Energy Consumption, Financial development and CO2 emissions in Pakistan

Javid Muhammad and Sharif Ghulam Fatima

Pakistan Institute of Development Economics, Islamabad Pakistan, King Saud University Riyadh Saudi Arabia

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Muhammad Javid and Ghulam Fatima Sharif[1]

Abstract

In this study, we analyzedthe effects of financial development, per capita real income, the square of per capita real income, per capita energy consumption and openness on per capita CO2 emissions in the context of Pakistan during 1971-2011. The bound F-test for cointegrationyieldedevidence of a long-term relationship among these variables. The results confirm the existence of an environmental Kuznets curve in Pakistan for both the short and long term. This finding indicates that at the initial stage of development, the level of CO2 increases with income, and after some threshold level of income, this relationship may change from positive to negative as more efficient infrastructure and energy-efficient technology are implemented during the development of the country. The findings of this study also reveal a significantly positive sign for the coefficient of financial development, suggesting that financial development has occurred at the expense of environmental quality. The findings of this study indicate that the key contributing factors of carbon emissions in Pakistan are income, energy consumption and financial development. In addition, the openness variable has no significant influence on carbon emission in either the short or long term.

Keywords: EKC; Energy; CO_2

[1]Corresponding Author: Muhammad Javid, is Research Economist at Pakistan Institute of Development Economics, Islamabad, PakistanP.O. Box 1091, Q.A.U. Campus Islamabad, Pakistan. Cell No. 0092-3005500290. E mail Address: javid@pide.org.pk. Ghulam Fatima Sharif is Ph.D scholar at Pakistan Institute of Development EconomicsIslamabad, Pakistan

1. Introduction

In recent years, development efforts have increasingly focused on environmentally friendly growth rather than simple growth. In this respect, energy consumption and environmental degradation have gained a large amount of attention worldwide. Energy consumption plays the dual role of providing the foundation for economic activity and human well-being as well as acting as the driving force for environmental degradation. Energy is indispensable for economic activity because all production and consumption activities are directly related to energy consumption. Fossil fuels have become the main source of energy sincethe Industrial Revolution. The rapid use of fossil fuels for economic growth has led to a significant increase in the global emissions of several potentially harmful gases. These gases not only cause deterioration of the environment but also adversely affect human life. The ever-increasing amount of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere is considered to be one of the world's greatest environmental threats. Among the greenhouse gases, CO_2 plays a powerful role in enhancing the greenhouse effect and is responsible for more than 60% of the greenhouse effect (Ozturk and Acaravci [1]).

An increasing body of empirical literature has focused on the relationship between income and environmental quality, and it is hypothesized that this relationship may change from positive to negative as more efficient infrastructure and energy-efficient technology are implemented in the development process within countries (de Bruyn and Opschoor[2]; Unruh and Moomaw [3];Frieddl and Getzner [4]; Coondoo and Dinda [5]; Managi and Jena [6]; Narayan and Narayan [7]; Esteve and Tamarit [8]). This inverted U-shaped relationship between economic growth and environmental quality is known as the environmental Kuznets curve (EKC). According to the EKC hypothesis, at early stages of economic growth, environmental quality decreases with increases in per capita income, but after a certain level, environmental quality begins to improving with an increase in the level of per capita income. Panayotou [9] argued that at low levels of development, as agriculture and resource extraction intensify and industrialization increases, both resource depletion and waste generation accelerate to generate an adverse effect on environmental quality (At higher levels of development, the economy is more oriented toward the service sector, and more efficient technologies result in the steady decline of environmental degradation. The earlier studies that primarily applied bivariate models are characterized as having problems related to omitted variable bias.

To avoid omitted variable bias, an enormous body of literature employs multivariate models rather than bivariate models. Studies based on multivariate models have focused on the relationship among carbon emissions, energy consumption, income, trade openness, gross fixed capital formation, labor and population density (see, for example, Suri and Chapman [10]; Soytas et al. [11]; Soytas and Sari [12]; Halicioglu [13]; Zhang and Cheng [14]; Ozturk and Acaravci [1]; Shahbaz et al. [15] ; Nasir and Rehman [16]; Esteve and Tamarit [8]).The studies by Stern [17] and Dinda [18] among others, provide extensive review surveys of studies at the intersection of economic growth and environmental pollution. However, these studies have ignored the effects of financial development on environmental quality.

Farnkel and Romer[19] have argued that financial development may attract foreign direct investment and higher degrees of research and development. Such an effect may influence the dynamic of environmental quality by increasing the level of economic growth and energy consumption. Ozturk and Acaravci[20] and Zhang [21] have noted that the income level is not the only indication of carbon emissions in a country; energy consumption, foreign trade and financial development may also be important sources of carbon emissions. Many economists argue that trade openness and financial development are crucial for establishing a comparative advantage, and both liberalization policies positively affect economic growth through several channels. However, these policies have consequences for an environmentally friendly atmosphere. Trade openness may increase pollution levels because pollution is generated in the production of goods for consumption in another country through international trade. Therefore, trade liberalization policy may have implications for the environment (Ozturk and Acaravci [20]. The links between carbon emissions and financial development have been investigated by several studies that have argued that financial development has a positive effect on carbon emissions (Sadorsky [22]; Zhang [21]; Dasgupta et al. [23, 24];Ozturk and Acaravci [20]). These studies have identified several channels through which financial liberalization may negatively affect environmental quality. First, stock market progress may support listed enterprises by minimizing risk, increasing financial channels, reducing financial cost and enhancing asset/liability structure; therefore, investment in new projects leads to increased energy consumption and carbon emissions. Second, financial development may attract foreign direct investment, which increases both economic growth and carbon emissions. Third, efficient and affluent financial institutions appear beneficial to consumers for personal loan activities, which may help consumers to buy goods such as automobiles, houses, refrigerators, air conditioners and washing machines and then emit more CO_2 (Zhang [21]).

Sadorsky [22] investigated the relationship between energy consumption and various indicators of financial development for a panel of 22 emerging economies and found a significantly positive relationship between financial development and energy consumption. The study of transitional economies by Tamzzian and Rao[25] argued that financial liberalization may be harmful for environmental quality if it is not accomplished within a strong institutional framework. The findings of Zhang [21] for China reveal that financial development is an important indicator of increases in carbon emissions. However, in their study of Turkey, Ozturk and Acaravci [20] argued that a financial development variable has no significant influence on carbon emissions. Meanwhile, Dasgupta et al. [24], Calessense and Feijin[26], Tamazian et al [27] and Jalil and Feridun [28] argued that the financial development variable may reduce carbon emissions and energy consumption by increasing energy efficiency and firm performance.

The choice of Pakistan is motivated by the substantial amount of financial reforms in Pakistan over the past two decades, which have significantly contributed to economic growth. There are a wide range of financial institutions in Pakistan, including commercial banks, investment banks, insurance companies, national savings schemes, stock exchanges, brokerage houses, leasing companies, microfinance institutions and Islamic banks.These institutions offer a number of products and services on both the asset and liability sides (Husain [29])[2]. Studies by Jalil and Ma [30] and Khan [31] argued that financial development exerts a positive effect on economic growth in Pakistan in both the short and long terms. It is generally believed that high economic growth leads to an increase in energy consumption, which is associated with carbon emissions. In fact, rapidly growing demand for energy as a result of economic and population growth led to a sharp rise in the consumption of oil, gas, coal and electricity during 1972-2010. In 2010, the consumption of oil, gas, coal and electricity were 7.0, 11.0, 6.0 and 14.0 times their 1972 levels, respectively (Pakistan Economic Survey). Similarly, in 2011, CO_2 emissions and primary energy consumption were 8.1 and 8.5 times higher than their 1972 levels, respectively (BP Statistical Review of World Energy [32]).

[2]The paper was presented at the Italy-Pakistan Trade and Investment Conference in Rome on September 28, 2004.

The studies of Shahbaz et al. [15] and Nasir and Rehman [16]on Pakistan addressed the relationship among environmental degradation, economic growth, energy consumption and trade but ignored the influence of financial development on the environment. The current study offers a contribution to the existing literature regarding the relationship between financial development and carbon emissions in Pakistan in addition to other variables. In this study, we also tested for the presence of a threshold level between per capita CO_2 emissions and per capita income for the Pakistani economy during 1972-2011. The remainder of the study is organized as follows. The methodology and data are presented in section 2. The empirical results are given in section 3. Finally, conclusions and policy recommendation are provided in section 4.

2. Methodology and data

The objective of this study is to examine the effect of energy consumption, per capita income, financial development and trade openness on carbon emissions in the case of Pakistan. A log linear econometric model has been used as suggested by Jalil and Feridun [27] and Ozturk and Acaravci[20]:

$$c_t = \alpha_0 + \alpha_1 e_t + \alpha_2 y_t + \alpha_3 y_t^2 + \alpha_4 fd_t + \alpha_5 op + \varepsilon_t \quad (1)$$

where c_t is CO_2emission per capita (measured in metric kilograms), e_t is total energy use per capita (measured in kilograms of oil equivalent), y_t is real gross domestic product (GDP) per capita (constant 2000 US\$), y^2 is the square of real GDP per capita, fd_t is the financial development indicator (domestic credit to the private sector as a percentage of GDP), op_t is the trade openness indicator (foreign trade as a percentage of GDP), and ε_t is the error term. The lower-case letters in Eq. (1) demonstrate that all variables are in natural logarithms. The annual time-series data are obtained from the World Development Indicators (WDI) online database for

1971-2011. In Eq. (1), we expect α_1 to be positive because a higher level of energy consumption results in an increase in per capita carbon emissions, which stimulates economic activities in the country. To support the EKC hypothesis, the sign of α_2 is expected to be positive, whereas a negative sign is expected for α_3. The inverted U-shaped pattern of EKC implies that per capita carbon emissions increase with an increase in per capita income up to a certain threshold level of per capita income, after which per capita carbon emissions decline. If α_3 is statistically insignificant, then there is a monotonic increasing relationship between per capita CO_2 emissions and per capita income. The sign of α_4 andα_5 may be positive or negative depending on the level of economic development of the country.

2.1 Econometrics methodology

The autoregressive distributed lag (ARDL) approach to cointegration proposed by Pesaran et al [33] has been used in this study. This approach has several advantages over other cointegration methods:

- It may be applied irrespective of whether the variables are I(0) or I(1) or a mixture of the two.
- It captures both short- and long-term dynamics when testing for the existence of cointegration.
- It offers explicit tests for the existence of a unique cointegration vector rather than assuming that this vector exists.
- It is preferable in small samples.
- Pesaran and Shin[34] argued that the appropriate lag selection in ARDL methodology is corrected for both serial correlation and endogeneity problems.

An ARDL representation of Eq. (1) is formulated as follows:

$$\Delta c_t = \alpha_0 + \sum_{i=1}^{p} \beta_{1i}\, \Delta c_{t-i} + \sum_{i=0}^{p} \beta_{2i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \beta_{3i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \beta_{4i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \beta_{5i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \beta_{6i}\, \Delta op_{t-i} + \beta_7 c_{t-1} + \beta_8 e_{t-1} + \beta_9 y_{t-1} + \beta_{10} y_{t-i}^2 + \beta_{11} fd_{t-i} + \beta_{12} op_{t-i} + \varepsilon_t \quad (2)$$

Eq. (2) is estimated through ordinary least squares (OLS) to explore the long-term relationship among the variables by performing an F-test for the joint significance of the lagged-level variables. The null hypothesis of no cointegration in Eq. (2) is H_0: $\beta_7=\beta_8=\beta_9=\beta_{10}=\beta_{11}=\beta_{12}=0$ against the alternative that H_1:$\beta_7 \neq \beta_8 \neq \beta_9 \neq \beta_{10} \neq \beta_{11} \neq \beta_{12} \neq 0$.

Pesaran et al. (2001) provided two sets of critical values for the F-statistic:the lower bound corresponding to the case in which all variables are I(0) and the upper bound corresponding to the case in which all variables are I(1). If the F-statistic lies below the lower bound, then there is no cointegration. If the F-statistic is above the upper bound, then cointegration is present. If the F-statistic falls between the upper bound and lower bound, then the test is inconclusive.

If the variables are found to be cointegrated in the first step, then in the second step, the long-term and short-term models can be estimated as represented by Eqs. (3) and (4) below, respectively:

$$c_t = \alpha_2 + \sum_{i=1}^{p} \gamma_{1i}\, c_{t-i} + \sum_{i=0}^{p} \gamma_{2i}\, e_{t-i} + \sum_{i=0}^{p} \gamma_{3i}\, y_{t-i} + \sum_{i=0}^{p} \gamma_{4i}\, y_{t-i}^2 + \sum_{i=0}^{p} \gamma_{5i}\, fd_{t-i} + \sum_{i=0}^{p} \gamma_{6i}\, op_{t-i} + \varepsilon_{2t} \quad (3)$$

$$\Delta c_t = \alpha_0 + \sum_{i=1}^{p} \beta_{1i}\, \Delta c_{t-i} + \sum_{i=0}^{p} \beta_{2i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \beta_{3i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \beta_{4i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \beta_{5i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \beta_{6i}\, \Delta op_{t-i} + \varphi ect_{t-1} + \varepsilon_{3t} \quad (4)$$

where φ represents the coefficient of error correction term (ect). ectis defined as follows:

$$ec_t = c_t - \alpha_2 - \sum_{i=1}^{p} \gamma_{1i}\, c_{t-i} - \sum_{i=0}^{p} \gamma_{2i}\, e_{t-i} - \sum_{i=0}^{p} \gamma_{3i}\, y_{t-i} - \sum_{i=0}^{p} \gamma_{4i}\, y_{t-i}^2 - \sum_{i=0}^{p} \gamma_{5i}\, fd_{t-i} - \sum_{i=0}^{p} \gamma_{6i}\, op_{t-i}$$

2.2 Causality Analysis

Although the ARDL cointegration approach confirms the existence or absence of a long-term relationship among the variables included in the model, it does not indicate the direction of causality. We use the vector error correction model (VECM) approach to detect the direction of causality. Toda and Philips [35] suggested that if a long-term relationship exists, then the direction of causality can be determined by the error correction model. The VECM equations can be written as follows:

$$\Delta c_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i}\, \Delta c_{t-i} + \sum_{i=0}^{p} \gamma_{1i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \delta_{1i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \theta_{1i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \vartheta_{1i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \mu_{1i}\, \Delta op_{t-i} + \varphi_1 ect_{t-1} + \varepsilon_{1t} \quad (5)$$

$$\Delta y_t = \alpha_2 + \sum_{i=0}^{p} \beta_{2i}\, \Delta c_{t-i} + \sum_{i=0}^{p} \gamma_{2i}\, \Delta e_{t-i} + \sum_{i=1}^{p} \delta_{2i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \theta_{2i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \vartheta_{2i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \mu_{2i}\, \Delta op_{t-i} + \varphi_2 ect_{t-1} + \varepsilon_{2t} \quad (6)$$

$$\Delta e_t = \alpha_3 + \sum_{i=0}^{p} \beta_{3i}\, \Delta c_{t-i} + \sum_{i=1}^{p} \gamma_{3i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \delta_{3i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \theta_{3i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \vartheta_{3i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \mu_{3i}\, \Delta op_{t-i} + \varphi_3 ect_{t-1} + \varepsilon_{3t} \quad (7)$$

$$\Delta y_t^2 = \alpha_4 + \sum_{i=0}^{p} \beta_{4i}\, \Delta c_{t-i} + \sum_{i=1}^{p} \gamma_{4i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \delta_{4i}\, \Delta y_{t-i} + \sum_{i=1}^{p} \theta_{4i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \vartheta_{4i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \mu_{4i}\, \Delta op_{t-i} + \varphi_4 ect_{t-1} + \varepsilon_{4t} \quad (8)$$

$$\Delta fd_t = \alpha_5 + \sum_{i=0}^{p} \beta_{5i}\, \Delta c_{t-i} + \sum_{i=1}^{p} \gamma_{5i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \delta_{5i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \theta_{5i}\, \Delta y_{t-i}^2 + \sum_{i=1}^{p} \vartheta_{5i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \mu_{5i}\, \Delta op_{t-i} + \varphi_5 ect_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta op_t = \alpha_6 + \sum_{i=0}^{p} \beta_{6i}\, \Delta c_{t-i} + \sum_{i=1}^{p} \gamma_{6i}\, \Delta e_{t-i} + \sum_{i=0}^{p} \delta_{6i}\, \Delta y_{t-i} + \sum_{i=0}^{p} \theta_{6i}\, \Delta y_{t-i}^2 + \sum_{i=0}^{p} \vartheta_{6i}\, \Delta fd_{t-i} + \sum_{i=0}^{p} \mu_{6i}\, \Delta op_{t-i} + \varphi_6 ect_{t-1} + \varepsilon_{3t} \quad (10)$$

where ectt-1 is the lagged errorcorrection term derived from the long-term cointegration relationship and $\varphi_i$represents the speed of adjustment showing the degree to which disequilibrium is corrected within one period.

An error correction model also enables us to distinguish between long- and short-term Granger causality. The direction of short-term Granger causality can be tested statistically by the joint significance of the coefficients of each explanatory variable. The direction of long-term Granger causality can be determined by assessing the significance of the coefficient of the error correction term in each equation using the t-test.

3. Empirical Results:

The time-series properties of the data are tested via the augmented Dickey-Fuller (ADF) and Philip-Perron (PP) test statistics. Table 1 displays the results of the ADF and PP tests on the integration of the variables. The results indicate that each variable is integrated of order one except for trade openness (op), indicating that all variables are non-stationary at their level and stationary at first difference, that is, I(1), and op is stationary at level, that is, I(0). Because the variables are not all integrated of the same order, ARDL is an appropriate estimation methodology for this setting.

Table 1: Results of unit root test

	ADF		Philips-Perron (PP)		
	Level	First Difference	Level	First Difference	Order of Integration
c	-0.69	-8.14*	-067	-7.54	I(1)
e	-2.38	-6.33*	-2.38	-6.35*	I(1)
y	-1.78	-5.768*	-1.87	-5.78*	I(1)
y^2	-1.82	-5.57*	-2.02	-5.60*	I(1)
fd	-2.99**		-2.54	-5.05*	I(1)
op	-5.20*		-5.12*		I(1)

Note: The regressions include an intercept. All of the variables are in natural logarithm form, and theSchwarz Bayesian Criterion (SBC) is used for lag length. ** and * indicate the rejection of the null hypothesis on the non-stationarity of the variable under consideration at the 5% and 1%significance levels, respectively.

For the cointegration analysis, Eq. (2) is estimated by OLS; a maximum of two lags is used in the estimation procedure on the basis of the Schwarz Bayesian Criterion (SBC); and the final ARDL model is selected when the estimated equations satisfy all diagnostic tests, including the Jarque-Bera statistic for the normality of residuals, the Breusch-Godfrey test for serial correlation, the ARCH residual for homoscedasticity and the Ramsey RESET test for specification error. The long- and short-term estimates, in addition to a diagnostic test and F-statistic of the joint null hypothesis that the coefficients of lagged-level variables are zero, are presented in Table 2.

The calculated F-statistics are higher than the appropriate upper-bound critical value; this finding indicates that the null hypothesis of no cointegration can be rejected. It may be concluded that a long-term relationship exists among per capita carbon emissions, per capita energy consumption, per capita real income, the square of per capita real income, financial development and openness at the 5% significance level.

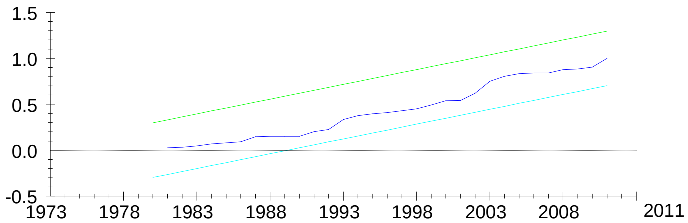
Because of structural changes in Pakistan's economy, it is expected that macroeconomic data for Pakistan may be subject to one or more structural breaks. Therefore, the stability of the coefficients is assessed through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests suggested by Brown et al. [36]. The Chow stability test requires prior knowledge of a structural break in the estimation period, whereas the CUSUM and CUSUMSQ tests do not require prior knowledge of where the structural break occurs (Ozturk and Acaravci, [20]). Figures 1 and 2 present the plot of the CUSUM and CUSUMSQ test statistics, which fall within the critical bounds of the 5% significance level. This finding indicates that the estimated coefficients are stable over the estimation period.

Table 2: Estimated long-and short-term elasticity coefficients

Short-term elasticities		Long-term elasticities	
Δet	0.97 (4.87)	et	1.50 (7.31)
Δyt	3.65 (4.27)	yt	5.64 (5.92)
Δyt2	-0.29 (-4.32)	yt2	-0.45 (-5.64)
Δfdt	0.08 (2.71)	fdt	0.12 (2.35)
Δopt	-0.01 (-0.25)	opt	-0.01 (-0.26)
Constant	-17.79 (-5.12)	Constant	-27.47 (-9.30)
Ecm_{t-1}	-0.65 (-5.09)		
Adjusted R^2	0.997	RSS	0.0104
DW	1.79		
F-test for Co-integration	5.41		
Diagnostics tests			
$\chi^2_{SC}(1)$	0.17 [0.685]	$\chi^2_{N}(2)$	0.55 [0.757]
$\chi^2_{FF}(1)$	2.32 [0.138]	$\chi^2_{H}(1)$	0.06 [0.802]

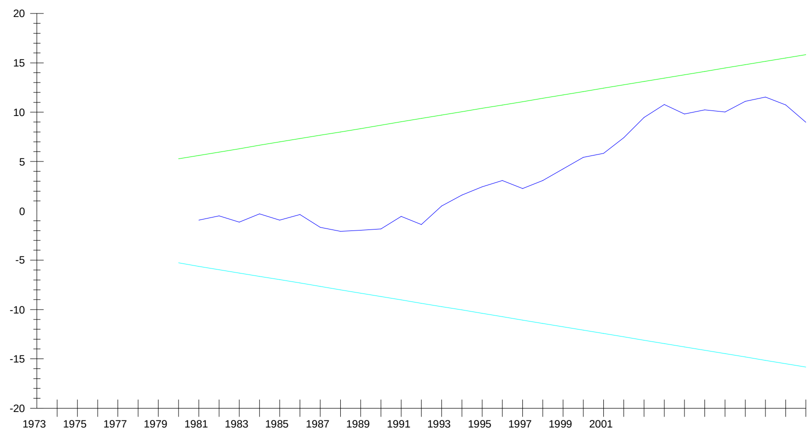
Note: t values are given in parentheses, and p-values are given in brackets. $\chi^2_{SC}(1)$are Lagrange multiplier tests of residual serial correlation, $\chi^2_{N}(2)$ is the Jarque-Bera test of normality based on a test of the skewness and kurtosis of the residual, $\chi^2_{H}(1)$ is a heteroskedasticity test based on the regression of squared residuals on squared fitted values and$\chi^2_{FF}(1)$ is Ramsey's RESET test using the square of the fitted values for functional form. The critical values for the lower I(0) and upper I(1) bounds are 2.86 and 4.19 for the 5% significance level, respectively, for CII(iii) Case III [Pesaran etal.[33].

Fig.1Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at the 5% significance level

Fig. 2Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at the 5% significance level

The estimated short- and long-term elasticities are reported in Table 2. The short- and long-term elasticity estimates of per capita carbon emissions with respect to per capita energy consumption are positive and significant. The coefficient of per capita energy consumption is 0.97 in the short term and 1.50 in the long term. This finding indicates that a 1% increase in per capita energy consumption in Pakistan will lead to a 97% increase in per capita carbon emissions in the short term and a 1.50% increase in the long term. The long-term elasticity estimate of per capita carbon emissions with respect to energy consumption is higher than the short-term elasticity estimates of carbon emissions with respect to energy consumption. From these short- and long-term elasticity estimates, it may be inferred that energy consumption leads to more carbon emissions in Pakistan over time. Furthermore, the long-term elasticity estimate of per capita emissions with respect to per capita real income is positive and statistically significant. The long-term elasticity estimate of carbon emissions with respect to the square of per capita real income is negative and statistically significant. The significantly positive coefficient of per capita real income and significantly negative coefficient of the square of per capita real income suggest that there is a positive relationship between per capita real income and per capita carbon emissions up to a certain threshold level of per capita real income. After this threshold level of per capita real income, per capita carbon emissions decline with an increase in per capita real income. These findings support the existence of the EKC hypothesis in the economy of Pakistan. Therefore, beyond a threshold level of per capita real income, which is 527 US$ according to the findings of our study, per capita carbon emissions are likely to decline with any increase in per capita real income in Pakistan.

The coefficient of financial development shows a positive and statistically significant effect on environmental degradation in both the short and long term. This effect may have been observed because Pakistan's banking and financial institutions have remained remarkably strong and resilient since the financial reforms of the 1990s. Pakistani banks have begun the aggressive marketing of consumer finance to the emerging middle class. The financing of these consumers primarily encompasses car financing, refrigerators and other electrical appliances, which leads to a deterioration in environmental quality through rising energy consumption in the country.

The coefficient of openness variable indicates a negative but statistically insignificant effect on carbon emissions. This finding suggests that an increase in the foreign trade-to-GDP ratio has no significant influence on environmental quality in Pakistan. Our finding supports the view of

Shahbaz et al. (2012), who argued that trade openness has a negative influence on CO_2 emissions in Pakistan through the technological effects in the country. Pakistan is a semi-industrialized economy, and trade openness is more oriented toward imports than exports. Pakistan's exports primarily encompass raw material and other agricultural products, which have no direct influence on environmental degradation. However, its imports include capital goods and technology, which may result in improvements in environmental quality through the use of energy-efficient equipment.

The short-term results reported in Table 2 indicate that the EKC hypothesis does hold in the short term in Pakistan. The coefficients of per capita real income and the square of per capita real income, respectively, have significantly positive and significantly negative effects on per capita CO_2 emissions. This result is consistent with the findings of Shahbaz et al.[15] for Pakistan. However, our result for short-term EKC is contrary to the findings of Nasir and Rehman [16] who reported that EKC hypothesis does not hold in the short term for Pakistan. It is noted that per capita energy consumption and financial development have significant positive effects on per capita carbon emissions in the short term, whereas openness has an insignificant effect on per capita carbon emissions. A negative and statistically significant coefficient of the ECM term at the 1% significance level confirms the long-term relationship among the variables that are included in our model. The long- and short-term results of our study are consistent. The signs of the short-term coefficients for all variables are similar to their corresponding long-term coefficients, but the magnitudes differ slightly. Specifically, the magnitudes of the short-term coefficients are smaller than the magnitudes of the respective long-term coefficients, indicating that the variables have a stronger effect in the long term.

In the next step, we perform the estimation of VECM as explained by Eqs. (5)-(10) to draw inferences regarding the direction of causality. The existence of a cointegration relationship among the variables, as shown by the cointegration statistics in Table 2, indicates that there is Granger causality in these variables in at least one direction, but it does not indicate the direction of this causality. Table 3 shows the results of errorcorrection-based Granger causality, including weak short-term Granger causality and long-term Granger causality. The results of the short- and long-term causality tests within the framework of VECM can be summarized as follows:

The long-term Granger causality test confirms the causal relationship from per capita energy consumption, per capita real income, the square of per capita real income, financial development and openness to carbon emissions in Pakistan. In the long-term causality test, per capita real income and the square of per capita real income appear to be weakly exogenous. Therefore, any change in per capita real income or the square of per capita real income that disturb the long-term equilibrium are corrected by counterbalancing changes in per capita energy consumption, fiscal development, openness and per capita carbon emissions. Therefore, it may be concluded that per capita real income and the square of per capita real income lead to per capita carbon emissions, per capita energy consumption, fiscal development and openness, but the former two variables are not caused by the latter four variables.

Table 3: Granger causality test results

The variable below is Granger-caused by the variables at right	Short-term χ^2 statistic						Long-term t-stat
	ΔCO	e	y	y2	fd	op	ECT
ΔCO		23.75 (0.000)	18.22 (0.000)	18.73 (0.000)	7.37 (0.007)	0.065 (0.798)	-5.094 (0.000)
e	29.35 (0.000)		13.65 (0.000)	15.34 (0.000)	3.85 (0.047)	0.36 (0.547)	-7.26 (0.000)
y	2.29 (0.130)	9.13 (0.003)		2166.3 (0.000)	0.52 (0.473)	0.11 (0.742)	-1.37 (0.178)
y2	2.17 (0.140)	9.16 (0.002)	10367 (0.000)		0.59 (0.440)	0.11 (0.740)	-1.54 (0.134)
fd	1.19 (0.275)	1.18 (0.277)	2.16 (0.141)	2.01 (0.156)		2.41 (0.121)	-3.79 (0.001)
op	0.04 (0.834)	0.176 (0.674)	0.487 (0.485)	0.438 (0.508)	0.60 (0.018)		-4.30 (0.000)

p-values are in parentheses

There is evidence of short-term bidirectional causality between per capita CO_2 emissions and per capita energy consumption in Pakistan. However, we find unidirectional causality from per capita real income, the square of per capita real income and financial development to per capita CO_2 emissions. There is also evidence of short-term bidirectional causality between per capita energy consumption and per capita real income as well as unidirectional causality from financial development to per capita energy consumption. There is also unidirectional causality from financial development to openness in the short term.

4. Conclusions and policyrecommendations

This study has analyzed the effects of financial development, per capita real income, the square of per capita real income, per capita energy consumption and openness on per capita CO2 emissions in the case of Pakistan for the 1971-2011periods. The bound F-test for cointegrationprovides evidence of a long-term relationship among these variables. The results confirm the existence of an environmental Kuznets curve in the case of Pakistan in both the short and long term. This finding indicates that at the initial stage of development, the level of CO2 increases with income, and after some threshold level of income,this relationship may change from positive to negative as more efficient infrastructure and energy-efficient technology are implemented during the country’s development. The findings of this study also revealed a significantly positive sign for the coefficient of financial development, suggesting that financial development has occurred at the cost of environmental quality. The key contributing factors of carbon emissions in Pakistan were found to be income, energy consumption and financial development. In addition, the openness variable has no significant influence on carbon emissions in either the short or long term.

This study also explored causal relationships among the variables using errorcorrection-based Granger causality tests. A long-term Granger causality test confirmed the causal relationship from per capita energy consumption, per capita real income, the square of per capita real income, financial development and openness to carbon emissions in Pakistan. In the short term, we found bidirectional causality between per capita CO_2 emissions and per capita energy consumption as well as unidirectional causality from per capita income, the square of per capita income and financial development to per capita CO_2 emissions.

In summary, the results indicate that financial development has become an important driving force for increases in carbon emissions, along with energy consumption and income. Although financial development is an integral part of the modern industry and service sector, the government of Pakistan should more extensively incorporate environmental concerns into its macroeconomic policies and in financial reform agendas to protect the environment and sustain economic growth.

The results of bidirectional causality between energy consumption and economic growth show that a sustainable energy supply is crucial for economic growth. Both short- and long-term dynamic causality results indicate that energy consumption leads to economic growth in Pakistan and viceversa. However, an increase in energy consumption for sustainable growth leads to a deterioration in environmental quality resulting from a rise in carbon emissions in both the short and long term. Higher energy consumption is necessary for higher economic growth, frequently at the expense of environmental degradation. Therefore, the government in Pakistan should focus on environmentally friendly energy sources to accelerate economic growth in the country.

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