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Impact of Fossil Fuel Energy Consumption on CO_2 Emissions: Evidence from Pakistan (1980-2010)

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1. INTRODUCTION

Global environmental problems are getting more attention especially the increase in earth temperatures and change in climate. Increase in world average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level are some evidences of global warming. A CO_2 emission, which is a global pollutant is the main greenhouse gas that causes 58.8 percent of global warming and climate change [The World Bank (2007a)]. The intergovernmental panel on climate change (IPCC) reported a 1.1 to 6.4 °C rise in the world temperatures and an increase in the sea level of about 16.5 to 53.8 cm at the end of 21st century [IPCC (2007)].

Combined global land and ocean surface temperature for January 2010 on the average was 0.60°C (1.08°F) above the 20th century average of 12.0°C (53.6°F) and the average global temperature for January 2010 at the surface air was recorded 0.83°C (1.49°F) above the 20th century average of 2.8°C (37.0°F). Global warming is partly resulting from higher night temperature and partly due to rapid urbanisation. Other factors adding to global warming are the continuously changing irrigation systems, desertification and variations in the use of local lands. The developing countries need more energy consumption for economic growth that's why these economies face more environmental issues.

Rapid increase of CO_2 emissions is mainly the result of human activities (development and industrialisation) over the last decades. Earlier studies focus on estimating the growth and CO_2 emissions nexus through testing the environmental Kuznets curve (EKC) hypothesis, which proposes a U-type relationship between environmental quality and income growth to determine whether continued increase in economic growth will eventually undo the environmental impact of the early stages of economic development or not.

Financial development can promote economic growth and reduce environmental pollution. As Frankel and Romer (1999) point out, developed financial market can help to increase inflow of foreign direct investment and stimulate the rate of economic growth. Recent studies show that financial development has direct impact on energy consumption

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[e.g., Sadorsky (2010)] and thus on CO_2 emissions [Tamazian, *et al.* (2009)]. A developed financial sector lowers borrowing cost, promotes investment in energy efficient sector, and reduces energy emissions [Tamazian, *et al.* (2009); Tamazian and Rao (2010); Sadorsky (2010); Shahbaz (2009a); Shahbaz, *et al.* (2010b)]. Jensen (1996) on the other hand found that financial development increases CO_2 emissions through industrial growth enhancing-effect. Specifically, the national, regional and local governments can take advantage of lower borrowing costs to fund environment friendly projects.

Fossil Fuels are fuels formed by natural processes such as anaerobic decomposition of buried dead organisms. Fossil fuels are hydrocarbons and include coal, oil (petroleum), and natural gas. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being discovered. The impact of economic growth on environment depends on the type of energy emissions, such as sulfur dioxide, carbon monoxide and nitrogen oxide have detrimental effects on health and environment. This relationship between air pollution and economic development also appears in an inverted-U shaped or monotonically decreasing form [Shafik and Bandypadhyay (1992); Hettige, *et al.* (1992); Diwan and Shafik (1992)].

2. ENVIRONMENTAL KUZNETS CURVE

The Environmental Kuznets Curve (1955) hypothesised environmental degradation and pollution increase in the early stage of economic development and after reaching a certain level of economic growth, environmental degradation will decrease. This implies that high income levels lead to improved environmental conditions. Therefore some economists believe that economic growth is a natural remedy for the environmental pollution and depletion of natural resources [Beckerman (1992)].

The Environmental Kuznets Curve (EKC) hypothesis claims that an inverted U-shaped relation exists between income and environmental pollution. Earlier empirical studies demonstrate the EKC between income and environmental pollutants such as sulfur dioxide (SO_2), nitrogen oxide (NOx), and suspended particulate matter (SPM).[1]

The EKC concept became widely popular starting in the early 1990s with background study of the World Development Report [Shafil and Bandyopadhyay (1992)] and study of potential impact of NAFTA[2] [Grossman and Krueger (1991)]. The inverted "U" shaped relationship of the environment degradation and income is supported by enough theoretical evidences. According to EKC concept, Carbon dioxide CO_2 emission (the indicator we used as environmental pollution) is expected to have a positive relationship with the level of economic growth.

Environmental Kuznets Curve and Pakistan

Pakistan is the sixth most populous country in the world. It relies on the imports of capital goods and energy resources to promote industrial growth and economic

[1]See Grossman and Krueger (1993, 1995), Selden and Song (1994), Suri and Chapman (1998), and Agras and Chapman (1999).

[2]North American Free Trade Agreement.

development. The imports of capital goods and energy resources jointly contribute above 70 percent towards its total imports while the consumption share of manufacturing and transportation ranges between 30-35 percent [FBS (2010)]. On the other hand, agricultural products are major exports in Pakistan, which are considered to be a lower CO_2 emitting sector as compared to industrial sector. Furthermore, Pakistan is a net importer of fertiliser and other chemical products, which emit highly contaminated gases.

The government of Pakistan launched an environmental policy in 2005 to control environmental degradation with sustained level of economic growth. The main objective of the National Environmental Policy (NEP) is to protect, conserve and restore Pakistan's environment. Meanwhile, the economic growth is enhanced by agricultural, industrial and services sectors of the economy. The rising growth rate in Pakistan is led by industrial sector generally and manufacturing sector particularly.[3] This industrial sector led growth enhances energy demand and as result environmental pollutants increase in the country.

In 2002-2003, industrial sector accounted for 36 percent of total energy consumption while 33 percent is consumed by transportation. Even though total energy consumption declined to 29 percent in 2008-2009, but the consumption by industrial sector has increased to 43 percent over the period.[4] High usage of petroleum to meet transportation demand is a major reason of CO_2 emissions in Pakistan.[5] In 2005, 0.4 percent of the world total CO_2 emissions were produced by Pakistan and this "contribution" is increasing day by day.

Objectives

The main objective of the study is to analyse the impact of fossil fuel energy consumption on CO_2 emissions for Pakistan from 1980-2010. We can discuss the broad objectives as follows:

- To empirically examine the environmental Kuznet's curve for Pakistan.
- To test the robustness of environmental Kuznet's curve in the presence of other variables.
- To empirically analyse the factors that affects the fossil fuel energy consumption in short run as well as long run.
- To propose suitable policy implications based on empirical findings.

3. LITERATURE REVIEW

Shafik (1994) and Holtz-Eakin and Selden (1995) conclude that the amount of CO_2 emissions monotonically increases with per capita income. Selden and Song (1994) confirm environmental Kuznets hypothesis after investigating the relationship between economic growth and a set of energy pollutants i.e. SO_2, NOx, CO_2. Lanoie, *et al.* (1998) argue that financial market can help to decrease CO_2 emissions by providing incentives to firms for compliance with environmental regulations.

[3]In 2009, economic growth rate is 2 percent due to poor performance of the industrial and manufacturing sectors (*Economic Survey of Pakistan, 2008-2009*).

[4]*Economic Survey of Pakistan, 2008-2009*, p. 226.

[5]The transportation has been converted to compressed gas consumption after hike in petroleum prices.

Dinda, *et al.* (2000) find that the use of advanced capital intensive techniques help environment and supports EKC relation. Dasgupta, *et al.* (2004) find that the firms in Korea lose market value if their names are made public for violation of environmental regulations. Liu (2005) concludes that the EKC for CO_2 exists. Persson, *et al.* (2006) notify that the cost to improve environment will be less if developing nations implement environment friendly policies at the initial stages of economic development. Richmond and Kaufman (2006) point out that there is limited support of the EKC in the case of OECD countries, but not in the case of non-OECD countries.

Alam, *et al.* (2007) find that increase in per capita GDP and energy intensity growth leads to 0.84 percent and 0.24 percent increase in the growth rate of CO_2 and CO_2 emissions. Ang (2007) finds stable long run relation between economic growth and CO_2 emissions and argues that the EKC hypothesis is satisfied in France. He explains that causality runs from economic growth to energy consumption and CO_2 emissions in the long run but in the short run energy consumption causes economic growth. Claessens and Feijen (2007) posit that good governance and financial development make it easier to adopt advanced technology in energy sector, which helps to reduce CO_2 emissions significantly and improve environmental quality.

Chebbi and Boujelbene (2008) clear that economic growth; energy consumption and CO_2 emission are related in the long-run and provide some evidences of inefficient use of energy in Tunisia. In the short run, results shows that economic growth exerts a positive effect on energy consumption growth and results from impulse response functions do not confirm the hypothesis that an increase in pollution level brings about economic expansion.

Ang (2008) finds that causality runs from output to energy consumption not only in the short, but also in the long run, the study also reports positive link between per capita GDP, energy consumption, and CO_2 emissions for Malaysia. Wagner (2008) also argues in favour of an inverted U-relationship between economic growth and energy pollutants i.e., CO_2 and SO_2. Song, *et al.* (2008) find long run relationship between economic growth and indicators of CO_2 emissions i.e. waste gas, waste water, solid wastes etc., which confirms an inverted U relationship.

Halicioglu (2009) argues that the most significant variable in explaining the carbon emissions in Turkey is income followed by energy consumption and foreign trade. Study also explores that energy consumption; trade and CO_2 emissions are the main contributors to economic growth in the long run. Jalil and Mahmud (2009) indicate that the carbon emissions are mainly determined by income and energy consumption in the long-run and trade has a statistically insignificant positive impact on CO_2 emissions. Akbostanci, *et al.* (2009) did not find any support for the EKC with Turkish data.

Lean and Smyth (2009, 2010) find a significant positive long run relation between electricity consumption and CO_2 emissions and support the existence of EKC for ASEAN countries. Apergis and Payne (2009) give evidence in support of the EKC hypothesis by extending the work of Ang (2007) and find unidirectional causality running from energy consumption and real output to CO_2 emissions in Central American countries. Esmaeili, *et al*. (2009) find support for the EKC by using oil exploitation factors e.g., oil reserves, oil price, population, political rights, and the Gini index in the oil producing countries.

Tamazian, *et al.* (2009) argue that trade openness and financial sector reforms help to decrease CO_2 emissions in BRIC nations, the United States and Japan. Iwata, *et al.* (2009) find that the effects of nuclear energy on CO_2 emissions are significantly negative both in the short run and long-run while, the effects of trade or energy consumption are insignificant and the causality tests confirm the uni-directional relationship running from income and nuclear energy to CO_2 emissions for France.

Fodha, *et al.* (2010) find evidence in support of an EKC between economic growth and SO_2 emissions, and but not with CO_2 emissions for Tunisia. Tamazian and Rao (2010) find that institutional, economic and financial development helps to lower CO_2 emissions; the study also supports EKC for the transitional economies. Yuxiang and Chen (2010) claim that financial development induces capitalisation, technology use, income increase and regulations that affect environmental quality in China. Jalil and Feridun (2010) indicate that financial development lowers CO_2 emissions in China by investigating the impact of financial development, economic growth and energy consumption on environmental pollution.

Shanthini and Perera (2010) suggest the probable existence of a co-integrating relationship between Australia's fossil-fuel based CO_2 emissions per capita and GDP per capita. In the short-run, 1 percent increase in GDP per capita growth in the previous year leads to 0.33 percent increase in the current growth in CO_2 emission per capita. Zhang (2011) evidence reveals that financial development significantly contributes to increase in environmental degradation. Study states that Chinese enterprises have easy access to external finance and bank loans at cheaper cost to enhance investment. This leads China's economic growth and CO_2 emissions to intensify, which depend on bank asset expansion.

Saboori, *et al.* (2011) do not support the EKC hypothesis for Indonesia and long-run results indicate that foreign trade is the most significant variable in explaining CO_2 emissions followed by energy consumption and economic growth. Saboori and Soleymani (2011) do not support the EKC hypothesis for Iran and the long-run results indicate energy consumption has a significant positive impact on CO_2 emissions. Anees and Ahmed (2011) find that CO_2 affect economic growth, agriculture and industrial growth in the long run for Pakistan. It is also evident that energy consumption uni-directionally Granger causes CO_2 emissions while, industrialisation and urbanisation bidirectionally Granger cause each other.

Tiwari (2011) finds that the energy consumption, capital and population Granger-cause economic growth not the vice versa in India. IRFs and VDCs results indicate that CO_2 emissions have positive impact on energy use and capital but negative impact on population and GDP. Energy consumption has positive impact on CO_2 emissions and GDP but its impact is negative on capital and population. This implies that in the framework of production function, capital and population/labour have been rapidly substituted by energy use in the production process.

Essien (2011) suggests that there exists a long run relationship among GDP per capita, electricity per capita, natural gas per capita, crude oil per capita, fuel woods per capita and CO_2 emission for Nigeria. Results reveal that electricity and gas consumption cause economic growth both in the short and long run but only fuel woods influence it in the long run while, it provides evidence that natural gas influences carbon emissions in the long run while fuel woods influence carbon emissions in the short run.

Alam, *et al.* (2012) indicate that uni-directional causality runs from energy consumption to economic growth both in the short and the long-run while bi-directional long run causality exists between electricity consumption and economic growth but no causal relationship exists in short- run for Bangladesh. Uni-directional causality runs from energy consumption to CO_2 emission for the short-run but feedback causality exists in the long-run.

Hedi, *et al.* (2012) show that in the long-run energy consumption has a significant positive impact on CO_2 emissions but there is poor evidence in support of the EKC hypothesis for 12 Middle Eastern and North African Countries (MENA).[6] Results also suggests that not all MENA countries need to sacrifice economic growth to reduce their emission levels as they may achieve CO_2 emissions reduction via energy conservation without negative long-run effects on economic growth.

Model Specification

Environment Kuznets Curve

Following the approach adopted by Ang (2007), Acaravci and Ozturk (2010), and Lean and Smyth (2010), the long-run relationship between fossil fuel energy consumption, economic growth and carbon emissions can be specified as follows:

$$CO_{2t} = \alpha_0 + \alpha_1 FFEC_t + \alpha_2 PCRGDP_t + \alpha_3 PCRGDP^2{}_t + \varepsilon_t$$

Where CO_2 is carbon dioxide emissions, FFEC is fossil fuel energy consumption; PCRGDP is per capita real GDP and also its square used as a proxy for economic growth. The expected sign of fossil fuel energy consumption is positive. The expected sign of per capita real GDP is positive while of its square is negative in order to reflect the inverted U-shape pattern.

In order to test the robustness of inverted U hypothesis we extend our model by incorporating some other variables;

$$CO_{2t} = \beta_0 + \beta_1 FFEC_t + \beta_2 PCRGDP_t + \beta_3 PCRGDP^2{}_t + \beta_4 INDVAD + \beta_5 FD + \beta_6 TO + \upsilon_t$$

Where INDVAD is industrial value added that represents the industrial sector growth, while FD is financial development and TO is trade openness. Industrial value added is expected to have positive sign while financial development' sign is ambiguous. Trade openness is expected to affect the CO_2 emission positively.

Energy Consumption

To test the long run determinants of energy consumption we have specified the following equation;

$$FFEC_t = \delta_0 + \delta_1 RGDP_t + \delta_2 GFCF_t + \delta_3 POP_t + \delta_4 MX + \delta_5 MM + \varepsilon_t$$

[6]Algeria, Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, and UAE.

Where FFEC is fossil fuel energy consumption, RGDP is real GDP used as a proxy for economic growth, GFCF is investment, POP is population, MX represents manufactured exports and MM represents manufactured imports. Economic growth, investment, population and manufactures exports are expected to have positive signs while manufactured import, sign is ambiguous.

Description and Sources of Variables

Variable	Description
CO_2	Log of CO_2 emissions (metric tons per capita) *Source:* World Development Indicators (WDI)
FFEC	Fossil fuel energy consumption (% of total) *Source:* World Development Indicators (WDI)
PCRGDP	Log of Per capita real GDP *Source:* International Financial Statistics (IFS)
$PCRGDP^2$	Square of Per capita real GDP
INDVAD	Industrial value added (% of GDP) *Source:* World Development Indicators (WDI)
FD	Log of credit to private sector *Source:* World Development Indicators (WDI)
MX	Manufacture exports (% of merchandise exports) *Source:* World Development Indicators (WDI)
RGDP	Log of real GDP deflated by CPI (2005.=100) *Source:* International Financial Statistics (IFS)
GFCF	Gross fixed capital formation (% of GDP) *Source:* World Development Indicators (WDI)
POP	Log of Population (millions) *Source:* International Financial Statistics (IFS)
MM	Manufacture imports (% of merchandise imports) *Source:* World Development Indicators (WDI)
TO	Total trade as % of GDP *Source:* World Development Indicators (WDI)

4. METHODOLOGY

Univariate Analysis

(a) *Unit Root Test*

Many variables are non-stationary for this we can use Unit Root Test in order to verify their order of integration. Then, only those variables are incorporated in the study which are stationary at 1st difference I (1).

(b) *Augmented Dickey-Fuller Test (ADF)*

The Augmented version of Dickey Fuller Test is used for larger and complicated models, which deals with the serial correlation in the error term μt by putting lagged values of dependent variable ΔYt

Multivariate Analysis

In order to find the existence and number of long-run relationship(s) the econometric framework we used in the study for analysis is the Johansen (1998) and Johansen and Juselius (1990) Maximum Likelihood Co-integration Approach. Two or more series are co-integrated if they observe same kind of stochastic behaviour. It is statistical property of time series variables and is applied when all the variables are stationary at I (1).

The co-integration approach in a multivariate system is similar to the ADF test, but requires the use of vector autoregressive (VAR). A vector autoregressive (VAR) model with a lag length of 1 was used to test for the number of co-integrating relationships between the variables. When two series are co-integrated it suggests that even if both processes are non-stationary, there is some long run relationship linking both series.

There are two likelihood ratio test statistics in the Johansen (1998) and Johansen and Juselius (1990) Maximum likelihood Co-integration Approach and the trace and the Maximum Eigenvalue. The Trace test is a joint test with null hypothesis that the number of co-integrating vectors is less than or equal to r, against alternative hypothesis that there are more than r co-integrating vectors. The Maximum Eigenvalue test conducted separate tests on each Eigenvalue with null hypothesis that there are r co-integrating vectors against the alternative hypothesis that there are (r+1).

Vector Error Correction Model

A main quality of co-integrated variables is that their time paths are affected by the extent of any deviation from the long-run equilibrium [Anders (2004)]. The error correction mechanism (ECM) term presents the percentage of correction to any deviation in the long-run equilibrium of dependent variable in a single period and also represents how fast the deviations in the long-run equilibrium are corrected. Depending on the presence of how many co-integrating vectors, we can then test for the short run dynamics using a vector error correction model. A vector error correction model (VECM) can test how changes in trade openness in short run contributed to its long run relation with inflation.

Granger Causality

In economics, systematic testing and determination of causal directions only became possible after an operational framework was developed by Granger (1969) and Sims (1972). Their approach is crucially based on the axiom that the past and present may cause the future but the future cannot cause the past.[7] In econometrics the most widely used operational definition of causality is the Granger definition of causality, which is defined as follows:

"X is a Granger cause of Y (denoted as $X \rightarrow Y$), if present y can be predicted with better accuracy by using past values of x rather than by not doing so, other information being identical."[8]

[7]Granger (1980).
[8]Charemza and Deadman (1992).

To test the bi-variate causality relationships the following causal model is used:

$$x_t = \sum_{j=1}^{p} a_i x_{t-j} + \sum_{j=1}^{p} b_i y_{t-j} + u_t \qquad\qquad y_t = \sum_{j=1}^{p} c_i x_{t-j} + \sum_{j=1}^{p} d_i y_{t-j} + v_t$$

Where μ_t and ν_t are two uncorrelated white-noise series and *p* is the maximum number of lags.

5. RESULTS AND DISCUSSION

Results of Unit Root Test

We test the null hypothesis of unit root against the alternative. The results of our study comprise that all variables have a unit root at their levels indicating that the levels are non-stationary. The first differenced series however, clearly reject unit roots suggesting that the differenced variables are all stationary.

Results of Unit Root Test

	Level			1st Difference			
Variables	Intercept	Trend and Intercept	None	Intercept	Trend and Intercept	None	Order of Integration
TO	–0.763653	–2.149911	–1.65445	–5.14054*	–5.05514*	–4.6966*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	
CO_2	–0.429700	–2.684728	–1.05273	–7.27443*	–7.15370*	–4.4043*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	
FFEC	–1.282973	–2.192627	–1.63578	–5.27039*	–5.30489*	–3.8114*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	
INDVAD	–1.776672	–2.345894	–0.51290	–5.98219*	–5.85061*	–6.0549*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(1)	LAG(1)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	
MM	–2.102556	–2.170191	–0.52357	–6.03881*	–6.16942*	–6.1414*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(1)	LAG(0)	LAG(0)	LAG(0)	
MX	–2.965731	–1.208926	–0.73884	–5.33068*	–7.22322*	–5.2478*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(1)	LAG(0)	LAG(0)	LAG(0)	
PCRGDP	–0.925548	–1.320890	–1.14490	–5.40851*	–5.68580*	–3.7570*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	
RGDP	–1.232317	–0.874471	–1.49878	–4.90488*	–5.99628*	–2.7765*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	LAG(0)	
POP	–2.484547	–2.188403	–0.34365	–3.46688*	–3.587844	–3.3622*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(3)	LAG(3)	LAG(3)	LAG(2)	LAG(2)	LAG(2)	
GFCF	–2.913031	–3.189074	–0.65837	–3.36582*	–3.35304*	–3.4127*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(2)	LAG(1)	LAG(1)	LAG(0)	LAG(0)	LAG(0)	
FD	–1.105499	–3.14839	–1.45771	–4.46427*	–4.52320*	–2.6397*	I(1)
	(–2.96)	(–3.56)	(–1.96)	(–2.96)	(–3.56)	(–1.96)	
	LAG(3)	LAG(3)	LAG(3)	LAG(2)	LAG(2)	LAG(2)	

Note: *Denotes the rejection of hypothesis at 5 percent level of significance.

Environment Kuznets Curve for CO_2 Emission

As results of unit root test show that all the variables are I(1). So we use Johansson co-integration test to test the long run relationship between fossil fuel energy consumption, economic growth and carbon emissions. As the first step in co-integration we test the lag order of model. We determine the lag order through AIC (Akaike information criterion) using VAR (vector auto regressive). In the second step we test the null hypothesis of no co-integration against the alternative through maximum Eigen statistics.

Lags Interval: 1 to 1

Eigen Value	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.716443	88.03858	53.12	60.16	None **
0.578956	51.48868	34.91	41.07	At most 1 **
0.534353	26.40313	19.96	24.60	At most 2 **
0.135951	4.237657	9.24	12.97	At most 3

*(**) denotes rejection of the hypothesis at 5 percent (1 percent) significance level.
L.R. test indicates 3 co-integrating equation(s) at 5 percent significance level.

Results of Maximum Eigen statistics show the evidence of three long run co integration relationships in our model. We reject the null hypothesis of two co integrating relations against alternative of three co-integrating relations.

Normalised Co-integrating Coefficients

$$CO2_t = \alpha_0 + \alpha_1 FFEC_t + \alpha_2 PCRGDP_t + \alpha_3 PCRGDP^2{}_t + \varepsilon_t$$

Dependent Variable: CO_2

Variables	Coefficients	Standard Error	t-Statistics
FFEC	0.845970	0.02760	30.6485*
PCRGDP	0.00298	0.00012	24.8333**
$PCRGDP^2$	–0.766665	0.33556	2.28473**
C	4.480726	0.16164	27.72404

Note: * show the significance at 1 and 5 percent respectively.

Fossil fuel energy consumption positively affects the CO_2 emissions as expected. A 1 percent increase in Fossil fuel energy consumption brings 0.84 percent increase in CO_2 emission. The higher level of energy consumption results in greater economic activity and stimulates CO_2 emissions. The findings are in line with Hamilton and Turton (2002), Friedl and Getzner (2003), Liu (2005), Ang and Liu (2005), Say and Yücel (2006), Alam, *et al*. (2007), Ang (2008), Halicioglu (2009), Jalil and Mehmud (2009), Nasir and Rehman (2011), Shahbaz, *et al*. (2011, 2013).

Per capita real GDP positively affects the CO_2 emission. These findings are consistent with those of He (2008) for China; Song, *et al*. (2008) for China; Halicioglu (2009) for Turkey; Jalil and Mehmud (2009) for China; Fodha and Zaghdoud (2010) for

Tunisia; Lean and Smyth, (2010) for ASEAN countries; Anees, *et al.* (2011) and Shahbaz, *et al.* (2010, 2011, 2013) for Pakistan.

The statistically significant sign of per capita real GDP square confirms the decrease in CO_2 emission at higher level of income, which provides the proof for the existence of environmental Kuznet curve. That the level of CO_2 emission initially increases with income, until it reaches maximum point, then it declines. In the early stages of the economic process, there is abundance of natural resource stock and a low production of wastes because of low economic activity.

As industrialisation takes off, resource depletion and waste production accelerate. At this phase of transition from agriculture to industry, industrialisation of the production process creates a positive relationship between per capita incomes (or else economic growth) with environmental degradation, in a general sense. At higher levels of economic development, the production process of the economy becomes more information based and the service sector is boosted. This shift in the composition of production, combined with improvements in technology and increased demand for environmental quality, results in a leveling-off and a steady decline of environmental degradation. These findings are consistent with the empirical evidence of He (2008), Song, *et al.* (2009), Halicioglu (2009), Fodha and Zaghdoud (2010) and Leanand Smyth (2010), Shahbaz, *et al.* (2011, 2013).

Error Correction Model

After Estimating long run coefficients we move toward VAR (vector error correction) model.

$$\Delta CO2_t = \alpha_0 + \alpha_1 \sum_{i=1}^{n} \Delta CO2_{t-1} + \alpha_2 \sum_{i=0}^{n} \Delta FFEC_{t-1} + \alpha_3 \sum_{i=0}^{n} \Delta PCRGDP_{t-1}$$
$$+ \alpha_4 \sum_{i=0}^{n} \Delta PCRGDP_{t-1}^2 + \lambda ECT_{t-1} + \varepsilon_t$$

Dependent Variable: ΔCO_2

Variables	Coefficients	Standard Error	t. Statistics
ECT(–1)	–0.799072	0.14648	–5.45519*
D(CO_2(–1))	0.257076	0.11794	2.17980**
D(FFEC(–1))	–3.71E–07	0.00045	–0.00083
D(PCRGDP(–1))	1.234524	0.92911	1.32871
D($PCRGDP^2$(–1))	–2.814629	1.35902	–2.07108**
C	0.030004	0.00561	5.34389
R-squared	0.714738	S.E. equation	0.014255
Sum sq. resids	0.004674	Log likelihood	85.48031

Note: *,** show the significance at 1 and 5 percent respectively.

Short run co-efficient estimates obtained from the ECM indicate that the estimated lagged error correction term (EC_{t-1}) is negative and significant. The feedback coefficient is –0.79, suggesting that about 79 percent disequilibrium in the previous year is corrected in the current year. Short run results show that previous period's carbon dioxide emission and per capita real GDP positively affect the CO_2 emission in current period. Previous period's energy consumption and per capita GDP square negatively affect CO_2 emission in current period. Most of the variables lose their significance in short run.

Robustness Checks for the Environment Kuznets Curve for CO_2 Emission

We test the null hypothesis of no co-integration against the alternative through maximum Eigen statistics.

Lags interval: 1 to 1

Eigen Value	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.880810	185.4220	131.70	143.09	None **
0.752966	123.7379	102.14	111.01	At most 1 **
0.624845	83.18928	76.07	84.45	At most 2 *
0.544144	54.75720	53.12	60.16	At most 3 *
0.477881	31.97541	34.91	41.07	At most 4
0.208002	13.12949	19.96	24.60	At most 5
0.197116	6.366808	9.24	12.97	At most 6

*(**) denotes rejection of the hypothesis at 5 percent (1 percent) significance level.
L.R. test indicates 4 co-integrating equation(s) at 5 percent significance level.

Results of Maximum Eigen statistics show the evidence of four long run co-integration relationships in our model. We reject the null hypothesis of three co-integrating relations against alternative of four co integrating relations.

Normalised Co-integrating Coefficients

We re-estimate the previous equation by including some other variables to test the robustness of environmental Kuznets hypothesis. Both the variables have expected signs but per capita real GDP loses its significance when we include some other variables. It shows that higher income is not the only factor to control the CO_2 emission, some other factors are also important. Moreover in developing countries a very small proportion of income is spent to control the environmental degradation.

$$CO2_t = \beta_0 + \beta_1 FFEC_t + \beta_2 PCRGDP_t + \beta_3 PCRGDP_t^2 + \beta_4 INDVAD + \beta_5 FD + \beta_6 TO + \upsilon_t$$

Dependent Variable: ΔCO_2

Variables	Coefficients	Standard Error	t-Statistics
FFEC	1.178385	0.10824	10.88673*
PCRGDP	0.01408	0.00144	9.7777*
$PCRGDP^2$	–0.085049	0.34868	–0.24391
INDVAD	0.011705	0.00244	4.79713*
FD	–0.006184	0.00239	–2.58744**
TO	0.003447	0.00088	3.90909*
C	5.017042	1.44981	3.46047

Note: *,** show the significance at 1 and 5 percent respectively.

Increase in the size of the economy (scale effect) is likely to increase pollution. Production and industrial activities involve energy as an essential input. Energy is one of the main resources of industrialisation. As industrial sector expands, energy consumption increases that leads to increase in environmental degradation. A 1 percent increase in the share of industrial sector increases the CO_2 emission by 0.011 percent supported by Anees and Ahmed (2011).

Developing countries are mostly net exporter of pollution-intensive goods [Grossman and Krueger (1995)] so trade openness results in the development of pollution-intensive industries and environmental degradation in developing countries. Natural resources are depleted due to international trade. This depletion of natural resources raises CO_2 emissions and causes environment quality to worsen [e.g. Schmalensee, *et al.*; Copeland and Taylor, Chaudhuri and Pfaff]. A 1 percent increase in trade openness increases the CO_2 emission by 0.003 percent supported by Nasir and Rehman (2011), Shahbaz, *et al.* (2013), Khalil and Inam (2006) who probed the hypothesis that international trade is harmful to environmental quality in Pakistan and Halicioglu (2009) who posited that foreign trade increases CO2 emissions in Turkey.

Financial development reduces CO_2 emissions through research and development enhancing effect due to economic growth. A developed financial sector lowers borrowing cost, promotes investment in energy efficient sector, and reduces energy emissions. The findings are consistent with those found by Birdsall and Wheeler (1993), Frankel and Rose (2002), Tamazian *et al.* (2009), Tamazian and Rao (2010), Sadorsky (2010), and Shahbaz, *et al.* (2009, 2010, 2013). Financial development may generally boost research and development (R & D) activities and sequentially improve economic activities, and hence, influence environmental quality [Frankel and Romer (1999)]. A1 percent increases in financial development decreases the CO_2 emission by 0.006 percent.

Error Correction Model

After Estimating long run coefficients we move toward VAR (vector error correction) model.

$$\Delta CO2_t = \alpha_0 + \alpha_1 \sum_{i=1}^{n} \Delta CO2_{t-1} + \alpha_2 \sum_{i=0}^{n} \Delta FFEC_{t-1} + \alpha_3 \sum_{i=0}^{n} \Delta PCRGDP_{t-1}$$
$$+ \alpha_4 \sum_{i=0}^{n} \Delta PCRGDP_{t-1}^2 + \lambda ECT_{t-1} + \varepsilon_t$$

Dependent Variable: ΔCO_2

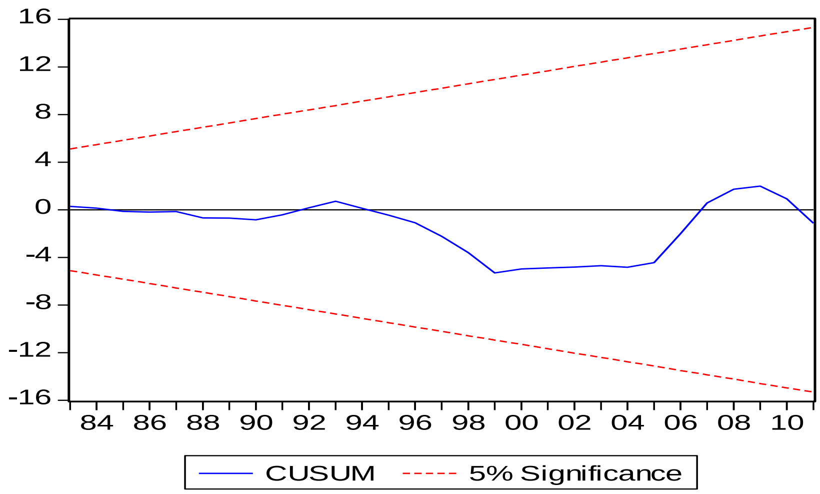
Variables	Coefficients	Standard Error	t. Statistics
ECT(–1)	–0.799072	0.14648	–5.45519*
D(CO_2(–1))	0.257076	0.11794	2.17980**
D(FFEC(–1))	–3.71E-07	0.00045	–0.00083
D(PCRGDP(–1))	1.234524	0.92911	1.32871
D($PCRGDP^2$(–1))	–2.814629	1.35902	–2.07108**
C	0.030004	0.00561	5.34389
R-squared	0.714738	S.E. equation	0.014255
Sum sq. resids	0.004674	Log likelihood	85.48031

Note: *,** show the significance at 1 and 5 percent respectively.

Short run co-efficient estimates obtained from the ECM indicate that the estimated lagged error correction term (EC_{t-1}) is negative and significant. The feedback coefficient is –0.43, suggesting that about 43 percent disequilibrium in the previous year is corrected in the current year. Short run results show that previous period's carbon dioxide emission, energy consumption, per capita real GDP and industrial value added positively affect the CO_2 emission in the current period. Previous period's financial development, trade openness and square of per capita real GDP negatively affect CO_2 emission in current period. Most of the variables lose their significance in short run.

Stability Test

The stability test is conducted by employing the commutative sum of recursive residuals (CUSUM). The CUSUM Plotted against the critical bound of the 5 percent significance level show that the model is stable overtime.



Energy Consumption

In the second step we test the null hypothesis of no co-integration against the alternative through maximum Eigen statistics.

Lags Interval: 1 to 1

Eigen Value	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised No. of CE(s)
0.930950	195.2346	102.14	111.01	None **
0.734948	117.7199	76.07	84.45	At most 1 **
0.720810	79.21286	53.12	60.16	At most 2 **
0.497735	42.21289	34.91	41.07	At most 3 *
0.397176	22.24268	19.96	24.60	At most 4
0.229610	7.564893	9.24	12.97	At most 5

*(**) denotes rejection of the hypothesis at 5 percent (1 percent) significance level.
L.R. test indicates 5 co-integrating equation(s) at 5 percent significance level.

Results of Maximum Eigen statistics show the evidence of five long run co-integration relationships in our model. We reject the null hypothesis of four co-integrating relations against alternative of five co-integrating relations.

Normalised Co-integrating Coefficients

$$FFEC_t = \delta_0 + \delta_1 RGDP_t + \delta_2 GFCF_t + \delta_3 POP_t + \delta_4 MX + \delta_5 MM + \varepsilon_t$$

Dependent Variable: ΔCO_2

Variables	Coefficients	Standard Error	t. Statistics
RGDP	0.466306	0.05544	8.41100*
GFCF	0.675773	0.06406	10.5578*
POP	1.711502	0.12600	13.5833*
MX	0.001804	0.00034	5.30588*
MM	–0.002196	0.00039	–5.63076*
C	–3.604879	0.16052	22.4570

Note: *,** show the significance at 1 percent level of significance.

Energy consumption in developing economies, to a large extent is due to the higher growth rate of these economies. Higher growth rates put increasing pressure on energy consumption. Therefore GDP is positively related to energy consumption in developing economies. When growth rate increases remarkably, there will be an increasing pressure on resources. Therefore the demand for expert labour force, capital and equipment increases and more raw materials and energy is consumed. A1 percent increase in the real GDP increases the energy consumption by 0.46 percent.

Capital Intensive projects especially in infrastructure need high level of energy. A great amount of GFCF is related to infrastructure and transportation. A1 percent increase in investment increases the energy consumption by 0.67 percent.

As the population grows the need for energy consumption also increases. The size of population coupled with rise in GDP growth and higher per capita income creates demand for various products and this leads to increase in energy consumption. A1 percent increase in the population increases the energy consumption by 1.71 percent.

Manufactured exports to different parts of the world require higher energy consumption. The demand for these products is increasing at a faster rate and the clients being the developed economies. This is because of the availability of these products at a much cheaper rate because of the low cost resources in developing economies, especially in China. A1 percent increase in the manufactured exports increases the energy consumption by 0.001 percent.

Manufactured imports have a negative effect on energy consumption. Increase in industrial products imports will lead to decrease in energy consumption if only the domestic produced goods, which are the substitute for industrial imported goods consume higher energy levels. A1 percent increase in the manufactured imports decreases the energy consumption by 0.002 percent.

Error Correction Model

After Estimating long run coefficients we move toward VAR (vector error correction) model.

$$\Delta FFEC_t = \delta_0 + \delta_1 \sum_{i=1}^{n} \Delta FFEC_{t-1} + \delta_2 \sum_{i=0}^{n} \Delta RGDP_{t-1} + \delta_3 \sum_{i=0}^{n} \Delta GFCF_{t-1}$$

$$+ \delta_4 \sum_{i=0}^{n} \Delta POP_{t-1} + \delta_5 MX + \beta_6 MM + \delta_7 MX + \phi ECT_{t-1} + \varepsilon_t$$

Dependent Variable: ΔFFEC

Variables	Coefficients	Standard Error	t-Statistics
ECT(–1)	–0.435842	0.33946	–3.25369*
D(FFEC(–1))	0.130433	0.26023	0.50121
D(RGDP(–1))	0.018820	0.20187	0.09323
D(GFCF(–1))	0.304252	0.28620	1.06309
D(POP(–1))	–0.450279	2.43720	–0.18475
D(MX(–1))	0.000700	0.00098	0.71625
D(MM(–1))	–0.001167	0.00135	–0.86638
C	0.026462	0.06518	0.40601
R-squared	0.637470	S.E. equation	0.014948
Sum sq. resids	0.003799	Log likelihood	88.48722

Note: *,** show the significance at 1 percent level of significance.

Short run co-efficient estimates obtained from the ECM indicate that the estimated lagged error correction term (EC_{t-1}) is negative and significant. The feedback coefficient is –0.43, suggesting that about 43 percent disequilibrium in the previous year is corrected in the current year. Short run results show that previous period's energy consumption, economic growth, investment and manufactured exports positively affect the energy consumption in current period. Previous period's manufactured imports and population negatively affect energy consumption in current period. Most of the variables lose their significance in short run.

Result of Causality Test

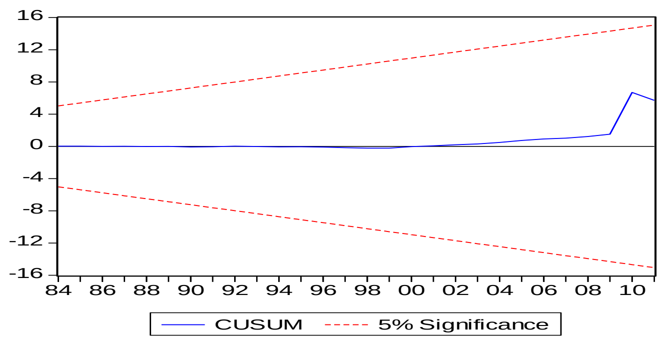
Pair Wise Granger Causality Tests
Sample: 1980–2010
Lags: 1

Null Hypothesis	Obs	F-Statistic	Probability
RGDP does not Granger Cause FFEC	30	0.07944	0.78020
FFEC does not Granger Cause RGDP		0.28508	0.59776
GFCF does not Granger Cause FFEC	30	0.19341	0.66359
FFEC does not Granger Cause GFCF		0.20836	0.65171
POP does not Granger Cause FFEC	30	**11.1012**	**0.00251**
FFEC does not Granger Cause POP		2.04059	0.16462
MX does not Granger Cause FFEC	30	**15.2334**	**0.00057**
FFEC does not Granger Cause MX		0.75407	0.39284
MM does not Granger Cause FFEC	30	0.82812	0.37087
FFEC does not Granger Cause MM		0.77980	0.38500

Results of the pairwise granger causality test provide the evidence of unidirectional causality running from population to energy consumption and from manufacture exports to energy consumption. These results are explained in the energy consumption equation.

Stability Test

The stability test is conducted by employing the commutative sum of recursive residuals (CUSUM). The CUSUM Plotted against the critical bound of the 5 percent significance level show that the model is stable overtime.



6. CONCLUSION

The main objective of the present study is to test the impact of fossil fuel energy consumption on CO_2 emissions for Pakistan from 1980-2010. Our broad objectives are to test the inverted U relationship between economic growth and fossil fuel energy consumption and also to test the impact of other factors that affect the energy consumption in Pakistan. We use the Johenson Co-integration approach to test the long run relationship between the variables while Vector Error Correction model is used to test the short run relationship.

A log linear quadratic equation is specified to test the long run relationship among CO_2 emission, energy consumption and economic growth. Energy consumption negatively affects the CO_2 emission. Results support the inverted U shaped environmental Kuznets curve for Pakistan. In order to test the robustness of EKC we re-estimate the equation by adding some additional variables; industrial value added, financial development and trade openness. Results again prove the inverted U hypothesis. Industrial value added and trade openness positively affect the carbon dioxide emission while financial development reduces the CO_2 emission.

Results of the energy consumption equation show that income, investment, population and manufactured exports positively affect the energy consumption while manufactured imports negatively affect the energy consumption.

7. IMPLICATIONS

Pakistan need to implement a wide range of environmental policies that would provide incentives to industries to adopt new technologies, which could help reduce the environmental pollution. The country also needs to give adequate boost to energy related research and development for the diffusion of cleaner technologies in the long-run. Some of the environmental damage in the form of pollution and economic growth is caused by various policy distortions such as protection of industry, energy subsidies, etc. Environmental damage can be reduced by applying property rights over natural resources and eliminating any policy distortions. Pakistan produces those products, which cause higher emissions, hence Pakistan need to emphasise on exporting those products, which cause low level of emissions. There is a need to redirect the financial sector to improve environment through issuing loans to environment friendly investment ventures, which not only increase the efficiency of all sectors but also improve the quality of life by saving the environment from degradation.

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