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ENVIRONMENTAL CONSEQUENCES OF ENERGY CONSUMPTION AND NATURAL RESOURCE RENTS: A MACROECONOMIC PERSPECTIVE FROM A DEVELOPING ECONOMY

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Abstract:
The growing size of carbon emissions is becoming a serious challenge to sustainable environment. The continuous use of traditional nonrenewable energy channels are becoming the primary source of this issue. In order to explore the factors responsible for environmental challenges, this study is designed. Manufacturing value added; renewable energy, fossil fuel energy consumption, oil and natural gas rents have been taken as determining factors of carbon emissions in this research. After utilizing ARDL bounds test on an annual data series from 1990 to 2023, this research suggest that manufacturing value added and nonrenewable energy are significantly increasing carbon emissions and hence leading to worse the environmental quality. The results further uncover that oil rents, renewable energy and natural gas rents are significantly reducing carbon emissions leading to improve environmental sustainability. These findings suggest that promoting environmental friendly energy sources; investing in low carbon generating infrastructure for earning rents from oil and gas sectors and encouraging such practices during manufacturing phase which may help in achieving sustainable environment.

Keywords: **Cleaner Energy; Oil and Gas Rents; Manufacturing Value Added (MVA); Carbon Emissions; ARDL Bounds Test**

Introduction:

The interaction of manufacturing value added, consumption of disaggregated energy and carbon emissions has been a hot topic of research among scholars and policy formulators. As expanding carbon emissions significantly influence climatic conditions in any economy therefore, it is imperative to explore its determining factors. Through this we will be able to suggest certain policy implications which may be helpful in controlling carbon emissions. The present research examines the impact of manufacturing value added, disaggregated energy consumption like renewable and nonrenewable energy consumption, rents from natural gas and rents from oil channels on carbon emissions for Pakistan economy. There are scholars who highlighted the significance of the macroeconomic factors in determining domestic production like Hanif et al. (2014); Chen et al. (2023); Hassan et al. (2018; 2019; 2022; 2023) and Nazli et al. (2018). There are several other scholars who also realized the significance of domestic production therefore, they also inquired the role of various indicators in findings their impact on economic activtieis and some of these scholars are Hassan and Siddiqi (2010); Alharthi and Hanif (2020); Wang et al. (2022); Hanif and Gago-de Santos (2017); Hanif et al. (2020); Satti et al. (2014); Huang et al. (2020) and Hassan and Kalim (2012; 2017.

Industrial activities are determined through manufacturing value added. The increase in industrial production through manufacturing value added tends to release more wastage in the air and canals/ rivers leading to expand carbon emissions. The expected impact of manufacturing value added on carbon emissions is positive because the production process in the industries is of energy-intensive in nature. Moving on, we have added another important indicator in our proposed function and that is renewable energy consumption. It helps in mitigating carbon emissions because it is the need of time to switch towards cleaner energy or environmental friendly products to protect the environment. Conversely, the dependence on nonrenewable energy products makes people to consumer more of oil, natural gas, coal and nuclear energy related products. This reveals increasing consumption of fossil fuels leading to expand carbon emissions. This suggests that rely on unclean energy exhibits $CO2$ emissions to expand leading to worsening environmental quality. Afterwards this study also incorporated the role of rents from natural gas and oil sources in order to capture the impact of resource rents upon carbon emissions. Rents from natural resources may have both way impact on $CO2$ emissions. It can increase carbon emissions and it can also reduce carbon emissions. The result section will uncover the findings for our case.

The rest of the study is organized as the next section highlights past scholars contribution on the similar topic. The data, model and method is shared in part 3. Results and explanation is presented in section 4. Last section will provide concluding remarks and will also provide possible policy implications.

Literature Review

Carbon emissions had significantly positive impact while utilization of renewable had significant and negative impact on sub-Saharan African’s carbon emission [Hanif (2018)]. The financial sector liberalization was found in escalating carbon emission in South African and Brazil while it was found in reducing carbon emissions in China and Russia [Haseeb et al. (2018)]. In another research, we witnessed Hanif et al. (2019)’s contribution in which they highlighted that carbon emission followed upward trend due to increase in fossil fuels in case of sekected Asian economies. This finding was also highlighted by Anser et al. (2020) and Hanif (2017) in their respective researches. After this, Yang et al. (2021) visited a case of SREB economies and uncovered that non renewable channels of energy expanded carbon emission while renewable energy channels of energy were found in diminishing carbon emission in the selected sample economies. The findings of Khalid et al. (2022) were consistent with the findings of Yang et al.

(2021) for G-7 economies. Later on, we came across with another research in which Huan et al. (2022) disclosed significantly positive impact of energy use on carbon emissions and similar sign for fossil fuels when it is determining ecological footprints in Chinese context.
Li et al. (2022) in their research highlighted that economic growth and rents from natural resources were found in boosting carbon emissions while renewable energy was found in reducing it in case of South East Asian nations. In another research we found Luo et al. (2023) in highlighted the significantly accelerating effects of economic growth on carbon emissions while they also uncovered the adverse effects of rents from natural resources in case of oil exporting nations. During the similar period, Liu et al. (2023) explored the determining factors of carbon emissions and highlighted that rents from natural resources and renewable energy were found in significantly reducing carbon emissions in extremely populous countries. After this, we found the study of Gao et al. (2023) in which they reported that renewable energy had negative impact while nonrenewable energy had positive impact on carbon emissions environmentally adverse economies. In a research executed by Fei et al. (2023), we witnessed the Asian and European context and the study disclosed the positive and significant impact of output upon carbon emissions. Considering sample of G-7 countries, Huihui et al. (2024) provided discussion of various sources of green energy. After this, we visited Jia et al. (2024) contribution for G-20 nations and they exposed that carbon emissions declined due to expansion in mineral and forest rents. According to Alharthi et al. (2024), the clean energy and globalization were found in mitigating carbon emissions while fossil fuels were found in escalating the carbon emissions in high polluting nations. After this; data, function and method is going to be discussed in the next section.

Data, Function and Method:
In the present research, data of proposed variables like carbon emissions, manufacturing value added, renewable energy, nonrenewable energy, rents from natural gas and rents from oil is selected over the period 1990-2023 from World Bank's (2023) data bank. The selected variables are used to propose following function for obtaining empirical results:

$$\ln CO2_t = f(\ln MG_t, \ln RE_t, \ln NRE_t, \ln RNG_t, \ln RO_t)$$

Whereas;

Table 1: Names of the Variables & their Demonstration

Indicators	Representation
Per Capita CO2 Emissions	$\ln CO2_t$
Manufacturing Value Added as percentage of GDP	$\ln MG_t$
Consumption of Renewable Energy as percentage of Total Energy	$\ln RE_t$
Consumption of Non Renewable Energy as percentage of Total Energy	$\ln NRE_t$
Rents from Natural Gas as share of GDP	$\ln RNG_t$

Rents from Oil as share of GDP	$lnRO_t$

In order to obtain empirical results for the above proposed function, we will consider different steps. The summary of primary stats of all the variables will be presented in the beginning. This will guide us about the normality status. After this, we will inquire about the status of significantly correlated regressors to diagnose presence of multicollinearity issue. For this purpose, VIF will be used. Besides this, the slope of all the variables will be found by using any suitable unit root test. After identifying the status of stationarity, we will then use any appropriate cointegration test to see whether our proposed function is related in the long run or not. In case if long run cointegration holds in our study then we will find long and short run coefficients to see how manufacturing value added, renewable and nonrenewable energy channels, rents from natural gas and oil impact carbon emissions in Pakistan. After this, we will visit diagnostic tests to see whether our proposed model will be reliable to take for policy implications or not. The following section will present empirical results:

Findings and Commentary:

This part provides the findings of the model suggested in the previous part of the study. Table 2 discusses mean values; variation from mean and status of normality of the factors selected in this study. The mean value (4.0707%) of nonrenewable energy is appeared to be highest while the mean value (-0.6498%) of rents from oil sources is witnessed as the minimum. We further consider the Jarque-Bera test to find out normality status, and our results suggest that except manufacturing value added and nonrenewable energy, all the other selected factors satisfy the conditions of a normal distribution. A variable is said to be normally distributed if the JB test provides insignificant probability value. Table 2 is provided as below:

Table 2: Summary Stats of the Variables

Variables	$lnCO2_t$	$lnMG_t$	$lnRE_t$	$lnNRE_t$	$lnRNG_t$	$lnRO_t$
Mean	-0.3577	2.3146	3.8859	4.0707	-0.2698	-0.6498
Standard Deviation	0.1536	0.1395	0.0830	0.0449	0.4336	0.5161
Jarque-Bera Test	1.0786	4.6262	1.5361	7.0100	1.0822	0.6828
Probability Value	0.5831	0.0990	0.4639	0.0300	0.5821	0.7108
Sample Size	34	34	34	34	34	34

The VIF test - Variance Inflation Factor test is utilized to see whether multicollinearity between explanatory variables prevails or not. The value of VIF below 10 shows insignificant correlation between two regressors while value of VIF above 10 represents that two regressors are significantly correlated. The significantly correlated regressors confirm presence of multicollinearity. Table 3 shows that value of VIF between regressors of our proposed function are below 10 therefore, regressors are insignificantly correlated hence indicating absence of multicollinearity problem between regressor pairs of this study. Table 3 is shared as below:

Table 3: VIF Matrix

Variables	$lnMG_t$	$lnRE_t$	$lnNRE_t$	$lnRNG_t$	$lnRO_t$
$lnMG_t$	-				
$lnRE_t$	4.6099	-			
$lnNRE_t$	3.4393	5.3274	-		
$lnRNG_t$	1.1687	1.1390	1.5392	-	
$lnRO_t$	1.0065	1.0462	1.0000	1.1846	-

Moving on, the stationarity of the factors taken in this study is going to be investigated by applying Phillips-Perron (1988) unit root test. With the help of this test, we will be able to see whether the slopes of our variables are zero/ nonzero. The alternate hypothesis of this test suggests that series is stationary while null suggests vice versa. The insignificant adjusted t-test will help us to accept the null hypothesis. Table 4 is provided as below:

Table 4: Phillips - Perron Unit Root Test

	At Level			At First Difference	
Variables	**Adjusted t-Test**	**Prob. Value**	**Variables**	**Adjusted t-Test**	**Prob. Value**
$lnCO2_t$	-1.7563	0.3947	$\Delta lnCO2_t$	-5.0167	0.0003
$lnMG_t$	-1.0558	0.7211	$\Delta lnMG_t$	-5.0303	0.0003
$lnRE_t$	-2.3076	0.1756	$\Delta lnRE_t$	-5.0883	0.0002
$lnNRE_t$	-3.2858	0.0238	$\Delta lnNRE_t$	-5.6321	0.0001
$lnRNG_t$	-1.5093	0.5165	$\Delta lnRNG_t$	-4.5757	0.0009
$lnRO_t$	-3.0088	0.0444	$\Delta lnRO_t$	-7.0590	0.0000

Table 4 suggests nonrenewable energy [-3.2858 (0.0238)] and rents from oil channels [-3.0088 (0.0444)] have significant adjusted t-test which concludes that both factors are stationary series at level specification. Other than these variables, all the factors have insignificant adjusted t-test at level therefore, all the variables are non-stationary. The results of Table 4 further uncover that all the factors have significant adjusted t-stats at first difference because the probability value for all the factors is below than 10%. Hence all variables are stationary series at first difference. Summing up our discussion, we conclude that nonrenewable energy and rents from oil are stationary at level while others like carbon emissions, renewable energy, manufacturing value added and rents from natural gas channels are stationary at first difference. Hence this research provides witness of mixed order of integration of the data series. Table 4 guides us on the basis of mixed order of data series that we need to employ Pesaran et al. (2001) method ARDL bounds test for finding cointegrating linkage between carbon emissions and its factors like manufacturing value added, renewable energy, nonrenewable energy, rents from both natural gas and oil in the long run. Table 5 reports that calculated F-stats = 4.9033 which exceeds 5% UCV – upper critical bound = 4.4732. This confirms the status of long run relation between carbon emissions and its explanatory factors taken in this research. Table 5 further provides results related to diagnostics like normality test, test of functional form, test for hetero and test for serial correlation. On the basis of insignificant probability values we would be accepting null hypotheses of the above stated tests. As we may see from the Table 5 that all these diagnostic tests have probability values over 10% which suggests that their null hypotheses are correct/ true. Table 5 is given as below:

Table 5: Pesaran et al. (2001) Estimates

Proposed -Function	$\ln CO2_t = f(\ln MG_t, \ln RE_t, \ln NRE_t, \ln RNG_t, \ln RO_t)$	
Lag-Order	(1 , 0 , 0 , 1 , 0 , 1)	
F –Test	4.9033	
Significance-Level	**Critical Bounds**	
	Lower	**Upper**
5 -percent	3.0624	4.4732
10 -percent	2.5341	3.7686
DIAGNOSTIC -TESTS		
Serial -Correlation	1.5362 [0.215]	
Functional -Form	0.2883 [0.591]	
Normality	0.7676 [0.681]	
Heteroscedasticity	0.3414 [0.559]	

“[]” carries probability values.

The diagnostics presented in the above Table 5 conclude that the error term of our selected ARDL model is normally distributed, our proposed function has correct specification, errors are not correlated serially and variance of error term of our model is not heteroskedastic. These results suggest that our selected ARDL model is correct and is reliable. Moving on, besides confirming cointegrating linkage between carbon emissions and its factors in the long-term, this study is now going to present the impact of each individual regressor upon carbon emissions. Table 6 is presented as under:

Table 6: Parameters for Long Run

Dependent Variable = $\ln CO2_t$

Regressors	Coefficients	Standard Error	t-test	P.Value
$lnMG_t$	0.2176	0.0869	2.5025	0.0195
$lnRE_t$	-0.1196	0.0223	-5.3709	0.0000
$lnNRE_t$	0.6428	0.3004	2.1400	0.0427
$lnRNG_t$	-0.3724	0.1291	-2.8839	0.0082
$lnRO_t$	-0.5524	0.1357	-4.0695	0.0004
C	1.1229	2.0267	0.5541	0.5847

Table 6 uncovers the significant and positive impact of manufacturing value added and nonrenewable energy on carbon emissions. This shows that increase in domestic production tends to raise employment, incomes and ability of people to consume more. This leads to escalate carbon emissions. On the other side, when consumption of fossil fuels expand this in turn also expands the size of carbon emissions in the society. As a result, environmental quality becomes worse. The magnitude of both indicators represent that due to 1% increase in manufacturing value added and nonrenewable energy consumption, carbon emissions significantly expand by 0.2176% and 0.6428%. Among both, the effect of nonrenewable energy consumption on carbon emissions is more stronger than the effect of manufacturing value added. The findings further reveal that renewable energy, rents from natural gas and rents from oil channels have significant and negative impact on carbon emissions. This means that when consumption of renewable energy, rents from natural gas and rents from oil escalate by 1% then carbon emissions decline by 0.1196%, 0.3724% and 0.5524% respectively. This shows that among these three indicators, we conclude that the impact of rents from oil channels is more stronger than the impact of the remaining two indicators. The consumption of these indicators help in improving environmental quality in Pakistan. The results of this section further highlight the role of the selected indicators in determining carbon emissions in the short run. Table 7 provides estimates for short-term period which is shared as below:

Table 7: Short-Run Estimates

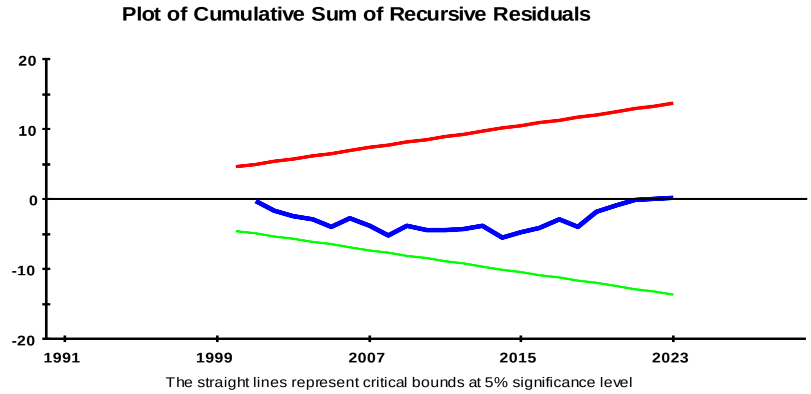
Dependent Variable = $\Delta lnCO2_t$				
Regressors	**Coefficients**	**Standard Error**	**t-test**	**P.Value**
$\Delta lnMG_t$	0.1827	0.0782	2.3376	0.0281
$\Delta lnRE_t$	-0.1004	0.0170	-5.8981	0.0000
$\Delta lnNRE_t$	0.9702	0.2672	3.6306	0.0013
$\Delta lnRNG_t$	-0.3128	0.1193	-2.6208	0.0150
$\Delta lnRO_t$	-0.2772	0.0906	-3.0590	0.0054

CointEq(-1)	-0.8400	0.0804	-10.4527	0.0000
Diagnostic Tests				
Adjusted R^2			0.8788	
F-Test with Prob. Value			39.9901 (0.000)	
D.W –Test			2.4022	

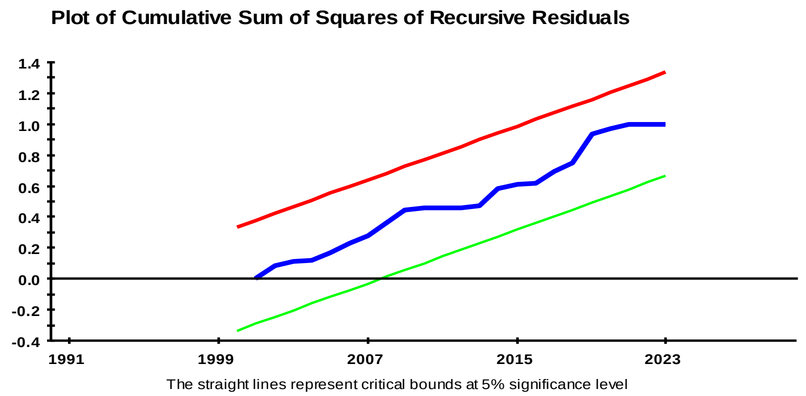
We can see from the Table 7 that both manufacturing value added and nonrenewable energy consumption have significant and increasing effects on carbon emissions. By escalating manufacturing value added and nonrenewable energy by 1%, we witness the increase in carbon emissions by 0.1827% and 0.9702% respectively. Between both indicators, the consumption of nonrenewable energy has larger impact on carbon emissions than manufacturing value added. Through this, we may conclude that both indicators are deteriorating environmental quality in the short run. This finding is similar to the finding of long run. The results further reveal that consumption of renewable energy, rents from natural gas sources and rents from oil sources have inverse and statistically significant effects on carbon emissions. Carbon emissions decline by 0.1004%, 0.3128% and 0.2772% respectively due to one percent improvement in consumption of renewable energy and rents from natural gas and oil sources. The magnitude of rents from natural gas is relatively stronger than the impact of rents from oil sources and renewable energy consumption. All these indicators help in mitigating carbon emissions and facilitate in improving environmental quality. The findings related to all these three indicators are similar to the long run finding. Additionally, the results reveal that ecm (t-1) has negative and significant coefficient which states that due to one percent increase in ecm (t-1), the disequilibrium will be removed by 0.84% each year. This means that each year error will be corrected with the speed of 84%. We will be attain stable and long-term equilibrium in about 1.19 years. The stability test is used to find out whether variance and mean of the error term appear to be stable during the suggested time period. This will be confirmed if the blue thick line appears to be inside the red and green lines – critical boundary of CUSUM - Cumulative Sum and CUSUM square – Cumulative Sum of Square graphs. s (CUSUM square) graphs. From the below provided graphs, we can see that both CUSUM and CUSUM square graphs are stable because both meet the stability criteria. This concludes that mean and variance of error term of the proposed model of this research are stable during the suggested period. Hence long and short term coefficients of this research are stable structurally. Figure 1 is provided as under for further clarity:

Figure 1: Stability Test

CUSUM



CUSUM Square



Conclusion:

This research probes into the role of manufacturing value added, renewable energy, nonrenewable energy, rents from natural gas and rents from oil sources in determining the changes into carbon emissions. For this purpose, we have considered the case of a developing country like Pakistan. For exploring the status of stationarity, Phillips-Perron (1988) unit root test is applied while ARDL bounds test is utilized for obtaining long-term cointegrating relation. The empirical results confirm the presence of mixed order of integration. The long term cointegration helps us to obtain long run and short run coefficients for the selected ARDL model. The results expose that both manufacturing value added and nonrenewable energy consumption have significant and accelerating effects on carbon emissions leading to worsening environmental quality. The role of nonrenewable energy is stronger than the role of manufacturing value added in determining carbon emissions. Moving on, the renewable energy, rents from natural gas and rents oil have negative and significant effects on carbon emissions. This means that among these three rents from oil in long run while rents from natural gas in short run have stronger effects in mitigating carbon emissions in Pakistan. All these three indicators facilitates in improving environmental quality. For policy perspective, targeting rents earning through both natural gas and oil channels can be helpful in mitigating carbon emissions while switching towards green energy may also help in improving quality of environment in Pakistan.

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