Journal of Policy Research, 10(2), 90-96
https://jprpk.com
https://doi.org/10.61506/02.00210

The Impact of Renewable Energy; Financial Development and Economic Growth on Carbon Emission: Empirical Evidence from a Developing Economy

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Abstract

This research investigates the impact of renewable energy; financial development, economic growth, nonrenewable energy and natural resource rents on carbon emissions in Pakistan. An annual data series ranging from 1990 to 2022 is used; while Pesaran's et al. (2001) cointegration test is utilized and empirical results confirm that renewable energy, financial development, nonrenewable energy and economic growth have long run cointegrating relation with carbon emissions. The results further provide evidence that utilization of clean energy combats carbon emission while financial development, economic growth and unclean energy promote carbon emission. Natural resource rents also help in combating carbon emission but only in long run. These results are reliable as guided by diagnostics used in this research. This research suggests that both clean energy and natural resources must be promoted to combat carbon emissions while financial development; economic growth and nonrenewable energy may be escalated carefully because these are promoting environmental pollution in Pakistan.

Keywords: Carbon Emissions, Renewable Energy, Financial Development, Economic Growth, ARDL Approach, Pakistan

1. Introduction

In the recent times, the link between carbon emissions and liberalization of financial sector has attained great consideration. The liberalized financial sector is important for economic health of the economy. The economic growth changes due to various macroeconomic factors as highlighted by Hanif and Gago-de Santos (2017); Hanif et al. (2014); Huang et al. (2020); Alharthi and Hanif (2020); Wang et al. (2022) and Hanif et al. (2020). Similarly; factor productivity also changes due to expansion in reforms related to trade highlighted by Nazli et al. (2018). The improvement in economic health in fact gives hike to incomes of the people and they start increasing both production and consumption activities hence ending with effecting environmental health of the country. Another argument is if more finances are invited in expanding green technology and production activities then it may help in improving quality of the environment in the country. This guides us that the impact of financial development on carbon emissions is depending upon its utilization. If it promotes consumption activities then it will harm environmental quality and if it leads to green energy and technological advancements then it will improve environment.

The impact of economic growth on carbon emissions is also explained in detail in literature. The linear term of economic growth leads to increase carbon emissions while the nonlinear term of economic growth helps in reducing carbon emissions. This actually evolves EKC relation between economic growth and carbon emission. The literature is rich with EKC version but in our research, we are only capturing the linear impact of economic growth on carbon emissions. The higher incomes help in expanding access to needs and hence facilitates in improving living standards of the people. When people have more access to needs then their consumptions also escalate. The increased consumptions lead to add emissions in the environment. Besides this, utilization of clean energy is helpful in controlling environmental health of any economy. Therefore, if more investments are invited in green energies, then it will help in reducing emissions from the environment. Similarly, if fossil fuels are kept on utilized in both production and consumption activities then these will harm quality of the environment tending to increase carbon emissions. Therefore, the role of energy utilization is very important in order to target carbon emissions. It is dependent on the context and objective that which type of energy is the priority of the authorities to use. If they promote consumption and utilization of clean or green energy then it will obviously improve environmental quality otherwise environmental degradation will be promoted. Rents from natural resources and emissions from carbon have two-fold relation. In some of the cases it may escalate carbon emissions and in some of the cases it reduces carbon emissions. It depends on the utilization of rents from natural resources. If the wealth from natural resources is utilized in cleaner production and consumptions then this will tend to control emissions from the environment and will help in improving environmental health. However, if the rents from natural resources are utilized in consuming coal, oil, gas related energies then it will surely add emissions in the environment tending to deteriorate environmental health of the country.

On the basis of this discussion, this study is aimed at investigating the impact of renewable energy, financial development, economic growth, nonrenewable energy and natural resource rent on carbon emission in Pakistan. The rest of the study will provide review of past studies in the next section. Sources, functional form and techniques will be discussed in section 3. Results and their explanation will be presented in section 4. In the last

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section, we will conclude our discussion and will provide certain policy implications based on the findings of this research.

2. Literature Review

For sub-Saharan African economies we witnessed Hanif (2018)'s contribution who disclosed that utilization of fossil fuels boosts environmental degradation while renewable energy had negative and significant impact on carbon emissions. In another study, we found Haseeb et al. (2018) who highlighted that financial development significantly reducing carbon emissions in Russia and China while it was significantly boosting environmental degradation in Brazil and South Africa. The expansion in economic growth and trade openness significantly elevated carbon emissions while financial development had negative but statistically insignificant impact on carbon emissions in small Island developing states [Seetanah et al. (2019)]. Afterwards; the contribution Hanif et al. (2019) suggested that fossil fuels had significant and increasing effect on carbon emissions in emerging countries from Asian region. The similar results were reported by Hanif (2017) and Anser et al. (2020) for Latin American and Caribbean states. The theoretical research was carried out by Gok (2020) and the study suggested that the impact of financial development on carbon emissions was dependent upon the measure used for financial development. It could impact carbon emission in both directions but as whole the study supported that it boosts environmental degradation. The ecological footprints were declining due to increasing trends in renewable energy while it was following upward rise because of increase in non renewable energy in the selected four Asian economies like Pakistan; Bangladesh, India and Sri Lanka [Xue et al. (2021)]. The contribution of Yang et al. (2021) highlighted that utilization of renewable sources of energy mitigated while consuming non renewable energy escalated carbon emissions in emerging SREB countries. Afterwards; nonrenewable energy and economic growth were found in increasing carbon emissions while renewable energy was found in reducing carbon emissions in G-7 countries [Khalid et al. (2022)]. The contribution of Shah et al. (2022) disclosed that financial development left negative impact on carbon emissions while GDP per capita was significantly deteriorating carbon emissions in low-income countries. Besides this, the negative and significant effects of renewable energy while positive and significant impact of economic growth and total natural resource rents were highlighted by Li et al. (2022) in their research for South East Asian countries.

The economic growth appeared as insignificant factor of carbon emissions as highlighted by Daniyal et al. (2023) for Pakistan economy. The increasing and significant effects of economic growth in low- and middle-income countries while negative and significant impact of natural resource rents in oil exporting economies were captured on carbon emissions by Luo et al. (2023). Afterwards, we came across with the findings of Liu et al. (2023) who suggested that clean energy and natural resource rents significantly mitigate carbon emissions in highly populous economies. Besides them; Fei et al. (2023) suggested that carbon emissions increased significantly due to increase in domestic production both Asian and European economies. In research by Jia et al. (2024) from recent times, they witnessed that both mineral and forest rents were important factors which helped in mitigating carbon emissions in G-20 economies. The contribution of Huihui et al. (2024) highlighted the sources of cleaner energy in G-7 economies.

3. Sources; Structure and Techniques

This research has obtained the historical facts of each selected indicator from World Bank (2024) databank. The frequency of the data is Annual. The following model is utilized for this research:

$\ln CO2_t = f\ (\ln GDPPC_t, \ln RE_t, \ln NRE_t, \ln FD_t, \ln NR_t)$, Whereas;

Table 1: Names of the Variables & their Demonstration

Indicator\s Name	Representation
Carbon Emissions Per Capita	$\ln CO2_t$
GDP Per Capita	$\ln GDPPC_t$
Renewable Energy as share of Total Energy	$\ln RE_t$
Non-Renewable Energy as share of Total Energy	$\ln NRE_t$
Financial Development	$\ln FD_t$
Total Natural Resource Rent	$\ln NR_t$

For obtaining basic stats of the variables taken in the study we will present descriptive stats table. To check multicollinearity between explanatory indicators, we will consider VIF matrix. The presence of unit root is going to be tested by ADF (1981) unit root test. Later on, whether both carbon emissions and its drivers have long run cointegrating relation with each other or not, it will be tested using ARDL bounds test developed by Pesaran et al. (2001). Afterwards, we will present long and short run coefficients for the selected ARDL function. The post regression diagnostics in the form of serial correlation; functional form, normality,

heteroskedasticity, CUSUM and CUSUM square graphs will suggest whether the estimated results are reliable or not.

4. Results and Discussion

This section will present results and discussion from descriptive stats table. The information shared in Table 2 exerts that carbon emission along with all its drivers have insignificant values of Jarque Bera test. The results further highlight that carbon emission has minimum mean value while the mean value of per capita GDP appears to be highest. Table 2 is presented as below:

Table 2: Descriptive Stats

Variables	Mean	Std. Dev.	Jarque-Bera	Probability	Observations
$lnCO2_t$	-0.3631	0.1527	0.8670	0.6482	33
$lnGDPPC_t$	11.7424	0.1770	2.5995	0.2726	33
$lnRE_t$	3.8912	0.0803	1.1528	0.5619	33
$lnNRE_t$	4.0804	0.0551	2.5672	0.2770	33
$lnFD_t$	2.9482	0.2163	3.8277	0.1475	33
$lnNR_t$	0.5018	0.3322	2.8400	0.2417	33

After this, the Table 3 presents the information about whether the multicollinearity between the drivers of carbon emissions is present or not. The multicollinearity refers significant correlation between the independent variables of any dependent variable. The correlation between two independent variables is confirmed if the VIF stat is witnessed as 10 or above. For all the explanatory variables taken for carbon emission in our research, we have found the absence of multicollinearity issue. This is because the calculated VIF stats are less than 10 for all the explanatory variables in our research. The results of Table 3 are presented as below:

Table 3: VIF Matrix

Variables	$lnGDPPC_t$	$lnRE_t$	$lnNRE_t$	$lnFD_t$	$lnNR_t$
$lnGDPPC_t$	-				
$lnRE_t$	4.0762	-			
$lnNRE_t$	5.0406	9.4998	-		
$lnFD_t$	2.0297	1.5119	1.5810	-	
$lnNR_t$	1.0017	1.0149	1.0197	1.0016	-

After this; the status of order of integration for all the selected variables of this research is tested using ADF (1981) unit root test. The null hypothesis of this test will suggest that series is nonstationary while the alternate hypothesis will suggest that series is stationary. The significant ADF test will allow us to reject null hypothesis. From the results presented in Table 4, we may see that all the data series have insignificant ADF test when these are tested for level specification while all these indicators have significant ADF test at first difference specification. This allows us to conclude that all the variables are I (1). This means that all have become stationary at first difference. The status of order of integration is same and one. The findings are shared as below:

Table 4: ADF Unit Root Test

At Level			At First Difference		
Variables	**t-Test**	**P.Value**	**Variables**	**t-Test**	**P.Value**
$lnCO2_t$	-1.9891	0.2898	$\Delta lnCO2_t$	-3.4669	0.0162
$lnGDPPC_t$	0.3801	0.9788	$\Delta lnGDPPC_t$	-3.3438	0.0216
$lnRE_t$	-2.4523	0.1366	$\Delta lnRE_t$	-3.8504	0.0064
$lnNRE_t$	-1.8442	0.3529	$\Delta lnNRE_t$	-2.8565	0.0630
$lnFD_t$	-1.4299	0.5549	$\Delta lnFD_t$	-3.1765	0.0315
$lnNR_t$	-1.9487	0.3068	$\Delta lnNR_t$	-3.4461	0.0170

The above Table 4 demonstrated same order of integration. The ARDL bounds test can be applied on mixed order of integration but it can also be applied on data series which report same order of integration but surely it should not be I(0). The results of cointegration are presented in the following Table 5 in which F-stat = 4.4997 which is greater than the 10% upper critical bound = 3.7883. On the basis of this finding we may conclude that carbon emissions have long run cointegrating relation with its drivers such as economic growth; renewable energy, non renewable energy, financial development and total natural resource rents. After these findings, if we look at the post regression diagnostics, we can see that all these diagnostics have insignificant probability values which demonstrate that error term is not serially correlated. The proposed functional form is not nonlinear and it is correctly specified. Errors follow normal distribution and variance of error term is not heteroskedastic. These results are provided in Table 5:

Table 5: Results of Cointegration using ARDL Approach

Proposed Function	$\ln CO2_t = f\ (\ln GDPPC_t, lnRE_t, lnNRE_t, lnFD_t, lnNR_t)$	
Lag Oder	(1 , 0 , 1 , 1, 0 , 1)	
F – statistics	4.4997	
Significance Level	**Critical Bounds**	
	Lower	**Upper**
5 percent	3.0693	4.5181
10 percent	2.5596	3.7883
	DIAGNOSTIC TESTS	
Serial Correlation	1.0263 [0.311]	
Functional Form	0.3986 [0.528]	
Normality	0.7484 [0.688]	
Heteroscedasticity	0.7046 [0.401]	

The values shared in the "[]" demonstrates P. values.

After confirming long term cointegrating relation between carbon emissions and its factors, now the long-term coefficients for the finalized ARDL model are presented in the Table 6. The results presented in the Table 6 suggest that economic growth significantly escalate carbon emissions. One percent increase in economic growth is significantly increasing carbon emissions by 0.2798 percent. Besides this, utilization of clean energy has negative and significant influence on carbon emissions. This finding further exerts that carbon emissions decreases by 0.7233 percent when clean energy expands by one percent. Afterwards, nonrenewable energy expands environmental pollution in Pakistan. The coefficient shows that if we increase nonrenewable energy by 1% then it will also escalate pollution by 0.1037%. The results further highlight that liberalization of financial sector raises incomes through the increase in production. The increased incomes allowed people to utilize goods and services which add pollution to the environment. This discloses that one percent expansion in financial development will further pollute environment by 0.5140 percent. The findings also expose that expanding natural resources in the economy help in controlling pollution in the environment. By increasing one percent investment on natural resources to increase rents then it will significantly reduce carbon emissions by 0.4185 percent. The results are shared as below:

Table 6: Long-Term Parameters

Dependent Variable = $\ln CO2_t$

Indicators	**Parameters**	**S.Error**	**t-test**	**P.Value**
$\ln GDPPC_t$	0.2798	0.0533	5.2531	0.0000
$\ln RE_t$	-0.7233	0.1280	-5.6508	0.0000
$\ln NRE_t$	0.1037	0.0200	5.1751	0.0000
$\ln FD_t$	0.5140	0.1936	2.6559	0.0144
$\ln NR_t$	-0.4185	0.1007	-4.1548	0.0004
C	-5.1974	1.3170	-3.9464	0.0007

The short-term coefficients for all the drivers of carbon emissions are presented in Table 7. The results demonstrate that renewable energy significantly but natural resource rents insignificantly are curtailing carbon emissions. This means that utilization of clean energy and expansion in natural resources rent are helpful in reducing pollution level in the country. The magnitude demonstrates that one percent expansion in clean energy and natural resource rents significantly reduce carbon emission by 1.1347% and 0.0598% respectively. Since the

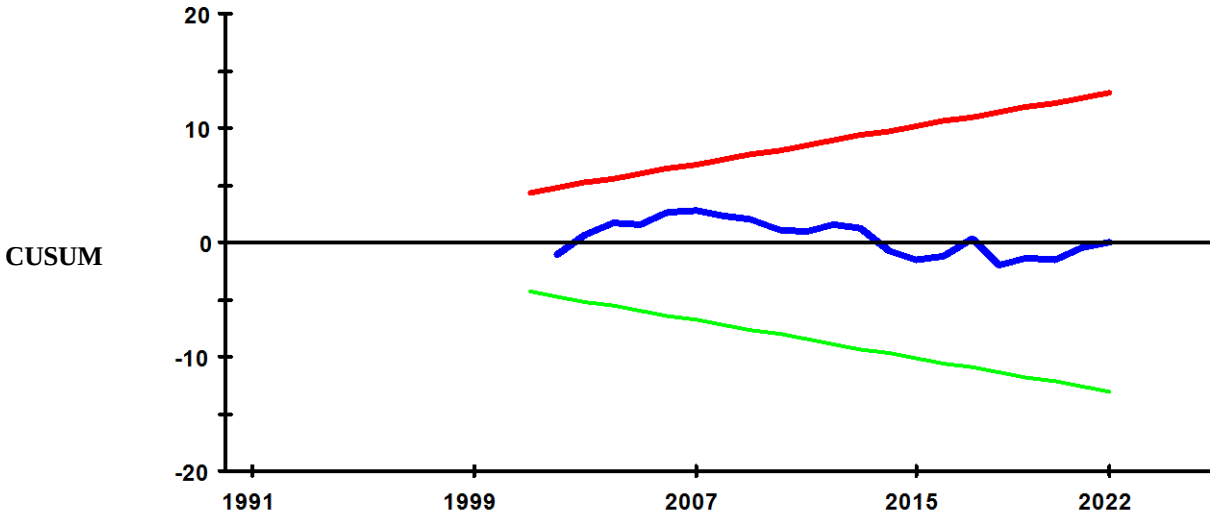
coefficient of natural resource is insignificant and weak therefore, it is ignorable. The results further expose that utilization of nonrenewable energy; economic growth and development of financial sector are significantly encouraging environmental pollution. This means that by increasing one percent nonrenewable energy, economic growth and financial development, the environment pollution will increase by 0.0571%, 0.2675% and 0.4914% respectively. In the short run, the impact of renewable energy is most strong than the financial development in order to mitigate environmental pollution. The results further disclose that disturbance term followed by one period lag has negative and significant coefficient which shows that convergence hypothesis is relevant for this study. The disequilibrium will be corrected by the 95.59% adjustment speed. The long-term equilibrium will be attained in about 1.0461 years. The short-term results are provided in Table 7:

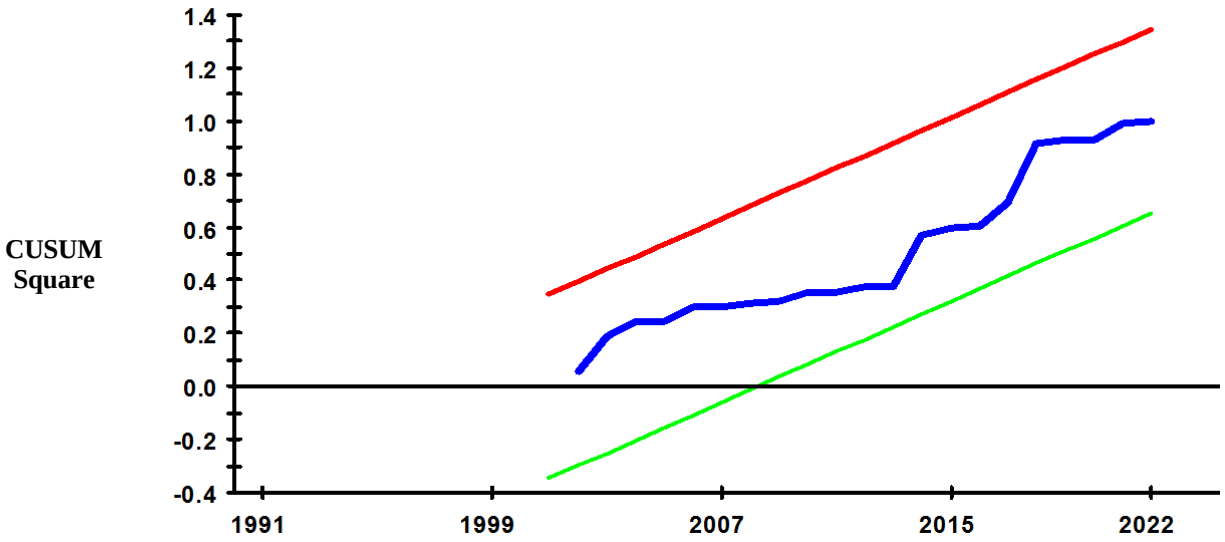
Table 7: Short-Term Parameters

Dependent Variable = $\Delta \ln CO2_t$

Indicators	Parameters	S.Error	t-test	P.Value
$\Delta \ln GDPPC_t$	0.2675	0.0584	4.5818	0.0001
$\Delta \ln RE_t$	-1.1347	0.1509	-7.5195	0.0000
$\Delta \ln NRE_t$	0.0571	0.0296	1.9283	0.0668
$\Delta \ln FD_t$	0.4914	0.2008	2.4477	0.0228
$\Delta \ln NR_t$	-0.0598	0.1664	-0.3595	0.7226
CointEq(-1)	-0.9559	0.1838	-5.2022	0.0000
Diagnostic Tests				
$\bar{R}^2$			0.8931	
F-Test (Probability Value)			44.6817 (0.000)	
DW-Test			2.2022	

After discussing short-term parameters, now we are going to present the discussion of stability test using two graphs such as CUSUM and CUSUM square. These graphs will guide us about the stability of mean and variance of error terms which ultimately will conclude that the estimated coefficients during the selected sample are stable if the said graphs are found within their corresponding critical bounds. As the graphs poses that both mean and variance are within their critical values therefore the estimated coefficients are stable during the said period in this research. These graphs are presented as below:





5. Conclusion

The role of financial development; renewable energy, economic growth, nonrenewable energy and natural resource rents is taken to capture their impact on carbon emissions in case of Pakistan. Annual data series is taken and ARDL bounds test is applied to obtain long run cointegrating relation between carbon emission and its drivers. The results confirm that carbon emissions have long run cointegrating relation with its determining factors. The results demonstrate that renewable energy has significantly reducing effects on environmental pollution while financial development; nonrenewable energy and economic growth have significant and elevating effects on carbon emissions. Among these three indicators, the impact of financial development is higher than economic growth and then nonrenewable energy. The results also highlight that natural resource rents only help in controlling carbon emissions in long run. However, among all the indicators, renewable energy appears the most important factor which helps in mitigating carbon emissions in Pakistan. These results are robust to all the diagnostics. Therefore, based on these results, we propose that renewable energy and natural resources rents may be expanded to retrieve their mitigating effects for carbon emissions. Moreover, financial development, economic growth and fossil fuels must be expanded carefully as these are escalating carbon emissions in Pakistan.

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