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The Impact of Economic Growth, Energy Consumption, and Trade Openness on Carbon Emissions in Pakistan

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Abstract
This study empirically examines the impact of economic growth, energy consumption, and trade openness on carbon emissions in Pakistan from 1980 to 2020. To achieve this, the Johansen cointegration test has been applied, revealing significant long-term relationships among the variables. The results indicate that the Environmental Kuznets Curve hypothesis holds true for Pakistan in the long run. According to the EKC, as an economy grows, carbon emissions initially increase but eventually decrease after reaching a certain level of economic development. The study highlights that both energy consumption and trade openness have a significant positive impact on carbon emissions in Pakistan. This finding implies that as Pakistan's economy expands and integrates more with global markets, the resultant increase in energy consumption and trade activities contributes to higher carbon emissions. This relationship underscores the environmental challenges associated with economic growth and globalization. Energy consumption, in particular, is a critical factor driving carbon emissions. In Pakistan, like many developing countries, the energy sector is heavily reliant on fossil fuels, which are major sources of carbon emissions. The increased demand for energy to support industrial activities, transportation, and urbanization leads to higher greenhouse gas emissions. Therefore, managing energy consumption is crucial for mitigating environmental impacts. Trade openness, while beneficial for economic growth, also poses environmental challenges. Increased trade activities can lead to higher production and transportation emissions. Additionally, trade can facilitate the import of energy-intensive goods and technologies, further exacerbating carbon emissions. The study's findings suggest that without proper environmental regulations, trade liberalization can lead to significant ecological degradation. Given these insights, there is an urgent need for Pakistan to formulate environmentally friendly policies concerning trade openness and energy consumption. Policymakers should consider strategies that promote sustainable trade practices and energy use. For instance, adopting cleaner and more efficient technologies can help reduce the carbon footprint of industrial and trade activities. Implementing stricter environmental regulations and standards for emissions can also ensure that economic and trade growth does not come at the expense of environmental health. Additionally, investing in renewable energy sources such as wind, solar, and hydropower can reduce dependence on fossil fuels and lower carbon emissions. Promoting energy efficiency in various sectors, including manufacturing, transportation, and residential areas, can also contribute to significant reductions in energy consumption and emissions.
Keywords: Economic Growth, Carbon Emissions, Energy Consumption, Environmental Impact, Trade Openness
JEL Codes: Q56, F18, O44

1. INTRODUCTION

The severe shortage of energy resources in Pakistan underscores the critical role of energy as a binding input in the production process. Energy consumption is a vital component of production that has a positive impact on GDP. However, the increase in energy consumption has led to environmental degradation in Pakistan. It is plausible, though, that environmental conditions may begin to improve after reaching a certain threshold of energy consumption, economic growth, and trade openness. Stern (1997) postulated that initial economic growth may exacerbate environmental degradation, but beyond a certain point, environmental conditions start to improve. This phenomenon is often referred to as the U-Shaped Environmental Kuznets Curve (EKC) in the literature. The EKC suggests that as economies develop and reach a certain income level, they become more capable of investing in environmental protection measures, leading to improvements in environmental quality despite continued economic growth. In the case of Pakistan, addressing the energy shortage while simultaneously managing environmental concerns is crucial. By implementing sustainable energy policies and investing in clean energy technologies, Pakistan can strive to achieve a balance between economic growth and environmental sustainability, ultimately progressing along the trajectory of the Environmental Kuznets Curve towards a cleaner and more prosperous future.

Frankel and Romer (1999) revealed in their study that a robust capital system fosters Foreign Direct Investment (FDI), which in turn can stimulate economic growth and contribute to improved environmental outcomes. Similarly, Antweiler, Copeland,

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and Taylor (2001) emphasized the role of trade in promoting specialization and increasing output. The relationship between trade openness and economic growth lays the foundation for diverse economic activities, particularly in the context of trade liberalization. Furthermore, Grossman and Krueger (1995), Tamazian et al. (2009), and Halicioglu (2009) underscored the significance of financial development as a key determinant of environmental performance. These studies suggest that a well-developed financial sector can facilitate investments in environmental conservation and sustainable development initiatives, thereby enhancing overall environmental outcomes. While trade liberalization is often associated with economic growth, it can also have negative implications for environmental quality. Studies by Lopez (1994), Cole (2003), and Atici (2009) have highlighted the potential adverse effects of trade openness on the environment. Despite this, there has been limited attention paid to environmental quality in Pakistan concerning trade openness, despite its crucial importance in the contemporary global context. Given the significance of this issue, it is imperative to prioritize the examination of environmental quality in relation to trade openness. This study aims to address this gap by analyzing empirical data from Pakistan and shedding light on the factors influencing environmental quality. By doing so, it seeks to provide valuable insights for policymakers to develop and implement effective policies aimed at improving environmental quality. Through an examination of the impact of energy consumption, trade openness, and economic growth on environmental quality in Pakistan, this study aims to inform policy formulation processes and contribute to efforts aimed at enhancing environmental sustainability in the country. The findings derived from this analysis can serve as valuable inputs for policymakers in crafting strategies and interventions to safeguard and improve environmental conditions in Pakistan.

2. LITERATURE REVIEW

Jalil and Mahmud's (2009) investigation into the environmental Kuznets curve for CO_2 emissions in China offers valuable insights into the complex relationship between economic development, energy consumption, and environmental degradation. By analyzing yearly time series data spanning three decades, they provided empirical evidence of a non-linear relationship between carbon emissions and income, indicating that as income initially rises, carbon emissions increase, but beyond a certain income threshold, emissions begin to decline. This finding underscores the importance of understanding the nuanced dynamics of economic growth and its environmental consequences, particularly in rapidly developing economies like China. In a similar vein, Asghar and Rahat's (2011) examination of the energy-GDP causal relationship in Pakistan sheds light on the intricate interplay between energy consumption and economic growth. Their utilization of the Granger approach, augmented by a Graph Theoretic Approach for Casual Inference, revealed a unidirectional causality from energy consumption to economic growth, implying that energy is a critical driver of economic expansion in Pakistan. This highlights the need for policymakers to adopt strategies that promote energy efficiency and conservation while fostering sustainable economic development.

Bekhet and Othman's (2011) analysis of the causal relationships in Malaysia's economy offers valuable insights into the determinants of economic growth, particularly the role of electricity consumption. Through the utilization of a vector error correction model, they uncovered a long-run relationship among gross domestic product, electricity consumption, foreign direct investment, and the consumer price index, with electricity consumption emerging as a significant determinant of economic growth. This underscores the importance of robust energy infrastructure and policies that encourage investment in the energy sector to support sustained economic development. Lastly, Poveda and Martínez's (2011) exploration of economic growth, poverty, and energy dynamics in Colombia provides critical evidence of the transformative impact of energy supply on poverty alleviation and economic growth. By analyzing the short-run and long-run relationships among variables using time series methodology, they demonstrated that increased gross domestic product and energy supply per capita play pivotal roles in reducing poverty and fostering economic growth. This underscores the importance of ensuring access to reliable and affordable energy services as a catalyst for socioeconomic progress.

Pao, Yu, and Yang's (2011) investigation into the relationship between energy use, CO_2 emissions, and economic growth in Russia provides valuable insights into the dynamics of environmental sustainability and economic development. By employing cointegration methods and causality tests, they sought to elucidate the dynamic interplay between contaminant emissions, energy utilization, and actual output over the period from 1990 to 2007. Their empirical findings revealed several key insights. Firstly, they found that output exhibited inelasticity while energy use demonstrated elasticity in long-run equilibrium. This suggests that energy consumption is responsive to changes in emissions, while the impact of output on carbon emissions is negative, contradicting the environmental Kuznets curve hypothesis. Moreover, the results indicated that policies aimed at promoting economic growth and energy consumption can effectively mitigate emissions without exerting a negative impact on economic growth. This underscores the potential for aligning economic development with environmental sustainability through targeted policy interventions. Additionally, the causality analysis revealed the presence of bidirectional Granger causality between output, energy, and emissions. This suggests that shocks to any of these variables can lead to short-run adjustments aimed at restoring long-run equilibrium, highlighting the interconnectedness of economic activity, energy consumption, and environmental outcomes. Pao, Yu, and Yang's study underscores the importance of adopting integrated approaches to address the complex interdependencies between energy use, emissions, and economic growth. By leveraging insights from empirical analysis, policymakers can design more effective strategies to promote sustainable development while mitigating environmental degradation.

3. METHODOLOGY

Following Jalil and Feridun (2011) and Ali et al. (2015), we use economic growth, energy consumption, carbon emission and trade openness in a single multivariate model. We include trade openness in our model in order to convert closed economy model specification into open economy model. The model is then specified in a log linear form in the following way:

$$co_2 = f(ec_t, gdp_t, gdp_t^2, to_t)$$

CO_2 The natural log of per capita carbon emission

gdp_t and $Lgdp_t^2$ The natural log of per capita GDP and its square term.

ec_t The natural log of per capita energy consumption

to_t The natural log of trade openness measured as ration of exports plus import to GDP

4. RESULTS AND DISCUSSION

Table 1 presents the results of the Augmented Dickey-Fuller (ADF) unit root test for various variables. The ADF test is a commonly used method to determine the stationarity of time series data and, consequently, the order of integration of the variables. For each variable, the table displays the ADF test statistics for both the level and first differences of the data. Additionally, it indicates the order of integration implied by the test results. Starting with the variable LCO2 (presumably representing carbon dioxide emissions), the ADF test statistic for the level is -1.81, while for the first differences, it is -5.98, both marked with asterisks denoting significance. This indicates that LCO2 is stationary at the first differences level, suggesting it is integrated of order 1, or I(1). Similarly, the variables LEC (likely representing energy consumption), LGDP (Gross Domestic Product), LGDP2 (GDP squared, possibly a transformed variable), and LTO (total output or another economic indicator) all exhibit significant stationarity at the first differences level, with ADF test statistics ranging from -4.58 to -5.756. Overall, these results suggest that all the variables are integrated of order 1, implying they are non-stationary in their original form but become stationary after differencing once. This information is crucial for further time series analysis and modeling.

Table 1: Results of unit root test

	ADF Test		
Variables	Level	First differences	Order of Integration
LCO_2	-1.81	-5.98***	1
LEC	-0.59	-4.92***	1
LGDP	-0.97	-4.58***	1
$LGDP^2$	-0.45	-3.98***	1
LTO	-1.55	- 5.756***	1

Table 2 presents the outcomes of the Johansen test for co-integration, a statistical technique utilized to determine the presence and number of co-integrating relationships among multiple time series variables. The table is structured into two sections: the Max-Eigen-value Test and the Trace Statistics. In the Max-Eigen-value Test section, the null hypothesis (H0) assesses whether the maximum eigenvalue (**λ**max) equals a specified value (r). For each value of r tested (r=0 to 4), the critical value (CV) at a 95% confidence level is provided for comparison. The associated probability (Prob) indicates the significance level of the test statistic. The test examines whether there exists a co-integrating relationship for various potential numbers of co-integrating vectors (r). Similarly, the Trace Statistics section evaluates the null hypothesis (H0) concerning the equality of the trace statistic to a specified value (r). Again, the critical value (CV) at a 95% confidence level is compared to the test statistic, and the probability (Prob) represents the associated p-value. This test also assesses the presence of co-integration across different potential numbers of co-integrating vectors (r). A rejection of the null hypothesis (H0) implies the existence of co-integration among the variables under examination. In the provided results, rejection of the null hypothesis for r=0 suggests the presence of at least one co-integrating relationship among the variables. However, the evidence for higher values of r (1, 2, 3, and 4) is less decisive, as indicated by the higher p-values, suggesting a more nuanced interpretation.

Table 2: Results of Johansen test for Co-integration

Max-Eigen-value Test				Trace Statistics			
H0	**λ**max	CV (95%)	Prob	H0	Trace	CV (95%)	
r=0*	26.164	19.231	0.000	r=0*	40.626	31.290	0.000
r =1	8.610	12.264	0.258	r =1	11.061	16.497	0.376
r =2	0.251	2.841	0.4018	r =2	0.541	2.841	0.5018
r =3	0.357	2.601	0.4012	r =3	0.556	2.740	0.4756
r =4	0.311	1.841	0.6083	r =4	0.652	2.561	0.3658

Table 3 provides the outcomes of the long-run estimation, offering insights into the coefficients and their corresponding t-values for each regressor integrated into the model. The regressors, delineated in the first column, represent the variables scrutinized in the regression analysis. These variables are integral components in understanding the relationships within the model and their impact on the dependent variable. Examining the coefficients, presented in the second column, reveals the estimated effect of each regressor on the dependent variable. These coefficients quantify the magnitude and direction of the relationships between the independent and dependent variables. T-values, delineated in the third column, serve as a measure of the significance of each coefficient. Computed by dividing the coefficient by its standard error, t-values provide insights into the statistical reliability of the estimated coefficients. Interpreting the results, several observations emerge. Firstly, the coefficient for LGDP (Log of GDP) stands at 0.875, indicating a substantial positive association with the dependent variable. This coefficient is highly significant, as evidenced by its robust t-value of 11.36. Secondly, LGDP2 (Squared Log of GDP) exhibits a coefficient of -0.534, suggesting a negative relationship with the dependent variable. Despite this negative association, the coefficient remains statistically significant, with a t-value of -3.58. Thirdly, LEC (Log of Energy Consumption) yields a coefficient of 0.254, indicating a positive relationship with the dependent variable. However, this coefficient's significance is marginal, as denoted by its t-value of 2.89. Lastly, the coefficient for LTO (Log of Trade Openness) stands at 0.145, implying a positive relationship with the dependent variable. Similar to LEC, this coefficient's significance is modest, with a t-value of 2.358. In summary, the results underscore the robust and statistically significant impact of LGDP and LGDP2 on the dependent variable. Meanwhile, LEC and LTO demonstrate weaker and less statistically significant effects, albeit still bearing some influence on the dependent variable.

Table 3: Long Run Estimation

Regressors	Coefficients	t-values
LGDP	0.875	11.36
$LGDP^2$	-0.534	-3.58
LEC	0.254	2.89
LTO	0.145	2.358

Table 4 presents the coefficients and corresponding t-values obtained from the Error Correction Model (ECM) based on the Johansen Co-integration test. Each row in the table represents a regressor included in the ECM, while the coefficients associated with these regressors are depicted in the second column. These coefficients signify the estimated effect of each regressor on the dependent variable, capturing both the magnitude and direction of the relationship. Accompanying each coefficient is its respective t-value, which serves as a measure of the coefficient's statistical significance. T-values are calculated by dividing the coefficient by its standard error, providing insights into the reliability of the estimated coefficients. Analyzing the results, several observations can be made. Firstly, the coefficient for DLGDP(-1) stands at 0.2547, indicating a positive relationship with the dependent variable. However, its associated t-value of 1.258 suggests marginal significance. Similarly, DLGDP2(-1) exhibits a coefficient of 0.588, denoting a positive association with the dependent variable. Despite this positive relationship, its t-value of 1.658 implies only moderate significance. Furthermore, the coefficient for DLEC(-1) is 0.014, indicating a minor positive impact on the dependent variable. However, with a t-value of 0.355, this coefficient lacks statistical significance. Additionally, DLTO(-1) yields a coefficient of 0.987, suggesting a substantial positive relationship with the dependent variable. Yet, its associated t-value of 1.256 indicates marginal significance. Notably, the intercept term presents a coefficient of 0.898, which is statistically significant with a t-value of 5.265. This intercept captures the constant term in the ECM, representing the baseline level of the dependent variable when all regressors are zero. Finally, the Error Correction Term (ECT) at lag -1 exhibits a coefficient of -0.587, suggesting a negative relationship with the dependent variable. With a t-value of -2.369, this coefficient is statistically significant, indicating the presence of cointegration and the speed of adjustment towards equilibrium in the ECM.

Table 4: ECM Results based on Johansen Co-integration test

Regressor	Coefficients	t-value
DLGDP(-1)	0.2547	1.258
DLGDP(-2)	0.125	0.568
$DLGDP^2(-1)$	0.588	1.658
$DLGDP^2(-2)$	0.214	0.987
DLEC(-1)	0.014	0.355
DLEC(-2)	0.005	0.145
DLTO (-1)	0.987	1.256
DLTO(-2)	0.258	0.875
Intercept	0.898	5.265
ECT(-1)	-0.587	-2.369

5. CONCLUSIONS

The focus of this paper is to assess the influence of economic growth, energy consumption, and trade openness on carbon emissions in Pakistan. To achieve this objective, the study utilizes a time series dataset spanning from 1980 to 2020. By examining this timeframe, the study aims to capture long-term trends and dynamics in economic activity, energy usage, trade openness, and carbon emissions in Pakistan. This comprehensive analysis will provide valuable insights into the complex relationship between these variables and their impact on environmental sustainability. Through rigorous statistical analysis and econometric modeling, the paper seeks to uncover the causal links and interdependencies among economic growth, energy consumption, trade openness, and carbon emissions. By elucidating these relationships, the study aims to inform policymakers and stakeholders about the potential drivers of carbon emissions in Pakistan and identify strategies for mitigating environmental degradation while promoting sustainable economic development. The Johansen co-integration test, accompanied by an error correction model (ECM), has been employed to elucidate the long-run and short-run dynamics among the variables under investigation. By conducting this test, the study aims to identify the presence of co-integration relationships among the variables, which would indicate the existence of stable long-term equilibrium relationships. The error correction model, derived from the co-integration analysis, allows for the examination of short-term adjustments towards restoring equilibrium following any deviations. This model provides valuable insights into the speed of adjustment and the extent to which past deviations from equilibrium impact current changes in the variables. Through the combined application of the Johansen co-integration test and the error correction model, the study endeavors to uncover the underlying relationships and dynamics among the variables, thereby enhancing our understanding of their interdependencies and facilitating more accurate forecasting and policy analysis.

The findings of the study indicate that in the long run, there exists a non-linear relationship between economic growth and carbon emissions. Initially, as economic growth increases, carbon emissions tend to rise. However, beyond a certain threshold of economic growth, there is evidence to suggest that carbon emissions begin to decline. This observation aligns with the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted U-shaped relationship between economic growth and environmental degradation. However, it is noteworthy that this relationship between growth and the environment is not evident in the short run, as indicated by the study's results. This suggests that in the short term, changes in economic growth do not have a discernible impact on carbon emissions. It is possible that other factors or dynamics may dominate in the short run, obscuring any underlying relationship between economic growth and environmental outcomes. Overall, these findings highlight the importance of considering both short-term and long-term dynamics when examining the relationship between economic growth and environmental quality. They also suggest the potential effectiveness of policies aimed at promoting sustainable economic development and mitigating environmental degradation over the long term. The study's findings highlight the significant contribution of energy consumption and trade openness to environmental degradation in the long run. This underscores the importance of adopting environmentally friendly energy consumption techniques and promoting trade in goods that have a positive impact on the environment. To mitigate environmental degradation, it is imperative for Pakistan to transition towards cleaner and more sustainable energy sources, such as renewable energy sources like solar, wind, and hydropower. By reducing reliance on fossil fuels and promoting the use of renewable energy technologies, Pakistan can lower its carbon footprint and mitigate the adverse effects of energy consumption on the environment. Additionally, trade policies should prioritize the exchange of environmentally sustainable goods and services. This could involve incentivizing the production and trade of eco-friendly products, as well as implementing regulations that promote environmental responsibility throughout the supply chain. By encouraging the trade of environmentally friendly goods and services, Pakistan can contribute to global efforts to combat climate change and preserve natural ecosystems. Overall, the study's conclusions underscore the importance of integrating environmental considerations into energy and trade policies. By prioritizing sustainability and environmental protection, Pakistan can work towards achieving both economic development and environmental conservation in the long run.

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