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The Impact of Sustainable Technologies, Urbanization, Human Capital, and Trade Openness on Load Capacity Factor: Evidence from BRICS Countries

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ABSTRACT

Carbon dioxide (CO_2) emissions have grown extensively due to high economic activities and environmental degradation. Therefore, the problem needs to be addressed by academia and practitioners. The presently scholarly discourse undertakes a rigorous evaluation of urbanization, human capital, trade openness, and sustainable technologies and their collective impact on load capacity factor within the economic landscape of BRICS nations. By employing CS-ARDL technique, the study in question discloses that urbanization, human capital, trade openness, sustainable technologies and industrialization positively influence load capacity factors. Findings imply that due to urbanization and industrialization, BRICS nations improve their human capital tendency and tend to show more engagement in global trade. As a result, the load capacity increases due to high demand. In addition, amalgamation of clean technologies also enhances the capacity, suggesting a synergetic effect between clean energy practices and load management. The findings suggest that when countries make tactical investments in these areas and pair it with trade policies, they can increase load capacity.

Keywords: Urbanization, Human Capital, Trade Openness, Clean Energy Technologies, Load Capacity Factor, Industrialization
JEL Classifications: Q56, O33, F18, R11

1. INTRODUCTION

There have been numerous challenges facing the world over the last few decades like economic instability, and environmental issues. One of the issues which affect the world at a swear level is environmental-related issues. This is the reason why environmental changes have strongly attracted the attention of the world during the past few decades. The reason is its terrible consequences due to which the world is paying special attention to finding a solution to this problem. As a result of environmental degradation, the world temperature is increasing and resulting in the melting of glaciers and the decrease of other natural resources. Moreover, this leads to several health problems like heat stroke. The industrialized nations are urging the developing world to concentrate on activities to control the variables that lead to ecological changes in light of these terrible repercussions. There are numerous causes of carbon and other related greenhouse gas emissions like transportation, electricity production, industry, residential and commercial, agriculture and land and forestry (Chen et al., 2018; Mardani et al., 2019). Transportation is one of the biggest carbon emissions in the world. Almost 27% of carbon emissions emanate from transportation industry, highlighting profound environmental challenges related to the industry (Walling and Vaneeckhaute, 2020). The electricity is considered second-largest cause of carbon emissions (Grigoratos et al., 2019). Agriculture produces almost 11% of carbon emissions (Andrew, 2019).

BRICS is the association of 5 nations like "Brazil, Russia, India, China, and South Africa" (Figure 1). All the economies of BRICS are expressing special attention towards economic as well as environmental issues. The economies of the BRICS nations have expanded quickly, amassed sizable foreign exchange reserves, and drawn substantial amounts of foreign direct investment. However, when taken as a whole, these all add to global carbon emissions (Karakurt and Aydin, 2023). Climate change is brought on due to higher (CO_2) emissions, which affect the environment and nature. The hazard posed by environmental deterioration is the one that receives the greatest attention. The BRICS countries' CO_2 emissions in 2013 were 14,110 million tons (Mt), about twice as much as they did in 2000. Furthermore, since 2009, the BRICS nations have contributed more than 40% of the global carbon emissions each year (Baloch et al., 2019; Su et al., 2021). Clean energy is in demand because of rising CO_2 emissions. Additionally, the BRICS nations want to boost both governmental and private efforts to lower the global temperature by up to 2°C by reducing CO_2 emissions (Adedoyin et al., 2020; Feng et al., 2025). It is dedicated to achieving a decrease in carbon and greenhouse gas emissions (GHGs). Therefore, a workable environmental plan is needed to reduce overall CO_2 emissions without jeopardizing the nation's development initiatives for bettering its energy resources and achieving optimal energy efficiency.

The literature witnessed that in the BRICS Russia has the largest per capita carbon emission which stands at 12.1 (per capita. After Russia, the highest carbon emission is in South Africa (Haseeb et al., 2018). The carbon emission in South Africa is 7.34 (per capita) in 2020. After that, the highest carbon emission is in China which is 8.05 (per capita). The reason for high carbon emissions in China, as well as Russia, is industrialization. Since the world prefers China for manufacturing which causes more industrialization and results in carbon emissions. After that Brazil emits the 2.28 (per capita) carbon emission in the world. The lowest % of emissions is in India which is 1.90 (per capita) (Baloch et al., 2019; Zhao et al., 2021). The carbon emission in BRICS is given in Figure 2. Also Figure 3, and Figure 4 show the current and forecasted energy consumption in BRICS, indicating greater potential of growth along with high human capital and natural resources.

The past literature gap which will address are (1) the horrible consequences of environmental degradation are one of the serious worries for the world. As the world temperature due to carbon emissions is increasing at a rapid pace, there is an urgent shift toward resource-friendly methodologies and resources. Although, plenty of studies have explored such factors from diverse perspectives, the full potential is yet to be disclosed which can be identified through in-depth exploration (2) Wang and Zhang (2021), explored the relationship between carbon emission and trade openness only particularly in 180 countries of the world, however, the present investigation focuses on variables like urbanization, human capital index, clean energy technologies, load capacity factor and industrialization particularly in BRICS with fresh data set, (3) Tokarska and Gillett (2018), worked on the carbon emission and global warming, however, the study's main focus is on load capacity factor along with urbanization, human capital index, trade openness, clean energy technologies, and industrialization in BRICS with fresh sample set, (5) Adebayo et al. (2021), explored urbanization and carbon emission particularly in Brazil, whereas the present study will check the relationship through the lens of load capacity factor along with addition of industrialization, human capital, trade openness in BRICS with fresh data set, (6) Haini (2021), explored human capital, ICT and carbon emission particularly ASEAN economies, whereas the present study focuses on load capacity factor along with industrialization, urbanization and trade openness particularly in BRICS perspective, (7) Rehman et al. (2021) explored energy imports, and economic growth and their impact on carbon emission particularly in Pakistan, whereas the present focuses on LCF and industrialization with the addition

Figure 1: BRICS geographical location

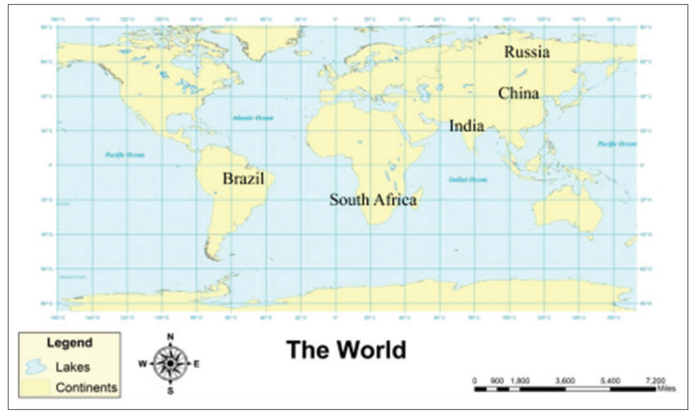


Figure 2: CO_2 emission in BRICS

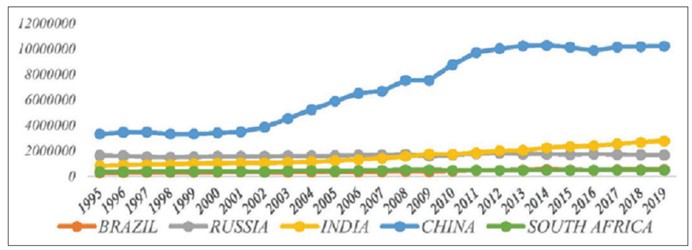


Figure 3: Current Energy Consumption in BRICS (BRICS Report 2020)

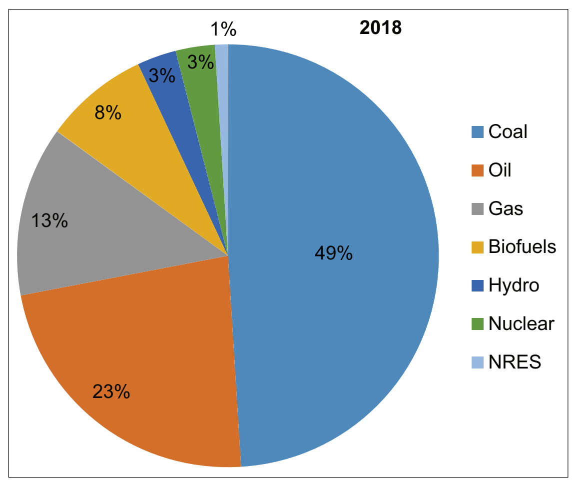
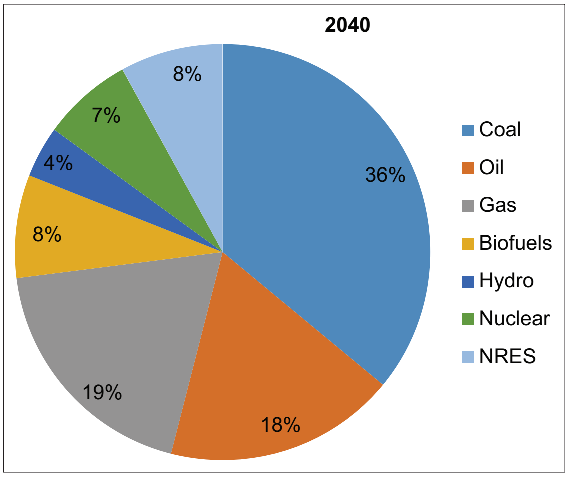


Figure 4: Forecasted Energy Consumption in BRICS (BRICS Report 2020)



of urbanization, human capital and trade openness in BRICS with fresh data sample.

Based on the above discussion, the study's contribution is threefold. Firstly, the study emphasizes the urgency of mitigating the rapid increase of carbon emissions which are multiplying catastrophic consequences. Secondly, the study offers valuable insight for practitioners and institutions, empowering economies to re-evaluate and modify their existing environmental policies aimed at stabilizing environmental quality by reducing emissions and protecting natural resources. Although various aspects of carbon emissions have been outlined in past literature, however, the study contributes to literature by uncovering new dimensions which are underexplored and demand further warrant.

2. LITERATURE REVIEW

The world is expanding at a rapid pace. This expansion is resulting in numerous issues like food shortage, resource shortage, and environmental instability in terms of carbon emissions. With the expansion of the population, the usage of world resources is also increasing (Adam et al., 2025). The increase in natural resource usage leads to resource depletion and higher carbon and other harmful emissions. In this context, Adebayo et al. (2021) revealed that while there is no conclusive link between trade openness and economic growth, however, Brazil's economic growth is significantly influenced by carbon emissions, higher energy consumption and urbanization. Similarly, Ahmed et al. (2019) revealed an inverse U-shaped association between CO_2 emissions and urbanization. Urbanization causes a rise in CO_2 emissions, however at a certain point, it has a negative effect. While trade openness has no discernible impact on CO_2 emissions, economic development and energy intensity do. Further, there is a one-way causal association of economic growth with emissions and energy intensity, as well as a feedback association between urbanization and emissions. Additionally, Ali et al. (2019) investigated the relationship in the context of Pakistan in a time span of 1921-2014. The results of the investigation revealed the cointegration of the variables.

Furthermore, Haini (2021), investigated the connection of ICT, human capital with environmental quality. The investigation was carried out in ASEAN economies covering the time period 1996-2019. The investigation applied the ARDL approach and revealed that human capital formation raises carbon emissions, and ICT decreases them. Moreover, the ICT infrastructure should therefore be developed by ASEAN officials to promote the reduction of carbon emissions. Similarly, Yao et al.'s. (2020), investigation was carried out on the 20 OECD economies in a time span of 1970-2014. Study outcomes exposed a significant association between human capital and carbon emission. The nature of association is negative. Additionally, Lin et al. (2021) used SYS-GMM approach and revealed that China's environmental degradation is lessened by creative human capital. Further, "environmental Kuznets curve" (EKC) exists when innovative human capital is taken into account in the model. It indicates that if China keeps building its creative people capital. However, there is a conflict between FDI and CO_2 emissions. The report also suggests all-encompassing measures to boost creative human capital for environmental sustainability.

Economic stability is the ultimate aim of the countries. This increase in economic activities is resulting in environmental issues, thus, governments should prefer the economic activities which impact the environment in fewer manners. In this context, Wang and Zhang (2021), investigated trade openness and carbon emission in 180 countries of the world. By employing FMOLS technique, an investigation revealed that trade openness helps in the reduction of carbon emissions. However, in low-income economies, the relation appears to be opposite. This variation of trade openness indicates a good influence on developed nations to decouple their economic development from harmful emissions; however, it is not the case for developing nations. Moreover, Dauda et al. (2021) revealed that in the case of Mauritius, Egypt, and South Africa, the findings supported an inverted U-shape link between innovation and CO_2 emission. The Environmental Kuznets Curve was also validated at the panel level in 4 out of 9 nations. The investigation proposed that, in order to promote green growth, regional integration and innovation absorption into all phases of development should be promoted. Similarly, Baloch et al. (2019) results exposed a significant link between trade openness and carbon emission, particularly in Tunisia. Moreover, Tunisia must increase its investment in environmentally friendly i.e., green projects with the aim to mitigate carbon emissions.

Energy has become one of the vital needs of the world. However, the increasing demand for energy is causing environmental issues like carbon emissions. In this context, Cai et al. (2025) revealed that clean energy technologies and carbon emissions are significant to each other. The increase in consumption of clean energy technologies results in a decrease in carbon emissions. Further, governments should encourage the usage of clean energy technology with a view to safeguarding the environment by controlling carbon emissions. Similarly, Ahmed et al. (2022) used the data set of 43 years of Japan and revealed that clean energy technologies need time to support the environment. As clean energy results in mitigating carbon emissions thus investment in clean energy is necessary for a country like Japan. Additionally, Doğan et al. (2021) exposed that clean energy technologies and carbon emissions share negative association. Clean energy technologies result in mitigating carbon emissions in the selected OECD economies.

The environment is witnessing more degradation with the passage of time. There are numerous reasons to stand behind it. One of the vital reasons is the usage as well as the production of energy from traditional resources like coal and fossil fuel. Due to the high demand for energy, it has become difficult for the countries to manage the load. Many times, this mismanagement of load results in complications in terms of industrial production. In this context, Leonard et al. (2018), worked on energy in terms of load capacity and carbon emission. Findings stated that load capacity impacts carbon emission negatively. Similarly, Zheng et al. (2020) checked whether load mitigation between data centers affects carbon emissions. The investigation was carried out in the PJM region in the time span of 2015-2019. The results of the investigation revealed that there is a significant association between load mitigation and carbon emission. The mitigation of the load results in a reduction in carbon emissions. Similarly, Akadiri et al. (2022), worked on the load capacity along with carbon emission. The investigation was carried out in India. Findings show that load capacity shares significant connection with carbon emission. It shows that the higher load capacity means higher emissions.

The ultimate goal of the any nation is to achieve economic stability, however, it will lead increased economic activities. These economic activities increased industrialization, further resulting in higher carbon emissions. Study of Rehman et al. (2021) revealed that industrialization has a positive effect on carbon emissions. Further, the fluctuating economic growth has had a negative influence on CO_2 emissions. Additionally, Mahmood et al. (2020) revealed that both industrialization and urbanization decrease environmental quality. Moreover, it is also revealed that industrialization imposes inelastic influences whereas urbanization appears to show elastic effect on emissions. Similarly, Dong et al. (2019), investigated whether industrialization along with urbanization effect carbon emissions. The investigation was carried out into 14 developed economies. The investigation applied the regression model to analyze the collected data sample. Findings revealed that urbanization and income have a large double-threshold impact on carbon emissions. Carbon emissions and urbanization in the low-urbanization stage do not significantly correlate from an urbanization standpoint. However, throughout the latter stages of urbanization, carbon emissions are negatively impacted.

3. RESEARCH METHODOLOGY

The article examines the impact of urbanization, human capital, trade openness, clean energy technologies, and industrialization on load capacity factors in BRICS countries. The article used the WDI and Global Footprint Networks to get the data of time span 2001-2018. The following is the equation constructed under the influence of chosen variables:

$$LCF_{it} = \alpha_0 + \beta_1\, URB_{it} + \beta_2\, HCI_{it} + \beta_3\, TRO_{it} + \beta_4\, CET_{it} + \beta_5\, IND_{it} + e_{it} \quad (1)$$

Where;
t = Time Period
i = Countries
URB = Urbanization
HCI = Human capital index
TRO = Trade openness
CET = Clean energy technologies
LCF = Load capacity factor
IND = Industrialization

In present study, load capacity factor was treated as DV whereas four predictors were considered to assess the relationship. Figure 5 presents the conceptual framework. These are urbanization, human capital, trade openness and clean energy technologies. Finally, the study has also used industrialization to predict CO_2 emissions as the control variable. These proxies used to assess study variables are explained in Table 1.

The present paper applies a descriptive method to study the properties of chosen variables. Besides, a correlation test was performed to assess the strength and weakness among study constructs. Moreover, the present research also applies the "cross-sectional dependency test" to find the cross-sectional dependency (CSD). This approach is meaningful when the cross-section (countries) is more essential than the time series (years). The estimated equation for the CSD test is mentioned below:

$$SD_{IT} = [\frac{IT(T-1)}{2}]^{\frac{1}{2}}\ \widehat{\bar{\rho}_T} \quad (2)$$

Where $\widehat{\bar{\rho}_T}$ represents "pair-wise correlation coefficients," while T indicates "time," and I indicates "cross-section units." In addition, the present research also applied the CIPS unit root test to find the unit root among the variables. This approach is more

Table 1: Variables with measurements

S#	Variables	Measurement	Sources
02	Urbanization	"Urban population growth (annual percentage)"	WDI
03	Human capital	"Human capital index" (scale 0-1)	WDI
04	Trade openness	"The ratio of exports plus imports over GDP"	WDI
05	Clean energy technologies	"Electricity production from renewable sources (percentage of total)"	WDI
06	Load capacity factor	"The ratio of actual energy produced and energy it would have produced."	Global Footprint Networks
07	Industrialization	"Industry value added (percentage annual growth)"	WDI

appropriate for homogeneous panels. The equation for the approach is mentioned below:

$$\Delta W_{i,t} = \varnothing_i + \varnothing_i X_{i,t-1} + \varnothing_i \bar{X}_{t-1} + \sum_{l=0}^{p} \varnothing_{il} \Delta \bar{W}_{t-1} + \sum_{l=0}^{p} \varnothing_{il} \Delta W_{i,t-1} + \mu_{it} \tag{3}$$

Where, $\bar{W}$ presented the mean "cross-section" and given as under:

$$W^{i,t} = \varnothing^1 \overline{URB}^{i,t} + \varnothing^2 HCI^{i,t} + \varnothing^3 \overline{TRO}^{i,t} + \varnothing^4 ECT^{i,t} + \varnothing^5 \overline{LCF}^{i,t} + \varnothing^6 IND^{i,t} \tag{4}$$

Therefore, the CIPS is established as below:

$$\widehat{CIPS} = N^{-1} \sum_{i=1}^{n} CADF_i \tag{5}$$

Where CADF represents cross-sectionally augmented dickey fuller test.

Moreover, the present research applied the Westerlund and Edgerton (2008) co-integration test to identify co-integration in the model. It has the ability to structural breaks and also has strong assumptions of CSD and is considered as the more powerful approach than the other traditional techniques. The estimation equation for the approach is mentioned below:

$$llog\left(L\right) = \alpha_0 - \frac{1}{2} \sum_{i=1}^{N} \left(Tlog(\sigma_{i.t}^2\right) - \frac{1}{\sigma_{i,t}^2} \sum_{t=1}^{T} eit^2) \tag{6}$$

Finally, the present research applied the CS-ARDL technique to find the long-run and short nexus among the under-research constructs. This approach is suitable for the panel data when time series are more than thirty and more than cross-sections. This approach also has the assumptions of slope heterogeneity, endogeneity, and CSD. The ordinary ARDL model could not address CSD even though it is the most widespread heterogeneous panel data estimator. Hence, the present research applied the CS-ARDL due to all these features. This approach is established by Chudik and Pesaran (2015), that have strict assumptions. The equation for the approach is mentioned below:

$$\Delta Y_{it} = \varphi_i + \sum_{l=1}^{p} \varphi_{it} \Delta Y_{i,t-1} + \sum_{l=0}^{p} \varphi_{il}^{'} EXV_{s,i,t} + \sum_{l=0}^{1} \varphi_{il}^{'} \overline{CSA}_{i,t-1} + \varepsilon_{it} \tag{7}$$

Hence, with the help of present research variables, the present research has developed the CS-ARDL equation given belows:

$$\Delta CO2E_{it} = \varphi_i + \sum_{l=1}^{p} \varphi_{it} \Delta CO2E_{i,t-1} + \sum_{l=0}^{p} \varphi_{il}^{'} URB_{s,i,t} + \sum_{l=0}^{p} \varphi_{il}^{'} HCI_{s,i,t} + \sum_{l=0}^{p} \varphi_{il}^{'} TRO_{s,i,t} + \sum_{l=0}^{p} \varphi_{il}^{'} ECT_{s,i,t} + \sum_{l=0}^{p} \varphi_{il}^{'} LCF_{s,i,t} + \sum_{l=0}^{1} \varphi_{il}^{'} \overline{IND}_{i,t-1} + \varepsilon_{it} \tag{8}$$

4. RESEARCH FINDINGS

Table 2 illustrates the descriptives of understudy variables. The outcomes indicated that the LCF average value was 89.582 followed by URB 1.862, HCI 0.503, TRO 44.442, CET 2.573, and IND 3.903.

Moreover, the present research also applies country-wise descriptive statistics to check the country-wise details of variables. The outcomes in Table 3 indicated that the CO_2E highest value was in South Africa, URB largest value was in China, while HCI highest value was in Russia and TRO biggest value was in South Africa. In addition, the outcomes also indicated that the CET highest value was in Brazil, while LCF largest value was in South Africa, and IND biggest value was in China.

In addition, the present research also applies year-wise descriptive statistics to check the year-wise details of variables. The outcomes in Table 4 indicated that URB largest value was in 2002, while HCI highest value was in 2018, and TRO biggest value was in 2008. In addition, the outcomes also indicated that the CET highest value was in 2015, while LCF largest value was in 2017, and IND biggest value was in 2004.

As discussed, the present research applied correlation tests to examine the correlation between the study predictors. Findings from Table 5 displayed that urbanization, human Capital, clean energy technologies and industrialization have a positive linkage with load capacity factors in BRICS countries.

Moreover, the present research also applies the cross-sectional dependency test to find the CSD. The research outcomes (Table 6) revealed that the P-values are >0.05, and the t-values <1.96. These values exposed no CSD exists.

In addition, the present research also applied the CIPS unit root test to find the unit root among the variables. The research outcomes (Table 7) revealed that the LCF, URB, HCI, and IND are stationary at the level. In contrast, the research outcomes revealed that the TRO and ECT are stationary at first difference.

Table 2: Descriptive statistics

Variable	OBS	Mean	SD	Min	Max
LCF	100	89.582	15.516	57.070	118.11
URB	100	1.862	1.164	−0.467	4.198
HCI	100	0.503	0.072	0.406	0.729
TRO	100	44.442	11.708	22.106	65.975
CET	100	2.753	3.277	0.013	12.609
IND	100	3.903	5.060	−12.591	15.051

SD: Standard deviation

Table 3: Descriptive statistics by country

Country	LCF	URB	HCI	TRO	CET	IND
Brazil	87.443	1.328	0.468	26.446	7.037	1.058
Russia	87.156	0.008	0.561	51.530	0.057	2.751
India	89.546	2.500	0.461	43.211	3.809	5.989
China	87.138	3.245	0.548	47.384	2.410	9.040
South Africa	96.626	2.228	0.476	53.640	0.452	0.678

Table 4: Descriptive statistics by years

	LCF	URB	HCI	TRO	CET	IND
2001	68.590	2.048	0.436	40.348	0.761	3.549
2002	70.464	2.096	0.445	42.597	0.834	5.474
2003	71.476	2.058	0.450	43.078	0.936	6.001
2004	73.206	2.028	0.456	45.783	0.965	8.678
2005	75.838	1.993	0.463	47.087	1.079	6.607
2006	75.732	1.944	0.470	48.949	1.221	7.569
2007	78.758	1.927	0.473	48.401	1.434	7.761
2008	87.616	1.924	0.482	51.519	1.645	4.099
2009	85.552	1.907	0.489	42.317	1.982	-0.397
2010	83.640	1.885	0.507	44.701	2.372	8.398
2011	92.730	1.860	0.508	46.594	2.568	5.297
2012	90.902	1.881	0.516	46.382	2.954	3.062
2013	97.208	1.867	0.515	46.307	3.390	3.253
2014	100.492	1.840	0.530	45.163	4.012	2.427
2015	100.330	1.798	0.538	42.885	4.872	1.893
2016	99.176	1.764	0.535	40.778	4.256	2.036
2017	109.494	1.729	0.563	40.621	4.532	2.523
2018	108.146	1.640	0.566	43.229	4.807	3.111

Table 5: Matrix of correlations

Variables	LCF	URB	HCI	TRO	CET	IND
LCF	1.000					
URB	0.506	1.000				
HCI	0.495	−0.179	1.000			
TRO	0.568	0.074	0.155	1.000		
CET	0.584	−0.009	−0.020	−0.666	1.000	
IND	0.155	0.433	−0.032	0.215	−0.238	1.000

Table 6: CSD analysis

Variable	Test stat (prob-values)
LCF	5.785*** (0.00)
URB	6.993*** (0.00)
HCI	10.564*** (0.00)
TRO	4.885***(0.00)
ECT	6.584*** (0.00)
IND	2.091*** (0.00)

Moreover, the present research applied the Westerlund and Edgerton (2008) co-integration test to find the co-integration in the model. Table 8 revealed that the P-values are >5%, and t-values are <1.96, hence, co-integration exists.

By employing CS-ARDL, Table 9 exposed that urbanization, human capital, clean energy technologies and industrialization have a positive linkage with load capacity factor in BRICS economies in the short and long-run.

5. DISCUSSION

Since it has been revealed that urbanization has positive association with load capacity factor, hence, backed up by Zhang et al. (2021), which proclaims that in urbanization, people migrate from rural areas to urban ones and adopt an urban lifestyle. These people gain know-how of innovative technologies and modern resources. Their engagement in utilizing novels means improving their work with the least pollution spreading. So, CO_2 emissions are minimal. In the similar context, Gao and Zhang (2021) also highlights that urbanization brings a change in people's thinking.

Table 7: Unit root test

Variables	I (0)		1st difference I (1)	
	CIPS	M-CIPS	CIPS	M-CIPS
LCF	−3.894***	−4.201***	-	-
URB	−3.334***	−3.883***	-	-
HCI	−4.3920***	−4.382***	-	-
TRO	-	-	−7.643***	−5.493***
ECT	-	-	−5.892***	−5.431***
IND	−5.090***	−4.102***	-	-

Table 8: Cointegration test

Test	Without break	Mean shift	Regime shift
Explained variable: GHGE			
$Z_{\phi}(N)$	−5.909***	−6.102***	−5.746***
P_{value}	0.000	0.000	0.000
$Z_{\tau}(N)$	−5.483***	−6.094***	−5.463***
P_{value}	0.000	0.000	0.000

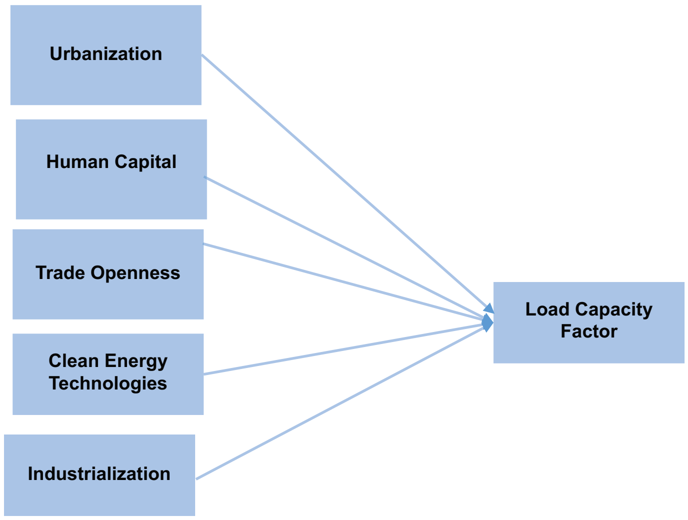
Table 9: CS-ARDL short run and long run analysis

Long run findings			
Variables	Coeff	t-stat	Prob
Explained variable: LCF			
URB	0.784***	4.456	0.003
HCI	1.982***	4.381	0.000
TRO	2.389**	2.091	0.039
ECT	1.272***	4.882	0.000
IND	0.872***	−3.901	0.001
CSD-statistics	-	0.037	0.841
Short run results			
URB	0.779***	5.993	0.000
HCI	0.982***	4.783	0.000
TRO	2.819**	2.009	0.041
ECT	0.654**	1.978	0.047
IND	0.663***	4.371	0.000
ECT(−1)	−0.545***	−3.653	0.008

They do not stick to backward procedures with environmental issues; rather, they have creative ideas and try to find solutions for environmental challenges. These people undertake their activities, causing less CO_2 emissions. These results also agree with Zheng et al. (2021), which posits that after urbanization, people have a visual experience of eco-friendly practices, which gives better outcomes. The migrated people are motivated to perform eco-friendly practices and save the ecosystem from CO_2 emissions.

The results showed that human capital increases the load capacity factor. Findings are consistent with Khan et al. (2021) which posits that when employees have better education and thorough knowledge of the economic undertakings and their influences on the environment and human health, their try to avoid the things or processes which cause CO_2 emissions hazardous gases for the environment. By producing similar evidences Sarkodie et al. (2020) stated that the investment in human capital, like the education and health of the employees, is useful to business organizations to develop sustainability in their performance with better environmental consequences of the operations. These employees are responsible and capable of reducing CO_2 emissions from business processes. These results also agree with Ahmed et al. (2021), which claims that if a country is rich in its human

Figure 5: Conceptual framework



capital, it has better capability to overcome the elements which cause CO_2 emissions.

Findings also confirmed that trade openness and LCF are positively associated. These results are also supported by Wang et al. (2022), which claims that trade openness adds to a country's environmental performance in many ways. It transfers development from foreign countries to inland, provides access to innovative resources, and enhances knowledge. So, it is possible to bring eco-friendly improvement in economic practices. The study of Li et al. (2021) also posits that trade openness allows the country to start and develop renewable energy production programs because trade openness supplies technologies and mechanical instruments. With the rise in renewable energy production, a change can be observed in energy consumption patterns which ultimately subdue the effect of CO_2 emissions. Findings are also consistent with Murshed (2020), which highlights that a country with a high rate of trade openness encourages eco-friendly programs related to natural resources production, renewable energy generation, and waste management. So, there is a reduction in CO_2 emissions.

The results showed that clean energy technologies and LCF are positively associated. Findings are backed up by Ahmed et al. (2021) which posits that when businesses apply clean energy technologies, the production or manufacturing units produce less amount of CO_2 emissions. By producing similar evidences, Lin and Raza (2020) also posits that clean energy technologies, like energy resources and the processes to generate energy, gives potential energy and run the plants, machinery, or appliances efficiently, producing less hazardous substances. Thus, clean energy technologies adoption helps control CO_2 emissions. These results also agree with Ozcan et al. (2021), which implies that clean energy technologies meet the energy requirements of businesses without creating pollution like CO_2 emissions.

According to findings, Industrialization and LCF are positively associated, hence, consistent with Jin et al. (2021), which highlights that industrialization promotes the production of electrical energy by raising the need and manufacturing essential instruments. When electrical energy consumption prevails in the economy, fossil fuel is discouraged, and the economy is found to emit less amount of CO_2. Similarly Ullah et al. (2020), also reveals that industrialization creates eco-friendly awareness in people living even in remote areas and also creates the ability in them how to observe environmental quality and reduce environmental challenges. These people are able to reduce CO_2 emissions from other than human resources. These results also agree with Appiah et al. (2021), which also shows that industrialization improves people's capability to combat CO_2 emissions.

6. CONCLUSION AND IMPLICATIONS

The objective of the study was to examine the role of urbanization, human capital, trade openness, clean energy consumption on load capacity factor in five BRICS economies. This information helps find the results that urbanization, human capital, trade openness, clean energy consumption, and industrialization have a positive association with load capacity. The results showed that after urbanization, people have better knowledge and skills which assist in overcoming CO_2 emissions. The results indicated that a country that is rich in human capital could better implement eco-friendly strategies and, thereby, overcome the elements which cause CO_2 emissions. The results also revealed that a country with a high rate of trade openness could have better social relations and access to effective management and technologies, which help to reduce CO_2 emissions. The study also found that clean energy technologies are useful to businesses to keep on their operations without the use of fossil fuels and save the environment from CO_2 emissions. Similarly, renewable clean energy is utilized under a higher load capacity factor, and there are lower CO_2 emissions. Moreover, the country makes technological advancements, has better human capital, and prefers to use renewable energy. So, CO_2 emissions are minimal.

This study is a guideline for researchers and academics to make contributions to the literature on environmental quality. This study investigates the role of urbanization, human capital, trade openness, clean energy technologies, and load capacity, including a controlling factor like industrialization in reducing CO_2 emissions. In order to create environmental protection awareness, the authors take an element like CO_2 as the subject of the study. It is also a great contribution to the literature that sheds light on the role of urbanization, human capital, trade openness, clean energy technologies, and load capacity factors in mitigating CO_2 emissions for BRICS countries.

The current study also has many empirical implications. It is significant for presenting solutions to CO_2 emissions. The study guides that government must facilitate the migration of rural people into urban areas so that CO_2 emissions can be controlled. The study suggests that the government must be active in developing human capital for the economy. It would enable the country to overcome CO_2 emissions. It is a suggestion that the country must be open to international trade at increased in order to create the ability to mitigate CO_2 emissions from the economy. The study also guides that clean energy technologies should be encouraged among businesses operating within the economy because these technologies can lead the country to overcome CO_2 emissions. The study guides the regulators in making regulations regarding the control of CO_2 emissions using clean energy technologies and load capacity factors. There is a guideline that the load capacity factor must be accelerated, and electrical energy should be generated from renewable energy utilization so that the country can mitigate CO_2 emissions. The study also conveys that there must be proper administration of industrialization to reduce CO_2 emissions.

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