSION

The prime purpose of this study is to investigate the dynamic relationship among CO_2 emission, energy consumption, economic growth and financial development in case of Pakistan for the period 1980-2012. For this purpose, Johansen co-integration approach has been applied and causality among the variables has also been examined. Results of the study show that in long run the coefficients of energy consumption, economic growth, and financial development are statistically significant and have expected signs. These results indicate that energy consumption, economic growth and financial development do significant contribute in explaining carbon emission in Pakistan. The results show that energy consumption has direct relationship with carbon emission. This is because of the fact that in Pakistan per capita energy consumption and the cumulative CO_2 emission are low, but the CO_2 per unit of energy consumption are relatively high. The energy sector is the most significant contributor to the greenhouse gas emissions.

Financial development is another variable which contributes the carbon emissions and this shows that Pakistan's banking and financial institutions are remained strong since financial reforms of 1990s. As these institutions finance different long-term and short-term consumer's loans for different activities, which leads to deteriorate the environmental quality by increasing the energy consumption.

The coefficients of GDP and it square of GDP are positive and negative respectively which indicate that initially carbon emission increases with the income increase then it reaches to its inflection point. When income further tends to increase the carbon emission tends to fall after the inflation point. This behaviour of carbon emission with income confirms the existence of EKC in Pakistan in long run.

Results of short run analysis are quite different from the results of long run analysis as all the coefficients of explanatory are insignificant except the coefficient of energy consumption which is significant. It means that only energy consumption significantly contribute to carbon emission in short run while all other explanatory variables used in the study don't contribute to carbon emission in short run. These results indicate that the hypothesis of EKC is not valid in short run.

The results of short run causality test reveal that there exits unidirectional causality between energy consumption and carbon emission running from energy consumption to carbon emission. There also exist unidirectional causality between financial development and economic growth running from financial development to economic growth. The results further show there is no causal relationship between carbon emission and economic growth in short run however, in long there exists unidirectional causality between carbon emission and economic growth running from economic growth to carbon emission.

Table 7: Results of causality test

Variables	Short-run results (F-stats)					ECT(-1)
	$Dlco_2$	Dlec	Dlm_2	Dly	Dly^2	(*t*-values)
$Dlco_2$	−	4.869*	0.588	0.857	0.121	−2.39*
Dlec	0.751	−	0.155	0.506	0.525	−0.71
Dlm_2	0.867	0.463	−	2.725*	2.751*	2.73*
Dly	1.622	0.059	1.114	−	0.503	2.74*
Dly^2	1.731	0.075	1.136	0.472	−	0.75

*Significance level at 5%

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