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RESEARCH ARTICLE

Nexus between energy use, industrialization, forest area, and carbon dioxide emissions: New insights from Russia

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Abstract
Greenhouse gas (GHG) emissions, especially carbon dioxide (CO_2) emissions, contribute significantly to global climate change, which in turn threatens the environment, development, and sustainability. The current study examines the nexus between Russia's energy consumption, industrialization, and forest cover in terms of the country's total CO_2 emissions. The Autoregressive Distributed Lag (ARDL) bounds testing technique and the Dynamic Ordinary Least Squares (DOLS) methodology were used to examine time series data from 1990 to 2020. Evidence of cointegration between the variables was found using the ARDL bounds test. An increase of 1% in energy consumption and industrialization is predicted to result in an increase of 1.3% and 0.23% in CO_2 emissions in Russia. In addition, it has been estimated that a 1% increase in forest area might lead to a 4.29% reduction in CO_2 emissions in the long run. This article proposed policies to reduce emissions in Russia and assure environmental sustainability through the use of renewable energy sources, green industry, and sustainable forest management.

Keywords: Climate change; CO_2 emissions; Environment; Renewable energy; Forest; Sustainability

Introduction

A large extent of greenhouse gases (GHGs) and carbon dioxide (CO_2) are present in the atmosphere, contributing significantly to global warming in the 21st century. These gases are mostly produced by human activities like the burning of fossil fuels and the degradation of forests (Raihan et al., 2021a). Climate change brought on by continued CO_2 emissions is predicted to have catastrophic impacts on all aspects of human society (Isfat & Raihan, 2022). To protect long-term growth and decrease the negative effects of climate change, reducing CO_2 emissions and improving the quality of the environment have become global concerns (Raihan & Tuspekova, 2022a). Russia is the fourth-largest CO_2 emitter in the world, and most of its emissions come from the burning of fossil fuels like gas, oil, and coal, therefore the country's contributions to global warming are significant. Around 4.6% of global emissions come from Russia's around 2 billion tonnes of CO_2eq (carbon dioxide equivalent) released annually. At 11 tonnes per person per year, carbon dioxide emissions are more than double the global average. Russia's commitment to combating climate change, however, was confirmed when the country ratified the Paris Agreement in April 2015. The Russian government established its long-term climate strategy in October 2021, with goals of achieving net-zero greenhouse gas emissions by the year 2060 and reducing emissions by 80% compared to 1990 levels by the year 2050. Policymakers in Russia are increasingly aware of the need for a holistic understanding of Russia's climate change vulnerability in order to find a middle ground between policies aimed at mitigating climate change and achieving sustainable development, and the implementation of measures that achieve both. The greatest challenge in making progress toward both goals at once is navigating the tension that arises while trying to reduce pollution while also fostering economic growth (Begum et al. 2020). Therefore, there is a significant debate over whether or not the goals of sustainable development and enhanced environmental quality (emissions reduction) are incompatible (Raihan & Tuspekova, 2022b). Russia's main sources of CO_2 emissions need to be investigated in order to provide a solution to the important topic of how Russia may cut CO_2 emissions, which arises.
Russia's GDP of USD 1.78 trillion in 2021 made it the eleventh largest economy in the world (World Bank, 2022). However, oil and gas exports are crucial to Russia's economy. In terms of natural gas, Russia has the greatest reserves in the world; in terms of coal, it has the second largest; and in terms of oil, it has the eighth largest. It ranks high among natural gas producers and exporters, third among oil producers, and second among oil exporters.

In 2021, oil and natural gas income accounted for 45 percent of Russia's federal budget, demonstrating the country's reliance on these commodities. The amount of crude and condensate produced in Russia reached 10.5 million barrels per day in 2021, accounting for 14% of the global supply. Additionally, industrialization in Russia has provided a new avenue for economic growth, contributing roughly 30% to GDP (World Bank, 2022). Steel production, railroads, mining, and chemical processing all played significant roles in Russia's industrialization. Russia is a modern, industrial power that can and will have an effect on the global economy. However, Russia's economy relies heavily on fossil fuels, which results in high energy consumption and carbon dioxide emissions. This means that industrialization is becoming an increasingly formidable obstacle to sustainability and carbon reduction in Russia. It is of great worry to the government that emissions are intensifying, especially those coming from the energy sector and industrialization. Therefore, this study attempts to investigate the effects of Russia's energy consumption and industrialization on carbon dioxide emissions.

Approximately one-fifth of yearly global CO_2 emissions come from agriculture, forestry, and other land use (AFOLU); and land use, land-use change, and forestry (LULUCF) activities making them the second-largest source of CO_2 emissions and a significant contributor to global climate change (IPCC, 2014). Urbanization, industrialization, settlements, mining, and agriculture have all contributed to the loss of forest cover (Jaafar et al., 2020). Alterations to land use, such as the cutting down of trees, can result in significant amounts of carbon dioxide emissions and climate change (Raihan et al., 2018). But forests are important because they act as carbon sources and sinks, altering the balance of the global climate (Raihan et al., 2021b). Carbon sequestration, the process by which forests remove CO_2 from the air and store it in tree biomass and soil, is an important climate change mitigation strategy (Raihan & Tuspekova, 2022c). About 300 billion metric tonnes of carbon dioxide are sequestered annually by forested areas, with an additional 3 billion metric tonnes of CO_2 expected to release into the atmosphere as a result of increased deforestation (Raihan et al., 2022a). Russia is the world's most forested country, accounting for more than 20.1% of the world's total forest area. Nearly half of Russia is covered by forests (World Bank, 2022). This has significant implications for the country's carbon balance. Therefore, studying the forest's potential to reduce carbon dioxide emissions in Russia is essential.

The problem of the environment-growth nexus is brought up by the fact that Russia has had a hard time in recent decades attaining rapid economic expansion without badly harming the environment. Despite its widespread interest among modern scholars, the connections between CO_2 emission and its causes have received scant attention in Russia. While most CO_2 research considers the BRICS (Brazil, Russia, India, China, and South Africa), only a minority of these studies include Russia. It is challenging to construct an accurate picture of the relationship between CO_2 and its drivers for Russia using only panel research due to the known limitations of panel analysis. For this reason, the current assessment employs econometric techniques to investigate the dynamic effects of economic growth, energy use, industrialization, and forest area on CO_2 emissions in Russia, with the intention of filling the resulting research gap. This study is valuable because it contributes to the advancement of both theoretical and practical knowledge in modern Russian literature and policy. This is the first study to evaluate the potential of forest areas to lower CO_2 emissions in Russia, and that is the main innovation of this research. In addition, the most up-to-date and thorough data that was available throughout a 31-year period (1990-2020) was included in this investigation. The study's findings provide policymakers with more thorough and insightful information for developing effective policies in the areas of low-carbon economy, promotion of the use of renewable energy sources, green industrialization, and sustainable forest management, all of which would ensure reductions in emissions in Russia. Further, the study's results may help other developing countries adopt climate change mitigation and adaptation methods and implement effective environmental sustainability strategies.

Methodology

Data

This study conducted an empirical examination of the dynamic effects of economic growth, energy use, industrialization, and forest area on CO_2 emissions in Russia using the DOLS approach of cointegration developed by Stock and Watson (1993). Time series data for Russia from 1990 to 2020 were retrieved using the World Development Indicator (WDI) dataset. In this analysis, CO_2 emissions served as the dependent variable, whereas GDP growth, energy consumption, industrialization, and forest cover all played the role of explanatory variables. Kilotons (kt) are used to measure carbon dioxide emissions, while Gross Domestic Product (in constant Russian rubles), energy consumption (in kg of oil equivalent per capita), industrialization (in the percentage of GDP), and forest area (in square kilometers) are the standard units of measurement for the other variables. To ensure that the data follows a normal distribution, the variables were transformed into the logarithm form. Table 1 displays the variables together with their logarithms, measurement units, and data sources. Figure 1 also shows the annual trends of CO_2 emissions, GDP growth, energy consumption, industrialization, and forest area in Russia.

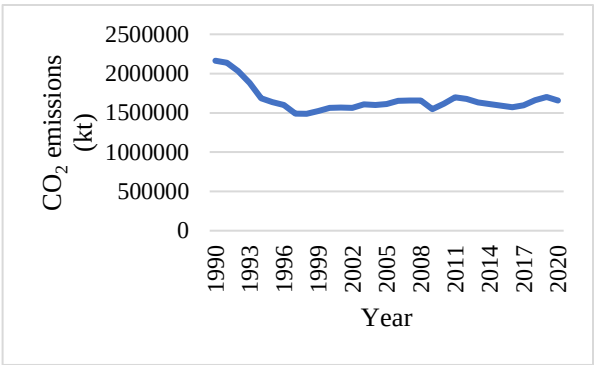
Empirical model

The emission of carbon dioxide is thought to increase in tandem with a growing economy and increased demand for energy. The following function is created within the context of the conventional Marshallian demand function (Friedman

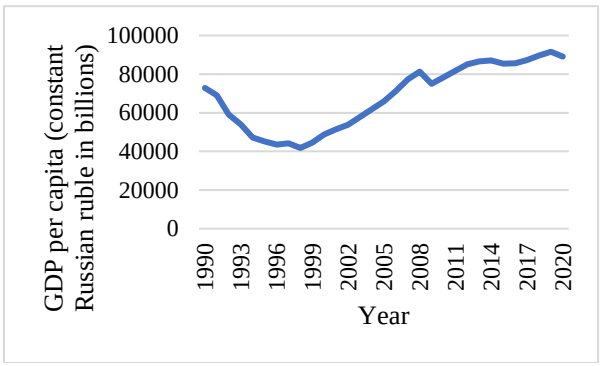
1949) at time t, assuming the market clearance situation where $CO_{2t} = f\ (GDP_t; EU_t)$ (1)
CO_2 emissions equal economic growth and energy use.

Table 1. Variables accompanied by their logarithmic representations, measurement units, and data sources

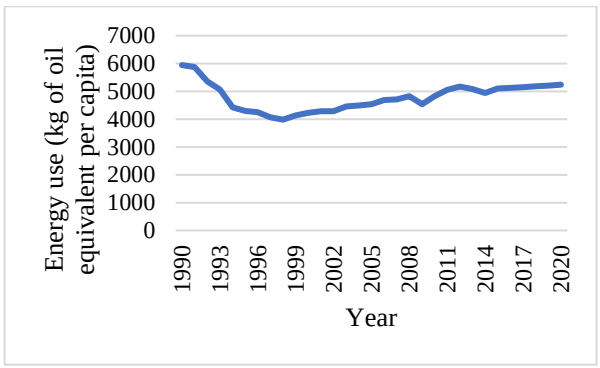
Variables	Description	Logarithmic forms	Units	Sources
CO_2	CO_2 emissions	LCO2	Kt	WDI
GDP	Economic growth	LGDP	GDP per capita (constant Russian ruble)	WDI
EU	Energy use	LEU	Kg of oil equivalent per capita	WDI
IND	Industrialization	LIND	Industry value added (% of GDP)	WDI
FA	Forest area	LFA	Sq. km	WDI



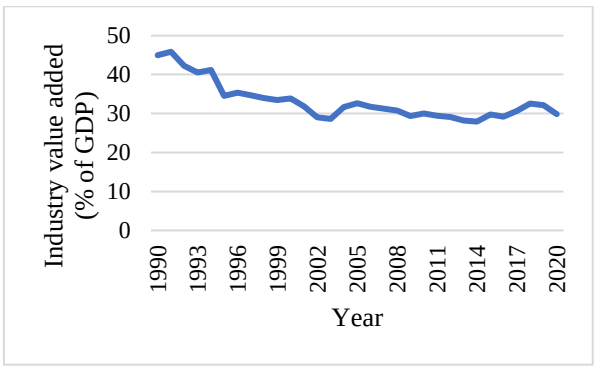
(a) CO_2 emissions



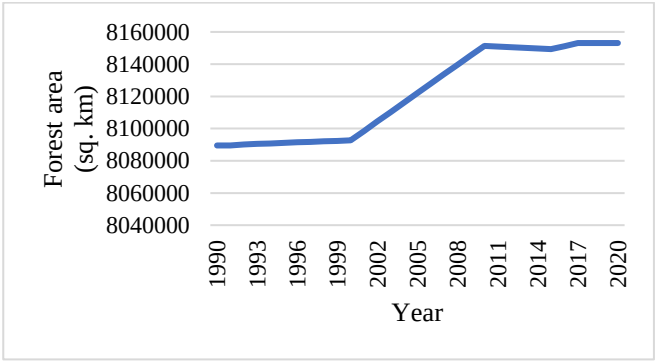
(b) Economic growth



(c) Energy use



(d) Industrialization



(e) Forest area

Figure 1. Yearly changes in the research variables
Source: World Bank (2022)

where CO_{2t} is the CO_2 emissions at time t, GDP_t is the economic growth at time t, and EU_t is the energy usage at time t.

The purpose of this study is to quantify the effects of industrialization and forest area on CO_2 emissions in order to assess their weight on environmental quality. It follows that Equation (1) can be rewritten as:

$$CO_{2t} = f\ (GDP_t; EU_t; IND_t; FA_t) \quad (2)$$

where IND_t is industrialization at time t and FA_t is the forest area at time t

The empirical model is depicted by the equation:

$$CO_{2t} = \tau_0 + \tau_1 GDP_t + \tau_2 EU_t + \tau_3 IND_t + \tau_4 FA_t \quad (3)$$

The econometric model may take the form below, with Equation (3) substituted in for.

$$CO_{2t} = \tau_0 + \tau_1 GDP_t + \tau_2 EU_t + \tau_3 IND_t + \tau_4 FA_t + \varepsilon_t \quad (4)$$

where τ_0 and ε_t are intercept and error term. Besides, τ_1, τ_2, τ_3, and τ_4 signify the coefficients.

Furthermore, the logarithmic procedure of Equation (4) can be finalized as follows:

$$LCO2_t = \tau_0 + \tau_1 LGDP_t + \tau_2 LEU_t + \tau_3 LIND_t + \tau_4 LFA_t + \varepsilon_t \quad (5)$$

Flow chart of the analysis

To investigate the dynamic effects of economic development, energy consumption, industrialization, and forest area on CO_2 emissions in Russia, the present study used the analysis methods illustrated in Figure 2.

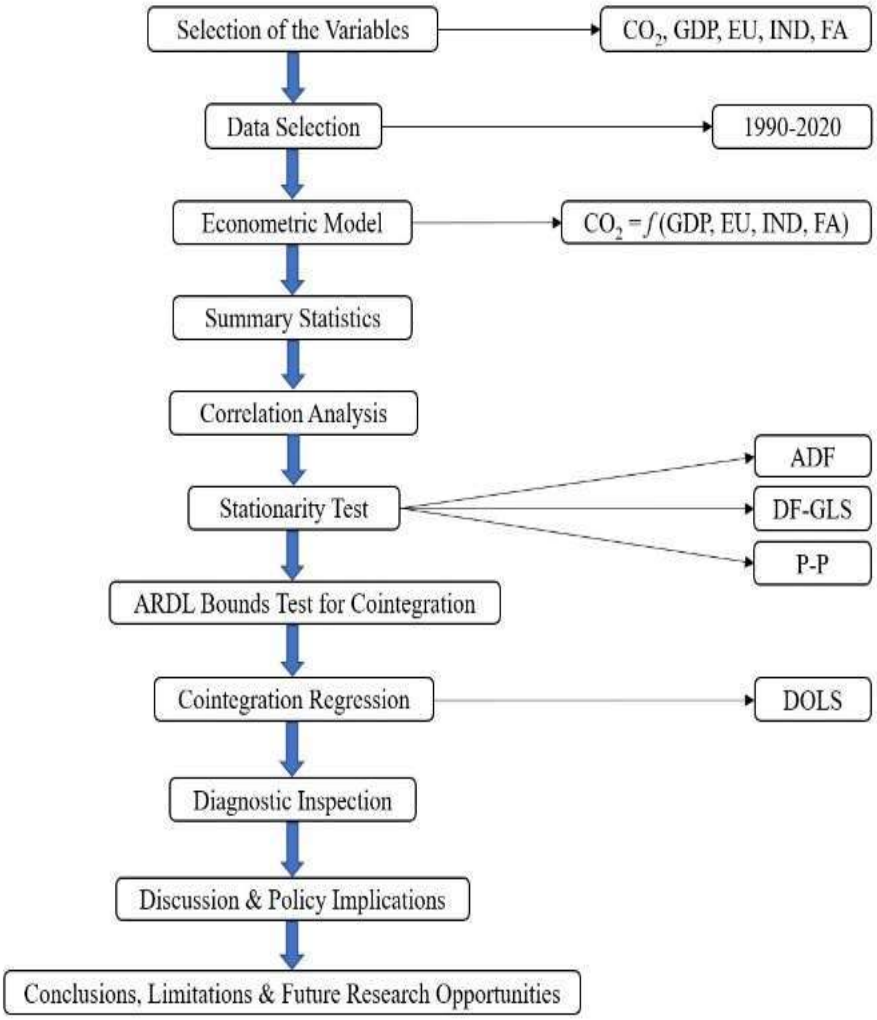


Figure 2. Flow chart of the analysis

Stationarity techniques for data

Using a unit root test is crucial for preventing erroneous regression. By differentiating the variables in a regression, this method ensures that they are stationary and that only stationary processes are used to estimate the equation of interest (Raihan et al., 2022b). For a full understanding of cointegration among variables, the empirical literature recognizes the importance of first defining the sequence of integration. Some research suggests that, due to the unit root tests' varying efficacy depending on sample size, it is essential to use multiple unit root tests when assessing the integration order of the series (Raihan et al., 2022c). Specifically, the Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1979), the Dickey-Fuller generalized least squares (DF-GLS) test proposed by Elliott et al. (1996), and the Phillips-Perron (P-P) test proposed by Phillips and Perron (1988) were all used to identify the autoregressive unit root. To ensure that no variables went outside the sequence of integration and to back the DOLS technique above conventional cointegration methods, the unit root test was used.

ARDL bounds test

To identify the presence of cointegration between the series, we used the ARDL bounds test suggested by Pesaran et al. (2001). When compared to alternative one-time integer approaches, the ARDL bounds test for cointegration valuation stands out as superior. Since the ARDL bounds test does not require that variables be integrated in a particular order, it can be used when series do not follow a uniform sequence of integration. Second, it has far higher reliability, especially for tiny samples. Finally, it provides a reliable forecast of the long-term model. In Equation (6), the investigation provides a snapshot of the ARDL bounds test.

$$\begin{aligned}\Delta LCO2_t = {} & \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LGDP_{t-1} + \tau_3 LEU_{t-1} \\ & + \tau_4 LIND_{t-1} + \tau_5 LFA_{t-1} \\ & + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LGDP_{t-i} \\ & + \sum_{i=1}^{q} \gamma_3 \Delta LEU_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LIND_{t-i} \\ & + \sum_{i=1}^{q} \gamma_5 \Delta LFA_{t-i} + \varepsilon_t \end{aligned} \quad (6)$$

where Δ is the first difference operator and q is the optimum lag length in Equation (6).

Critical values were proposed by Pesaran and Timmermann (2005) based on the F-distribution and the ARDL bounds test. The F-test is used to assess the joint significance of the coefficients of the lagged variables, and the estimating method begins with Equation (6) through the use of OLS. With this method, the present research conducted a test for a potential link between the factors across time. According to the null hypothesis (H_0), the regressors do not exhibit any cointegrating correlations. F-statistics can be compared to upper and lower bounds' critical values, just like in Pesaran et al. (2001). If the F-statistic is above the upper critical value, suggesting the presence of a long-term connection between the variables, the null hypothesis is rejected. However, if the F-statistics are less than the lower critical value, the null hypothesis is accepted. If the observed F-statistics fall between the lower and upper crucial values, the test results are inconclusive.

DOLS cointegration regression

To examine the time series data, the DOLS method (which stands for "discounted" or "extended" ordinary least squares estimation) was used. In the DOLS cointegration test, explanatory variables and the leads and lags of their initial difference terms are incorporated into the covariance matrix of errors, which is then used to regulate endogeneity and calculate standard deviations (Raihan et al., 2022d). The orthogonalization of the error term is shown by the inclusion of the leading and trailing terms of the individual ones. The standard deviations of the DOLS estimator have a normal asymptotic distribution, hence it can be used as a trustworthy test of statistical significance (Raihan & Tuspekova, 2022d). The DOLS method is useful for estimating the dependent variable on explanatory variables in levels, leads, and lags when a mixed order of integration occurs, hence allowing for the integration of individual variables in the cointegrated outline (Raihan & Tuspekova, 2022e). The mixed order integration of individual variables in the cointegrated outline is the primary benefit of the DOLS estimation. Some of the other variables in the regression were also I(1) variables with leads (p) and lags (-p) of the initial difference, while some of the other variables were I(0) variables with a constant term. This estimate eliminates problems of small-sample bias, endogeneity, and autocorrelation by summing the leads and lags among explanatory factors (Raihan et al., 2022e). In any case, after ensuring that the variables are cointegrated, the study employed Equation (6) to estimate the long-run coefficient via the DOLS method.

Results and Discussion

Summary statistics

The outcomes of the summary processes between variables, as well as the results of many normality checks, are displayed in Table 2 (skewness, probability, kurtosis, and Jarque-Bera). Russia's annual data from 1990 to 2020 was sampled 31 times for each indicator. The skewness estimates close to 0 indicate that all of the variables are normal. Furthermore, kurtosis was employed to distinguish between light-tailed and heavy-tailed series by comparing them to a normal distribution. The

empirical data shows that all sets are platykurtic, with outcomes less than 3. Moreover, the Jarque-Bera probability calculations show that all of the variables are normally distributed.

Table 2. The statistical summaries of the variables

Variables	LCO2	LGDP	LEU	LIND	LFA
Mean	14.32248	31.82020	8.468984	3.490481	15.91002
Median	14.29660	31.89751	8.480330	3.458845	15.91009
Maximum	14.58725	32.14842	8.689731	3.825699	15.91391
Minimum	14.21292	31.36367	8.289414	3.329756	15.90608
Std. Dev.	1.775874	0.265915	0.103370	0.136920	0.003345
Skewness	0.091417	-0.378472	0.171201	0.142473	-0.016803
Kurtosis	2.556251	1.638359	2.318753	2.353489	1.219451
Jarque-Bera	2.473456	1.134916	0.750893	1.905167	1.096499
Probability	0.782478	0.108575	0.686983	0.131664	0.128960
Sum	443.9968	986.4264	262.5385	108.2049	493.2105
Observations	31	31	31	31	31

Correlation analysis

Table 3 displays the results of the correlation analysis performed on the aforementioned set of variables. The analysis shows that there are correlations between all of the factors. All four of these variables (LCO2, LGDP, LEU, and LIND) show a positive correlation with each other, suggesting that if the value of one grows, the value of the other tends to rise as well. However, LFA has a negative correlation with every other variable, showing that an increase in forest area results in a decrease in the value of every other variable. This investigation proceeded to conduct unit root tests to ensure the variables were stationary based on the results of the correlation analysis.

Table 3. Correlation analysis findings

	LCO2	LGDP	LEU	LIND	LFA
LCO2	1.000000	0.387160	0.762947	0.727599	-0.345612
LGDP	0.387160	1.000000	0.741559	0.890743	-0.420815
LEU	0.762947	0.741559	1.000000	0.631718	-0.494849
LIND	0.727599	0.890743	0.631718	1.000000	-0.726141
LFA	-0.345612	-0.420815	-0.494849	-0.726141	1.000000

Results of unit root tests

Unit root tests have been performed to prove that the DOLS estimation model is preferable to employing only cointegration by ensuring that no parameter exceeds the integration order. Table 4 displays the outcomes of unit root testing with the ADF, DF-GLS, and P-P tests. Level and first-order integration both show that the variable is stationary at the combined levels, hence the DOLS method is superior to the more common cointegration method.

Table 4. Results of ADF, DG-GLS, and P-P unit root tests

Logarithmic form of the variables	ADF		DF-GLS		P-P	
	Log levels	Log first difference	Log levels	Log first difference	Log levels	Log first difference
LCO2	-3.566**	-3.118**	-1.409	-3.338***	-3.406**	-3.323**
LGDP	-0.196	-2.584*	-1.230	-2.438**	-0.858	-2.401*
LEU	-2.080	-3.527**	-1.262	-3.585***	-2.189	-3.461**
LIND	-2.140	-4.064***	-1.098	-4.102***	-3.091**	-5.303***
LFA	-1.423	-2.664*	-1.202	-2.609*	-0.495	-2.773*

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

Results of ARDL bounds test

After verifying the series' stationarity properties, this study employed the ARDL bounds test for cointegration valuation. Based on the minimum values of Akaike's Information Criterion (AIC), the F-statistic was calculated using a suitable lag period in this investigation. The ARDL bounds test, employed to examine the cointegration relationship, yielded the findings shown in Table 5. If the estimated F-test value is larger than both limits, then a long-run connection between the variables is proven by the results (lower and upper bound). The calculated F-statistic value (6.470895) was found to be more than 10%, 5%, 2.5%, and 1% of the critical upper limit in the order zero and one, thereby rejecting the null hypothesis and confirming the existence of a long-run relationship between the variables.

Table 5. Findings from cointegration with ARDL bounds testing

F-bounds test		Null hypothesis: No levels of relationship		
Test statistic	Value	Significance	I(0)	I(1)
F-statistic	6.470895	At 10%	1.92	2.89
K	4	At 5%	2.17	3.21
		At 2.5%	2.43	3.51
		At 1%	2.73	3.90

The results of the DOLS

The DOLS analysis outcomes are shown in Table 6. Assuming all other factors are constant, a 1% rise in economic growth may result in a 0.02% increase in CO_2 emissions, as the expected long-run coefficient of LGDP is positively significant at the 5% level. The findings suggest that further economic growth in Russia won't have much of an effect on the country's carbon emissions in the long run. The green economy concept has the backing of the Russian economy, which is interested in long-term expansion. Russia, in collaboration with international organizations like the United Nations Environment Programme (UNEP), has established a system of environmental institutions and legislative frameworks to promote equitable and sustainable growth. The estimated long-run coefficient of LEU is positive and statistically significant at the 1% level, which indicates that a 1% increase in energy use leads to a 1.13% increase in CO_2 emissions. Pollution, rubbish production, and environmental damage all rise in tandem with the needs of society as a whole, which in turn is driven by the rising use of fossil fuels and the completion of development projects (Raihan & Tuspekova, 2022f). The growth of Russia's economy is essential to ensuring the country has access to the resources it needs to keep producing energy. Increasing Russia's reliance on renewable energy sources instead of fossil fuels would have many positive effects on the country's economy and environment, including fostering growth and reducing pollution, but it would also position the country to take the lead in the international system and increase competition with more developed nations. In addition, the anticipated long-run coefficient of LIND is notably positive at the 5% level, indicating that every rise of 1% in industry value added is related to an increase of 0.23% in CO_2 emissions. According to the findings, rising Russian emissions can be attributed in part to the country's increasing industry. There is concern that industrialization will increase the use of fossil fuels and cause pollution from industrial effluents, hazardous goods, and heavy metals. During the early stages of industrialization, there is a transition from agriculture to heavy manufacturing based on natural resources. These changes are mostly manifested in the scale and composition of production rather than the rate of technological development. As a result, early industrialization has a greater CO_2 emission rate due to the high demand for energy and the lack of energy-saving equipment (Raihan et al., 2022e). Industrialization may undergo shifts as a result of this evolutionary process, leading to less harmful activities and more environmentally friendly manufacturing.

Table 6. DOLS test results: LCO2 is a dependent variable

Variables	Coefficient	Standard Error	t-Statistic	p-value
LGDP	0.021541**	0.131928	1.632824	0.0157
LEU	1.127779***	0.194210	5.807008	0.0017
LIND	0.232016**	0.101611	2.283375	0.0115
LFA	-4.285113***	0.254562	-16.83333	0.0003
C	37.98929	6.047974	6.281325	0.1047
R^2	0.943708			
Adjusted R^2	0.935048			
Standard error of the estimate	0.023298			
F-statistic	108.9690			

Prob (F-statistic)	0.000000
Root mean square error (RMSE)	0.021337
Mean Absolute Error (MAE)	0.017075

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The long-run coefficient of forest area is notably negative at the 1% level, suggesting that a 4.29% reduction in CO_2 emissions is the result of a 1% increase in the forest area. However, the research shows that deforestation, forest degradation, and forest fires account for an additional 4.29 percent of CO_2 emissions in Russia for every one percent drop in forest cover. According to the research, forest ecosystems raise the quality of Russia's environment by removing CO_2 from the air and storing it in the flora and soil of forests. Expanding forest reserves and thus increasing forest carbon sinks reduces environmental degradation in the long run, as shown by empirical research. Forest fire accounted for 52.8 million ha of forest loss in Russia between 2001 and 2021, whereas all other causes accounted for 23.2 million ha. Additionally, due to removing land for agriculture and logging, deforestation in Russia occurs at a rate of roughly 2 million hectares each year. Logging, both legal and illicit, is encouraged by foreign investment, demand for resources, export of wood products, and the substantial profits from forest exports. A major issue of contention in the modern climate science community is the importance of restoring, improving, and protecting forests as a means of reducing greenhouse gas emissions (Raihan & Tuspekova, 2022g). Russia joined more than a hundred other countries in signing the first major agreement of the COP26 international climate conference in Glasgow, which calls for an end to deforestation by the year 2030. The most cost-effective strategy for halting environmental decline and slowing global warming is increasing forest carbon sequestration (Raihan et al., 2019). Carbon sequestration, biodiversity conservation, ecosystem rejuvenation, and societal production of products and services are just some of the many benefits of forestry-based mitigation methods (e.g., forest protection, forest conservation, afforestation, reforestation) (Raihan and Said, 2022). Russia's forestry sector has enormous potential to mitigate global climate change by reducing CO_2 emissions and enhancing forest biomass, so increasing the country's carbon sink, through the widespread implementation of forestry-based mitigation techniques. To sum up, improving forest areas may be an effective method to reduce Russia's carbon emissions. In a nutshell, reducing forest fires and felling, and improving forest management may be effective means of reducing Russia's carbon emissions.

Based on the result, energy consumption and industrialization worsen Russia's environmental quality by increasing CO_2 emissions, while expanding the country's forest cover could help the country achieve environmental sustainability by reducing emissions. Furthermore, the signals of the expected coefficients are identical from both a conceptual and a pragmatic vantage point. In addition, several diagnostic tests were used to assess the goodness of fit of the computed model. First, the obtained regression model fits the data pretty well; the R^2 and adjusted R^2 values are 0.9437 and 0.9350, respectively. That means that the explanatory variables may account for 99 percent of the variation in the predictor variables. Finally, the F-statistic proves that the DOLS model is supported by both the dependent and independent variables. The regression model is statistically significant with a p-value of F-statistic of 0.0000. Third, the root mean square error (RMSE) and the mean absolute error (MAE) were successfully used to estimate the accuracy of the model's predictions. The DOLS modeling yielded findings that were a virtually perfect match to the data, as seen by the RMSE and MAE statistics being close to zero and non-negative. Furthermore, Table 7 displays the results of tests for normality, heteroscedasticity, and serial correlation that were performed to verify the robustness of the cointegration valuation. There is no autocorrelation or heteroscedasticity, as shown by the model, and the data are normally distributed. The CUSUM and CUSUMQ tests, which check for model stability by adding up all the residuals from each iteration, were also used in this inquiry. The cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMQ) graphs at the 5% level of significance are shown in Figure 3. The confidence intervals are depicted as red lines, while the residual values are displayed as blue lines. Results reveal that the values of the studied residuals continue to fall within the 95% confidence interval, indicating that the model is robust.

Table 7. Results from diagnostic tests

Diagnostic tests	Coefficient	p-value	Decision
Jarque-Bera test	1.239507	0.2034	Residuals are normally distributed
Lagrange Multiplier test	1.998602	0.4473	No serial correlation exits
Breusch-Pagan-Godfrey test	2.530813	0.1109	No heteroscedasticity exists

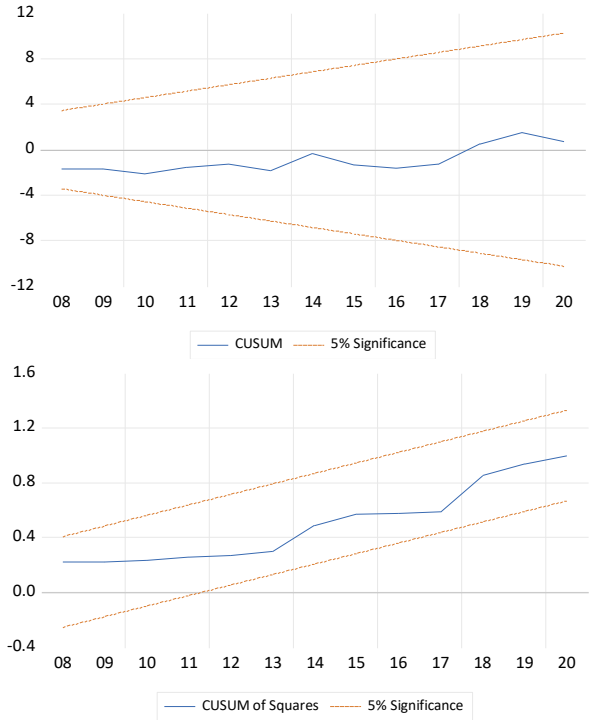


Figure 3. Graphical representations of the CUSUM and CUSUMQ tests (critical boundaries at the 5% level of significance)

The findings of this study suggest that the Russian government should implement an environmental management system to reduce CO_2 emissions and keep economic growth on track. The transition to a low-carbon economy is the best hope for Russia to combat climate change. The study suggested that the government aid markets by adopting strict regulation that boosts emission reduction goals over the long term and consistently backs cleaner output with carbon-reducing technologies. To reduce carbon dioxide emissions from burning fossil fuels for electricity generation and other industrial uses, the Russian government can enact regulations like high carbon taxes, carbon capture and storage, and emission trading schemes. In addition, encouraging the economic move to renewables is vital for reducing environmental impacts associated with economic growth. By replacing traditional energy sources that produce a lot of carbon dioxide, these measures would boost economic growth and increase the use of renewable energy in total energy consumption. Using renewable energy sources for energy production is essential for guaranteeing sustainable development and reducing the effects of climate change. Wind, hydro, geothermal, biomass, and solar energy are only a few examples of Russia's abundance in renewable energy sources, in addition to oil, gas, and coal. However, at the moment, fossil fuels account for the vast majority of Russia's energy consumption, while the country's immense and varied renewable energy resources are underutilized. Due to growing international concern for the environment, it is urgent that Russia make the transition to renewable energies. This will allow for the creation of a more eco-friendly economy. Russia may be able to grow its renewable resources in a decisive manner and create networks of technical assistance with other countries. Increased government funding would do wonders for the spread of renewable energy. Renewable energy can assist to reduce emissions, thus Russia may implement policies to lower the cost of renewable energy while restricting the use of fossil fuels in industry, businesses, and homes. It's possible that the government may use the media to spread the word about its green lifestyle concept and encourage people to adopt low-carbon ways of living and consumption habits.

Findings from this study suggest that industrialization is a critical issue that needs to be emphasized while creating sustainability programs. To maintain economic growth through cleaner production while decreasing CO_2 emissions, the industrial structure must be appropriately modified and optimized. The Russian government should require polluting industries with a track record of endangering public health to implement stringent pollution control measures. Moreover, in order to adopt greener production and industrialization strategies, international investors must adhere to restrictions and constraints. For green industrialization to take place, consumption and production of energy, especially the use of renewable energy, must be sustainable. In addition, the authority may employ administrative measures to strengthen the reformation of heavy and high-emissions firms, all while fostering zero- and low-emissions industries by bolstering industrial diversification. For a more hygienic production system, it is imperative that environmentally sound methods be mandated across the board in industry, and that older, more polluting technologies be phased out entirely. In addition, the government may provide funding to businesses for the purchase of emission-control equipment. Politicians may impose ecological taxes on sectors that don't embrace environmentally friendly technologies. Further, both public and private R&D establishments are required to create cutting-edge technology for reducing pollution and promoting the use of recycled industrial waste as an energy source, thus reducing emissions.

Specifically, this research found that reducing CO_2 emissions through forest development could be a priority for Russian policymakers seeking to create environmentally sound and climate resilient policies. With the goal of lowering carbon dioxide emissions and raising forest biomass through protection and conservation, the Russian government may raise investments while creating stringent forest legislation. By creating commercial forest plantation areas, the government can further encourage private sector participation in sustainable forest management. Forest conservation, forest protection, afforestation, reforestation, sustainable forest management, enhanced natural regeneration, and similar forestry-based mitigation strategies have the potential to strengthen Russia's capacity to mitigate climate change by increasing forest carbon sinks. The Russian government may

increase investment and implement strong forest laws and policies to limit CO_2 emissions from deforestation and forest fires. For Russia to preserve its biodiversity, forest fires and deforestation must be prevented at all costs. Last but not least, if Russia's forestry policy were to be put into action as intended, the country might achieve net zero emission status by increasing its national carbon sink, fostering national green growth, and ensuring the sustainable management of its forest ecosystems.

Conclusions

This study utilized time series data from 1990 to 2020 to analyze the dynamic effects of Russia's energy consumption, industrialization, and forest area on the country's CO_2 emissions. In this research, the integration order of the dataset was determined using the ADF, DF-GLS, and P-P unit root tests. In addition, there was long-run cointegration among the variables, as shown by the ARDL bounds test. The DOLS model was used to determine how environmental influences had an impact over time. According to the estimates, a 1% increase in Russia's GDP, energy consumption, and industrialization will lead to a 0.02%, 1.13%, or 0.23% increase in the country's CO_2 emissions. The reduction in carbon dioxide emissions of 4.29% is another way in which an increase of just 1% in forest area improves environmental quality. The findings illuminated the potential for Russia to achieve environmental sustainability through the utilization of renewable sources and forest land. Further, the findings suggested approaches in which Russia could move toward sustainable development by way of bolstering regulatory policy instruments meant to slow down the rate at which the environment degrades. Additional growth variables, such as trade openness, financial development, foreign direct investments, urbanization, institutional quality, globalization, technology innovation, natural resources, ecological footprint, etc., can be taken into account in future studies. However, CO_2 was used in this study to represent environmental deterioration. Carbon emissions from consumer activities are one proxy for environmental degradation; other emissions that could be studied to better Russia's environment include nitrous oxide (N_2O), sulfur dioxide (SO_2), methane (CH_4), carbon monoxide (CO), ground-level ozone (O_3), hydrogen sulfide (H_2S), and other short-lived climate forces (SLCF). Even though CO_2 emission is not the only source of environmental damage, it was used as a stand-in in the present investigation. Future research for the instance of Russia could include additional environmental contamination indicators, such as water pollution and land pollution.

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RESEARCH ARTICLE

Innovations, energy consumption and carbon dioxide emissions in the global world countries: An empirical investigation

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Abstract
Technological innovations are the important sources of economic growth of a country and it is inter associated with other factors such as energy consumption, economic growth and carbon dioxide emission. A change in these factors affect the capability of technological innovation and thus the effect of these factors on innovations need to be explored. This study investigates the effect of carbon dioxide, energy consumption and economic growth on innovations proxies by different innovations indicators. The sample data is collected from 1980 to 2019 of the world 181 countries and OLS, fixed effect, two step Generalized method of moments and panel quantile regression models were employed for data analysis. The results reveal that carbon dioxide and economic growth increase technological innovations while the inflow of FDI decrease innovations output. Energy consumption also negatively affects innovation indicators except for research and development. In the case of quantile regression, energy consumption is positive while carbon dioxide and foreign direct investment are negative across different quantiles for research and development. Energy consumption and foreign direct investment reduce technological innovations proxy by patent application residents while carbon dioxide and economic growth increase it. The findings of this study have considerable policy suggestions for the global countries.

Keywords: Innovations; carbon dioxide emission; energy consumption; economic growth

Introduction

Improved level of innovations help acquiring the sources of renewable energy, rise energy efficiency in production and reduce carbon emissions which can leads to sustainable development. Innovations improvement is important to increase economic growth (Aghion & Howitt, 1990), however the innovations determinants such as such as energy consumption, economic growth, foreign direct investment and carbon dioxide emission need investigation to identify its role in innovation output as a change in these factors affect the capability of technological innovation. Due to the importance of innovations in economic growth, researchers have focused to investigate the determinants of innovations which indicate that an increase in research and development cannot be the only source to enhance technological innovation while technology transfer and spillovers, international trade, education, institutions and foreign direct investment (Chunying, 2011); (Varsakelis, 2006); (Furman, Porter, & Stern, 2002), however, some other researchers believes that there is no association between foreign direct investment and technological innovation (Yang & Qi, 2001); (Haddad & Harrison, 1993). However, several others argue that technological innovation negatively affects foreign direct investment when it is below the level threshold while positive when it is above the threshold level (Loukil, 2016). The empirical literature has not considered carbon emission and energy consumption in such a case however, it is commonly believed that technological innovation affects energy consumption, economic growth, foreign direct investment and environmental quality. Such investigation has not been done which investigated the effect of carbon dioxide, energy and foreign direct investment on technological innovation. Both foreign direct investment and technological innovations are linked such as innovation facilitates foreign direct investment while foreign direct investment brings new management skills, new technology and capital that affect

the level of innovation. Energy is used for production and other economic activities such as foreign direct investment which in turn boosts economic growth thus a rise in the use of energy, foreign direct investment and economic growth increase carbon dioxide emission. However, this effect can be varied in different countries due to different environmental regulations, the level of energy use and foreign direct investment. Innovations are required in these activities such as a rise in innovation level facilitated foreign direct investment, raising energy efficiency and increasing economic growth while these factors in turn influence technological innovations. Consequently, it is important to study the effect of foreign direct investment, carbon emission and economic growth on technological innovation. Based on the above discussion and statements, we believe that such a complex study has not been done in prevailing literature however, some studies have only considered the effect of foreign direct investment or economic growth on technological innovations. Likewise, commonly used proxies of innovations such as patent application residents or high technology export are used however this study used four indicators to proxy for technological innovations. Similarly, carbon dioxide, energy consumption, and foreign direct investment have not been taken in the same study to examine their impact on technological innovation as these factors are very important to each other. By considering all these factors this study, it will deeply examine the effect of these variables on each indicator of technological innovations which has not been attempted before. Consequently, this study examines the effect of carbon dioxide, energy consumption and foreign direct investment on technological innovation indicators by considering other most important factors in a sample of 179 global countries. Dynamic panel models and panel quantile regression were used to investigate this association both in a dynamic way and its effect on technological innovation across different quantiles to achieve the most efficient results. The findings confirm that all proxies of innovation are negatively affected by foreign direct investment while it's been increased by carbon emission and economic growth. Energy consumption is also negatively related with all proxies except research and development while trade is negatively related with patent applications nonresidents and positive with all other proxies of innovation. The quantile regression results indicate that foreign direct investment negatively affects patent applications nonresidents in the first quantiles while insignificant at the highest quantile whereas carbon dioxide emission and financial development are strongly positive and increase innovations proxy by patent applications nonresidents. Energy consumption and trade are negative while economic growth is positive across quantiles for patent applications nonresidents. Foreign direct investment and carbon dioxide are negative across different quantiles for research and development while financial development and energy consumption are positive. Trade is also negatively related to research and development while economic growth is insignificant. Foreign direct investment, trade and energy consumption are negatively related to patent applications residents while carbon dioxide and financial development are positive. Likewise, economic growth is positively related to patent applications residents in the middle quantiles. In the case of technology, foreign direct investment, financial development, energy consumption, and trade are positive while carbon dioxide is negative in the first few quantiles and positive in the highest quantile for technology. Such analysis in the previous studies has not been done while our findings are very beneficial for the sample countries regarding technology, innovation, enhancing economic growth and environmental policies as well foreign direct investment attraction.

The remaining parts of the study are structured as follows; section 2 is composed of a literature review, part 3 present the variables and methods, section 4 presents discussions and results while section 5 gives recommendation, suggestions and conclude the study.

Literature review

In preceding literature, a large number of researchers explore the effect of technological innovations, foreign direct investment, energy consumption and related factors on carbon emission however the effect of these factors on technological innovation is limited. Even in some studies conducted in the preceding literature on the impact of these factors on innovation or technology but with little accord such as the previous studies have used some commonly used indicators of innovation or have to find the effect of single factor on innovation such as foreign direct investment. For example, a study conducted by (Adikari, Liu, & Marasinghe, 2021) examine the relationship between foreign direct investment and innovation in Sri Lanka for the period 1990 to 2019 using the ARDL model. The authors illustrate that there was a negative effect of foreign direct investment on innovations however education and research and development were positive. The authors claim that research and development are vital factors that effectively explain technological innovation. Similarly, (Chunying, 2011) investigated the technological from and foreign direct investment nexus in China from 1987 to 2009 by using the quantile regression method. The results of their study show that foreign direct investment positively affects technological innovation in China at the bottom distribution while this effect was found negative at the top conditional distribution. They further indicate the low-level effect of foreign direct investment on only low-level innovations while the negative role of foreign direct investment on high-level technological innovation. In the case of developing and emerging countries, financial development has also been considered as (Loukil, 2020) examined the financial development effect on innovation in developing and emerging countries from 1980 to 2009. The author found that there is a nonlinear effect between innovation and

financial development. They found that there is a threshold value of economic growth below, the effect of financial development on innovation was insignificant, while the effect is positive of financial development on economic growth above the threshold value. Their findings suggest that financial institutions can promote innovations in presence of healthy economic development. The effect of foreign direct investment on technological innovation in Chinese provincial data from 2009 to 2018 is studied by (W. Li, 2021). The authors used a threshold regression model where the results show that regional innovation capability intellectual property intensity is significantly affected by foreign direct investment. They further indicate that foreign direct investment maximizes regional innovations capability when the intellectual property protection intensity is maintained near the level threshold. Likewise, another study also considered the effect of foreign direct investment on innovation. (Loukil, 2016) studied the developing countries' foreign direct investment and innovations from 1980 to 2009. The study also uses the threshold model and found that foreign direct investment has a negative effect on innovation below the threshold while positive when the value is above the threshold value. They indicate that such a level of innovation is not enough for economic policy to attract foreign direct investment. (Wang, Liu, & Wang, 2021) studied the technological innovation effect in China enterprises produced by Foreign direct investment from 2015 to 2017. They found that improvement in Foreign direct investment activities in Chinese enterprises promotes the level of technological innovations. They further indicate that the research and development-related activities of Foreign direct investment perform a very active role in promoting the enterprises' technological innovation ability. Likewise, economic growth has also been added to such associations as (Pala, 2019) studied economic growth and technological innovation in 25 developing countries and employed a random coefficient model to the data for analysis. The authors found that economic growth is affected negatively by research and development in some of the sample countries while positive in a group of some countries. On the other hand, several studies indicate that there is an association between carbon dioxide, foreign direct investment, economic growth and technological innovation as a study on the linkage between foreign direct investment, technological innovation and economic growth is conducted by (Sheng Yin & Hussain, 2021). The study findings reveal that these indicators positively affect economic growth and foreign direct investment. They also argue that economic growth, foreign direct investment and tourism were also the positive factors contributing to the ecological footprint. They further confirm the two-way casual association between tourism and ecological footprint, technological innovation and ecological footprint, and a one-way casual association between technological innovation, foreign direct investment inflow, and tourism. A similar study is conducted by (Sheng, Miao, Song, & Shen, 2019) who examined the linkage between innovation, carbon emission, and urbanization in 48 cities in China from 2001 to 2015 using a spatial econometric model. They found a U-shaped and N-shaped curve across different cities and found that innovation positively affects the carbon dioxide reduction in some of the cities while this effect is insignificant in some of the sample cities however they confirm that innovation play moderating role between carbon emission and urbanization. (Uddin, Pan, Saima, & Zhang, 2021) considered the changes in socio-economic factors and examine the effect of energy intensity and technological innovations in 23 countries of Europe. By using threshold regression, the authors found that both stock and banks affect energy intensity and rely on the level of technological innovations. Likewise, (Hu et al., 2021) studied the effect of innovation and economic openness on the environment for the period 1990 to 2014 in Asian countries. By using dynamic and fully modified OLS estimators, the authors found that energy consumption and trade openness increase the level of emission while GDP, foreign direct investment, and patents depress carbon dioxide emission in Asian countries. Likewise, different proxies for innovation have been used and found its impact on economic growth as (Pece, Simona, & Salisteanu, 2015) studied the long-term effect of innovation on economic growth. They used multiple regression models and investigated such associations in CEE countries. The authors found that innovation and economic growth were positively linked. The effect of technology innovation on carbon emission was also studied by (R. Li, Lin, Jiang, Liu, & Lee, 2021) in 66 countries considering economic development in this association. The authors show that the relationship between technological innovations and carbon dioxide was U-shaped and this relationship was positively and negatively affected by economic development cases when economic growth crosses the threshold level. The authors found both N and U-shape correction in the sample of OECD and High-income countries and argue that technological innovations and advancement have a dynamic influence on carbon emission in a different sample of countries.

Methodology

This study examines the effect of foreign direct investment, carbon emission, and economic growth on technological innovation in the global panel of 179 countries from the period of 1980 to 2019. The baseline model is as follows;

$$TIN_{it} = \beta_0 + \beta_1 TIN_{it-1} + \beta_2 FDI_{it} + \beta_3 CO2_{it} + \beta_4 GDP_{it} + \beta_5 FND_{it} + \beta_6 ENR_{it} + \beta_7 TO_{it} + \varepsilon_{it} \quad (1)$$

In equation 1 given above, TIN represents technological innovation proxy by four innovation indicators, FDI represent the inflow of foreign direct investment taken as a

percent of GDP, CO2 is carbon dioxide emission (metric tons per capita), GDP is per capita gross domestic product used to represent economic growth, FND is financial development proxy by domestic credit to the private sector by the bank as % of GDP, and TO represents international trade. Four indicators are used to proxy innovations that include patent application residents (number per thousand population) (Wusiman & Ndzembanteh, 2020); (Rodríguez-Pose & Wilkie, 2019). The second indicator of innovation is patent application nonresidents (number per thousand population). This proxy is used by (Qamruzzaman, Tayachi, Mehta, & Ali, 2021). Likewise, the third proxy is research and development expenditure (percentage of real gross domestic product). This proxy is recently used by (Coluccia, Dabić, Del Giudice, Fontana, & Solimene, 2020); (Knott & Vieregger, 2018) ; (Chunying, 2011; Maradana et al., 2017). The fourth indicator of innovation in our study is high-technology exports (percentage of real gross domestic product). Descriptive statistics and variables are shown in Table 1 while the correlation matrix is given in Table 2.

The study use OLS, Fixed effect, Generalized method of moments (GMM) and panel quantile regression for data analysis. The reason for using several estimators is to compare our results with previous studies while the main focus of this study will be based on system GMM and quantile regression. We use the OLS estimator as a basic econometric technique and compare its results with quantile regression and the system GMM model. Static models that induced OLS and fixed effect t may lead to several econometric issues and thus may give inefficient results. (Arellano & Bond, 1991) developed two steps Generalized method of moments estimator and further developed by (Blundell & Bond, 1998) is finally considered for analysis to control for endogeneity in our regression model. two-step model is considered more efficient compared to a one-step GMM(Law & Azman-Saini, 2012) and thus we focus on a two-step estimator. The system GMM estimator is based on additional conditions as it adds equations in level to the equation of first difference and the explanatory variables lagged difference as instruments (Bond, Hoeffler, & Temple, 2001). The system GMM works to combine the set of all previous equations into levels. (Blundell & Bond, 1998) present that difference estimators have persistence in the lagged dependent variables and that's why they may perform not well. (Arellano & Bover, 1995) proposed a system GMM estimator which has been considered to perform better than the first difference estimator (Blundell, Bond, & Windmeijer, 2001). It's also explained the time-series variation and accounts for individual unobserved country-specific effects. It's also included the dependent variable as independent and better control endogeneity of independent variables (Beck et al. 2007). The method is recently used by (Johansson & Wang, 2012), (Khan, Weili, Khan, & Khamphengxay, 2021); (Seven & Coskun, 2016); (and Khan, Weili, & Khan, 2021). In addition, to validate our instruments, we use the standard Hansen/Sargan test. The null hypothesis states that the instrumental variables do not correlate with residuals. Moreover, we conduct the serial correlation test (AR2), whose null hypothesis states that there is no second-order serial correlation between error terms.

The baseline model for system GMM can be stated as follows;

$$TIN = \beta_0 + \beta_1 TINV_{it-1} + \beta_2 Y_{it} + \beta_3 X_{it} + \varepsilon_{it} \dots\dots\dots\dots\dots\dots (2)$$

Where TIN is innovation, TINit-1 is the lag dependent variable, Y represents explanatory variables, X represent control variables *and* ε is the error term.

Table.1. Descriptive statistics

Variable	Description	Mean	Std. Dev	Min	Max
FDI	Foreign direct investment	5.095	38.537	-1275.19	1282.633
GDP	Economic growth	1.842	6.006	-64.992	140.367
PT1	Patent application residents	10691.75	64078.21	1.000	1393
PT2	Patent application nonresidents	4926.64	21020.49	1.000	336
RD	Research and development	0.938	0.946	0.005	4.952
TECHNOLOGY	High technology export	10.706	11.492	0.0001	78.476
CO2	Carbon dioxide emission	4.488	7.914	0.0001	266.483
FND	Financial development	38.904	35.27	0.001	304.575
ENR	Energy consumption	2404.708	2951.99	9.548	28902.85
TO	International trade	81.98762	49.836	0.02	437.326

Table.2. Correlation matrix

Variables	FDI	PT1	PT2	RD	Technology	CO2	GDP	FND	ENR	TO
FDI	1.0000									
PT1	-0.0585	1.0000								
PT2	-0.0567	0.7242	1.0000							
RD	-0.0872	0.3385	0.2916	1.0000						
Technology	0.2534	0.2249	0.1976	0.3599	1.0000					
CO2	0.0436	0.2215	0.3236	0.4597	0.1996	1.0000				
GDP	-0.0428	0.0932	0.0409	-0.1999	-0.0294	-0.1658	1.0000			
FND	0.2462	0.1522	0.0258	0.5001	0.4556	0.2897	-0.2730	1.0000		
ENR	-0.0040	0.0987	0.1861	0.5044	0.2579	0.6802	-0.1773	0.3545	1.0000	
TO	0.2693	-0.2004	-0.2099	0.0160	0.3495	0.2649	0.0343	0.1268	0.1931	1.0000

In addition, we used quantile regression to evaluate the concomitant relationship in the conditional distribution. (Balsvik & Haller, 2011) also used quantile regression to investigate the effect of foreign direct investment on innovation. The choice of quantile regression methods is also inspired by existing non-contemporary and contemporary studies that show the importance of using empirical strategies to clarify countries with different levels of outcome variables (Roger Koenker & Gilbert Bassett Jr, 1978); (Tchamyou & Asongu, 2017). Compared with alternative techniques based on the average of outcome variables, these studies acknowledge that the methods are also consistent in their robustness in providing conditional survey results. These alternative methods provide survey results with comprehensive policy implications (Koenker & Ng, 2005); (Okada & Samreth, 2012); (Hao & Naiman, 2007); (Asongu & Odhiambo, 2019). Using traditional regression methods may result in overestimation or underestimation of correlation coefficients, or may fail to successfully detect important relationships because these techniques focus on average effects (Binder & Coad, 2011). Panel quantile regression was introduced by (R Koenker & G Bassett Jr, 1978) in their seminal work. Quantile regression in redistribution is more robust, but it cannot deal with heterogeneity that is not observed in a country. Therefore, the current paper uses panel quantile fixed effects to examine conditional heterogeneity and unobserved individual heterogeneity. (Lamarche, 2010) and (Galvao Jr, 2011) have considered econometric theory to apply quantitative regression to panel data. The generalized form of the median regression analysis for other quantiles can be expressed in the following form in equation 3, while the fixed effect panel quantile regression can be explained as in equation 4;

$$Q_{yi}(\tau \mid x_i) = x_i^T{}_{\beta_\tau} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

$$Q_{yi}(\tau_k \mid \alpha_i x_{it}) = \alpha_i + x'_{it}(\tau_k) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

There is a major problem with fixed-effect panel quantile regression. The existence of a large number of fixed-effects is due to incidental parameter problems (Lancaster, 2000); (Neyman & Scott, 1948). When individuals tend to infinity, there will be inconsistencies, but each cross-section has a fixed observation value. The purpose of the fixed effect is to eliminate the unobserved effects of the fixed effect. These methods are expected to be linear and its not the reason of conditional quantiles (Canay, 2011). In order to overcome with these problems, (Koenker, 2004) proposed a method which deals with the unobserved fixed effects. The author fixes this with parameters and estimates them collectively with the covariate effects of different quantiles. Penalty term is used in this problem of calculation is minimized of estimated parameter. The calculation meted of parameter estimation is as follows;

$$\min_{(\alpha,\beta)} \sum_{\mathrm{k}=1}^{K} \sum_{t=1}^{T} \sum_{i=1}^{N} w_k P_{\tau k}\left(y_{it} - \alpha_i - x_{it}^T \beta(\tau_k)\right) + \lambda \sum_{I}^{N} \mid \alpha_I \mid, \dots\dots\dots\dots (5)$$

In the given equation, the country (N) index is represented by I where T, *K* represent the number of country observation in the quantile index. Likewise, x represents the explanatory variables matrix and P_{tk} is the quantile of the loss function. W_k given in the equation is the *k-th*, the weight of the quantile is used to control the contribution of the *k-th* quantile to the fixed effect estimate. Equal weight quantile in this research is focused which is given by (Alexander, Harding, & Lamarche, 2011). In addition, λ represents the tuning parameter which is used to improve the β estimation and reduce individual effects to zero. When λ becomes zero, the penalty term will disappear, and then the usual fixed effect estimator can be obtained. However, if the λ term tends to infinity, we will get model estimates without individual influence. The current paper λ has been set equal to 1 (Damette & Delacote, 2012). The specification of the τ quantile function of the baseline model variables in the current research can be as follows:

$$Q_{yi}(\tau \mid \alpha_i, \xi_t, x_{it}) = \alpha_i + \xi_t + \beta_{i\tau} TINV_{it} + \beta_{2\tau} fdi_{it} + \beta_{3\tau} CO2_{it} + \beta_{4\tau} GDPPC_{it} + \beta_{5\tau} FND_{it} + \beta_{6\tau} ENR_{it} + \beta_{7\tau} TO_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where *i* represent countries, time is t, y_{it} is the indicator TIN, the description of all other symbols is given above.

Results and Discussions

Results of OLS and fixed effect models

Table 3 present the results of OLS and fixed effect models. We don't explain the results of OLS and FE in detail because we use these two estimators just for comparison purposes with our targeted econometric models and compare our results with previous studies. As discussed in the methodology section that OLS or fixed-effect models may lead to several econometric problems and may give unreliable and inefficient results. That's why our main focus is system GMM and Quantile regression models and we consider the findings of these estimators.

The effect of foreign direct investment on patent applications nonresidents in both models is significant while carbon dioxide is positive only in OLS model. The estimated coefficient of financial development and economic growth are significant and positive in OLS model while the coefficient are insignificant in fixed effect estimator. The effect of energy consumption and international trade exert significant but negative effect on patent application shown by their estimated coefficients in OLS model however the sign in the fixed effect model is positive. The estimated coefficient of foreign direct investment in OLS and fixed effect are negative significant indicates that foreign direct investment reduces research and development while the effect of carbon dioxide on research and development in both models are positive which shows that carbon dioxide increases research and development. Economic growth is negative in fixed effect while positive in OLS, financial development is positive significant both in OLS and fixed effect model which indicates that financial development significantly and positively affects research and development. Energy consumption positively affects research and development in the OLS model while trade positively affects research and development in fixed effect and negatively and significantly in the OLS model.

Table 3: OLS and FE results

	PT2		RD		PT1		Technology	
VARIABLES	OLS	FE	OLS	FE	OLS	FE	OLS	FE
FDI	-6.220	5.352	-0.004***	-0.000***	-175.0**	-30.82*	0.032**	0.007*
	(25.66)	(19.79)	(0.000)	(0.000)	(69.31)	(49.33)	(0.014)	(0.008)
CO2	2,254***	375.6	0.004***	0.028***	4,131***	6.485***	-0.147	1.310***
	(157.4)	(299.5)	(0.006)	(0.007)	(392.5)	(709.9)	(0.105)	(0.322)
GDP	449.5***	-82.35	0.000**	-0.006***	1,093***	-184.5	0.188**	0.010
	(97.37)	(66.13)	(0.005)	(0.001)	(244.8)	(155.9)	(0.091)	(0.049)
FND	39.59***	8.734	0.009***	0.002***	382.8***	133.6***	0.109***	0.040**
	(11.11)	(12.75)	(0.000)	(0.000)	(27.85)	(29.75)	(0.008)	(0.016)
ENR	-0.837**	1.267**	0.000***	-1.380	-4.024***	3.607***	0.000**	-0.002***
	(0.334)	(0.580)	(1.480)	(1.300)	(0.826)	(1.356)	(0.000)	(0.000)
TO	-116.6***	77.72***	-0.001***	0.004***	-274.7***	65.19	0.042***	-0.008
	(8.324)	(17.34)	(0.000)	(0.000)	(20.78)	(40.90)	(0.006)	(0.016)
Constant	2,444***	5,20***	0.143***	0.312***	-525.2	40,512***	-0.458	10.04***
	(852.3)	(1,847)	(0.0499)	(0.064)	(2,158)	(4,413)	(0.824)	(2.801)
Obs	2,339	2,339	1,318	1,318	2,242	2,242	819	819
R-squared	0.211	0.019	0.437	0.162	0.194	0.084	0.314	0.059
N.ID		120		117		116		119

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The effect of foreign direct investment on patent applications residents is negative significant both in OLS and fixed effect model while the effect of carbon dioxide is positive significant both in OLS and fixed effect model which indicates that foreign direct investment reduces and carbon dioxide increases patent applications, residents. Economic growth and financial development significantly and positively affect patent applications residents in the OLS model while economic growth is insignificant in the fixed-effect model. Energy consumption and trade are positively significant in fixed effect while negative significant in OLS. The coefficients of foreign direct investment and financial development are positive significant both in OLS and fixed effect indicating that these

two variables significantly increase technology while carbon dioxide is positively significant in fixed effect and insignificant in OLS. Economic growth positively and significantly increases technology in OLS while the coefficients are insignificant in fixed effect. Energy consumption is positive and negative in OLS and fixed effect respectively while trade is positive in OLS and insignificant in the fixed-effect model.

Two-step system GMM results

Table 4 presents the two-step system GMM results on the effect of explanatory variables on technological innovation. The results indicate that the estimated coefficient of foreign direct investment is negative and significant for all dependent variables. The results indicate that foreign direct investment reduces innovations in the sample countries. More specifically, the findings show that if there is a percent increase in foreign direct investment will reduce patent application nonresidents by 0.515, patent application residents by 1.04, research and development by 0.01 and high technology export by 0.011 percent. Our results are reinforced by the findings of (Loukil, 2016). (Adikari et al., 2021) also found the negative effect of foreign direct investment on innovation in Sri Lanka which is similar to our findings. Foreign direct investment can bring advanced technology and spillover effects which can enhance innovations however it may still be below the desired level in some countries in the panel that reduces innovation levels such as low income or developing countries. These countries' innovations are negatively affected by foreign direct investment as these countries are forced only on rising economic growth to enhance their living standard thus they are not yet in a position to focus on advanced level technology transfer of foreign direct investment to rise innovations. (Berger & Diez, 2008) argues that foreign direct investment affects technological advancement through strategic impact, human resource development and forward and brain-led information diffusion. Our sample countries, there include lower-income and developing countries that may still attract foreign direct investment to enhance economic growth to attain higher living standards and they may not focus to rise innovation capability. There may be the transfer of obsolete technology by multinational corporations to the host countries because they may afraid to transfer advanced technology which can reduce the future competition and loss of intellectual property. Low-income countries even try to attract such foreign direct investment to raise economic growth. Domestic companies of these countries may work with foreign investors as a joint venture to get advanced technology from abroad which can create an innovative atmosphere and thus can raise the level of innovations.

Likewise, the estimated coefficient of carbon dioxide is positive significant for innovations proxy by patent applications nonresidents and technology while negative and significant for research and development and patent applications residents. This result shows that an increase in carbon dioxide emission significantly increases patent applications for nonresidents and technology while reducing research and development and patent applications for residents. Carbon dioxide discharge can be the reason for higher economic growth in developing countries as these countries are rising economic growth through production, industrialization and other economic activities such as foreign direct investment and trade. An increase in these activities, in turn, raises energy demand thus rising carbon dioxide emissions. Thus, higher economic growth may raise the level of innovations. Thus, the findings reveal that carbon dioxide in the sample countries rise technological innovations proxy by patents nonresidents and high technology export however its effect on patent application residents and research and development expenditure is negative. The country's carbon emission in turn degrades environmental quality and increases economic growth however the innovations capability may be raised due to economic activities. Thus, the findings further illustrate that developing and low-income countries may have a high level of environmental degradation due to high carbon emission discharge through economic activities however a rise in innovation may reduce environmental pollution and a rise in economic growth in future after the countries reach a certain level of development. This phenomenon is termed is innovation Claudia curve in the previous studies however we have not used it in this study as this study only focuses on the effect of these factors on technological innovations.

The estimated coefficient of economic growth for patent applications nonresidents, patent applications residents, and technology is highly significant and positive while negative significant for research and development. The results show that an increase in economic growth significantly increases the level of innovation, patent applications nonresidents, patent applications residents, and technology while reducing research and development. The findings suggest that economic growth is increased through economic activities such as foreign direct investment and production, and industrialization and thus these activities rise carbon emissions. We found that carbon emission and economic growth both are positively related to rise in innovations as the countries going to be developed, innovations might be increased. However, economic growth and carbon emission have environmental consequences. (Loukil, 2020) also found similar results which reinforce our findings.

The coefficient of financial development is highly significant and the sign is positive for research and development and technology which indicates that an increase in financial development increases these two factors of innovation. More specifically, the results indicate that if there is a percent increase in financial development will increase research and development and technology by 0.001 and 0.014 percent respectively in the sample countries. The results suggest that the countries' financial institutions

have an important role in countries' innovation level. A well functional financial system facilitates projects related to economic activities and raises the level of innovation. (Hsu, Tian, & Xu, 2014)) also argues that well-established and effective financial markets overcome moral hazards and reduce the external costs of firms which in turn enhance innovation. Likewise, (Aristizabal-Ramirez, Botero-Franco, & Canavire-Bacarreza, 2017) shows that the soundness of innovations depends on a well-established and well-functioning financial market which improves resource allocation and investment in strategic sectors and enhances technology.

Table 4: System GMM results

Variables	PT2	RD	PT1	Technology
FDI	-0.515***	-0.000***	-1.041*	-0.011***
	(0.166)	(4.750)	(0.611)	(0.000)
CO2	8.242***	-0.001***	-28.35***	0.052***
	(2.111)	(0.000)	(7.019)	(0.018)
GDP	36.39***	-0.001***	151.5***	0.007**
	(0.458)	(8.860)	(4.607)	(0.003)
FND	0.0341	0.0001***	0.700	0.014***
	(0.172)	(3.420)	(0.451)	(0.000)
ENR	-0.017***	3.030***	-0.083***	-0.000***
	(0.002)	(4.420)	(0.012)	(2.100)
TO	-0.423***	3.920***	5.619***	0.008***
	(0.087)	(6.740)	(0.330)	(0.000)
$PT2_{it-1}$	1.041***			
	(0.000)			
$R\&D_{it-1}$		0.998***		
		(0.004)		
$PT1_{it-1}$			1.064***	
			(0.000437)	
$Technology_{it-1}$				0.834***
				(0.004)
Constant	-40.45***	0.008**	-667.6***	0.562***
	(10.97)	(0.003)	(46.47)	(0.079)
Observations	2,136	1,118	2,051	693
Number of id	117	101	110	115
AR2	0.45	-1.62	-0.05	0.59
	(0.649)	(0.105)	(0.959)	(0.022)
Sargan test	1986.70	1364.56	8049.11	0.59
	(0.207)	(0.000)	(0.000)	(0.769)

Note. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Our findings regarding technology and research and development show that financial markets play important role in rising research and development and technology in the sample countries. Financial markets have improved resource allocation and reduced the external costs of firms that have contributed to technology improvement. On the other hand, financial development does not affect patent applications nonresidents and patent applications, for residents. (Loukil, 2020) found that when the economic development threshold values are below, the financial development does not affect innovation while above the level of the threshold has a positive effect of financial development on innovation. They indicate that a healthy economic environment is essential for financial institutions to provide high-quality financial services and promote more innovation.

The coefficient of energy consumption is highly significant for all dependent variables while the effect is negative on patent applications nonresidents, patent applications residents, and technology while positively affecting research and development. The results show that an increase in energy consumption significantly reduces innovation except for research and development in which energy consumption exerts a positive effect. The estimated coefficient of trade openness is highly significant in all models while the effect is negative while positive on other dependent variables. The results show that an increase in trade openness significantly reduces patent applications for nonresidents while increasing other innovation indicators.

Results of Panel Quantile regression

We use panel quantile regression as a robust check to the system GMM model as well to examine the effect of the explanatory variables on each innovation indicator across different quantiles. Table 5 presents the results of Quantile regression on the impact of explanatory variables on innovations (patent nonresidents) where the effect of foreign direct investment on patent applications nonresidents is negative significant from the 5th quantile to the 60th higher quantile while it becomes insignificant at the highest quantile from 70th to 95th quantile. The results are almost similar to the system GMM model however, the quantile regression results show that this effect becomes insignificant in the highest quantiles. The results indicate that foreign direct investment significantly reduces innovations in the first quantiles till 60th while this effect becomes insignificant when reaches the higher quantile after the 70th. The coefficients of carbon dioxide from the 5th quantile to the last quantile 95th are highly significant and positive which indicates that carbon dioxide emission significantly increases patent applications for nonresidents. The estimated coefficients of economic growth are insignificant in the first two quantiles while it's become positive and significant in the 20th and 30th quantiles while again becomes insignificant in the 40th and 50th quantiles. Again, the effect is positive and significant when reaches the 60th and 70th while in the highest quantiles the effect becomes insignificant.

The coefficient of financial development is positive and significant in all quantiles from the 5th to the 95th quantile which indicates that financial development significantly increases patent applications for nonresidents.

The coefficient of energy consumption is negative significant mostly in all quantiles except 10th, and highest 80th, 90th while again it becomes negative significant at the

Table 5: Results of Quantile regression

Dependent variable: Patent Nonresidents											
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
FDI	-21.24***	-1.093***	-1.885***	-2.973***	-7.313*	-21.24***	-14.91**	-10.64	-12.59	-30.45	-26.43
	(6.962)	(0.361)	(0.528)	(1.071)	(4.085)	(6.962)	(6.150)	(10.41)	(29.75)	(62.52)	(96.14)
CO2	368.9***	7.247***	18.14***	35.10***	103.5***	368.9***	590.2***	763.4***	1,277***	3,523***	5,795***
	(42.69)	(2.214)	(3.237)	(6.568)	(25.05)	(42.69)	(37.71)	(63.83)	(182.4)	(383.4)	(589.5)
GDP	41.50	1.039	3.313*	7.586*	19.95	41.50	61.43***	87.92**	119.6	178.8	347.4
	(26.42)	(1.370)	(2.003)	(4.064)	(15.50)	(26.42)	(23.33)	(39.49)	(112.9)	(237.2)	(364.8)
FND	23.27***	0.534***	1.593***	3.481***	8.476***	23.27***	32.67***	44.75***	52.39***	49.16*	93.51**
	(3.015)	(0.156)	(0.229)	(0.464)	(1.769)	(3.015)	(2.663)	(4.508)	(12.88)	(27.07)	(41.63)
ENR	-0.305***	-0.00530	-0.0135**	-0.0295**	-0.0990*	-0.305***	-0.454***	-0.573***	-0.609	-1.288	-2.228*
	(0.0906)	(0.00470)	(0.00687)	(0.0139)	(0.0532)	(0.0906)	(0.0801)	(0.135)	(0.387)	(0.814)	(1.251)
TO	-17.24***	-0.802***	-1.694***	-3.163***	-6.607***	-17.24***	-22.96***	-28.01***	-33.39***	-61.37***	-111.0***
	(2.258)	(0.117)	(0.171)	(0.347)	(1.325)	(2.258)	(1.995)	(3.377)	(9.649)	(20.28)	(31.18)
Constant	606.4***	59.36***	122.5***	205.3***	334.7**	606.4***	705.1***	820.0**	1,007	2,994	6,206*
	(231.2)	(11.99)	(17.53)	(35.57)	(135.7)	(231.2)	(204.2)	(345.7)	(987.9)	(2,076)	(3,193)
Obs	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339

Note. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

highest quantile 95th. This result indicates that energy consumption significantly reduces patent applications' nonresidents. The effect of international trade in all quantiles is highly significant and negative which indicates that it significantly reduces patent applications for nonresidents.

Table 6 presents the results of Quantile regression on the impact of explanatory variables on research and development where the effect of foreign direct investment on research and development is negative significant which is almost similar to the impact of foreign direct investment on patent applications nonresidents however the coefficient is insignificant at the top highest quantiles 90th and 95th. The results are also similar to the dynamic model results given in the above tables. The results indicate that the inflow of foreign direct investment significantly reduces research and development in the 1st quantile while when it reaches the top, then exerts an insignificant impact on research and development. This means that foreign direct investment reduces innovation proxies by research and development. The coefficient of carbon dioxide is also negative mostly in all quantiles however the effect of carbon dioxide in the 5th quantile is insignificant and then it is negative significant at the 10th. Again from 20th to the 50th quantile the coefficients are insignificant and from 60th to the 80th are negative significant while at the top highest quantile, 95th, it becomes positive. The results indicate that carbon dioxide significantly reduces research and development until it reaches the highest quantile.

Table 6: Quantile regression

Dependent variable: research and development											
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
FDI	-0.002***	-0.001	-0.003***	-0.003***	-0.004***	-0.002***	-0.001	-0.001*	-0.001*	-0.002	-0.003
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.002)
CO2	-0.0039	-0.039**	-0.001	-0.002	-2.050	-0.003	-0.041***	-0.079***	-0.081***	-0.005	0.066***
	(0.0070)	(0.006)	(0.009)	(0.005)	(0.005)	(0.007)	(0.009)	(0.006)	(0.007)	(0.0157)	(0.017)
GDP	0.0012	0.006	0.006	0.005	0.003	0.001	0.003	0.0040	-0.001	-0.008	-0.015
	(0.0053)	(0.004)	(0.007)	(0.004)	(0.003)	(0.005)	(0.007)	(0.005)	(0.006)	(0.0120)	(0.013)
FND	0.006***	0.003***	0.005***	0.005***	0.005***	0.006***	0.006***	0.009***	0.010***	0.0118***	0.0135***
	(0.0005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.0013)
ENR	0.0002***	0.000***	0.000***	0.000***	0.0001***	0.000***	0.0003***	0.000***	0.000***	0.000***	0.0002***
	(1.480)	(1.330)	(2.050)	(1.240)	(1.110)	(1.480)	(1.980)	(1.470)	(1.680)	(3.320)	(3.760)
TO	-0.000**	-0.001**	-0.000	-0.000**	-0.000*	-0.000**	-0.001**	-0.001***	-0.002***	-0.002***	-0.002**
	(0.0003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.0003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.0244	0.0274	-0.046	-0.035	-0.009	0.024	0.0010	0.078	0.135**	0.237**	0.344***
	(0.0500)	(0.044)	(0.0691)	(0.0416)	(0.037)	(0.0500)	(0.066)	(0.0497)	(0.0567)	(0.112)	(0.127)
Obser	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The effect of financial development in all quantiles is positively significant which indicates that financial development significantly increases research and development in the panel countries. This result is similar to the System GMM results which confirm that financial development strongly affects research and development and an increase in financial development by the bank will enhance research and development. Likewise, energy consumption and trade are highly significant while the sign for energy consumption is positive and negative for trade which indicates that energy consumption significantly increases research and development while trade lowers it.

Table 7 present the results of Quantile regression on the impact of explanatory variables on patent applications nonresidents where the estimated coefficient of foreign direct investment is most significant and negative in the first quantiles from 5th to 50th while insignificant at the highest quantiles. The results indicate that foreign direct investment reduces patent applications, and residents, in the beginning until it reaches the highest quantiles. Likewise, the coefficients of carbon dioxide and financial development are positive and highly significant in all quantiles which indicates that carbon emission and financial development significantly increase patent applications for residents in the sample countries. the results indicate that if there is a rise in these two variables will raise the level of patent applications residents in the global panel. similarly, the trade coefficients is highly significant in all quantile while the sign is negative which indicates that an increase in trade significantly reduce patent applications residents while the effect of energy consumption on patent applications residents is positive and negative significant across different quantiles which indicates that it reduces or increase patent applications residents across different quantiles. The coefficient of economic growth is positive in a few quantiles while insignificant at the highest quantiles indicating that its increases patent applications residents.

Table 7: Quantile regression results

Dependent variable: patent applications residents											
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
FDI	-7.076***	-1.001***	-3.709***	-6.143***	-7.236***	-7.076***	-5.336	-5.749	-22.59	-65.53	-262.8
	(2.083)	(0.287)	(1.129)	(1.188)	(1.189)	(2.083)	(3.581)	(17.44)	(49.97)	(288.9)	(377.3)
CO2	101.2***	9.558***	57.21***	88.23***	89.87***	101.2***	161.5***	352.2***	1,678**	5,593***	10,002***
	(11.80)	(1.627)	(6.392)	(6.730)	(6.731)	(11.80)	(20.28)	(98.73)	(283.0)	(1,636)	(2,136)
GDP	17.21**	1.608	4.838	11.41***	11.98***	17.21**	24.42*	39.86	165.0	515.0	1,069
	(7.358)	(1.015)	(3.987)	(4.198)	(4.199)	(7.358)	(12.65)	(61.59)	(176.5)	(1,021)	(1,333)
FND	8.543***	1.033***	3.557***	5.753***	6.883***	8.543***	12.19***	18.27***	65.79**	332.6***	1,545***
	(0.837)	(0.115)	(0.454)	(0.478)	(0.478)	(0.837)	(1.439)	(7.007)	(20.08)	(116.1)	(151.6)
ENR	0.0700**	-0.0106***	-0.0270**	-0.00786	0.0512**	0.0700**	0.0960**	-0.0179	-0.709	-3.005	-9.759**
	(0.0248)	(0.00342)	(0.0135)	(0.0142)	(0.0142)	(0.0248)	(0.0427)	(0.208)	(0.596)	(3.443)	(4.496)
TO	-5.937***	-0.696***	-2.928***	-4.461***	-5.062***	-5.937***	-8.589***	-14.94***	50.14**	-164.0*	-428.4***
	(0.624)	(0.0861)	(0.338)	(0.356)	(0.356)	(0.624)	(1.074)	(5.227)	(14.98)	(86.61)	(113.1)
Constant	73.80	21.46**	33.34	13.99	39.60	73.80	126.7	373.0	903.5	3,373	12,702
	(64.84)	(8.944)	(35.14)	(37.00)	(37.00)	(64.84)	(111.5)	(542.8)	(1,556)	(8,994)	(11,745)
Obser	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242	2,242

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table.8: Quantile regression

Dependent variable: Technology											
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
FDI	0.0701***	0.0224***	-0.006	0.037***	0.032**	0.070***	0.067***	0.056***	0.073***	0.030	0.022
	(0.016)	(0.009)	(0.012)	(0.010)	(0.012)	(0.0163)	(0.018)	(0.018)	(0.021)	(0.033)	(0.091)
CO2	-0.157	-0.322***	-0.271***	-0.302***	-0.150	-0.157	-0.040	0.239*	0.317**	0.513**	0.452
	(0.120)	(0.072)	(0.091)	(0.076)	(0.093)	(0.120)	(0.133)	(0.137)	(0.160)	(0.249)	(0.673)
GDP	0.126	0.001	0.018	0.029	0.068	0.126	0.165	0.211*	0.218	0.022	0.360
	(0.104)	(0.062)	(0.079)	(0.066)	(0.081)	(0.104)	(0.116)	(0.119)	(0.140)	(0.217)	(0.586)
FND	0.125***	0.044***	0.078***	0.098***	0.111***	0.125***	0.131***	0.115***	0.108***	0.142***	0.074
	(0.009)	(0.005)	(0.007)	(0.006)	(0.007)	(0.009)	(0.010)	(0.0111)	(0.013)	(0.020)	(0.054)
ENR	0.000**	0.000***	0.000***	0.000***	0.000**	0.000**	0.000**	0.000**	0.000**	5.860	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
TO	0.015**	-0.005	0.005	0.002	0.003	0.015**	0.034***	0.049***	0.077***	0.0710**	0.072*
	(0.007)	(0.004)	(0.005)	(0.004)	(0.005)	(0.007)	(0.007)	(0.008)	(0.009)	(0.014)	(0.040)
Constant	-1.193	-0.402	-0.961	-0.617	-0.632	-1.193	-1.937*	-1.322	-1.079	2.970	11.87**
	(0.936)	(0.563)	(0.717)	(0.597)	(0.729)	(0.936)	(1.040)	(1.073)	(1.255)	(1.948)	(5.264)
Observations	819	819	819	819	819	819	819	819	819	819	819

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 8 present the results of Quantile regression on the impact of explanatory variables on technology where the effect of foreign direct investment on technology is positive mostly in all quantiles while insignificant at the highest quantile. This result on the impact of foreign direct investment on technology differs from the effect of foreign direct investment on other indicators of innovation. This result shows that foreign direct investment increases technology while in other tables, the foreign direct investment effect on other innovation indicators is mostly negative.

The effect of economic growth on technology is insignificant while carbon dioxide is negative significant at the 10^{th}, 20^{th}, and 30^{th} quantiles and then insignificant from 40^{th} to the 60^{th}. At the higher quantiles from 70^{th} to 90^{th}, the effect of carbon dioxide on technology becomes positive while again it's become insignificant the top highest quantile 95^{th}. The results indicate that carbon dioxide both negatively, positively, and insignificantly affect technology. The effect of energy consumption and financial development are positively on technology mostly in all quantiles while its insignificant at the highest quantiles. The results indicate that both financial development and energy consumption significantly increase technology. If there is a rise in these two factors will increase technological innovation. On the other hand, trade is significant and positive at the 5^{th} quantile and insignificant from 10^{th} to 40^{th} quantile however it's become positive significant from 50^{th} to the 95^{th} quantile. The result indicates that trade also increases technology in the global panel countries.

Conclusion

This study investigates the impact of foreign direct investment, carbon dioxide emission, economic growth, and energy consumption on technological innovation in the global panel for the period of 1980-2019. Static models, system Generalized Method of Moments, and panel quantile regression have been used for analysis where the results of system GMM indicate that all proxies of innovation are negatively affected by foreign direct investment while it's been increased by carbon emission and economic growth. Energy consumption is also negatively related with all proxies except research and development while trade is negatively related with patent applications nonresidents and positive with all other proxies of innovation. The quantile regression results indicate that foreign direct investment negatively affects patent applications nonresidents in the first few quantiles while insignificant at the highest quantile however, carbon dioxide and financial development are strongly positive and increase patent applications nonresidents. Energy consumption and trade are negative while economic growth is positive across quantiles for patent applications nonresidents. Foreign direct investment and carbon dioxide are negative across different quantiles for research and development while financial development and energy consumption are positive. Trade is also negatively related to research and development while economic growth is insignificant. Foreign direct investment, trade and energy consumption are negatively related to patent applications residents while carbon dioxide and financial development are positive. Economic growth is positively related to patent applications residents in the middle quantiles. In the case of, technology, foreign direct investment, financial development, energy consumption, and trade are positive while carbon dioxide is negative in the first few quantiles and positive in the highest quantile for technology.

From the findings of this study shown by system GMM, it is concluded that foreign direct investment reduces all kinds of innovations that include research and development, patent applications residents, and technological innovations. The results of quantile regression also confirm the results of the system GMM model which shows that foreign direct investment is negatively related will all the proxies of innovation except technology. The quantile regression shows that foreign direct investment increases technological innovation proxies by high technology export. The effect of energy consumption is negative with all proxies of innovation while the effect of energy consumption on research and development is positive which shows that it increases research and development expenditure explained by system GMM. While the quantile results confirm these results for all indicators except for technology where the energy consumption sign is positive. Financial development is highly significant and positive in all models for all innovations which strongly indicates that financial development increases all types of innovation in the sample countries. Trade is negative mostly in all models for all innovation proxies while it is been found that trade increases technology (technological innovation proxied by high technology export). Our findings indicate that foreign direct investment reduces innovations which can be the reason that countries in the panel still didn't reach the desired level to attract foreign direct investment with advanced technology and foreign direct investment yet didn't contribute to the host countries' innovations however it enhances technological innovation (high technology export). Energy consumption has also not contributed yet to enhancing innovation level however energy consumption has raised research and development innovation. Carbon dioxide, economic growth, and financial development are enhancing innovations which indicates that they have a high contribution to enhancing the level of innovation. The findings also conclude that foreign direct investment should be improved through strong policies which can bring new technologies and new knowledge and in turn this can enhance the level of innovations as well promote economic growth. The energy sector should be improved which is related to innovation and an increase in innovation can in turn enhance energy efficiency by lowering the use of energy use. Innovation can also help acquire renewable

energy sources and thus enhance environmental quality. Its means that innovations are very important in this modern world, as it enhances most of the economic activities such as foreign direct investment, trade, enhance energy efficiency, acquire renewable energy sources and may help reduce carbon emission and enhance environmental quality. In this regard, the factors used in this study should be considered to enhance the level of innovation and an improvement in innovation will raise environmental quality as well economic growth. That's why our study suggests the sample countries consider the weak factors for each indicator of innovation analyzed in our study to enhance innovation level. Our study is limited to the global panel, future studies should conduct such studies on different samples such as developing and developed countries as the level of innovation, foreign direct investment, and other related factors are different in developing and developed countries and thus can get very useful recommendation and policy implication for developing and developed countries. Future studies may also include other closely related factors such as institutions and education level in such study as institutions can be linked with foreign direct investment, financial sectors, and other related factors to find its role in innovation while findings the effect of these factors on innovation.

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RESEARCH ARTICLE

The Financial availability and Innovation link with Firms & Environmental Performance

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Abstract: Conventionally, organizations tend to rely on financial performance and profit capacity to flow shareholder wealth. Currently, in adding to environmental and financial results, it had also developed a vital effort. Though, all organizations are unable to achieve financial and environmental results, especially medium and small-sized enterprises that need performance-enhancing financial resources. This analysis confirms the part of financial obtainability in financial, and environmental performance with a mediating role in recognizing the opportunity. Pragmatic tests are accumulated through framework questionnaires from 305 SMEs working in Pakistan developing markets. The hypotheses are verified in the AMOS by, Structural Equations Modeling (SEM). The results show that suitable financial resources have contributed to the performance of financial instruments, but they also play a significant part in environmental performance. Our study results indorse CEOs and senior administrators effectively use their financial resources to gain the benefit of a new opportunity, excellent financial and environmental performance. Also, companies with sufficient financial capital identify innovative opportunities significantly via recognition of opportunity mediator where they partially mediate the link among financial performance and financial obtainability.

Keywords: Financial performance; Environmental performance; Corporate social responsibility

Introduction

Generally, the management method is based on higher financial performance as a maximum shareholder income. On the contrary, the maintainable business enterprise takes into account stockholders, clients, customers and societies that focus on the collapse of consequence while utilizing social value (Abdullah, Ismail, & Smith, 2018). Expected to stormy market economic globalization pressure and managerial pressure, a deep style has started to transform the firms' traditionalist and financial vigorous into charitable activities (Abolfathi, Rasouli, Zamahani, & Estiri, 2018). Firms, nonetheless of their nature and size of the company, don't just focus on financial-performance, even if they are constantly striving to improve environmental performance (Adu, Al-Najjar, & Sitthipongpanich, 2022). CSR (*Corporate social-responsibility*) is currently offered by strategy makers, who conduct various directions in business such as, the environment consumers, human rights, technology, Science and employment. Putting into the practice of *CSR* work around the world has been a sudden change in Corporation, where they lean towards behaving socially responsibly about different anxiety (Ahmad, 2015). In line with these new changes, scholars have begun to turn their notice to the environ-mental and sustain-able development practices integrated into companies. It's caused as important consequences based on shareholder thinking, and the (RBV), where a company can achieve development in financial-performance by disclosing environ-mental and sustainable development practices, its stockholders who recognize it as an assessment of the chances and risks of companies. To do this, several studies were collected and factors can contribute to environmental and financial performance (Akter, Fosso Wamba, & Dewan, 2017; Alas & Elenurm, 2014). Likewise, companies can inspire IT management to improve the digital process (Ananzeh, 2022) and immorality versa. Top administrators are responsible for strategic decision making and long term objectives. The overhead studies were considered elusive ideas, which stated that small and large businesses are more knowledgeable to achieve environmental and financial results. Overall, small businesses have required a cost-effective option to improve their performance in the long term. The recognition of opportunities needs acceptable sources e.g. finance, that can

offer a sustain-able competitive position. In added, less comparative studies have been identified to examine the financial resources of smaller and medium-sized enterprises (SMEs) that lead directly to high performance or create new occasions through finance. Companies need different sources and capabilities to drive their operations. However funding is necessary at any stage that can indirectly or directly improve the company's performance. Besides, this study tests the importance of the financial resource to the recognition of opportunities that contribute to environmental performance and financial. Also, the novelty of this research lies in the test of the role of financial gain and the recognition of opportunities. A lack of support and resources, SMEs area until unable to more improve their performance (Franco & Haase, 2010). As an outcome, financial resources have become a vital predictor during this perception, where companies can pay money on profit-able opportunities. This study contributed to the RBV theory (Boyd, Bergh, & Ketchen Jr, 2010), which included the recognition of opportunities as a reserve in which a company might gain a sustainable reasonable benefit and better performance. The theory of RBV has fueled environ-mental activities, where a company could also achieve great performance. Though, empiric arguments about RBV in terms of the environment are rare, particularly in the SME sector. On the contrary, our study has attentive on finance opportunities as substantial incomes for countless financial and environmental performance that are occasionally discussed in the *(RBV)* view. Our study has helped highest management and SME firm's owners apply sufficient economic resources to recognize opportunities. This study gives credibility to the statement made here that allows responsible operators and high authorities to encourage and support SMEs financially and nonfinancial, which in turn gives to economic development and GDP.

Theoretical Background

Financial Performance and Financial Obtainability

After the RBV view, suitable financial wealth can spur maintainable competitive advantage. Economic capital can also guard a company against unpredicted events and can assist them in turbulent marketplaces once they need good enough finance. Especially a company's assets and competencies in rising economies don't configure corporations' sustainability and aggressive benefit unless associate finance is avail-able for numerous operating activities (Khan, An, & Imran, 2020). In an emergent marketplace like South Korea, manufacturing firms face big economic and financial restraints to reduce their achievement and development (KHAN, ZHANG, & SALIK, 2020a). In such areas, company growth and innovatively competencies can be completed through plenty get entry to financial capital. Furthermore, in rising economies like Pak, an organization can advantage sustain-able modest benefit through a different selection of assets, where in financial capital is the factor that suggestively contribution to sustainable aggressive gain. Subsequently, we contend that a company with sufficient financial capital obtainability should make a sustain-able modest place in the turbulent marketplace by spending cash into effectual resources.

H1. *Organizations with enormous financial obtainability use a vast financial performance.*

Environmental performance and financial obtainability

When a company's financial capitals decline, its investment and participation in CSR assets decrease (Cajias, Fuerst, & Bienert, 2014). Consequently, sufficient funding would be allocated to endorse CSR and environ-mental events to help societies (Luetkenhorst, 2004) . The main predominant motive why small trades going financial ruin is the lack of monetary resources. Because of this important problem, many SMEs don't longer actively engage in environ-mental and anti-environmental practices (Ottman, 2017). On the contrary, suitable and enough financial-resources could provide a viable modest location and environmental practices to businesses. We consequently believe that the SMEs zone needs sufficient funding to spend in (CSR) and environmental practices. Therefore, CSR-oriented companies must have passable financial capitals to carry out sustainability practices, i.e. greater financial performance of companies can support environ-mental and *CSR* performs. Companies with a stable financial position favor to spend money in progressive activities, while companies with a financially dejected position role are not interested in investing in social activities, and practices.

H2*. Organizations with high financial obtainability it reveal environmental performance.*

Financial obtainability and opportunities recognition

Financial assistance is additionally important for the company startup and generates a premium opportunity for the commercial enterprise proprietor (Turner & Endres, 2017).

In adding, funding has a powerful influence on the collection of new options for entrepreneurs. In addition, the literature in this favor recommended that economic advantage has an impact on the organization's performance toward innovation, while ornamental the decision making of managers and the possibility of increasing financial resources (Ruett, Whitney, & Luedeling, 2020). To this end, financial rewards and economic benefits inspire managers to perceive and identify new opportunities. For these details, it has been recognized that the availability of financial capital has a significant effect on the fact that nascent businesspersons can progress in new possibilities and start-ups (Tötterman & Sten, 2005) . In standard, SMEs with acceptable funding more effective in finding opportunities in markets.

H3. Organizations with massive financial obtainability can identify new prospects.

Recognition of opportunity and Performance

In spite of control sources and recovery, SMEs cannot make investment an acceptable amount in large schemes (Sarbutts, 2003). Those motives push them towards the recognition of the opportunity that could improve achievement and survival. In addition, the recognition of brand new opportunistic not only helps to enhance the overall performance of corporations but also supports at different levels: (a) the exploration for current markets and territories which could provide excessive financial profits have created their social benefits and innovation (KHAN, ZHANG, & SALIK, 2020b). Therefore, the intention of sustainable development and innovation needs for the approval of new opportunities (Caffaro, Roccato, Micheletti Cremasco, & Cavallo, 2019) stated that opportunity-oriented companies ought to have better benefits in gaining a modest advantage from their active commitment to environmental and social activities.
SMEs want proactive and high-level capabilities to recognize opportunities to enhance their modern performance. Recognizing innovative opportunities can accelerate many welfares for companies, which include the advantage of getting new technologies that are very vital facilitating the progressive technique of companies. Not like old approaches to CSR events. SMEs today attention to CSR primary based opportunities to improve their achievement and overall performance. Over-all, we propose that SMEs spot opportunities boost their environmental and financial performance (Yang & Jang, 2020).

H4. *Recognition opportunity has absolutely connected to financial performance.*

H5. *Recognition opportunity has absolutely connected to environmental performance*.

Mediating part of recognition opportunity

Re-cognition opportunity is a cognitive procedure, which trusts on reserve evaluation and negotiation to recon-figure and stimulates commercial enterprise perceptions. SMEs want monetary funds for their working actions in order to improve their performance. Financial capital can protect businesses from unexpected difficulties, along with offering the resources needed for creative thoughts and finding and recognizing new opportunities that may collaboratively stimulate performance and achievement. As an alternatively, this benefit new chances stimulates solidity (2010), in which managers who obtain financial rewards are extra motivated in the search for new opportunities from companies that have brought production of the latest (Herzberg, 2008). According to RBV's perception, companies with adequate economic resources have shown excessive performance and a modest gain, as they have more power to understand new possibilities (Barney, 1991). A company with passable assets (monetary and human) is higher than spotting new possibilities than a company with fewer sources.
Unpaid a loss of financial capitals, the SME segment may also favor to invest in much less risky possibilities rather than investing a huge sum of money in advanced schemes and benefits that can shape its performance. (, 1984). In addition, the financial incentive of senior managers is important to determine to a large extent a company's efforts to participate in new schemes and events. Environmental Practices are especially high overprices for SMEs (Alonso & Ogle, 2010). Senior decision-making managers and SME proprietors do not exhibit spiritually friendly behaviors in the practice of sustainability activities (Zhang, Khan, Lee, & Salik, 2019).
Therefore, investing in new and valuable profit opportunities can permit them to contribute to environmental advantages. In little, we suggest that suitable financial capital encourages SMEs to recognize opportunities inclusive of the provision of too high monetary, and environmental performance.

H6. *Recognition Opportunity mediates the connection among financial obtainability and financial performance.*

H7. *Recognition Opportunity mediates the connection among financial obtainability and environmental performance.*

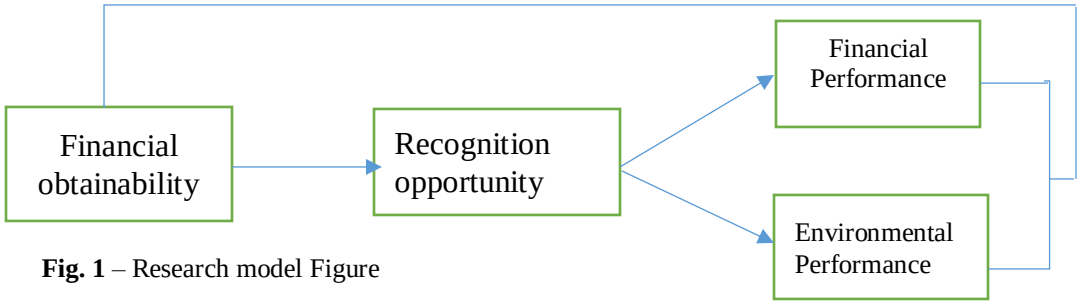

Fig. 1 – Research model Figure

Table 1: Organizations Profile

	Portrayal	Occurrence	Ratio
Nature of Firms			
1.	Manufacturing Industrial	110	36.4
2.	Trading Industries	105	34.5
3.	Services Industries	90	29.6
Academic degrees			
1.	Intermediate and less	70	23.5
2.	Bachelor	84	27.7
3.	Master	125	41.2
4.	PhD	26	8.5
Firms size			
1.	10–50 workers	51	16.7
2.	50–100 workers	54	17.7
3.	100–150 workers	70	23.1
4.	150–200 workers	74	24.3
5.	200–250 workers	56	18.4
Organizations age			
1.	5 years and less	47	15.4
2.	10–20 years	83	27.3
3.	20–30 years	56	18.4
4.	30–40 years	51	16.7
5.	40 and above	68	22.3
	Total (*n*)	**305**	**100**

Research Objective, Methodology and Data Nature

Data analysis

The selected research population is made up of SMEs operating in the regions: Islamabad Lahore and Karachi (Pakistan). Companies employing between 20 and 250 people are considered in SMEs. We obtained lists of SMEs registered by the Karachi stock exchanges, Lahore stock exchanges, and Islamabad stock exchanges. The Sample size

of 305 was nominated based totally on the probability-based sampling method usage of the 6% error margin and a 94% sureness interval. We distribute 800 questionnaires among SMEs. The information from this analysis was collected inside 4 months by a structured form. SMEs are regularly indisposed to deliver their facts to the overall public. We indicated a hard copy paper questionnaire due to the fact an email review has a minor response ratio. The form was organized in English, as is without problems understood with the aid of the managers. SMEs do not release their data. In total 320 replies were received. The 15 inacceptable replies were accepted due to inadequate answers. So the entire quantity of answers from all firms was 305 finalized analyses. An effective response rate of 38.12%. Companies participating in this analysis are displayed in Table 1. The pattern of queries that were considered throughout the survey reported at the end of this article. In this way, every beginning of the questionnaires we disclose that the data contained in this survey will only be used for study purposes while not revealing the details of public enterprises. We ask proprietors and senior managers as they are more conscious of the company's strategic and policy assessments.

Measures

A complicated procedures in the preceding research for financial obtainability. Perhaps, it is calculated with financial-incomes and volumes to increase their operating actions. Companies want acceptable economic resources to stimulate their movements. One instance describes. We have sufficient financial wealth for the improvement of the latest products. “High-quality describes the companies' capacity and the capability to identify and discover new possibilities. A corporation can view many options by spending its abilities and resources. In this entire research, we used three adopted elements from (Crals & Vereeck, 2005). to assess the popularity of the possibilities. An example item is “I think of many ideas for new businesses in the past month.” *To measure overall financial performance*, alternates such as (ROI), (ROE) and (ROA) are used within the registered organizations while financial statistics are available. SMEs are commitment they do not share their economic data to the public. As a result scholars use self- informed method to obtain the FP of SMEs where proprietors and managers were queried; “to what extent, your firm perform based on the given information (return on equity, return on assets and return on investment, etc.) as compared to your major competitors since the last three years.” in this studies, we used six objects for financial performance which are followed from (Danso, Adomako, Amankwah-Amoah, Owusu-Agyei, & Konadu, 2019). In this research, we used four elements to measure modern performance, as suggested by the use of (Ni, Egri, Lo, & Lin, 2015). The range of recent or improved internal procedures is better than the common range of the company and the feature used these factors for SMEs. A model element indicates "product and packaging for reuse, recovery, or recycling."

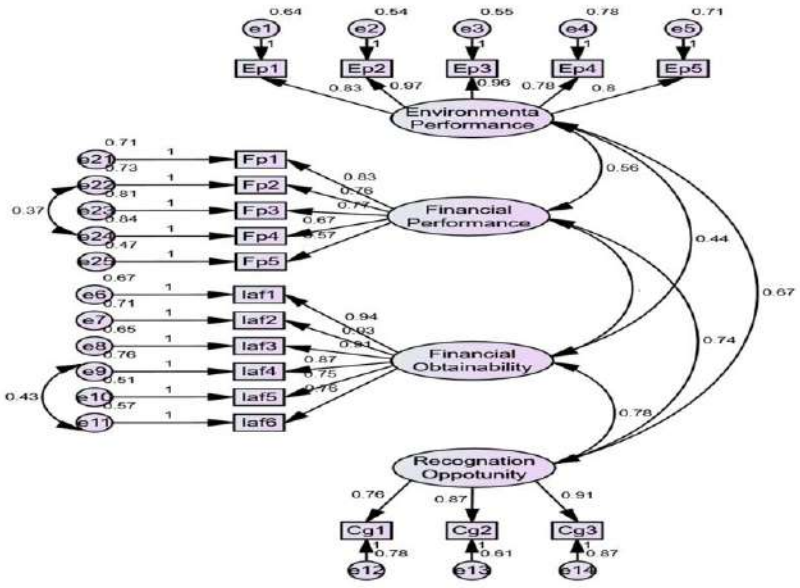

Fig. 2 – *Measurement model*

Descriptive Measurements

Descriptive measurements display in Table 2, Mean value, 'Standard deviation and Recognition of opportunity has the maximum average, while environmental performance has the deepest. Also, recognition chance has the maximum SD, while *EP* has the deepest. Our statistics are standard as all the factors have their skewness and kurtosis values less than +2 (Cain, Zhang, & Yuan, 2017).

Table. 2– Descriptive measurement

Variables	Mean	Std. Deviation	Skewness	Kurtosis
Financial obtainability	3.7023	0.46366	-1.371	6.046
Recognition opportunity	3.3118	0.4105	−.428	3.377
Financial performance	3.6079	0.45794	−726	4.451
Environmental performance	3.2622	.40878	−.597	2.476

Common method bias

In the cross-sectional data, (CMB) occurs that can influence the performance (Podsakoff & Organ, 1986). We performed Harmon's one-factor test to check for the CMB issue. We found four, factors with Eigen-values larger than 1, the first factor described only *25.73%* variance which is low than 50%. This infers that there is no presence of CMB in the information.

Confirmatory factor analysis

We performed (CFA) see figure 2, which is performed to verify the validity, reliability, and loading of items. The physical shape of the model wellness has affirmed as CMIN/DF is 2.048, which is lower than 3 as suggested by (Caffaro et al., 2019; Hair, Anderson, Babin, & Black, 2010; Hu & Bentler, 1999) AGFI = 0.88, GFI = 0.91, TLI = 0.95 and NFI = 0.91, values are in the reasonable range and show a palatable adjustment of the model fit (2010). RMR = 0.012 and RMSEA = 0.056 are also providing acceptable values (less than 0.08 as suggested by (Hair et al., 2010). In addition, all the items are ($p < .01$) loaded significantly on their relevant factors displayed in Table 3, which displays convergent validity, discriminatory validity, and reliability. Convergent validity. Providing acceptable values (overhead 0.50) as suggested by (Hair et al., 2010). Cronbach α has been the execution that given a suitable limit (above 0.70) in Table 3 all the factors are presented. Discriminant-validity (also known √Average variance extracted) gained suitable values (from above, 0.70) for all the items (Hair et al., 2010; Hu & Bentler, 1999). Composite reliability values are greater than 0.70. On the other hand, for reliability.

Table. 3– Standardized factor loading, validity, and reliability

Variables and items	Estimate	AVE	√AVE	CR	*α*
Financial obtainability		0.65	0.80	0.91	.91
Fo6	0.87***				
Fo5	0.83***				
Fo4	0.84***				
F03	0.86***				
Fo2	0.87***				
Fo1	0.83***				
Recognition opportunity		0.67	0.830.87	0.87	.86
Ro3	0.90***				
Ro2	0.62***				
Ro1	0.91***				
Financial performance		0.54	0.73	.88	*.89*
Fp6	0.74***				
Fp5	0.61***				
Fp4	0.79***				
Fp3	0.75***				
Fp2	0.83***				
Fp1	0.67***				
Environmental performance		0.58	0.76	0.87	.87
ep5	0.68***				
ep4	0.86***				
ep3	0.74***				
ep2	0.88***				
ep1	0.58***				

AVE, and; CR, ***p value (.001).

Results and Discussion

To articulate the study and the consequences in an improved way, first, we check the direct associations. We verified the effect of financial advantage potential on overall performance. The outcomes have shown in Table that the ability to make a financial gain has an important effect on financial performance, such as (β = .409, p <.05.) and (β

=187, p<.05), which support *H1* properly. But, the ability to achieve financially does not have a substantial effect on environmental performance (β = 021, p > .05), which are not supported to H3. In the II model the impact of financial obtainability on the recognition of opportunities was verified. The marks (shown in Table) display that the financial obtainability of the measurement model Figure 2 also has a significant impact on the "recognition opportunity (β = .354, p.05), which H4 has supported. Table displays that recognition of opportunity donates significantly to *financial performance* (β = 241, p <.05), and *environmental performance* (β = 0.293, p< .05), that assist H5, H6, and H7 at the same time. Structural model has the core model that tests the mediation role of the recognition of opportunity among financial obtainability and performance is verified. The consequences imply that the indirect effect of financial earning potential on *financial performance* is significant (β = .065, p <. 05). This infers an immediate have an effect of financial obtainability on the financial performance that has remained significantly and partly contributed. Likewise, the indirectly influence of financial obtainability performance is substantially (β = 061, p < .05). This implies that the direct association also remained substantially and partly supported. Though, the indirect impact of financial obtainability on environmental performance is absolutely (β =109, p < .05), while the direct impact of financial obtainability on environmental overall performance has become negligible and sustained. The outcomes of the combination are created by the control variables. R square shows a 38% change in financial performance, a 24% change in only 10% variance in the ecological exhibition that can be portrayed by way financial obtainability in the existence of the control variables just as recognition opportunity as a mediator. The validity model develops, we perform out the Mediation Analysis using *SPSS* displayed. The consequences made by regression evaluation usage of AMOS that model the strength of the results. For example, the results could point out a comprehensive mediation role in recognizing the possibilities between financial and environmental performance. In the meantime, there is a partial mediation role in the recognition of opportunities: a) among financial gain and financial performance and b) among financial gain.

Discussion

This study examined the part of financial sources in financial and environmental performance by using recognition opportunities as a mediator. Though, present research in this respect has shown the connection among financial re-sources and financial results and CSR activities (Krause, 2018; Su, Liu, & Teng, 2020). Especially, no previous studies had been carried out to find that it is a recognition opportunity that it mediates the connection between other performance factors, such as among financial obtainability and financial performance. Among financial obtainability and environmental performance, while our results may find that financial obtainability directly con-tributes to the performance of firms mediating the previous performance factors. AS an example, we examine the need for SMEs to identify new possibilities through their present incomes (financing) to take part in the atmosphere. Similarly, the RBV concept has currently expanded its limits to considered opportunities as a valuable resource that would provide a modest. Inspected that sufficiently funded organizations are better able to be recognized for opportunities than others, in which these changes improve their performance. The essential model based on the RBV concept. In adding, it is showed that environmental practices and CSR at the moment are inside the RBV concept (Krause, 2018) where our studies have additional new proof to the RBV concept of CSR arrangement and environmental practice. Our consequences in part supported the outcomes recorded in (Kickul, Liao, Gundry, & Iakovleva, 2010) confirming that SMEs usage of their finances to recognize opportunities and depend directly on financial results. In a comparable framework, it is claimed that financial wealth stimulates inventive overall performance when a company has higher investment opportunities in future schemes. Our results do not assist the results reported to who said that companies with adequate economic assets are actively involved in environ-mental practices and therefore their environmental-performance is enhancing (Howes, Skea, & Whelan, 2013). In addition, their conclusions said that SMEs don't, 'directly recover, their *EP* until they re-cognize and investment in possibilities. In this way, we approve that the recognition of new opportunities, significantly enables the financial and environmental performance of companies in accord with the statement made in (Meng, Zeng, Shi, Qi, & Zhang, 2014). SMEs tirelessly seek new obtainability to contest in the marketplace and attain excessive performance. In add, our results could also support the consequences report in (2018), where they examined that companies understand opportunities to begin new and advanced tactics. Also, our outcomes give credibility as noted in which indicates that organizations often identify opportunities to contribute to the CSR and environmental practices.

Conclusion

Too much research has been carried out to verified numerous performance factors, inclusive economic and environmental. Though, specifically in rising economies, empiric research was not taking these performance factors into account in this study. Indeed, the part of financial obtainability and recognition opportunity has rekindled less interest inside the framework of SMEs. Hypotheses are verified in AMOS use SEM. Our research findings ought to suggest suitable financial resources that considerably donate to financial performance and show an irrelevant role in *EP* Organizations with meaningfully monetary capital notably understand the latest opportunities. Financial obtainability and financial performance causing a connection among financial obtainability and performance, while it completely mediates the connection between financial obtainability and environment performance. This research fulfills the space by examining the part of mediating the recognition of opportunities between financial obtainability and the performance of SMEs. The practical proof is collect and our models are verified structured questionnaires from 305 SMEs working in Pak markets. Our results suggested proprietors and directors in SMEs to apply the financial resources in a capable way by taking the benefit of a new recognition of opportunity include the highest financial and environmental performance. Furthermore, this study offers alarming signals to specialists and strategy manufacturers in markets to frame their policies in the fulfillment of SME's development that can support in turn to economic development.

Implications

This study has developed numerous essential suggestions for professionals, proprietors, and managers. As explained in section 2.2, companies that tend regardless of their size and the environment of their activities are committed to improving financial, and environmental performance. Senior directors would a lot of investment in various activities and improve performance. We confirm that monetary assets are vital for financial results in the SME sector. As the outcome, managers must use their finances capable of more advance their performance. We consider that financial obtainability is an important arranger in the recognition-opportunities. Therefore, you need enough attention to managing finances in the business. As recommended by and (Kusi, Opata, & Narh, 2015) recognition of opportunity is the most significant and precious training of industrialists in the turbulent market. In particular, in SMEs, the recognition of a saving action to growth its performance. SMEs don’t straightly use their monetary capital, then recognize opportunities to improve their, environmental performance and sustainability. The significance of this study is very suitable within the framework of SME and the environment due to a huge number of SMEs, where the director's environmental-contribution is not acceptable. Senior executives need to acquire, manage and use finances in order to articulate their goings-on efficiently. In our study, we examine that financial obtainability doesn’t straightly contribute to environmental-performance. But, companies understand, opportunities thru finance that during flip ought to help environmental presentation. According to the current discussion of the RBV principle, which indicated that the sustainable viable benefit and the super performance may be acquired via tangible and intangible sources as recommended in (Eniola & Ektebang, 2014) we place greater emphasis on efficient use of new opportunities that represent performance. In different words, we inspire SMEs to encourage environmentally advantages. As a result, SMEs are needed to usage their monetary capitals, efficiently to pinpoint the most treasured chances that could involve the values for their environ-mental performance. Further, this study recommends financial images and accountable authorities to facilitate SMEs in terms of financing. In this way, they could classify new chances and teach them to supports performance. Similarly, the SME growth authority and management bodies are invited to grant without interest loans to SMEs for their operating activities in accordance with the Sustainable Development Aims.

Limitation And Future Research

We used pass sectional statistics on this study, which reasons CMB and non-reaction bias. Upcoming scholars can use repeated observations data to keep away from this problem and discover valid insight. In this research, we use self-reported info that exacted CMB. Yet to come scientists can take the interview with senior managers to discover helpful ideas for better implementation. In Pakistan that examined for this research model which could not produce actual productive consequences due to his intuitive configuration. As an outcome, scholars in emerging and evolving markets are endorsed to check the model in other environmental series. But elements that include the CSR and technology capabilities can be examined as brokers to limit themselves to companies if their performance is growing towards monetary capital with the presence of CSR and equipment. In addition, it’s improved to test administration incentives if

they can help them inside the recognition of opportunities in the event of a lack of assets in SMEs. Our research is restricted most effective for the function of mediating opportunities among financial obtainability and SME developments.

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RESEARCH ARTICLE

Carbon Emission Dynamics in India Due to Financial Development, Renewable Energy Utilization, Technological Innovation, Economic Growth, and Urbanization

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Abstract
Concerns about climate change, emission reduction, and environmental sustainability have become crucial in accomplishing long-term development goals. The present study explored the dynamic effects of financial development, renewable energy utilization, technological innovation, economic growth, and urbanization on carbon dioxide (CO_2) emissions in India. This investigation quantifies short- and long-run dynamics using time series data from 1990 to 2020 and an Autoregressive Distributed Lag (ARDL) model. The outcomes from ARDL short- and long-run analysis revealed a positive and significant effect of financial development, economic growth, and urbanization on CO_2 emissions in India. In contrast, both the short- and long-term coefficients for renewable energy utilization and technological innovation are negative and statistically significant, suggesting that expanding these variables will lead to lower CO_2 emissions. The findings were validated by employing the Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegration Regression (CCR) methods. This research provides novel findings that add to the current literature and may be of special relevance to policymakers in the country because of the role that the financial system plays in environmental concerns.

Keywords: Carbon emission; Financial development; Renewable energy; Technological innovation; Environmental sustainability

Introduction

Growing populations, increased urbanization, improved living standards, technological advancements in manufacturing, and increased economic competitiveness all contribute to an increased demand for energy (Raihan et al., 2022a). The increasing usage of fossil fuels sequentially increases atmospheric CO_2 levels and has detrimental effects on the environment, such as climate change (Raihan et al., 2019; Isfat & Raihan, 2022). There has been a rise of 31% in CO_2 emissions over the course of the preceding 200 years, as well as a rise of 0.4-0.8 degree Celsius in the average temperature of the planet during the course of the last century. In recent decades, emissions of carbon dioxide have been the most important contributor to pollution of the environment all around the world (Raihan et al., 2021a; Islam et al., 2022). In recent years, governments have been more cognizant of the issue (Begum et al., 2020; Raihan & Said, 2022). For instance, in 2005, the Kyoto Protocol went into effect to reduce the cumulative emissions of greenhouse gases by developed nations. In addition, the Commission of the European Union (EU) provides funding for a variety of research projects with the objectives of reducing dependency on fossil fuels, increasing energy efficiency, and developing cutting-edge technology, particularly in the field of renewable power.

The use of power derived from renewable sources has the potential to be a substantial contributor to the efforts to achieve the objective of greater energy diversification (Voumik et al., 2022a). By decreasing the dependency on fossil fuels, it is possible to reduce the storms that rage in the energy market (Raihan & Tuspekova, 2022a). The development of renewable energy comes with the extra benefit of possibly lowering the risk of additional damage being done to the natural environment (Raihan et al., 2022b). However, making the transition from producing energy using fossil fuels to producing energy using renewable sources could prove to be difficult. The expense involved in making the transition to renewable sources of energy is one of the most significant barriers. When compared to the costs associated with producing energy

from fossil fuels, the costs associated with developing the necessary infrastructure, operating the business, and initiating operations are all significantly higher. The generation of cash, the promotion of transparent and honest dealings, and the management of capital are all responsibilities that fall under the purview of the financial sector, which is why this sector is critical to the operation of any economic system. Stronger economic growth is the result of a safe and dependable financial system that enables the effective movement of cash and assists firms in operating more smoothly (Ali et al., 2019). This system also contributes to the overall stability of the economy. Both the effectiveness of the economy and the state of the environment are impacted by the activities of the financial sector (Yu & Qayyum, 2021). A robust financial system helps stimulate the economy, and a wealthy economy is typically connected with a stable and safe financial system. A well-developed financial system helps stimulate the economy.

A robust economy also fosters the development of technology that are less polluting and more efficient, which companies can then put to use in their operations. The same is true for India, where an increase in funding for renewable energy is vital since in order to satisfy these obligations by 2022, an expenditure of over 189 billion USD will be required. In spite of this, the Climate Policy Initiative (CPI) anticipates that the actual, realized contribution might fall short of the criteria by a margin of 29% (or USD 17 billion) for stock and by a margin of 27% (or USD 36 billion) for debt. In order to close the funding gap and advance the development of the renewable energy industry, India has initiated a wide range of institutional changes at both the national and state levels. The federal government has provided support in the form of rapid depreciation, generation-based subsidies, and viability gap funding. Policy support at the state level often takes the form of feed-in tariffs, net metering, and tax/duty discounts. When commercial banks are relied on excessively for credit funding, it is inevitable that financial difficulties will occur, regardless of how favorable federal and state regulations may be. The cost of financing projects related to renewable energy in India is often greater than the cost of financing projects of a comparable nature in the United States or Europe. This is a significant obstacle in the way of their general acceptance. When compared to the limited resources that are at the government's disposal, the lofty goals that have been set for renewable energy mean that officials will need to carefully consider whether the advantages of their support outweigh the costs.

A highly developed financial system, on the other hand, encourages economic expansion and urbanization, both of which contribute to an increase in emissions and substantial environmental damage. Even if doing so increases a company's energy consumption and emissions of greenhouse gases, having access to loans with reasonable interest rates from a solid financial system helps firms expand their output, which in turn helps the businesses (Saud et al., 2019a). Despite this, there have been relatively few studies conducted to determine how India's growing GDP and financial system affect the country's carbon footprint. As a result of the growing interest in the topic of financial development's potential adverse effects on the natural world, this study adds financial development to the energy-growth-environmental linkages and examines its significance in India for long-term growth. This is done as a result of the fact that the linkages between energy, growth, and the environment have been studied extensively in recent years. As a result, the primary objective of the study is to analyze the ways in which India's developing middle class, increased access to renewable energy sources, technical breakthroughs, expanding economy, and expanding metropolitan regions all affect the size of the country's carbon footprint.

India was selected despite the fact that it has one of the most rapidly expanding economies because of the significance of the financial industry to the total economy of the country. The commercial banks, non-banking financial institutions, rural banks, pension funds, mutual funds, and insurance companies that make up the pillars of India's financial sector are its most important institutions. Since the beginning of the Financial Sector Assessment Program (FSAP) in 2011, both the economy of India and the variety of financial instruments that it uses have expanded at a rapid rate. This expansion has been made possible by significant structural shifts as well as improvements to the country's overall trade balance. The expansion of the financial industry has been helped along by an increase in the sector's diversification, commercial focus, and integration driven by technology, in addition to sufficient governance, legislative, and disciplinary procedures. However, the banking sector is beset with issues, and the expansion of the economy has slowed down. The slow deflation and the rebuilding of corporate balance sheets, together with high levels of nonperforming assets, are putting a burden on the soundness of the financial system, which in turn is constraining growth. Therefore, it is essential for the decision-makers in India to have an awareness of the connection between the expansion of the economy, the development of new technologies, and the emission of carbon dioxide. In order to carry out econometric research, the most recent time series data are applied to the econometric method that is considered to be the most suited for time series (the ARDL model). In addition, FMOLS, DOLS, and CCR methodologies are utilized in order to conduct an investigation into the reliability of the results obtained from this study. On the basis of the findings, this article presents key policy implications that should be considered by the government and policymakers.

The rest of the article is structured as follows. The Introduction is followed by the section Literature Review, where relevant research studies have been discussed. The third section is the Methodology section, followed by the

Results and Discussion section. Subsequently, the last section presents the Conclusion, policy recommendations, limitations of the study, and future research directions.

Literature Review

The environmental growth-energy model has recently been updated to account for numerous aspects related to financial development. Researchers have examined the financial growth nexus for many samples of countries and regions, employing a wide variety of proxies and approaches, with conflicting results (Bibi & Sumaira, 2022). Dogan and Seker (2016) state that attempts to include the measurements of financial development are not unrealistic in the discussion on the relationship between environmental concerns, economic development, and energy use. Foreign direct investment, specialized knowledge and research, and new ideas can all contribute to a reduction in energy use and a general improvement in the economy. In turn, this improves environmental quality. Saud et al. (2019b) analyzed the effects of CO_2 emissions on the economies, financial growth, energy use, and international commerce from 1980 to 2016, and reported that increasing energy consumption and economic growth are detrimental to the environment, whereas more trade and financial development are good for the environment since they minimize pollution. In a similar vein, Zafar et al. (2019) examined the results of financial development and globalization on carbon emissions and reached the same conclusion: these two factors significantly enhance environmental performance by decreasing pollution. Using data collected between 1995 and 2015, Kahouli (2017) found a correlation between economic growth, energy efficiency, and financial development in six nations in the South Mediterranean. Kahouli (2017) exposed the long-term cointegration of variables and proposed that financial development is the crucial factor in enhancing energy use. However, several studies argued that the demand for energy brought on by economic development has negatively impacted the atmosphere due to rising carbon emissions. To investigate how financial development affects carbon emissions, Guo et al. (2019) analyzed province data from China between 1997 and 2015. Guo et al. (2019) came to the conclusion that the level of carbon emissions grew due to the volume of stock trading and the stability of financial development. Moghadam and Dehbashi (2018) investigated the connections between Iran's economic growth, exports, and ecological footprint and concluded that economic growth has hastened the contamination of natural areas.

Renewable energy sources including wind, hydro, solar, and many others have gained appeal as an eco-friendly alternative to traditional fuels like coal, gasoline, and oil. It is clear that these forms of energy have the potential to deliver non-carbon clean energy at levels comparable to those given by carbon-based energy while simultaneously reducing atmospheric concentrations of greenhouse gases. Over the past few years, numerous research have been conducted to understand how and to what extent the use of renewable energy can reduce carbon dioxide emissions. For instance, Zoundi (2017) analyzed the relationship between CO_2 emissions and the utilization of renewable energy in 25 African economies from 1980 to 2012. According to Cherni and Essaber Jouini (2017), renewable energy use reduced CO_2 emissions as Tunisia's economy grew, while the use of fossil fuels increased emissions. Between 1980 and 2014, Chen et al. (2019) examined the connection between China's CO_2 emissions, economic growth, renewable energy utilization, and foreign trade. Chen et al. (2019) reported that the use of renewable energy sources is inversely related to carbon dioxide emissions. Charfeddine and Kahia (2019) examined the impact of renewable energy consumption and financial development on CO_2 emissions in the Middle East and North Africa (MENA) from 1980 to 2015, and found that the two factors had a negligible impact on CO_2 levels. By using an advanced panel quantile regression model, Azam et al. (2022) reported a positive relationship between economic growth and CO_2 emissions, and a negative relationship between renewable energy and CO_2 emissions in the top-five emitter countries, covering the data from the period from 1995–2017. Raihan and Tuspekova (2022a) reported a positive relationship between economic growth and CO_2 emissions while a negative relationship between renewable energy use and CO_2 emissions in Peru utilizing the data over 1990-2018. Liu et al. (2017a) utilized time data over 1992-2013 to establish a negative association between renewable energy use and CO_2 emissions in the BRICS countries. Furthermore, by using time data over 1970-2013, Liu et al. (2017b) revealed a positive association between economic growth and CO_2 emissions while a negative association between renewable energy use and CO_2 emissions in Indonesia, Malaysia, the Philippines, and Thailand.

Moreover, the relationship between technological innovation and CO_2 emissions has been examined comprehensively in recent years as increased research and development (R&D) spending can enhance economic production efficiency and resource usage efficiency. Technological advancements are expected to have a major effect on pollution reduction. With the help of environmental protection programs, new technologies have reduced CO_2 emissions and improved environmental performance in many countries. Previous research shows that a lot of focus has been placed on the potentially positive effect of technological innovations on CO_2 emissions. The majority of academics choose patents as a measure for technological innovation because they protect company and intellectual property rights that help create technologies to address environmental problems. According to Chen and Lee (2020), technical innovation in high-income nations efficiently decreases CO_2 emissions and is thus considered environmentally beneficial green technology innovation.

Several studies have shown that technological innovation reduces CO_2 emissions. According to Shahbaz et al. (2020), China's technological innovation efficiency have a significant positive impact on environmental performance. Rahman et al. (2019) reported that the adoption of clean technology by international businesses might enhance environmental quality in Pakistan by lowering carbon emissions. Ahmed et al. (2016) reported that technological innovation improves environmental quality by reducing CO_2 emissions in 24 European nations. Raihan et al. (2022b) utilized time data over 1990-2019 to establish a positive association between economic growth and CO_2 emissions while a negative association of renewable energy use and technological innovation with CO_2 emissions in Malaysia. Furthermore, Raihan and Tuspekova (2022b) revealed the positive effects of economic growth on CO_2 emissions, and the negative effects of renewable energy use and technological innovation on CO_2 emissions in Kazakhstan utilizing the data over 1996-2018. It is now commonly acknowledged that technical advancements play a significant role in lowering emissions while maintaining economic growth; as a result, any improved understanding of the process of technological innovation is likely to expand our knowledge of mitigation options (Raihan et al., 2022b). Furthermore, there has been a lot of research done recently on the connection between urbanization, economic growth, and CO_2 emissions. Zhang et al. (2021) reported that economic growth and urbanization have positive influences on CO_2 emissions in Malaysia. Adebayo and Kalmaz (2021) exposed a positive contact of economic growth and urbanization on CO_2 emissions in Egypt by using the data from 1971 to 2014. Nondo and Kahsai (2020) uncovered positive impacts of economic growth and urbanization on CO_2 emissions in South Africa from 1970 to 2016. Kirikkaleli and Kalmaz (2020) found positive influences of economic growth, and urbanization on CO_2 emissions in Turkey during 1960-2016. Liu and Bae (2018) revealed the positive impacts of economic growth and urbanization on CO_2 emissions in China from 1970 to 2015. By utilizing yearly data between 1971 and 2014, Ahmed et al. (2019) reported that economic growth and urbanization trigger CO_2 emissions in Indonesia. Al-Mulali et al. (2013) utilized time-series data from 1980 to 2009 and found a positive association between urbanization and CO_2 emission in MENA countries. By using time series data over 1985-2013 for 20 African countries, Raheem and Ogebe (2017) found that economic growth and urbanization increase CO_2 emissions. By utilizing a nonparametric additive model for South Asian countries over 1978-2011, Irfan and Shaw (2017) found that urbanization positively influence CO_2 emissions. Sehrawat et al. (2015) found that economic growth and urbanization increase CO_2 emissions in India. Rehman et al. (2022) demonstrated that urban population growth has an adverse influence on CO_2 emissions.

Despite the hopeful economic and financial development in India, the mechanisms of knowledge accumulation remain a mystery, and the true potential of renewable energy use and technological innovation to reduce CO_2 emissions is yet unknown. Therefore, the present study intends to fill up the existing literature gap in the case of India by examining the dynamic impacts of financial development, renewable energy consumption, technological advancement, economic expansion, and urbanization on CO_2 emissions using several econometric approaches.

Methodology

Data

The goal of this study was to apply the ARDL method to analyze the interplay between India's financial growth, renewable energy consumption, technological advancement, economic expansion, and urbanization on the country's CO_2 emissions. This analysis makes use of data from the years 1990 all the way through the year 2020. The data for all the variables were obtained from the World Development Indicators (WDI) (World Bank, 2022). The variable names and their measurement unit are presented in Table 1. All the variables were logged to ensure conformity to normality. Moreover, the annual trend of the study variables is presented in Figure 1.

Table 1. Variables with description

Variables	Description	Logarithmic structures	Measurement	Sources
CO_2	CO_2 emissions	LCO2	Kilotons	WDI
FD	Financial development	LFD	Domestic credit to private sector (% of GDP)	WDI
RE	Renewable energy use	LRE	Percentage of total final energy use	WDI
TI	Technological innovation	LTI	Number of patent applications	WDI
GDP	Economic growth	LGDP	Constant Indian rupee	WDI
U	Urbanization	LU	Number of urban populations	WDI

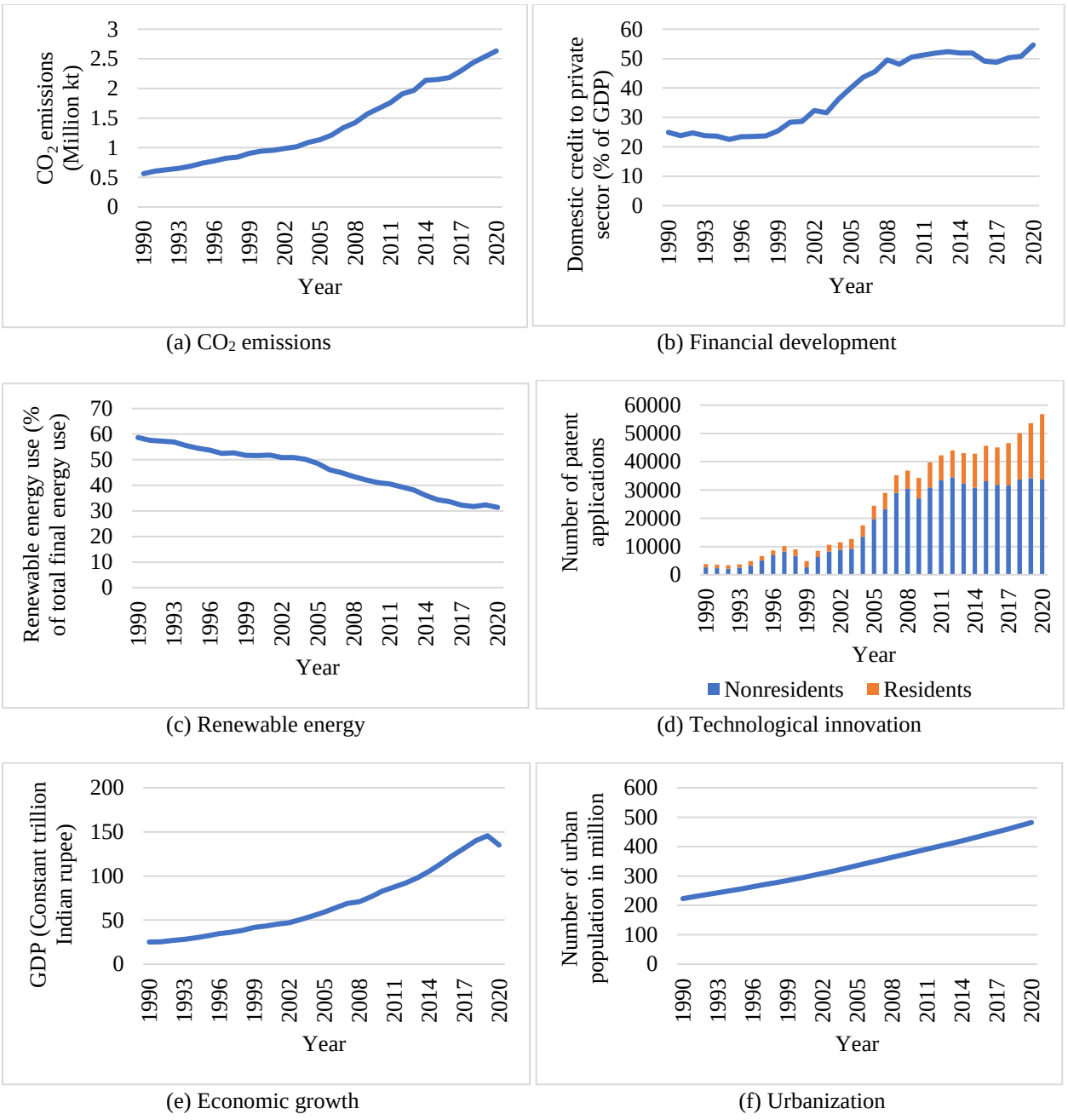

Figure 1. Annual trends of the study variables

Theoretical framework and model specification

This study investigated the relationship between urbanization, economic expansion, the development of new technologies, and the use of alternative energy sources and their impact on CO_2 emissions. Even while financial development is necessary for both economic progress and a healthy climate, the two are inexorably intertwined (Voumik et al. 2022b). In addition, developed and robust financial sectors improve environmental performance in a number of ways, including but not limited to: providing businesses with access to clean technology; making low-cost credit available for environmentally friendly initiatives and technological advancements; and rewarding businesses for adhering to environmental standards and guidelines (Raihan & Tuspekova, 2022b). If expansion plans involve the use of energy-efficient equipment and if the use of renewable energy sources is emphasized, then the use of renewable energy sources may have an effect on environmental performance (Raihan et al., 2022c). One area in which advancements in technology could potentially have an effect

on environmental consequences is the efficacy and efficiency of energy production. Because it requires a significant amount of energy use, economic development is also a key contributor to increasing CO_2 emissions (Raihan & Tuspekova, 2022c). This, in turn, has a detrimental impact on the efficiency with which natural resources are utilized. The previously noted connection between urbanization and economic growth influenced an investigation of the correlation between urbanization and higher standards of environmental protection. The following criteria were employed according to these statements in order to build the detailed CO_2 emissions model that was used in this investigation:

$$CO_{2t} = f\ (FD_t, RE_t, TI_t, GDP_t, U_t) \quad (1)$$

The empirical model with the logarithmic form of the variables is represented by the following equation:

$$LCO2_t = \tau_0 + \tau_1 LFDt + \tau_2 LREt + \tau_3 LTIt + \tau_4 LGDPt + \tau_5 LUt + \varepsilon_t \quad (2)$$

where τ_1, τ_2, τ_3, and τ_4 represent the coefficients of the regressors. Moreover, ε_t represents an error term.

Strategies for estimation

A number of cutting-edge econometric techniques were applied to the defined empirical model to produce trustworthy findings for use in policymaking. Because of this, the stationarity property of the time series data by employing ADF, DF-GLS, and P-P unit root tests was the initial focus of the inquiry. When the integration order of the series was defined, the study confirmed the stated model's long-term relationship. The analysis followed the method proposed by Pesaran et al. (2001), known as the ARDL model, as an effective estimating methodology to expose both short- and long-term relationships among the parameters of the specified model. This method has many advantages over the previous cointegration methods. The integration property of a series needed to be discovered before employing other cointegration procedures, whereas this method did not necessitate any such preliminary testing. By considering the lag length of the variable, the ARDL model can be utilized to account for endogeneity. Second, it is applicable in any investigational series integration scenario. Finally, the ARDL model maintains validity even with a little number of observations. As indicated in Equation (3), the ARDL bound testing strategy can be written using the econometric model given in Equation (2).

$$\begin{aligned}\Delta LCO2_t = {} & \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LFD_{t-1} + \tau_3 LRE_{t-1} \\ & + \tau_4 LTI_{t-1} + \tau_5 LGDP_{t-1} + \tau_6 LU_{t-1} \\ & + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LFD_{t-i} \\ & + \sum_{i=1}^{q} \gamma_3 \Delta LRE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTI_{t-i} \\ & + \sum_{i=1}^{q} \gamma_5 \Delta LGDP_{t-i} + \sum_{i=1}^{q} \gamma_6 \Delta LU_{t-i} + \varepsilon_t\end{aligned}$$

The short-run coefficient needs to be captured once the long-term relationship between series has been established. So, as indicated in Equation (4), this investigation assessed the error-correction model and glean the short-run coefficients.

$$\begin{aligned}\Delta LCO2_t = {} & \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LFD_{t-1} + \tau_3 LRE_{t-1} \\ & + \tau_4 LTI_{t-1} + \tau_5 LGDP_{t-1} + \tau_6 LU_{t-1} \\ & + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LFD_{t-i} \\ & + \sum_{i=1}^{q} \gamma_3 \Delta LRE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LTI_{t-i} \\ & + \sum_{i=1}^{q} \gamma_5 \Delta LGDP_{t-i} + \sum_{i=1}^{q} \gamma_6 \Delta LU_{t-i} \\ & + \theta ECT_{t-1} + \varepsilon_t\end{aligned}$$

The error-correction dynamics and long-term linkages between the series are displayed in the aforementioned equation. The lag length of the series is denoted by q in Equations (3) and (4), and Δ stands for the first difference operator. In addition, ECT stands for the error correction term, and θ is the ECT's coefficient.

As a robustness evaluation, this investigation employed the FMOLS, DOLS, and CCR on the stated model to look at how different factors throughout time affected the CO_2 output. There were two main factors that prompted the need to employ these methods. To begin, the cointegration condition among the I(1) parameters must be satisfied before the FMOLS, DOLS, or CCR may be used. Second, these methods deal with endogeneity and serial correlation biases that arise from the cointegration relationship (Raihan & Tuspekova, 2022d). As a result, it yields outcomes with asymptotic efficiency. The analysis flowchart is shown in Figure 2.

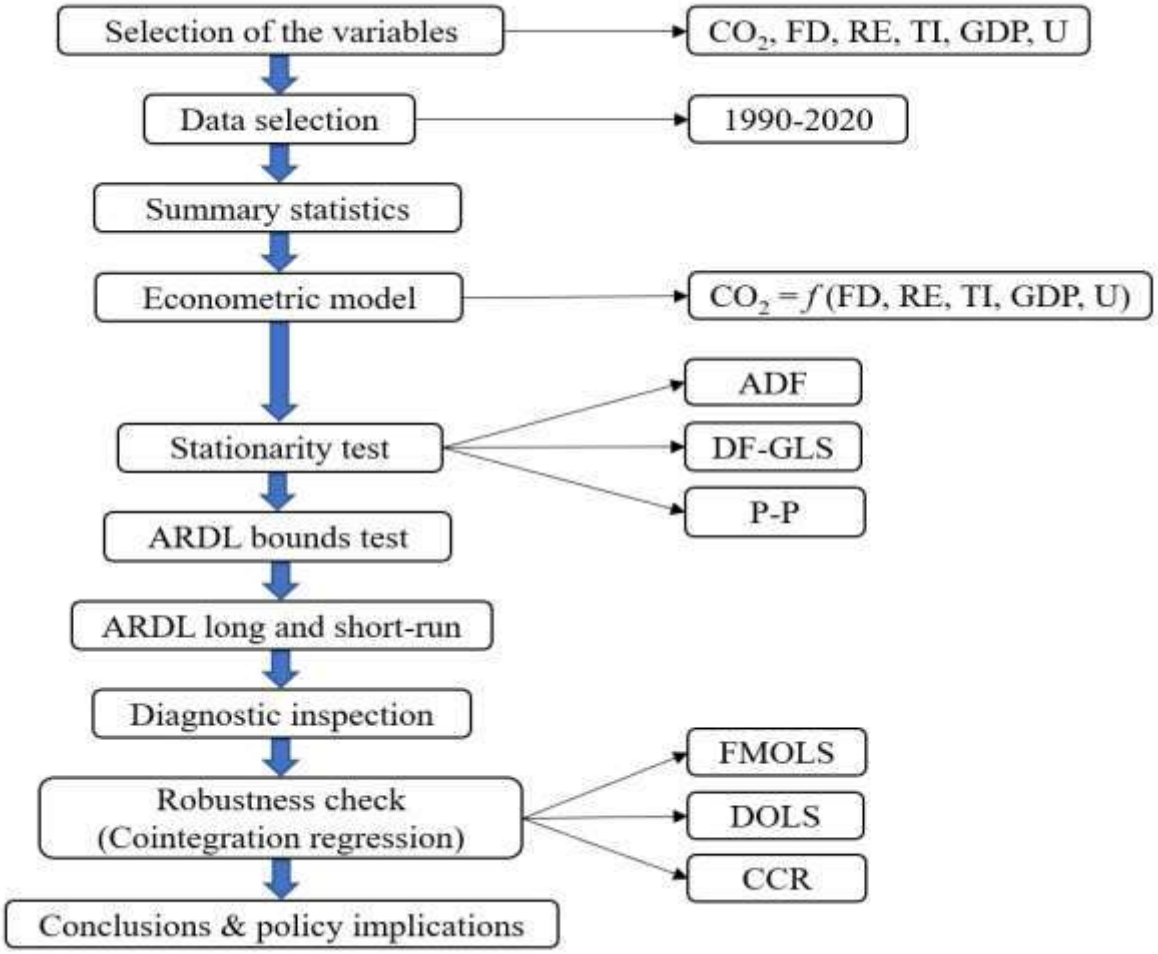

Figure 2. The analysis flowchart

Results and Discussion

The results of multiple normality tests are shown alongside a description of the data in Table 2. It was clear that the dataset was normal because the skewness values were near to zero. In addition, kurtosis values below 3 were indicative of platykurtic variables. All the variables are normally distributed, as shown by the Jarque-Bera and probability values.

The fundamental goal of this study was to investigate the development of a lasting connection between the series under consideration. The evaluation of the unit root test provides crucial information on the integration characteristic of the parameters, which is necessary for employing the approaches in the creation of a long-term interrelationship. Therefore, the integration qualities of the series were investigated using a battery of conventional root tests, including the ADF, DF-GLS, and PP tests. The findings of the stationarity test are summarized in Table 3.

According to the canonical tests of unit root output, all variables exhibited the unit root problem at level before becoming stationary after the first difference.

Based on the unit root observations, this study found that the series under examination is an I(1) series. Therefore, the current investigation used the ARDL-based bounds test technique to evaluate the long- and short-term connections between the series under investigation. The model's consistent results from each alternative's information criterion led to settling on the Akaike information criterion (AIC) as the lag specification. Table 4 shows that the calculated F-statistic (7.762475) for the cointegration analysis is higher than the upper critical threshold. This investigation, therefore, concludes that the independent variable and the regressors are cointegrated.

Table 2. Statistical summaries of the variables

Variables	LCO2	LFD	LRE	LTI	LGDP	LU
Mean	14.01616	3.591260	3.759587	9.765203	31.72137	3.382792
Median	13.94344	3.690578	3.787819	10.10160	31.71103	3.375367
Maximum	14.71417	4.000980	4.071636	10.94678	32.60885	3.553232
Minimum	13.24206	3.113994	3.471636	8.138565	30.85570	3.240520
Std. Dev.	0.480383	0.340624	0.210310	0.979248	0.564657	0.095557
Skewness	0.040435	-0.199575	0.036449	-0.370346	0.039371	0.205197
Kurtosis	1.638421	1.280313	1.491181	1.605142	1.727702	1.790822
Jarque-Bera	2.403065	4.025664	2.947388	3.221742	2.098885	2.106106
Probability	0.300733	0.133610	0.229078	0.199714	0.350133	0.348871

Table 3. Unit Root test results

Logarithmic form of the variables	ADF		DF-GLS		PP	
	Log levels	Log first difference	Log levels	Log first difference	Log levels	Log first difference
LCO2	-1.2152	-3.7061***	-1.0469	-3.7390***	-1.0734	-3.7924***
LFD	-0.2630	-2.9146**	-0.6055	-2.6553**	-0.4754	-4.8820***
LRE	-0.9464	-4.5273***	-0.0627	-4.5768***	-0.9160	-4.5550***
LTI	-1.0002	-4.9207***	-0.0981	-4.7089***	-1.0233	-4.9930***
LGDP	-1.6294	-3.0137**	-1.8257*	-3.5403**	-0.5945	-3.0137**
LU	1.8904	-2.3462*	0.4129	-2.5908**	-0.3462	-3.6701***

The significance levels depicted by *, **, and *** are 1%, 5%, and 10% respectively.

Table 4. ARDL bounds test results

F-bounds test		Null hypothesis: No degrees of relationship		
Test statistic	Estimate	Significance	I(0)	I(1)
F-statistic	7.762475	At 10%	2.57	3.86
K	6	At 5%	2.86	4.19
		At 2.5%	3.13	4.46
		At 1%	3.43	4.79

Table 5. ARDL long and short-run results

Variables	Long-run			Short-run		
	Coefficient	t-Statistic	p-value	Coefficient	t-Statistic	p-value
LFD	0.6132**	2.7639	0.0274	0.2921**	2.0173	0.0419
LRE	-0.8889***	-3.2173	0.0005	-0.4416***	-3.5623	0.0071
LTI	-0.4445**	-2.1634	0.0265	-0.0136**	-2.6731	0.0392
LGDP	1.3174***	6.6731	0.0002	0.7620***	4.9468	0.0008
LU	1.8629***	7.1191	0.0004	0.8294***	5.7823	0.0061
C	32.4764	8.1076	0.1012	-	-	-
ECT (-1)	-	-	-	-0.5219	-0.1332	0.0029
R^2	0.9912			0.9925		
Adjusted R^2	0.9864			0.9871		

The significance levels depicted by *, **, and *** are 1%, 5%, and 10% respectively.

Table 5 displays the findings of the ARDL long- and short-run estimation. The empirical findings provide some encouraging evidence that there is a connection between India's economic expansion and increases in carbon dioxide emissions. Both in the long run and the near term, there is a significant and favorable correlation between rising financial growth and rising emissions of carbon dioxide.

Therefore, the effects of environmental deterioration are made worse by the expansion of the economy (Raihan & Tuspekova, 2022e). The coefficient of LFD indicates that a one percentage point increase in economic development has a negative impact on environmental performance by increasing CO_2 emissions by 0.61 percent in the long run and 0.29 percent in the short run. This is the case even when all other factors are held constant. These findings are consistent with those discovered by Saud et al. (2019b) for countries in Central and Eastern Europe as well as those discovered by Zakaria and Bibi (2019) for South Asian countries. The results of this study provide some insight into the way in which India's rising standard of living is affecting the country's ability to maintain its natural resources. It's possible that the easy access to financial resources was a contributing factor in this outcome, as it enabled polluting enterprises and investors to thrive. This is another evidence that India's banks are not supporting environmentally friendly projects. It is not out of the question that financial institutions are looking to improve their earnings by providing start-up capital to new businesses. The advantages of manufacturing on a small scale, which include lower service costs and less pollution, attract more investors who are prepared to put up more money in exchange for those advantages. Consequently, the scale of the manufacturing operation can increase. As a direct consequence of these actions, there will be a greater demand for energy, which will in turn lead to an increase in carbon emissions, which will have a detrimental impact on the natural environment (Raihan et al., 2022d).

Furthermore, the coefficient of LRE was negative and statistically significant, indicating that a 1% increase in the usage of renewable energy might lead to a 0.89% (long-term) and 0.44% (short-term) reduction in CO_2 emissions. Inferences about renewable energy being beneficial to environmental sustainability were drawn from the outcome. The findings of this study, which suggest that increasing the usage of renewable energy enhances environmental efficacy, are consistent with those of other research that have been done on the topic (Raihan & Tuspekova, 2022f). Based on these findings, higher utilization of renewable energy sources should be considered as a possible policy instrument for enhancing India's environmental performance. In addition, the coefficient of LTI was negative and statistically significant, suggesting that a 1% increase in LTI contributes to the reduction of CO_2 emissions by 0.44% (long-term) and 0.01% (short-term). This exemplifies how the progression of technology is beneficial to the environment by lowering the amount of carbon dioxide emissions. The results of this experiment are consistent with those obtained from earlier experiments (Raihan et al., 2022e; Raihan et al., 2022f). The implementation of novel technology, as discovered by the researchers, resulted in a lower overall level of pollution (Raihan et al., 2022g). As a result, the results of this study suggest that encouraging technological innovation can be an efficient policy instrument for lowering environmental pollution in India. The result indicates that if India invests more in technical innovation, it may be able to slow the rate of environmental deterioration.

The empirical results demonstrated a positive and statistically significant coefficient of LGDP, which means that a 1% increase in GDP leads to a 1.32% (long-term) and 0.76% (short-term) increase in CO_2 emissions, respectively. In assertion, India's rapid economic development has negative effects on the environment both immediately and over the long term. Previous research (Raihan & Tuspekova, 2022f; Raihan et al., 2022h) found that there is a positive link between GDP and CO_2 emissions. It should come as no surprise that India's energy consumption has increased in tandem with the country's growing gross domestic product. This is a significant factor that contributes to the emission of greenhouse gases in India. According to the LU coefficient, an increase of one percent in urbanization results in an increase of 1.86 and 0.83 percent in CO_2 emissions over the long and short terms, respectively. The findings are in agreement with what Irfan and Shaw (2017), Raihan and Tuspekova (2022f), and Sehrawat et al. (2015) have discovered in their research. According to this conclusion, the rapid urbanization that took place in India led to a rise in energy consumption, which was driven by sources of fossil fuel, which in turn led to an increase in CO_2 emissions.

The increasing number of urban residents in India is driving up the demand for automobiles and other kinds of personal mobility. The rise in popularity of automobiles has resulted in an increase in the consumption of fossil fuels, which in turn has led to a worsening of the environment's conditions (Raihan & Tuspekova, 2022g). In India, where the standard of public transportation is generally low, there has been a rise in the number of people purchasing private automobiles. The growth in urban density has been attributed, in part, to the rapid development of housing and factories. There has been an increase in the utilization of products that have a high demand for energy in both the industrial and domestic settings (Raihan & Tuspekova, 2022h). The residential sector has overtaken the commercial sector as the primary consumer of energy in recent years as a direct result of increasing urbanization (Raihan & Tuspekova, 2022i). As urbanization has spread throughout the region, increases in waste output, forest loss, and alterations in land use have all occurred concurrently (Raihan et al., 2018; Jaafar et al., 2020; Raihan et al., 2021b). This has resulted in a significant rise in the levels of pollutants, as well as traffic congestion and electrical consumption, in metropolitan areas (Raihan & Tuspekova, 2022j). Even in India, the rate of industrialization is accelerating, which means that urbanization implicitly contributes to a decline in air quality as a result of the industrial revolution (Raihan & Tuspekova, 2022k).

The ECT was also found to have very detrimental results. This estimate of 0.464 showed how the short-run

equilibrium evolved as it moved toward a stable long-run equilibrium, with annual adjustments of 46%. It demonstrated the value of the feedback system in maintaining stable CO_2 emissions in India. Finally, there was no evidence of serial correlation or heteroskedasticity in the residuals, and the residuals followed a normal distribution without any signs of misspecification, as shown in Table 6 of the diagnostic test findings. Figure 3 further displays the results of the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) stability tests, which demonstrated the model's stability at the 5% significance level.

Table 6. Diagnostic tests results

Diagnostic tests	Coefficient	p-value	Decision
Serial Correlation	1.8495	0.147	No serial correlation exits
Heteroskedasticity Test	1.1787	0.198	No heteroscedasticity exists
Normality Test	1.1489	0.563	Residuals are normally distributed

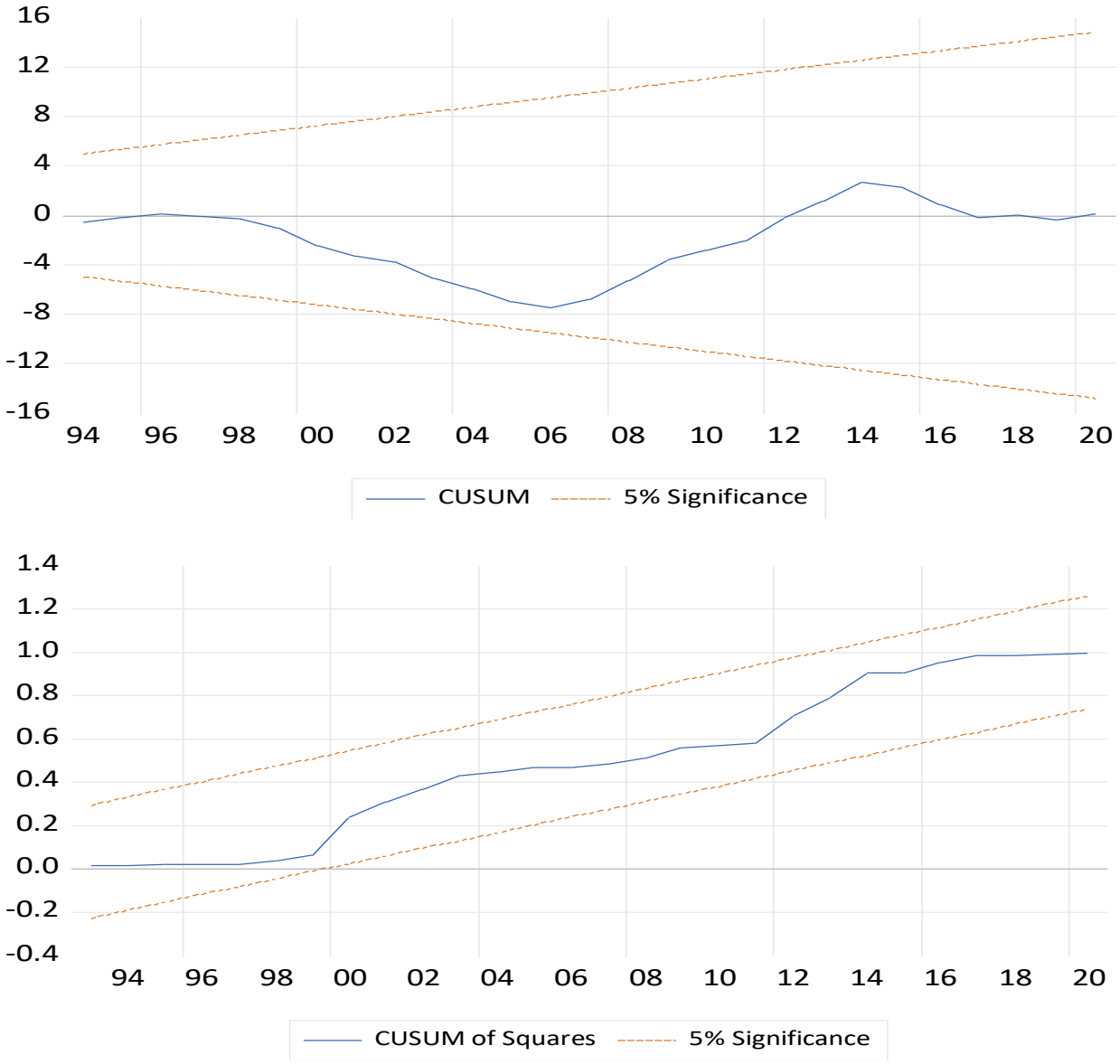

Figure 3. Results of the CUSUM and CUSUMQ tests

The findings of the ARDL framework were also tested over the long term with the help of the FMOLS, DOLS, and CCR tests. Table 7 displays the projected results from the use of FMOLS, DOLS, and CCR. The sign and reliability of the FMOLS, DOLS, and CCR results were all shown to be consistent and dependable. This causes them to produce the same results as the ARDL simulations in the long term. Specifically, the data showed that increasing financial development, GDP, and urbanization increases CO_2 while increasing renewable energy and technical innovation decreases CO_2 emissions. As a result, decisions can be made with an element of certainty based on the findings.

Table 7. Robustness results

Variables	FMOLS		DOLS		CCR	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
LFD	0.5873**	2.1523	0.5982**	1.8685	0.5984**	2.4756
LRE	-0.8735***	-5.2477	-0.8756***	-3.6467	-0.9271***	-4.8804
LTI	-0.4425**	-1.9368	-0.4513**	-1.9631	-0.4605**	-1.5534
LGDP	1.2391***	4.8117	1.3574***	6.2697	1.2554***	5.0928
LU	1.4957***	3.9167	1.8934***	6.0289	1.8595***	7.1996
C	16.277	3.6867	14.0281	5.0667	19.932	4.9906
R^2	0.9967		0.9969		0.9955	
Adjusted R^2	0.9960		0.9962		0.9945	

The significance levels depicted by *, **, and *** are 1%, 5%, and 10% respectively.

Conclusions and Policy Implications

This article covers India's CO_2 emissions from 1990 to 2020 from the perspectives of financial growth, use of renewable energy, technological advancement, economic expansion, and urbanization. The time period covered is from 1990 through 2020. In this investigation, the evaluation of the long-term correlations that exist between parameters was accomplished by the utilization of the ARDL cointegration approach. It was discovered that financial development, economic growth, and urbanization each had a positive and significantly favorable effect on CO_2 emissions. However, there is a negative link between the consumption of renewable energy and technological innovation, and this association is statistically significant. This suggests that increasing these measures will reduce CO_2 emissions both in the short term and in the long run. In this research, an examination of the reliability of the ARDL outcomes was carried out by employing FMOLS, DOLS, and CCR techniques.

The empirical findings of the study have the potential to have significant repercussions for the direction that India's economic policies will take in the future. The findings of the study also indicate that the current strategies of India to grow financial institutions are potentially damaging to the environment and ought to be rethought as a result of these findings. In addition, India has to improve the state of its financial infrastructure so that businesses can use cutting-edge technologies, reduce the amount of energy they use, and contribute to the preservation of the environment. It is possible to improve environmental performance by utilizing the financial system as a tool, and legislators can propose reforms that encourage and compensate enterprises that utilize environmentally friendly technologies. This will push enterprises to employ environmentally sustainable technologies so that they can save money, minimize costs related to energy, and reduce emissions of greenhouse gases. This study also discovered that making use of current technology and renewable forms of energy leads to a reduction in the amount of carbon dioxide that is released into the environment. It is strongly suggested that India put these policies into effect in order to significantly enhance the quality of the environment. In a similar line, rising urbanization has resulted in the residential sector becoming the primary consumer of energy. This is due to the rise in the number of people living in urban areas. As a consequence of this, it has been suggested that homes limit the amount of energy they use by installing solar panels and switching to more energy-efficient electrical appliances.

This study has some limitations, despite the fact that the present study's outcomes have important consequences for public policy. The unavailability of data beyond the study period restricted the econometric methodologies used by the study. Furthermore, it may be possible to add to the existing body of knowledge by doing research into the link between environmentally responsible finance and consumption-based carbon emissions. It is possible to conduct additional research on India's economic growth and CO_2 emissions by including factors such as the country's political unpredictability, the volume of remittances received, the quality of its institutions, the degree to which the economy fluctuates, and data relating to the social dimension, such as employment rates.

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RESEARCH ARTICLE

Green Human Resource Management Perception in the Corporate Sectors of Khyber Pakhtunkhwa, Pakistan

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Abstract

Green Human Resource Management (henceforth, green HRM) has gained worldwide recognition nowadays. It brings together human capital for the welfare and sustainability of the organization. Green HRM undertook eco-friendly human resource practices, promoting higher efficiency, lowering costs, and better relationships among employees. It also helps the organization reduce CO_2 emissions by resorting to e-filing, online job advertising, online conferencing, online interview, online advertisement so on and so forth. This study, therefore, aims to examine the manager's perception about Green Human Resource Management and its practices in the corporate sector of Khyber Pakhtunkhwa (henceforth, KP), Pakistan. Data has been collected from the corporate sector of KP using a questionnaire. The sample size consists of 64 managers. A total of 24 questions have been asked from the managers of KP's corporate sector about green HRM. The questionnaire was divided into three different categories. The data analysis shows that on average 63 percent of the managers do green practices and 38 percent do not, 64 percent of managers do eco-friendly practices in their industries while 53 percent of managers do not, and 42 percent of managers are working to expand the sphere of green HRM practices but 57 percent of managers do not work as such to expand green HRM practices in their organization. The study suggests that organizations need to start giving training on Environmental Management, designing waste management policy, using public transport, employees' hiring and firing based on green actions, using software to go green, and incentives to employees for maintaining a green work environment.

Keywords: Green HRM; Corporate Sector; Manager's Perception; Khyber Pakhtunkhwa; Green Initiatives; Environmental Management

Introduction

Environmental sustainability has appeared as one of the world's most challenging concerns. The incidence of natural disasters, depletion of natural resources, and climate change have become very distressing (Markey et al., 2019). The disproportionate cutting of trees, burning of fossil fuel, and release of carbon monoxide due to organizational and other human activities are the reasons for the awful situation of the environment today. Now a day's societies have become much more aware and concerned about environmental issues. Therefore, to alleviate these effects, governments, most notably those of developing countries, have made pledges to global movements such as AGENDA 2030 and implemented policies to encourage organizations to pursue environmentally friendly practices. In response to this, many organizations are inclined towards ensuring that their daily operations are less damaging to the environment through the application of environmental management systems (henceforth, EMS) or green initiatives. These initiatives include reducing carbon emissions, such as reduced electricity and office materials usage; and consciously recycling materials appropriately. The environmental performance of employees and their disposition are paramount to the success of these green initiatives in organizations (Mazzi et al., 2016). To boost the environmental performance of an organization, it is prudent to focus on developing the environmental skills, attitudes, and behavior of employees. Nevertheless, more studies have focused on green initiatives or EMS, which are organizational-based studies. Environmental sustainability in an organization has been widely studied (Jabbour & Santos, 2008; Yong et al., 2019a). Yong et al. (2019a) studied the role of green human resource management practices on the sustainability and environmental performance of manufacturing organizations, Pham et al. (2019) assessed the effect of some green HRM practices on the environmental performance of hotels, and Mohamed et al. (2020) highlighted the best practices of ensuring a successful EMS in higher education sectors. Mohamed et al. (2020)

posited that in the higher education sector, employee behavior is crucial in reducing environmental degradation and ensuring a successful environmental performance, which has a ripple effect on society.

Green Human Resource Management comprises two core essentials, one is eco-friendly human resource (henceforth, HR) practices and the other is knowledge capital protection. Green HRM is a part of sustainable HRM directed to generate value for businesses stakeholders by simultaneously considering efficiency social and ecological facets (Stankevičiūtė & Savanevičienė, 2018). Human Resource activities play a significant part in the everyday application of sustainable development policies (Ulrich et al., 2009) while also in creating a sustainable development culture (Liebowitz, 2010). Similarly, Knowledge is an essential variable in the successful implementation of environmental sustainability in an organization. The absence of environmental knowledge may lead to a feeling of intimidation and avoidance of pro-environmental tasks (Chan et al., 2014). This means that, when action-related environmental knowledge is absent, no environmentally friendly behavior will be exhibited among working staff, which could hamper the efforts of environmental management initiatives. Studies have shown the importance of green HRM in the development of environmental knowledge (Matsuo, 2015). Similarly, Baumgartner and Winter (2014) reported that green HRM increases environmental awareness and knowledge among staff, enabling them to develop abilities and confidence to effectively lessen ecological problems, which will lead employees to perform environment-friendly behavior in the offices.

Keeping this in perspective, corporations are using human resource policies to produce environment-friendly merchandise and service for humanity. Now businesses are progressively recognizing the fact that having a green employer reputation is an effective way of attracting talented new people from the market (Reed et al., 2009). These Corporations promote the use of less paper and encourage employees to turn off lights when not in use. They also encourage online messages, meetings, trainings, and virtual conferencing interview. Thus, bringing into line corporate goals with HRM for commercial sustainability is called Green HRM. Moreover, several studies have been done on the environmentally friendly behavior of employees (Blok et al., 2015; Dumont et al., 2016; Kim et al., 2019), other have shown that the support of employees ensures the successful implementation of EMS (Mazzi et al., 2016). However, studies have not been directed explicitly toward managers in the corporate sector. Since managers are significant employees in corporate sectors. Furthermore, for the goal of achieving an environmentally sustainable corporation, managers are vital components in the success of such implementation, based on policymaking and behavioral support through their involvement and participation. This includes the alignment of human resource practices that direct and motivate employees to be environmentally conscious in the workplace (Renwick et al., 2016).

However, today the need for green HRM is vital and has been studied in various industries such as the hospitality industry (Kim et al., 2019; Pham et al., 2019), health industry (Jia et al., 2018; Saeed et al., 2019), manufacturing industry (Chaudhary, 2019; Dumont et al., 2016; Saeed et al., 2019; Yong et al., 2019b), and information technology industry (Ojo & Raman, 2019), but the perception about green HRM has seldom been studied. The ecological imbalance is rising day by day because of human activities. Reducing the usage of natural resources by using alternative sources, has a significant positive impact, by keeping less environmental footprint, and reusing material to decrease waste to the possible extent (Dallas, 2008). That is why the method of human resource management is crucial to environmental goals' attainment. Green HRM states using every worker's knowledge to approve ecological practices and to rise worker interest and abilities in the matter of sustainability (Mandip et al., 2012). Green HRM is evolving as an important chunk in the management (Mehta & Chugan, 2015). Fayyazi et al. (2015) suggested that there is a necessity to assimilate ecological management (EM) with HRM. According to Jabbour and de Sousa Jabbour (2016) building and enforcing eco-friendly activities in businesses are better off competitively. Moreover, Dumont et al. (2016) postulated that eco-friendly initiatives are the main green HRM practices that require employees' action for the organizations to obtain their environment-friendly goals. Therefore, customers and workers in recent times demanded firms to improve their accountability regarding the environment (Yuriev et al., 2018).

Moreover, in recent times, green HRM research on individual performance has received more attention. For instance, existing empirical studies have examined green HRM in relation to employee performance such as pro-environmental behavior (Ojo & Raman, 2019), environmental passion and environmental performance (Gilal et al., 2019), environmental commitment and employee's green behavior (Pham et al., 2019), employee's green behavior (henceforth, EGB) of employees with mediations such as organizational identification (Chaudhary, 2019), pro-environmental psychological capital (Saeed et al., 2019), psychological green climate (Dumont et al., 2016) and organizational commitment (Kim et al., 2019). Nevertheless, the study of green HRM's role on employee behavior remains in its infancy (Yong et al., 2019b) and needs to be studied in a different organizational context such as exploring the perception of management about green HRM. Besides further studies should be done to understand the

underlying mechanisms between green HRM and employee's green behavior (EGB), like environmental knowledge (Ren et al., 2018).

Green practices are supportive for the organization as well as for humanity to defend and measure ecological facets. It has directed corporations to cut costs and attain viable benefits. According to Pham et al. (2020), green HRM activities are important for workers to take part in eco-friendly creativities consistent with the companies' vision. Mohamed et al. (2020) established the view that in the higher education sector, worker behavior is essential in decreasing ecological degradation as well as safeguarding a successful environmental performance, which has a continuous effect on society. Alqudah et al. (2021) find that green HRM practices have a positive impact on environmental sustainability as well as that green HRM is comparatively new in corporations because of the nonexistence of standard signs that supports green HR activities. Simply, green HR is the one who is fully cognizant of eco-friendly actions and commits himself to resolve ecological problems by practicing green habits. On the same line, Ahakwa et al. (2021) suggested for officials and businesses, especially manufacturing businesses, embolden green actions, manufacturing as well as processing goods in the rewarding incentives-based effective system, that results in consumer reliability. Moreover, incentives for innovation have a significant effect on green eco-friendly actions.

The nexus between green HRM and EGB has been investigated by prior work (Dumont et al., 2016; Kim et al., 2019; Saeed et al., 2019), but researchers have paid little attention to the important and mediating role of environmental knowledge towards green HRM–EGB relationship. The impact of environmental knowledge on green HRM practices has not been explored enough (Ren et al., 2018). Some believe that when green HRM practices are implemented, employees still lack the proper knowledge to execute environmentally friendly behavior (supported by our findings). The implication is that green HRM practices must be effectively implemented to impact the essential ability, motivation, and performance of employees. Employees who have gone through green training (GT) become more knowledgeable and aware of environmental issues and how to mitigate these issues (Pinzone et al., 2019). Hence, this research study contributes to the literature by bridging the gap of previous studies by expanding the understanding of environmentally friendly behavior by exploring how green HRM affects employee's green behavior (EGB) through the study of environmental knowledge (Ren et al., 2018). The goal of this study is to explore the manager's perception about green human resource management of environmental knowledge. Thus, this study seeks to determine whether green HRM affects employee's green behavior through the environmental knowledge of managers from five multinational corporations located in Khyber Pakhtunkhwa (KP). The remainder of this study is organized as follows: Section 2 presents a relevant literature review. Section 3 gives information on the methodology and data, followed by results and discussion in Section 4. Section 5 offers a conclusion and ends with recommendations.

Literature review

Numerous studies concluded that green HRM to be an effective force in creating EGB in the workplace, corporations should have recruit, hiring and retain workers possessing environmental beliefs and values like motivation. Thus, organizations that consider employee environmental performance and effective training programs, as well as provide employees with the opportunity to get involved and participate help to improve the environmental awareness, behaviors, skills and knowledge of their employees (Dumont et al., 2016; Renwick et al., 2013). For instance, Chan et al. (2014) reported that green HRM practices improve the knowledge of employees about the environment which motivate them to use this knowledge to achieve organizational goals, which lead to carrying out environmentally friendly behavior at the workplace. Indeed, employees are known to avoid behaviors for which they lack sufficient knowledge to engage in. Therefore, the role of green HRM practices is to increase the environmental knowledge of employees, so that they can execute EGB at the workplace. However, green management plays a key role in the organization. It helped companies to increase not only profit but also its goodwill. Kapil (2015) concluded that green activities results in higher output, low costs and make an environment in which have better workers participation, that helps the corporations to work in eco-friendly business activities. Ahmad (2015) used secondary data and found that eco-friendly HR work force had yielded in higher efficiencies, decrease in costs, workers retaining as well as better productivity. Moreover, he said that green HRM future is favorable for all the related parties of HRM, from employer to employees, from practitioners to academicians. Therefore, linking the professional green HRM practices, research and teaching ecological management is needed. Madhavi (2016) concluded that green HRM seems to be hopeful to those by whom the green process would be adopted in times to come. He also said that organization would benefits if it follows green HRM practices by retaining good employees.

Javed and Cheema (2017) found that with implementations of green HRM there were higher chances of increased organizational outcomes. The study revealed that people hardly know about green HRM in Pakistan. Therefore, there is crucial need to increase the green HRM practices to improve organizational performance which are beneficial for the firm. It's been

said by Mohanty and Nayak (2017) in this study that green HRM was aiming at reducing wastages and too much concerned about environment.it has resulted in higher productivity. They also said that recruitment, selection, induction, performance appraisal, compensation and reward system based on green actions are effective tools to make employees more green for businesses to keep going for long time. Another study by Sharma and Sunita (2017) in Indian banks, they discovered that ecological issues are not fully inserted in old HR activities for environmental performance. The study also found that there was imbalance between HR practices to maintain ecological management. However, the study evidently depicted that several variables related to human resource like management team, preparation, culture, incentives etc., all support ecological management. That is why green HR strategies should be adopted by organization to promote environmental sustainability.

Rubel et al. (2021) analyzed 365 frontline workers' perception in banking sector in Bangladesh, they concluded that there was a positive significant direct impact of green HRM on green service behavior and knowledge sharing. Moreover, they found that there was significant intervening impact between green HRM and eco-friendly employment attitude. Tahir et al. (2020) collected data from 223 workers who working some of the CPEC construction and IT-related companies. They found that there is a little know-how about the use of green HRM among IT and firms of CPEC working in Pakistan. additionally, they found that green HRM has significant positive impacts on OCB-environment and firm's environment functioning. Further they suggested that the significance of green HRM is reducing the pressure on natural environment which will have a long-term positive effect on natural environment. Another study conducted by Malik et al. (2021) collected data from 437 employees from different businesses and they concluded that green HRM has a significant effect on environment related creativity and innovation. The study also found that this creativity significantly facilitates the link between green HRM and green innovation.

Naz et al. (2021) collected data from 370 employees directly engaged in implementing green practices in china's Jiangsu manufacturing firm, they found that the green HRM performance and firms eco-friendly strategy are directly related to the psychological green environment of the firm and that results in pro-environmental actions in employees. Ahmad et al. (2021) also studied in Gilgit-Baltistan (GB) area of Pakistan and found that green HRM has positive effect on employees' eco-friendly creativity. Woo and Kang (2021) suggested two business elements for those who design policy in green organization that the arrangement of business environmental approach with HR should include, a corporate culture that supports worker eco-friendly activities and worker flexibility skill to react to the growing ecological problems as key element of analysis. Similarly, Saeed et al. (2019) argued that an increase of environmental knowledge strengthens the effect of green HRM practices on EGB. Further, Rayner and Morgan (2018) argued that environmental knowledge could be enhanced through ability, motivation and opportunities in an organization to enable employees to perform EGB. Ren et al. (2018) stressed the roles that employee cognition plays for green HRM in influencing the performance of EGB to support EMS. For green HRM practices to influence the performance of green jobs, higher cognitive and interpersonal skills such as environmental knowledge (Rayner & Morgan, 2018) are needed (Consoli et al., 2016; Ren et al., 2018). Hence, developing environmental knowledge through green HRM results in creating responsible environmental behavior, and people's behaviors reflect the level of their environmental knowledge. Hence, this argument hypothesizes that green HRM practices will affect the environmental knowledge of the employees.

Theoretical Framework

Green and sustainable HRM has been addressed from various theoretical perspectives, such as institutional theory (DiMaggio, 1983; Scott, 1987), stakeholder theory (Freeman, 1984), paradox theory (Poole & Van de Ven, 1989), risk society theory (Beck et al., 1992), organizational development theory (Porras & Robertson, 1986), system theory (Von Bertalanffy, 1950), a resource-based view (Wernerfelt, 1984), and signaling theory (Spence, 1973). However, the ability, motivation, and opportunity (AMO) theory (Appelbaum et al., 2000) is the one most often applied in the literature, given that it provides a conceptual model which clarifies the strategies and implications of the HR functions that promote sustainable performance (Gholami et al., 2013; Guerci et al., 2016; Renwick et al., 2016; Renwick et al., 2013; Stone, 2000).

The AMO theory, which is developed by Appelbaum et al. (2000) anchors this study. The theory postulates that the possession of necessary skills, appropriate motivation, and opportunities given to take part in key decision-making initiatives are compulsory to ascertain employee performance. This theory claims that HRM practices contribute to organizational performance by improving the ability, motivation, and opportunities of working staff to perform EGB, which is aligned with the strategic goals of the organization. Through the lens of AMO theory, the argument could be made that HRM contributes to green organizational performance by recruiting and developing a highly competent workforce with green values; improving employee motivation and commitment through green-based strategies and incentives and efficient performance management; and providing employees with the opportunity to engage in knowledge-sharing and

problem-solving activities through employee involvement programs (Renwick et al., 2013). Studies have suggested that green HRM encourages the EGB of employees in the workplace (Saeed et al., 2019) where workers are equipped with the abilities to perform EGB and have support from management in implementing green recruitment, selection, and training. Furthermore, when employees' performance is measured and incentivized based on an EGB, they will feel motivated to accomplish even more because they know what is expected of them. The avenue to participate and get involved in environmental management initiatives would make employees feel obligated towards an initiative while sharing knowledge and giving feedback on how to make the initiative much more effective. Hence, the nexus of this AMO would encourage employees to perform EGB.

When green valued employees are recruited into an organization, they are passionate about contributing to environmental management initiatives (Jia et al., 2018). When employees are trained, they become more knowledgeable about what and how to mitigate environmental degradation, consequently becoming green champions. Giving incentives to employees based on their environmental performance increases their desire to learn more and find more ways to protect the environment (Ren et al., 2018). Finally, the participation of the employees in decision making through feedback and suggestions reassures their confidence of organizational support for the environment. At the same time, this involvement develops their commitment to the environment through knowledge sharing (Saeed et al., 2019). When employees are more knowledgeable about the environment, then they will be committed and compelled towards performing EGB. Rayner and Morgan (2018) indicated that green HRM should ensure the development of the ability, motivation, opportunity and environmental knowledge of employees to allow them to perform the desired green behavior at workplace. Hence, this current study uses AMO theory to explain the role of green HRM on EGB, through the mechanism of the environmental knowledge of employees, which will lead to a competitive advantage for a business corporation.

Methodology

The design of the research is quantitative, the study aims to find that what should be done for the organization to become green, what are the practices through which employees can be converted into green employees and to identify the perceptions of managers about green practices in the corporate sector of Khyber Pakhtunkhwa in Pakistan

Participants and Procedure

The Population of the study is the workers, particularly the management staffs of the corporate sector in Khyber Pakhtunkhwa, Pakistan. i.e., Cherat Cement Industry, Pakistan tobacco company, Northern Bottling Company, Coca Cola corporation, and Nestle corporation in Khyber Pakhtunkhwa, Pakistan. To identify managers' perceptions, the questionnaire has been divided into three sections green HRM practices, ecofriendly practices and expanding sphere of green HRM. these corporations had been taken as the population of the research study.

Data were collected through a self-administered survey. The sample was taken from the above population and primary data was collected through questionnaire. Questionnaires were randomly distributed among the managers of selected corporations. All questionnaires were distributed and collected manually except British American Tobacco (BAT) to whom questionnaire was sent through Email and back then, they sent the response back by post office. The sample size was 64 in the study and the same responses were collected. Based on our sample size, the response rate 100 percent. The participating managers were requested to fill the questionnaire to measure their green behavior, environmental knowledge and green HRM practices in their corporation. The study used the quantitative method using SPSS software to process the collected data gathered via questionnaire. Data has been descriptively analyzed to address the objectives of the study. Data has been collected on a nominal type scale of 1 stood for (yes) and 2 stood for (no).

Results and Discussion

Table 1 explains the questionnaire responses about green HRM practices, on average 63 percent of the managers do green practices. And 38 percent do not do practices. It follows that, most of the people are using green practices in their own fields and few of them are not using green HRM practices in their respective domain.

Table 1. Green Human Resource Management Practices

S. No	Questions	Yes(percent)	No(percent)
1	Do you unplug the appliances, when you are not using it?	79	21
2	Are you considering telecommuting, if you live far away from your work or office?	76.6	23.4
3	What kind of transport you are using? Public or Private	6.3	93.7
4	What type of water you are using? Tap Water or Bottled Water.	73.4	26.6
5	Are you using both sides of paper?	75	25

6	Do you shut down your computer before the ending time of your daily work (30 minutes in advance)?	46	56
7	Do you conserve energy?	98.4	1.6
8	Do you educate or teach your employees about efficiency?	80	20
9	Do you discipline or dismiss employees for Environmental Management breach?	14.1	85.9
10	Does your company conduct internal environment & energy audit in the organization?	59.4	40.6

Source: Authors' calculations based on questionnaire data

Table 2 describes manager's responses regarding Eco-friendly practices, some practices are close to fully acted upon and some are less to half are acted upon. But overall, on average, 64 percent of managers do ecofriendly practices in their own industries but, while 53 percent of managers don't adopt eco-friendly practices in their organizations.

Table 2. Ecofriendly Practices

S. No	Items/Questions	Yes (percent)	No (percent)
1	Does your organization has active policy to reduce carbon emission?	67.2	32.8
2	Do you involve employees in green suggestion?	43.8	56.3
3	Are you considering knowledge about environment as recruitment criteria?	57.8	42.2
4	Does your company do eco-friendly or go green survey?	35.9	64.1
5	Do you use software to go green?	28.1	71.9

Source: Authors' calculations based on questionnaire data

Table 3 elaborates questionnaire responses related to expanding the sphere of GHRM practices. Most of the managers said that they were not doing something to extend the sphere of green HRM practices in their own departments, but, few responded that they were intending to expand its sphere. But, overall, 42 percent of managers working to expand the sphere of green HRM practices. While 58 percent of managers do not work as such to expand green HRM practices in their businesses.

Table 3. Expanding Sphere of Green HRM

S. No	Items/Questions	Yes (percent)	No (percent)
1	Does your organization has carpooling or public transportation usage, because it promotes an environmentally-friendly atmosphere?	50	50
2	Do you share the green practices with your employees?	71.9	28.1
3	Do you have green team?	28.9	71.9
4	Do you give employees incentives for maintaining a green work environment?	18.8	81.3
5	Have you introduced training on Environmental management?	29.7	70.3
6	Do you link participation in green initiative to promotion?	50	50
8	Would you like to plan in near future to start or increase green HRM practices in your organization?	64.1	35.9
7	Does your company reward those who show green actions?	25	75

Source: Authors calculations based on questionnaire data

Theoretical Contribution

The findings of this study make important contributions to the body of knowledge. Particularly, in the AMO theory. First, green HRM is rarely used in exploring environmental knowledge in organization management. It is believed that staff equipped with the necessary capability, knowledge, skills, and opportunities to do green actions will enable them to mitigate ecological issues. This is supported by Saeed et al. (2019), that implementing green HRM practices and mitigating environmental problems is based on the environmental know-how of the employees. Secondly, regarding the mediating role of environmental knowledge between green HRM and EGB, this study contributes to the work of Marin-Garcia and Tomas (2016), which recommended that AMO could be improved relating to behavior by improving environmental knowledge. The findings are consistent with Rayner and Morgan (2018), which postulated that environmental knowledge positively impacts employees' behavior with the support of upper management. Hence, the current study contributes to the literature of green HRM by studying managers' perceptions in Khyber Pakhtunkhwa corporate sector. Since managers are the drivers of HR in the workplace. Their instructions could result in protecting the environment both in the workplace and in the community

as a whole. This study can help understand the means to increase the green behavior of managers and make them see green HRM and environmental knowledge that pro-environment green behavior is their core role as managers and models in an organization.

Practical Contribution

Although this study was conducted on the perceptions of the managers in the corporate sector of Khyber Pakhtunkhwa province. However, the study findings have relevant implications for a green workforce which can be applied in general. The study's conclusion is based on the premise that having a green workforce in an organization is imperative to tackle global climate issues (Ren et al., 2018). Therefore, to deal with environmental concerns, corporations should implement green HRM practices efficiently, which support efforts in environmental management. This study highlighted the importance for corporations in implementing appropriate green HRM practices as this assists in developing employee awareness, and knowledge of environmental issues and how to tackle them. It results in the successful environmental performance of corporations and society. These functions include the recruitment and selection process that shows the green values of the corporations, the orientation of new workers that emphasizes the importance of environmental consideration while working, environmental training that entails equipping managers and other employees with the ability to mitigate environmental issues at work, and the performance appraisal of employees that is linked with their environmentally friendly activities (Fawehinmi et al., 2020).

It is, therefore, strongly recommends that HR and top management in corporations create key organizational principles for environmental management when developing green HRM strategies. It may also be imperative for HR departments to hire people having similar environmental protection principles. HR practitioners can set an example by presenting the environmental ethics of their organization in work advertisements and by evaluating the green values of applicants through scenario issues related to environmental protection in the interview process (Fawehinmi et al., 2020). Moreover, HR specialists should provide instructors with instruction and training associated with environmental protection, which will assist them in fully understanding the environmental policies of the corporations and increasing their knowledge about the importance of environmental sustainability. Subsequently, awareness attained from such green training programs can make workers more thoughtful about environmental degradation and prevention procedures such as collecting data on waste and carbon emissions and determining the pollution sources and procedures needed to curtail such occurrences (Fawehinmi et al., 2020). Additionally, the HR department in corporations should link performance appraisal to the green performance of employees. A target can be set for paper usage within the specific period of time, and evidence of proper disposal on the content of recycling bins, leaving the lights, air-conditioning or computers switched on after working hours could be used as part of an appraisal. Subsequently, incentives should be given to green performer workers. Moreover, re-training, involvement in green management activities, and encouraging feedback are procedures that could be used for post-performance appraisal measures to ensure the development of green knowledge and behavior of employees (Fawehinmi et al., 2020).

Conclusion and Recommendations

This paper shed light on the perception of managers about green HRM and its practices in the corporate sector of Khyber Pakhtunkhwa. The data has been collected from the corporate sector of Khyber Pakhtunkhwa using a questionnaire. The questionnaire questions have been divided into three different categories namely Green Human Resource Management Practices, Eco-friendly Practices, and Expanding Sphere of green HRM. The data analysis shows that on average 63 percent of the managers do green practices and 38 percent do not, 64 percent of managers do eco-friendly practices in their own industries while 53 percent of managers do not, and 42 percent of managers are working to expand the sphere of green HRM practices but 58 percent of managers do not work as such to expand green HRM practices in their organization. Green HRM is not only important for making the environment green but it is also important for the growth of corporate sectors. Because nowadays the world is going towards sustainability and environment-friendly practices due to global warming and climate change. The following recommendations are made on the basis of the empirical findings of the study. In green HRM practices, the response of managers on some items was weak and need improvement; using public transport, designing waste management policy, and employees' hiring and firing based on green actions. In Eco-Friendly practices, the managers need to adopt using software in their organization to go about green. In the expanding sphere of green HRM; the organization needs to start giving training on Environmental management to employees and providing incentives to employees for maintaining a green work environment.

Limitations and Future Studies

This study has limitations that can serve as an avenue for future researchers. First, this study was conducted in five corporations in the Khyber Pakhtunkhwa province of Pakistan. Hence, the findings of this study cannot be

generalized due to their varying organizational structure. Further, this study cannot be generalized to other countries due to different cultural contexts, therefore, caution should be taken when interpreting the results. Secondly, Environmental knowledge fully mediated the relationship between green HRM and green behavior. Nonetheless, a need exists to determine the role of other variables in explaining the relationship between green HRM and green behavior. Henceforth, future studies should use other variables such as self-efficacy and environmental concern, etc., to understand the underlying mechanism (Fawehinmi et al., 2020). Employees having self-confidence would behave eco-friendly in the workplace (Meinhold & Malkus, 2005), therefore, future studies should investigate their mediating role between green HRM and EGB. Lastly, a wider scope for future researchers to study the topic with the increased sample within the country and globally.

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RESEARCH ARTICLE

Causal Relationship between Energy Consumption, Economic Growth, and Financial Development: Evidence from South Asian Countries

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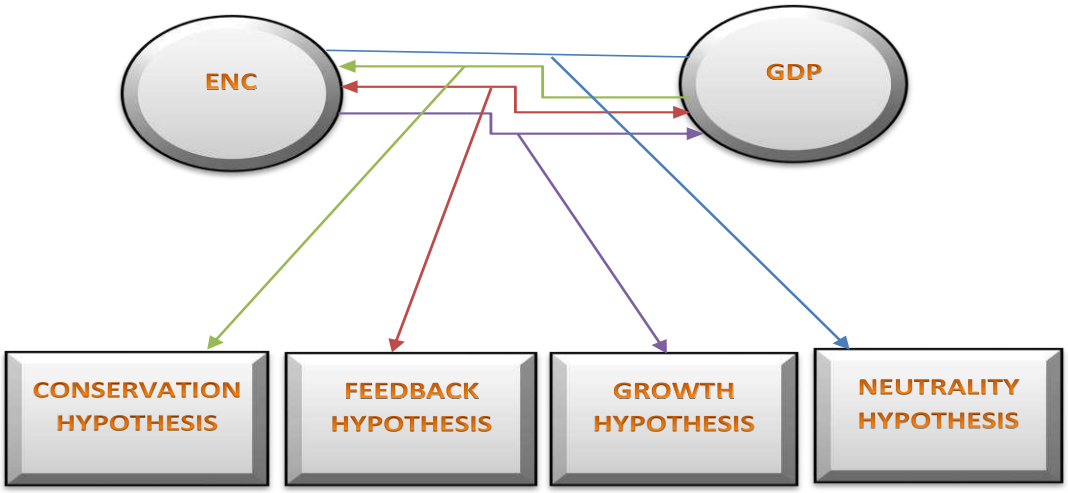
Abstract
Energy is a challenging and emerging problem in the world. Most South Asian countries have limited means but they cannot utilize a major part of their resources due to the high cost of exploration. However, few countries in this region have sufficient capacity and abundant energy resources to overcome the issues related to energy, but due to several reasons, they are not going to play an effective role in this field. As we know South Asian economies have limited resources and facing energy crises due to these reasons, we conduct research on this region as well. The aim of this study is to examine the relationship between economic growth (GDP), financial development (FD), and energy consumption (ENC) for South Asian countries for the period 1991-2020. For the empirical purpose, panel co-integration approaches are applied. However, the Pooled Mean Group (PMG) long-run result shows that the impact of financial development (FD) and economic growth (GDP) on energy consumption (ENC) is positive and significant. Based on the Vector Error Correction Methodology (VECM) Granger causality results, Conservation Hypothesis holds between the economic growth (GDP) and energy consumption (ENC) in the South Asian Region both in the short-run as well as in the long run. Moreover, the results also indicate that two-way causality exists between financial development (FD) and energy consumption.

Keywords: Energy Consumption; Financial Development; Economic Growth; Conservation Hypothesis; ARDL; VECM

Introduction

The energy sector is probably the biggest global industry after the financial sector with the widest effect on almost all other sectors of the economy since all the economic activities depend on energy both in the rural as well as in urban areas. For the functioning of the economy, energy accessibility is considered a prerequisite and it also affects the production cost of the commodities. Energy is also considered the important foundation for the development and growth of an economy because energy is used for multi-purposes in different sectors. Hypotheses related to the direction of the causality between ENC and the GDP can be expressed as economic growth is to be considered the evolution of GDP in the long, medium, and short terms. The causal relationship between GDP and ENC has been characterized by four different hypotheses (Acaravci & Ozturk, 2010; Apergis & Payne, 2010a, 2010c). Scale effect and method effect are both positively and adversely associated with energy usage, according to Shahbaz, Sinha, and Kontoleon (2022) energy consumption is increased by the composition impact and economic globalisation. On the other hand, energy usage falls as a result of financial progress and rising oil prices.

First, "Growth Hypothesis" when causality association running from ENC towards GDP, in this situation the dependence of the country's economy on energy is too high that shocks in the energy supply lead to a negative impact on the growing process of the economy, additionally, in this case, energy saving-oriented strategies may have a harmful effect on the GDP (Masih & Masih, 1998). Second, the "Conservation Hypothesis" is valid only in one situation when a one-way causal association runs from the GDP towards ENC, in this case, there is less use of energy, then there will be no negative effect of energy-saving policies on the GDP (Jumbe, 2004). The third one is the "Feedback Hypothesis" which indicates the two-way causality association between GDP and ENC. In this scenario, a decrease/increase in the use of energy leads to a decrease/increase in the GDP and vice versa. The last, one is the "Neutrality-Hypothesis" which discusses that both GDP and the ENC do not affect each other, in other words, there is no causality among the variables (Yu & Choi, 1985).



Fig#1

Energy is a challenging and emerging problem in the world. Most South Asian countries have limited means but they cannot utilize a major part of their resources due to the high cost of exploration. However, few countries in this region have sufficient capacity and abundant energy resources to overcome the issues related to energy, but due to different reasons, unfortunately, they are not going to play an efficient role in this field. i.e. Pakistan is not politically stable and has not had enough funding to resolve this issue. Environmental issues are increasing day by day due to the inefficient use of energy e.g., increasing the level of pollution. For the standard life of citizens, a clean and friendly environment is a necessity. Researchers are working on the issue of how to make efficient use of energy and achieve the requirements. As we know South Asian economies have limited resources and facing energy crises due to these reasons, we conduct research on this region as well. Hence, the present study is an attempt to add to the present literature in such a way. First, we have made some modifications in the model as compared to the previous studies as we take some additional variables (industrialization, urbanization, foreign direct investment, trade, and energy prices) in our model. In the existing literature, none of the studies has checked the association of ENC with FD, GDP, IND, URB, FDI, trade, and energy prices in the same model. Furthermore, unlike the previous studies which focus on a single country we examine the impact of the FD and GDP on ENC for the South Asian region by using the Panel Autoregressive distributed lag (ARDL) model and the VECM Granger causality technique. We also examine which hypothesis exists among these four hypotheses i.e., the Conservation Hypothesis, the Growth Hypothesis, the Feedback Hypothesis, and the Neutrality Hypothesis in the case of the South Asian region which contribute in the literature. The rest of the study is formed in a manner that part two is related to the review of the literature, section three is related to estimation methods, and the model, Section four shows the result's discussion as well as conclusions.

Literature

In previous literature, many studies examined the association between ENC and GDP from both prospectives empirically and theoretically, see (Altunbas & Kapusuzoglu, 2011; Apergis & Payne, 2010b, 2011; Apergis & Tang, 2013; Bartleet & Gounder, 2010; Belloumi, 2009; Chontanawat, Hunt, & Pierse, 2008; Huang, Hwang, & Yang, 2008; Narayan, Narayan, & Prasad, 2008; Narayan & Smyth, 2008; Ozturk & Acaravci, 2013; Ozturk, Aslan, & Kalyoncu, 2010; Saatçi & Dumrul, 2013; Sari & Soytas, 2007; Stern, 1993; Tang & La Croix, 1993; Yu & Choi, 1985). Similarly, these studies (Ciarreta & Zarraga, 2010; Menegaki, 2011; Pirlogea & Cicea, 2012) have also checked the association between ENC and GDP but in the case of EU countries. While some studies have shown the important role of the ENC on GDP in recent years (Al-Yousif, 2002; Feng, Sun, & Zhang, 2009; Kar, Nazlıoğlu, & Ağır, 2011; Masten, Coricelli, & Masten, 2008). Furthermore, Yu and Choi (1985) examine the association between ENC and GDP and used the granger causality test. While, Stern (1993) examines the association between ENC and GDP by using the vector autoregressive model; Kivyiro and Arminen (2014) check the association between CO_2 emissions, ENC, GDP, and FDI by using the panel ARDL approach for Sub-Sahara Africa; Fuinhas and Marques (2013) also use the ARDL bound testing methodology to check the association between ENC and the GDP; Yoo (2006) implied Grange causality and Co-integration test for Malaysia; Chen, Kuo, and Chen (2007) also used the Co-integration and the

Granger test for Malaysia. In previous years, the causality association between ENC and GDP has got the attention (Bekhet, Matar, & Yasmin, 2017; Omri, 2013; Omri & Chaibi, 2014; Omri & Kahouli, 2014; Saidi & Hammami, 2015; Shahbaz, Bhattacharya, & Mahalik, 2018; Shahbaz & Lean, 2012). On the other hand, in various studies unidirectional causality exists, i.e. Stern and Cleveland (2004) identified that the one-way causality association that is running from the ENC to the GDP while, an opposite view is that causality is running from GDP to the ENC (Simson, Sharma, & Aziz, 2011). Altunbas and Kapusuzoglu (2011) examine the association between ENC and GDP. The finding shows a one-direction causal relationship, running from the GDP towards ENC, and has found that there is no co-integration between the gross domestic product (GDP) and the ENC. Likewise, some studies have also argued on the basis of empirical results, that there is no long-term connection between the ENC and the GDP**.** In their study, Apergis and Payne (2009) investigated the connection between ENC and GDP. Two-way causality has been found in the long run between GDP and ENC while one-way causality has been found in the short-term running from the ENC toward GDP. Apergis and Payne (2010b) check the connection between GDP and ENC with the multivariate structure and used Pedroni's test for the panel of heterogeneous co-integration and found a statistically significant and positive association between ENC and the GDP. Yildirim, Aslan, and Ozturk (2014) have investigated the connection between ENC and GDP for a group of eleven countries. Their findings confirmed the neutrality hypothesis for all countries excluding Turkey and have found a one-direction causality connection running from EC towards GDP. To check the causality association between ENC and GDP for seven Sub-Saharan African countries, Jacques Loesse (2010) has applied the Bound testing methodology and has found a co-integration between GDP and ENC. The finding shows a one-direction causal relationship running from the GDP to the ENC in Congo, Furthermore, a two-way causality association has been found between real GDP and ENC in, Congo, South Africa, Cameroon, and, Cote d'Ivoire.

While contrary to the above studies, some studies have found bidirectional short-term and the long-term causality association between GDP and ENC i.e. (Abu-Bader & Abu-Qarn, 2008; Akkemik & Göksal, 2012; Al-Mulali, Fereidouni, Lee, & Sab, 2013; Al-Yousif, 2002; Calderón & Liu, 2003; Demetriades & Hussein, 1996). Murry and Nan (1994) also found a two-direction causal association between GDP and the ENC in Malaysia. The study by Aqeel and Butt (2001) checks the causality association among GDP, ENC, and employment in the case of Pakistan. The result indicates that both the GDP and the gasoline consumption have no impact on one another while it leads to the growth of the use of petroleum. Zhang and Broadstock (2016) investigate the causality connection between EC and GDP. However, in only one study, panel granger causality has been found, as Kahouli (2017) examines the causality association among ENC, GDP, and urbanization (URB). The findings of the bivariate analysis show the causality association running from urbanization to GDP and ENC and from GDP to ENC, Furthermore, tri-variate analysis shows panel granger causality connection runs from GDP and ENC to URB, URB, and GDP towards ENC, and from URB and ENC to GDP. In their study, Shahbaz, Lean, and Farooq (2013) recheck the link between the GDP and ENC in the case of Pakistan. The finding shows that ENC granger causes the exports (X) and co-integration among variables. Furthermore, Shahbaz, Chaudhary, and Shahzad (2018) examine the association between ENC and foreign capital inflows by including currency devaluation, exports, and GDP for Pakistan. The findings indicate that in the long run currency depreciation and foreign capital inflows decrease the ENC. However, the feedback effect has been found between ENC and foreign capital inflows. Furuoka (2015) examines the association between ENC and FD in Asian countries. However, the finding shows that ENC causes FD and also found the long-term relationship between ENC and FD. Kakar (2016) explores the relationship between FD and ENC in Pakistan. Shahbaz, Islam, and Butt (2011) examine the connection between ENC, FD, and CO_2 emissions in Pakistan. Similarly in another study, Islam, Shahbaz, Ahmed, and Alam (2013) also examine the link between the ENC and the FD by incorporating industrialization and urbanization in the case of Malaysia. Furthermore, Danish, Shah, and Muhammad (2018) & Saud, Baloch, and Lodhi (2018) check the connection between the FD and ENC by incorporating industrialization in the case of Next-11 countries. In the energy-growth nexus some studies add the financial development variable and confirm that an association exists between FD, ENC and GDP e.g., (Chang, 2015; Islam et al., 2013; Kakar, 2016; Shahbaz & Lean, 2012). Furthermore, in existing literature, few studies examine the association between ENC and FD (Islam et al., 2013; Mahalik, Babu, Loganathan, & Shahbaz, 2017; Sadorsky, 2010).

The models and methods

Many studies have used different variables and different econometric methodologies to check the association of energy consumption with other variables. We have made some modifications in the model as we take some additional variables (industrialization, urbanization, foreign direct investment, trade, and energy prices) into our model. In the existing literature, none of the studies has checked the association of ENC with FD, GDP, IND, URB, FDI, trade, and energy prices in the same model for the South Asian region by using the Autoregressive distributed lag (ARDL) technique and the VECM Granger causality approach but here we have estimated this model by using advanced econometric methodologies. Several studies such as Manan (2016), Shahbaz and Lean (2012), and Sadorsky (2010)

have incorporated the FD and GDP which is supposed to affect the ENC. Furthermore, FDI, trade, and energy prices also have been found to be affecting energy consumption (Bilgili, Koçak, Bulut, & Kuloğlu, 2017; Mahadevan & Asafu-Adjaye, 2007). Moreover, some other studies have added industrialization and urbanization to affect energy consumption (Manan, 2016; Shahbaz & Lean, 2012). Based on the above-mentioned studies, we utilize the model to examine the impact of the FD and GDP on ENC which is given below;

$$\ln ENC_{it} = \beta_0 + \beta_{it}\ln FD_{it} + \beta_{2t}\ln GDP_{it} + \beta_{3t}\ln IND_{it} + \beta_{4t}\ln URB_{it} + \beta_{5t}\ln FDI_{it} + \beta_{6t}\ln T_{it} + \ln EP_{it} + \varepsilon_{it} \quad (1)$$

In equation (1) i= 1……. N indicates the country and t= 1…...T represents time. ENC represents the consumption of energy (kg of the oil equivalent per capita), where the FD is going to be used to represent the financial development (domestic credit to the private sector percentage of the GDP), GDP is the economic growth (constant 2010 US$), IND is the industrialization (industry including construction % of GDP), URB denotes to the urbanization (urban population % of the total population), FDI is the foreign direct investment (net inflows % of the GDP), T is the trade (% of the GDP) and EP is the energy price (consumer price index CPI 2010=100) and ε_{it} is the residual term that is considered to be normally distributed having the zero mean and the constant variance. Furthermore, all the variables which are included in this model are taken in the log form.

Econometric Methodology

Data

For empirical purposes pannel data for South Asian region (i.e., Pakistan, India, Bangladesh, Sri Lanka and, Nepal) from 1991 to 2020 were obtained from the World development Index (WDI). Description of variables given below;

Table 1: Variables description

Variables	Notations	Unit
Energy Consumption`	ENC	Energy use (kg of the oil equivalent per capita)
Financial Development	FD	Domestic credit to the private sector (% of the GDP)
Economic Growth	GDP	GDP (constant 2010 US$)
Industrialization	IND	Industry (including construction) value-added [% of GDP]
Urbanization	URB	Urban population (% of the total population)
Foreign Direct Investment	FDI	FDI, net inflows (% of the GDP)
Trade	T	Trade (% of the GDP)
Energy Price	P	Consumer price index (CPI) [2010=100]

Source: World Development Indicators

Panel Unit Root Test

In the case of the panel data context, several unit root tests have been given to understand the characteristics of stationarity. However, it is necessary to analyze the stationarity of the data before the estimation because the estimation of non-stationary data gives us spurious results. The present study employed the Levin-Lin-Chu test proposed by Beck and Levine (2004), the Breitung unit root test, and the IM-Pesaran unit root test assumes the cross-sectional independence and ADF Fisher-type test presented by the Maddala and Wu (1999) and Choi (2001) to check the null hypothesis (Ho) that variables are non-stationary means having unit root. While Levin-Lin-Chu and Breitung tests are used for the common unit root process while IPS and the Fisher ADF test assume that an individual unit root process across the cross sections exists.

Co-integration analysis

Kao test for Co-integration

Kao presented (1999) the panel co-integration test namely the Kao test which is similar to the Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) type techniques. The model can be written as follow

$$Y_{it} = \alpha_i + \beta X_{it} + \hat{u}_{it}$$

The residual test for co-integration could be applied according to the above equation.

$$\hat{u}_{it} = \rho\hat{u}_{it-1} + v_{it}$$

$\hat{u}_{it}$ = estimated residual from the 1st equation. The OLS estimate for the co-efficient (ρ) is given below

$$\hat{\rho} = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{u}_{it}\,\hat{u}_{it-1}}{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{u}^2{}_{it}}$$

The equation of t statistic is written below

$$t_{\rho} = \frac{(\hat{\rho}-1)\sqrt{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{u}^2{}_{it}}}{{}^{1}/_{(NT)}\sum_{i=1}^{N}\sum_{t=2}^{T}(\hat{u}_{it}-\hat{\rho}\,\hat{u}_{it-1})^2}$$

Furthermore, Kao presents the four different forms of the Dickey fuller methodology that are given below

$$\text{DF}\quad \rho = \frac{\sqrt{NT}\,(\hat{\rho}-1)\,3\sqrt{N}}{\sqrt{10.2}}$$

$$\text{DF}\quad t = \sqrt{1.25t_{\rho}} + \sqrt{1.785N}$$

$$\text{DF}\quad \dot{\rho} = \frac{\sqrt{NT}\,(\hat{\rho}-1)+3\sqrt{N}\,\sigma^2{}_v/\sigma^2{}_{0v}}{\sqrt{3+36\,\hat{\sigma}^4{}_v/(5\hat{\sigma}^4{}_{0v})}}$$

$$\text{DF}\quad \dot{t} = \frac{t_{\rho}+\sqrt{6N}\;\hat{\sigma}_v\,/(2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}^2{}_{0v}/(2\hat{\sigma}^2{}_v)+3\hat{\sigma}^2{}_v/(10\hat{\sigma}^2{}_{0v})}}$$

The relationship between errors and the regressors is considered to be strongly exogenous in the two first two equations, while in the last two equations the association between the errors and the regressors is endogenous. An Augmented Dickey-Fuller (DF) test has also been presented by Kao (1999) which is given as

$$u_{i,t} = \rho u_{i,t-1} + \sum_{j=1}^{n}\phi_j\,\Delta u_{i,t-j} + v_{it}$$

The null hypothesis of the Augmented Dickey-Fuller test is the absence of co-integration while the alternative hypothesis is that co-integration is present among the variables. The statistics of the ADF test follow the Standard normal distribution and can be calculated as follows

$$\text{ADF} = \frac{t_{ADF}+\sqrt{6N\hat{\sigma}_v}/(2\hat{\sigma}_{0v})}{\sqrt{\hat{\sigma}^2{}_{0v}/(2\hat{\sigma}^2{}_{0v})+3\hat{\sigma}^2{}_v/(10\hat{\sigma}^2{}_{0v})}}$$

Padroni's tests of co-integration

The co-integration tests recommended by Padroni (1997, 1999, and 2000) permit considerable heterogeneity in the case of panel data models. The panel regression model for Pedroni is presented in the following section

$$Y_{i,t} = \alpha_i + \delta_t + \sum_{m=1}^{M}\beta_{mi}\,X_{mi,t} + \mu_{i,t}$$

For the detection of between and within-dimension effects in his, model Pedroni suggested seven different types of co-integration statistics. Pedroni classified the co-integration test into two different categories. In the first category, four tests are incorporated, which are depending on the pooling (besides the within dimension). These tests are almost alike to the previous co-integration tests, furthermore, the test statistics can be written as follow

Panel v-statistic:

$$T^2N^{2/3}Z_{\hat{v}NT} = \frac{T^2N^{2/3}}{(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}\hat{u}^2{}_{it})}$$

Panel ρ statistic:

$$T\sqrt{N}Z_{\hat{\rho}NT} = \frac{T\sqrt{N}(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}(\hat{u}^2{}_{it-1}\Delta\hat{u}^2{}_{it}-\hat{\lambda}_i))}{(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}\hat{u}^2{}_{it})}$$

Panel t-statistic (non-parametric form)

$$Z_{tNT=}\sqrt{\tilde{\sigma}^2{}_{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}}\,\hat{u}^2{}_{it-1}\,(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}(\hat{u}^2{}_{it-1}\Delta\hat{u}^2{}_{it}-\lambda_i))$$

Panel t-statistics (Parametric form)

$$Z_{tNT=}\sqrt{\tilde{\sigma}^{*2}{}_{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}}\,\hat{u}^{*2}{}_{it-1}\,(\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}^{-2}{}_{11i}(\hat{u}^{*2}{}_{it-1}\Delta\hat{u}^{*2}{}_{it}-\lambda_i))$$

The other three types of (between dimension) Pedroni co-integration tests are incorporated in the second category, the other three test statistics are given below.

Group ρ statistic (parametric form)

$$T\sqrt{N\tilde{Z}}_{\tilde{\rho}NT} = T\sqrt{N}\;\frac{\sum_{t=1}^{T}(\hat{u}^2{}_{it-1}\Delta\hat{u}^2{}_{it}-\hat{\lambda}_i)}{\sum_{i=1}^{N}(\sum_{t=1}^{T}\hat{u}^2{}_{it-1})}$$

Panel t-statistic (non-parametric form)

$$\sqrt{N}\tilde{Z}_{tNT-1} = \sqrt{N}\;\sum_{i=1}^{N}(\sqrt{\tilde{S}^{*2}{}_i\;\sum_{t=1}^{T}\hat{u}^{*2}{}_{it-1}}\,)\;\sum_{t=1}^{T}(\hat{u}^{*2}{}_{it-1}\Delta\hat{u}^{*2}{}_{it})$$

Panel t-statistic (parametric form)

$$\sqrt{N}\tilde{Z}_{tNT-1} = \sqrt{N}\;\sum_{i=1}^{N}(\sqrt{\tilde{\sigma}^2{}_i\;\sum_{t=1}^{T}\hat{u}^2{}_{it-1}}\,)\;\sum_{t=1}^{T}(\hat{u}^2{}_{it-1}\Delta\hat{u}^2{}_{it}-\hat{\lambda}_i)$$

Panel Autoregressive Distributed Lag (ARDL) Approach

In panel ARDL we have two different types of estimators. First is the "Pooled Mean Group estimator" (PMG) and the second is the "Mean Group (MG) Model". Furthermore, the speed of the adjustment (ECT) about the long-term equilibrium and the error variances are supposed to be heterogeneous country by country, whereas on the other hand the long-term slope coefficients are constrained to be homogenous across the states. In the PMG model, the long-term co-efficient might change from the error variances but the long-run co-efficient is to be equivalent to the error correction model. Furthermore, the PMG estimator is constructed under the postulation of heterogeneity of the long-term slope coefficients (Pesaran, Shin, & Smith, 1999). The primary conditions are treated as fixed or random and the long-term co-efficient are the combinations of the short-run coefficients. However, the base of the Pooled Mean Group (PMG) is the estimation of the Autoregressive Distributed Lag (ARDL) model (m_i, n_i, p_i, q_i, s_i, v_i, w_i, z_i).

Furthermore, the ARDL model includes the long-run relationship between the variables according to Pesaran et al. (1999) which can be written in the following form.

$$\Delta ENC_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta ENC_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta FD_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta GDP_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta IND_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta URB_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta FDI_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta T_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 ENC_{i,t-1} + \sigma_2 FD_{i,t-1} + \sigma_3 GDP_{i,t-1} + \sigma_4 IND_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i T_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2a)$$

$$\Delta FD_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta FD_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}ENC + \sum_{r=0}^{p-1} \gamma_{ir}\Delta GDP_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta IND_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta URB_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta FDI_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta T_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 FD_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 GDP_{i,t-1} + \sigma_4 IND_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i T_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2b)$$

$$\Delta GDP_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta GDP_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta ENC_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta FD_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta IND_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta URB_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta FDI_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta T_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 GDP_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 FD_{i,t-1} + \sigma_4 IND_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i T_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2c)$$

$$\Delta IND_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta IND_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta ENC_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta FD_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta GDP_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta URB_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta FDI_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta T_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 IND_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 FD_{i,t-1} + \sigma_4 GDP_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i T_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2d)$$

$$\Delta URB_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta URB_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta ENC_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta FD_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta GDP_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta IND_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta FDI_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta T_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 URB_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 FD_{i,t-1} + \sigma_4 GDP_{i,t-1} + \sigma_i IND_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i T_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2e)$$

$$\Delta FDI_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta FDI_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta ENC_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta FD_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta GDP_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta IND_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta URB_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta FDI_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 FDI_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 FD_{i,t-1} + \sigma_4 GDP_{i,t-1} + \sigma_i IND_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i T_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2f)$$

$$\Delta T_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta T_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta ENC_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta FD_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta GDP_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta IND_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta URB_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta FDI_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta EP_{i,t-g} + \sigma_1 T_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 FD_{i,t-1} + \sigma_4 GDP_{i,t-1} + \sigma_i IND_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i EP_{i,t-1} + \varepsilon_{1i,t} \quad (2g)$$

$$\Delta EP_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\Delta EP_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\Delta ENC_{i,t-l} + \sum_{r=0}^{p-1} \gamma_{ir}\Delta FD_{i,t-r} + \sum_{h=0}^{q-1} \theta_{ih}\Delta GDP_{i,t-h} + \sum_{u=0}^{s-1} \delta_{iu}\Delta IND_{i,t-u} + \sum_{x=0}^{v-1} \rho_{ix}\Delta URB_{i,t-x} + \sum_{d=0}^{w-1} \eta_{id}\Delta FDI_{i,t-d} + \sum_{g=0}^{z-1} \zeta_{ig}\Delta T_{i,t-g} + \sigma_1 EP_{i,t-1} + \sigma_2 ENC_{i,t-1} + \sigma_3 FD_{i,t-1} + \sigma_4 GDP_{i,t-1} + \sigma_i IND_{i,t-1} + \sigma_i URB_{i,t-1} + \sigma_i FDI_{i,t-1} + \sigma_i T_{i,t-1} + \varepsilon_{1i,t} \quad (2h)$$

Where ENC_{it}, FD_{it}, GDP_{it}, IND_{it}, URB_{it}, FDI_{it}, and EP_{it} indicates the log of the dependent variables, α_i represents the co-efficient that expressed the specific country, while the coefficients of the short-run dynamics are β_{ij}, φ_{il}, γ_{ir}, θ_{ih}, δ_{iu}, ρ_{ix}, η_{id}, ζ_{ig} that are related to each country and ε_{it} is the residual term in the model. Furthermore, it is assumed that long-term coefficients are identical to whole countries. Moreover, we can say that long-term association exists between dependent and independent variables if the value of β_{ij} is negative and significant. The PMG methodology is in the form of panel ARDL technique and can be used to estimate the autoregressive distributed lag model through the maximum likelihood.

VECM Granger Causality Approach

We used the panel VECM test proposed by Engle and Granger (1987) to examine the causal association among the different variables. Firstly, we estimate the long-term model to find the residuals by adopting the two-step procedure.

$$\ln ENC_{it} = \alpha_{it} + \delta_i t + \gamma_{1i}\ln FD_{it} + \gamma_{2i}\ln GDP_{it} + \gamma_{3i}\ln IND_{it} + \gamma_{4i}\ln URB_{it} + \gamma_{5i}\ln FDI_{it} + \gamma_{6i}\ln T_{it} + \gamma_{7i}\ln EP_{it} + \varepsilon_{it} \quad (3)$$

$$\begin{bmatrix} \Delta \ln ENC_{it} \\ \Delta \ln FD_{it} \\ \Delta \ln GDP_{it} \\ \Delta \ln IND_{it} \\ \Delta \ln URB_{it} \\ \Delta \ln FDI_{it} \\ \Delta \ln T_{it} \\ \Delta \ln P_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \\ \alpha_8 \end{bmatrix} + \sum_{p=1}^{r} \begin{bmatrix} \beta_{11p} & \beta_{12p} & \beta_{13p} & \beta_{14p} & \beta_{15p} & \beta_{16p} & \beta_{17p} & \beta_{18p} \\ \beta_{21p} & \beta_{22p} & \beta_{23p} & \beta_{24p} & \beta_{25p} & \beta_{26p} & \beta_{27p} & \beta_{28p} \\ \beta_{31p} & \beta_{32p} & \beta_{33p} & \beta_{34p} & \beta_{35p} & \beta_{36p} & \beta_{37p} & \beta_{38p} \\ \beta_{41p} & \beta_{42p} & \beta_{43p} & \beta_{44p} & \beta_{45p} & \beta_{46p} & \beta_{47p} & \beta_{48p} \\ \beta_{51p} & \beta_{52p} & \beta_{53p} & \beta_{54p} & \beta_{55p} & \beta_{56p} & \beta_{57p} & \beta_{58p} \\ \beta_{61p} & \beta_{62p} & \beta_{63p} & \beta_{64p} & \beta_{65p} & \beta_{66p} & \beta_{67p} & \beta_{68p} \\ \beta_{71p} & \beta_{72p} & \beta_{73p} & \beta_{74p} & \beta_{75p} & \beta_{76p} & \beta_{77p} & \beta_{78p} \\ \beta_{81p} & \beta_{82p} & \beta_{83p} & \beta_{84p} & \beta_{85p} & \beta_{86p} & \beta_{87p} & \beta_{88p} \end{bmatrix} \times \begin{bmatrix} \Delta \ln ENC_{it-p} \\ \Delta \ln FD_{it-p} \\ \Delta \ln GDP_{it-p} \\ \Delta \ln IND_{it-p} \\ \Delta \ln URB_{it-p} \\ \Delta \ln FDI_{it-p} \\ \Delta \ln T_{it-p} \\ \Delta \ln P_{it-p} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \\ \lambda_7 \\ \lambda_8 \end{bmatrix} (ECT_{it-1}) + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \\ \varepsilon_{6it} \\ \varepsilon_{7it} \\ \varepsilon_{8it} \end{bmatrix}$$

The optimal lag length is selected in each equation through AIC and HQ criteria (Pao & Tsai, 2011).

In the VECM model, the direction of the causality association among the variables is tested in the panel context. When the co-integration is present among the variables, it indicates that the long-term relationship among the variables, more, the causality exists among variables in at least one of the directions (Engle & Granger, 1987; Oxley & Greasley, 1998). Furthermore, the ECT term can also be incorporated into the model. As a result, Vector Error Correction Model (VECM) is constructed to reestablish the information missing in the process of differentiation and establish the short-run as well as the long-term equilibrium. Furthermore, the (ECT_{t-1}) is the lagged value of the residuals, the error-correcting dynamics model can be represented as follow: The panel VECM is specified as above (Belloumi, 2009; Pao & Tsai, 2011), Δ indicates to the first difference, αi is the representation of the constant term, λ is the parameter; where t=1,…., T represents to the time period where i=1,……, N indicates to the country or individuals, ECT is considered the lagged error term and derived from the long-term co-integrating association while ε_{it} is the representation of the error term which is supposed to be serially uncorrelated.

The results

Panel Co-integration Test Results

Pedroni (1999; 2004) suggests several co-integration tests for panel analysis based on co-integrating residuals ε_{it} i.e. the between dimension. The between-dimension tests are formulated by dividing the numerator with the de-numerator earlier adding over the N dimensions. The remaining other four tests are based on the within-dimension tests that can be stated as panel co-integration tests and obtained after

adding both de-numerator and numerator statistics separately over the N dimension. Here we used the Kao test and Pedroni (2004; 1999) panel co-integration test as a benchmark. These tests are used to examine the residuals. The residuals must be stationary when the variables are co-integrated. The results of the Kao and Pedroni's panel co-integration tests show that in the South Asian region we can reject the (Ho) in the Panel V-statistic means co-integration exists, the Panel PP-statistic, Panel ADF-statistic, Group PP-statistic, and the Group ADF-statistic at 1% the level of the significance. However, we can conclude that co-integration exists among all of them.

Panel ARDL results

The MG and PMG were recommended by Pesaran et al. (1999) and Pesaran and Smith (1995). These two estimators are based on the Autoregressive Distributive Lag (ARDL) model and Maximum Likelihood procedure by taking into account the long-run equilibrium along with accounting for the heterogeneity of the adjustment process (Demetrades & Law 2006). Though the Mean Group (MG) estimates are persistent, Pesaran and Smith (1995) discussed that these estimates become more reliable if the long-term homogeneity restrictions are accurate, and in this scenario, the MG estimates will be ineffectual which may give ambiguous results.

Table 2: Pedroni's and Kao Panel Co-integration test results for South Asian countries

Pedroni Test	
Alternative hypothesis: the common AR co-eff. (within dimension)	
Panel v-Statistic	2.3856***
	1.6375**
Panel rho-Statistic	1.2123
	1.2053
Panel PP- Statistic	-2.0990***
	-2.3714***
Panel ADF- Statistic	-2.1188***
	-2.3756***
Alternative hypothesis: individual AR co-eff (between dimensions)	
Group rho-Statistic	1.8348
Group PP- Statistic	-2.5130***
Group ADF- Statistic	-2.5174***
Kao Test	
	-0.257

Note: here, ***, **, *, indicates significance at the 1% if (P<0.01), at the 5% if (p<0.05) and at the 10% (p<0.1)

Table 3: PMG short-run estimate for South Asian Countries

	BRICS Countries		
Variables	**Co-efficient**	**t-stat**	**P-value**
Constant	-0.0070	-1.348383	(0.18)
D(ENC(-1))	0.4951***	4.460772	(0.00)
D(FD)	0.0002*	-2.040981	(0.07)
D(FD(-1))	-0.0005	-1.563087	(0.12)
D(GDP)	0.6337***	7.750008	(0.00)
D(GDP(-1))	-0.4098***	-4.066646	(0.00)
D(IND)	0.0039*	2.441908	(0.01)
D(IND(-1))	-0.0009	-0.555596	(0.57)
D(URB)	0.0273	0.499809	(0.61)
D(URB(-1))	-0.0213	-0.390390	(0.69)
D(FDI)	0.0036*	2.000124	(0.08)
D(FDI(-1))	-0.0001	-0.046386	(0.96)
D(T)	0.0001	0.294956	(0.76)
D(T(-1))	-2.1301	-0.050463	(0.95)
D(P)	-0.0006*	2.582694	(0.01)
D(P(-1))	-0.0004	0.489663	(0.62)
ECT(-1)	-0.0832***	-5.752407	(0.00)

Note: The values in the parenthesis are the corresponding P-values. ECT: Speed of Adjustment Co-efficient. Here, ***, **, *, indicates significance at the 1% if (P<0.01), at the 5% if (p<0.05) and at the 10% (p<0.1)

The above empirics show that short-run PMG results. As the outcomes show, that the co-efficient of the ECT term has negative sign and also statistically significant this suggests that a long-term association is present among the variables. Likewise, we can also assume ENC, FD, GDP, industrialization, urbanization, FDI trade, and the price, in the long run, have similar trends of movement. Moreover, when the co-efficient of the ECT term is less than one in the absolute term, it shows that the system is dynamically stable and converges towards the long-run equilibrium (Khan, Rehan, Chhapra, & Bai, 2022). Moreover, financial development, trade, urbanization, and foreign direct investment have the statistically insignificant effect on the ENC. Consequently, In the short run the results are mixed (Komal & Abbas, 2015; Mujtaba, Jena, Bekun, & Sahu, 2022).

Table 4: PMG Long run-results for South Asian Countries

Independent Variables	**Dependent Variables**							
	ENC	FD	GDP	IND	URB	FDI	T	P
ENC		4.0087	-10.7***	2.5748	12.278***	0.1346	-155.48*	-29.361
		(0.90)	(0.00)	(0.38)	(0.00)	(0.73)	(0.06)	(0.77)
FD	0.0005***		0.036**	0.0009	-0.117*	0.0011	0.0508	-0.9873

	(0.00)		(0.03)	(0.98)	(0.07)	(0.80)	(0.83)	(0.19)
GDP	0.11117***	-8.044*		3.7794	1.0689*	-0.0158	-12.85***	4.0393
	(0.00)	(0.09)		(0.51)	(0.06)	(0.68)	(0.00)**	(0.63)
IND	-0.0009	1.0984	0.0148		-0.4692**	0.0416**	1.0013	5.1169
	(0.61)	(0.31)	(0.85)		(0.04)	(0.02)	(0.55)	(0.22)
URB	0.1304***	-2.514	0.4785**	1.6923		0.0517*	4.2070	-8.1992
	(0.00)	(0.11)	(0.02)	(0.65)		(0.11)	(0.15)	(0.19)
FDI	-0.0176***	3.684***	0.2691	3.174***	0.0120		5.7313	8.1917
	(0.00)	(0.00)	(0.27)	(0.00)	(0.96)		(0.02)	(0.43)
T	0.0034***	-0.1709*	-0.04***	0.1501***	0.0293*	4.160		-0.6659
	(0.00)	(0.09)	(0.00)	(0.00)	(0.06)	(0.98)		(0.38)
P	-0.0019***	0.1035	0.029***	0.0417	-0.0771**	0.0015	-0.1440*	
	(0.00)	(0.21)	(0.00)	(0.54)	(0.02)	(0.27)	(0.09)	

Note: The values in the parenthesis are the corresponding P-values. Here, ***, **, *, indicates the significance at the 1% if (P<0.01), at the 5% if (p<0.05) and at the 10% if (p<0.1)

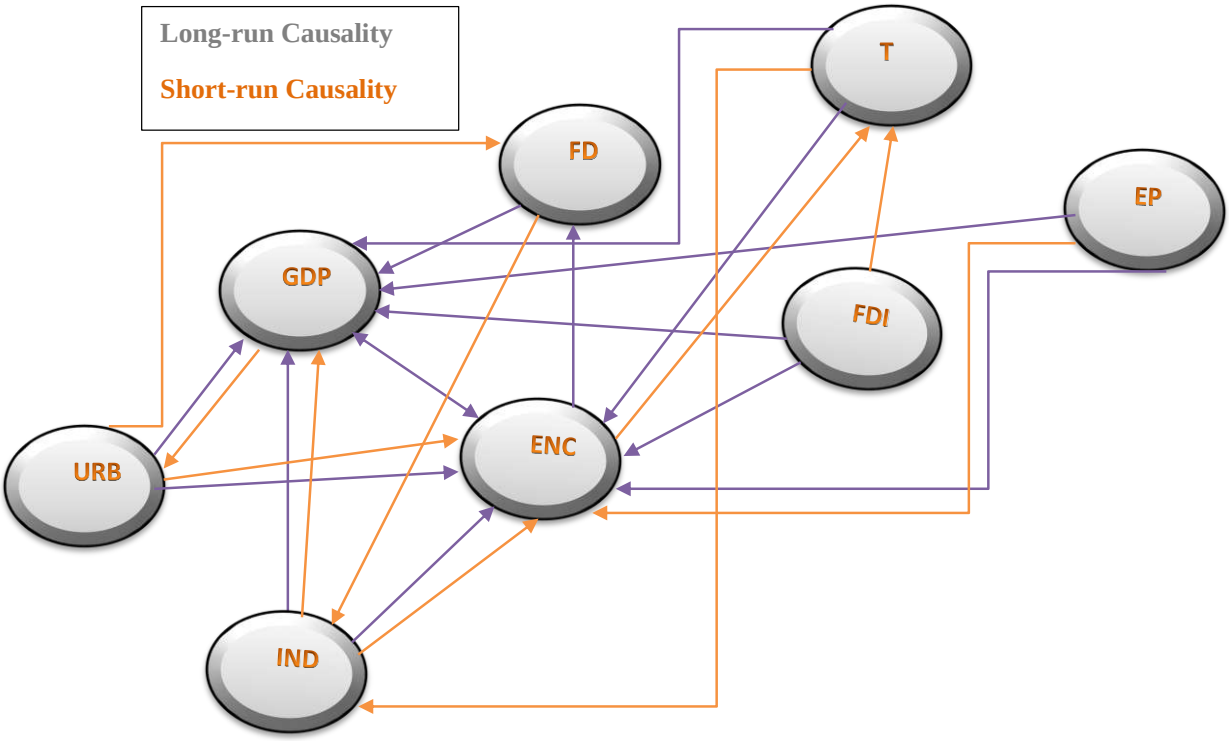
The above results show that the effect of GDP and FD on ENC is positive and significant at the 1% level of significance. The positive association between the GDP, FD, and the ENC indicates that as GDP and FD increase, it requires more energy hence these both are essential for the development of the economy. Furthermore, the positive association of FD with ENC shows that financial sector development derives the ENC through domestic and industrial users in these countries. Likewise, policies that are aimed at the development of the financial sector has also implications for energy demand in South Asian countries. Similarly, the long-run impact of URB is positive and significant on ENC which indicates that more people living in the urban areas encourage housing and economic activities that lead to the many structural shifts in the economy which all become cause to increase in the energy demand. In other words, URB proceeds, people tend to use modern energy products, household appliances, and transportation, and new ENC patterns steadily emerge these all become cause to increase in the ENC. Likewise, the impact of IND is negative and insignificant on ENC. Furthermore, ENC decreases with the increase in FDI and prices. However, the price is negatively associated with the ENC which follows the law of demand. Trade has a positive impact on ENC(Ali, Gohar, Chang, & Wong, 2022).

VECM Granger causality test results

In the VECM Granger causality methodology, the direction of the causality between ENC, FD, GDP, URB, IND, foreign direct investment, trade, and energy prices is to be tested in the panel context. When the co-integration is present among the variables, it indicates the long-term connection among the variables. Moreover, causality exists among the variables in at least one direction (Engle & Granger, 1987; Oxley & Greasley, 1998).

The above figure shows that the one-way causality relationship is running from the GDP towards ENC, which is similar to the results of (Aqeel & Butt, 2001) and (Asghar, 2008). These findings support the conservation hypothesis which suggests that economies are comparatively less dependent on energy and also maintaining the same level of energy consumption (by using different measures such as a decrease of greenhouse gas emissions, and energy demand managing strategies) will have a marginal effect on the GDP. Many studies in literature, support our results e.g.Ozturk et al. (2010), Masih and Masih (1996) in the case of Indonesia and Pakistan, and Huang et al. (2008) for the Lower and Upper Middle-income groups. Hye and Riaz (2008) confirmed the causality from GDP to ENC in Pakistan. Additionally, FD causes the ENC in this region. The uni-directional causality is running from FD, GDP, IND, URB, FDI, trade, and price towards ENC, from ENC, FD, IND, URB, FDI, trade, and price towards GDP in the period of the long run. However, the results in the short run indicate an absence of the causality between the FD and the GDP, FDI and FD, price and FD, FDI and GDP, URB and IND, FDI and IND, FDI and URB, trade and URB, URB, and price, FDI and trade. Likewise, one-way causality is running from IND to ENC, URB to ENC, FDI to trade, price to ENC, URB to FD, ENC to trade, IND to GDP, GDP to URB, IND to trade, and FD to IND.

Fig#2



Conclusion and the recommendations

The basic objective of this empirical examination is to examine the short-run as well as the long-run relationship and the direction of the causality between FD, GDP, and ENC in South Asian countries, For empirical analysis, we use the annual data from 1991-2020. We employ different unit-root tests, e.g. the Levin Lin Chu (LLC) unit root test, Fisher ADF chi-square test, and Breitung unit root test including the IM-Pesaran-Shin Unit root approach to analyze the stationarity of the data. Likewise, we used the Schwarz-Bayesian Criterion (SIC) and the Hannan-Quinn (HQ) information criterion for the purposes of optimal lag selection. The results indicate that one or two of the variables are I(0) while the other variables are I(1). Additionally, none of the variables is integrated into order two. After these steps, we employ the Pedroni (2004; 1999) and Kao panel co-integration test. The finding of these tests indicates that the co-integration exists among the variables. After the confirmation of the co-integration, we apply the Panel ARDL and the VECM Granger causality approach. Furthermore, the outcomes of the PMG short-run approach show that the co-efficient of the ECT term has a negative significant value. This significant value of the coefficient of the ECT term shows that a long-term relationship exists among the variables. Whereas, the PMG long-run results indicate that the impact of the economic growth on energy consumption (ENC) is positive as well as significant which shows that economic growth can be achieved with more energy consumption generally. Furthermore, the impact of the FD on the ENC is also positive and statistically significant. This indicates that with the increase in the FD, the ENC will also go to increase. However, more easy access to loans, debts, or to credits would lead to an increase in the confidence of the investors for more business activities as a result the demand for energy will also be increased. Along with this, financial resources to the customers at a low rate of interest inspire the common man to borrow more than before, hence this leads to an increase in the purchasing power of the public for durable products e.g., air conditioners, vehicles, and refrigerators, these all increase the demand for energy. Likewise, FD encourages manufacturing growth and enables to build of new plants and factories that all enhance the demand for the energy. Moreover, an increase in the GDP also increases the demand for the energy. Another view is that increasing economic activities (consumption, purchases, and investment) will also lead to an increase in the demand for energy.

The findings of the that VECM Granger causality approach show the one-way causal connection exists, running from the GDP to ENC means GDP stimulates ENC. This also shows that a reduction in energy use will not have a

substantial effect on the GDP hence the energy conservation policies in this region will decrease the unnecessary loss of energy. In the other words, in these regions, our empirical findings support to the "conservation hypothesis". However, when energy use increases with the increase in GDP then in this form the externality cost of ENC will be set back to GDP. We can also say based on empirical results, that these countries are less energy-dependent and also maintaining the same level of ENC (by using different measures such as a decrease of greenhouse gas emissions and energy demand managing strategies) will have a marginal impact on the GDP. These findings are in line with those (Abid & Mraihi, 2014; Ahmed et al., 2013; Akinlo, 2008; Altinay & Karagol, 2005; Chen et al., 2007; Cheng, 1997; Chiou-Wei, Chen, & Zhu, 2008; Faisal, TÜRSOY, & REŞATOĞLU, 2017; Huang et al., 2008; Hye & Riaz, 2008; Lee & Chang, 2007; Ozturk et al., 2010; Shahbaz, Tang, & Shabbir, 2011; Wolde-Rufael, 2006; Yasar, 2017; Yoo, 2006). Likewise, on the basis of empirical findings, we conclude that ENC and FD are interdependent means bi-directional causality is present between the ENC and FD in South Asian countries in the short run as well as in the long run. Bi-directional causality means both ENC and FD are complementary to each other. Because development in any economy could never be achieved without both main pillars of the economy e.g., a developed financial system and sufficient energy supply. Few studies support these results in the previous literature (Danish et al., 2018; Faisal et al., 2017; Roubaud & Shahbaz, 2017; Sbia, Shahbaz, & Ozturk, 2017; Shahbaz & Lean, 2012). However, the results of other variables are mixed. In South Asian countries, causality is running from GDP to ENC means the "Conservation Hypothesis" is confirmed. Therefore, these results provide a better understanding to the policymakers and they can formulate the policies relevant to energy on the basis of these results. However, when, GDP leads to ENC then the externality of the energy consumption (ENC) will be set back to the GDP. Hence, in this scenario the conservation policy is necessary. These conservation policies should be environment friendly like demand-side management policies and efficiency improvement measures, whose purpose is to decrease the wastage of energy and would not harmfully impact the economic activities in the long run.

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Conflict of Interests

The authors declare that they have no conflict of interests.

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