Do Trade, Foreign Direct Investment and Economic Growth Influence the Renewable Energy Consumption? A Case of BRICS Countries

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Abstract

To safeguard the natural environment and promote sustainable economic development, countries worldwide are designing and implementing policies to enhance the use of renewable energy in production processes and other economic activities. In this context, this study examines the significant determinants of renewable energy consumption, including trade, foreign direct investment, and economic growth, in the BRICS countries—Brazil, Russia, India, China, and South Africa. The study covers data from 2001 to 2020 and employs a panel ARDL approach for estimation. The research outcomes indicate that in this region, the mere presence of GDP has a positive impact on the adoption of renewable energy. Based on the findings, the study recommends that these countries should achieve economic growth through sustainable means to increase further the use of renewable energy for industry, transportation, and domestic use in the region.

Keywords: Renewable Energy, Economic Growth, Foreign Direct Investment, Trade, BRICS.

Introduction

Renewable energy means any energy obtained from sources that do not deplete upon use, such as the sun or wind. Humans can continually harness solar and wind energy because it is abundant; thus, we can utilise these sources of renewable energy indefinitely (Renewable Energy Sources, 2021).

While the adoption of sustainable energy is often viewed as a modern technological method, harnessing environmental resources has been a traditional approach to heating homes, illuminating structures, powering vehicles, and serving various purposes. For centuries, seafarers have employed wind energy to drive their ships across the seas. For an extensive period, farmers have relied on wind power to drive their windmills and grind grain. Furthermore, historically, people have used solar energy for cooking and starting fires (Renewable energy sources, 2021).

The progress of emerging states hinges on the adaptation of green energy. Reliable and affordable electricity is crucial for driving revenue growth and alleviating poverty. The International Renewable Energy Agency's 2019 study states that clean energy offers autonomous and off-grid alternatives, expanding electricity availability to isolated and neglected populations. Developing countries often feel the impact of climate change repercussions, and transitioning to renewable

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sources can lower greenhouse gas emissions, thereby supporting global climate change mitigation efforts (United Nations Development Programme, 2019).

Entities contemplating foreign direct investment usually explore opportunities in open economies with skilled labour forces and promising growth potential, aiming to select suitable firms or projects. Less stringent governmental oversight is often highly valued. Foreign Direct Investment (FDI) extends beyond simple capital injection, encompassing management, technology, and the provision of equipment. An essential aspect of FDI is its ability to exert substantial control or considerable influence over the decision-making procedures of foreign businesses (Hayes, 2023). China's overall energy usage is negatively impacted by the freedom of trade and foreign direct investment, especially when it involves the utilisation of clean energy sources (Omisakin, 2009). Bezerra et al. (2020) suggest that as the Brazilian economy has grown, there has been a rise in energy consumption, wherein renewable sources are becoming increasingly pivotal in fulfilling this demand. They emphasise how expenditures on projects utilising clean energy, notably in wind and solar power, have increased as a result of the economy's revival.

The transfer of sustainable energy technologies to developing countries is greatly aided by trade. Developing countries can learn to adopt and utilise cleaner energy solutions by leveraging the advanced renewable energy industries available in developed countries. This sharing of technology helps remove the barriers of high start-up costs and a shortage of technical expertise, thereby accelerating the adoption of renewable energy sources (United Nations, 2019).

Additionally, trade has the potential to increase the availability of sustainable energy sources in less developed countries. With the importation of cutting-edge renewable energy technologies and tools, such nations can increase their renewable energy capacity and reduce their reliance on fossil fuels. Subsequently, this may lead to increased energy availability in inaccessible and unserved rural and remote areas, where sources of conventional energy may be limited or unreliable (World Trade Organisation, 2018). Trade is a factor that enhances energy security in the underdeveloped countries. Expanding the assortment of resources through trade means reducing dependence on costly fossil fuel imports, which in many cases are exposed to partially unpredictable price fluctuations and geopolitical instabilities. Facilitating the growth of renewable energy and trade helps developing countries become more independent in their energy supply and more resilient (International Renewable Energy Agency, 2020). Write your Own words as good words. Consider factors such as trade regulations, the import/export cycle of sustainable technologies, and how trade agreements can either enhance or hinder the adoption of sustainable energy.

Analyse how FDI will drive green energy in the BRICS countries. Illustrate the contribution of FDI inflows in financing renewable energy investments and technology transfer, as well as to develop infrastructure and open new frontiers of investment. Discuss also the challenges or limitations that may be encountered with FDI in the sector of renewable energy. Discuss the connections between the dependence of the BRICS on clean energy and economic growth. Colisae is evaluating the impacts of GDP growth, industrialisation, urbanisation, energy demand and their conversion to renewable energy sources.

Identify any existing gaps and weaknesses in the body of knowledge on how trade, foreign direct investment (FDI), economic growth, and the utilisation of clean energy sources are affected within the BRICS nations, in particular. Insist on empirical studies to give a detailed picture of these interconnections and their implications for sustainable development.

Trade effects, foreign direct investment (FDI) effects, economic growth effects, and green energy utilisation effects have been independently analysed for the BRICS countries; however, the complementary effects have not been explored. A better understanding of the interrelationship

among these variables can bring significant insight into the changing trends of green energy uptake in developing countries. This research also aims to answer the following research questions: the correlation between trade, FDI, and economic growth, and the role of green energy in BRICS countries.

- What is the influence of FDI on sustainable energy consumption?
- What is the effect of trade on renewable energy usage?
- What is the impact of economic expansion on renewable energy utilisation?

Literature Review

Wang et al. (2021) examined the relationships between renewable energy performance in China and financial and economic development. They applied panel data in their study from 1997 to 2017. They evaluated the short-term and long-term correlations between financial development, economic growth, and clean energy adoption using the ARDL method. Constant economic growth in China tends to promote the utilisation of sustainable energy, whereas financial growth does the opposite. Although the increase in investments is a beneficial factor affecting RE consumption, economic growth can hurt it only in the short term. These conclusions will provide valuable insights into formulating policies that can enhance the development of the renewable energy sector.

Lin Moubarak (2014) conducted a study regarding the economic growth of China in relation to the utilisation of renewable energy. Their data Collection spanned from 1997 to 2011. The methodologies used included the autoregressive distributed lag (ARDL approach) approach and Johansen cointegration approaches, which incorporated employment variability, labour, and carbon dioxide emissions. They also employed the Granger causality test to determine the relationship between these variables, which forms the causal relationship. The findings indicate that there are extensive long-term interdependent relationships between economic growth and the use of RE. This performance suggests that China's sustainable energy manufacturing virtuous cycle will depend on the growth of its economy, thereby enhancing the overall economic composite. Although the short-term contribution to renewable energy would affect labour costs, there is no evidence that both short-term and long-term renewable energy consumption and carbon emissions are causally related. It implies that not a great deal of renewable energy is utilised.

The purpose of the study by Choi and Chue (2004) is to examine the relationship between the BRICS-T nations, which include Brazil, Russia, China, India, South Africa, and Turkey, and their economic growth. The statistical methods employed in this study include the FMOLS test, the Padroni cointegration test, the second-generation panel cointegration test, and the test by Westerlund and Edgerton (2008), which was conducted between 1990 and 2014. This analysis suggests that the use of energy and economic expansion in the BRICS-T countries have a reciprocal cause-and-effect relationship. The rate at which GDP changes depends on how energy is consumed, and as GDP increases, energy consumption also increases. This study highlights the importance of countries using two approaches to promote economic growth.

Kumaran et al. (2020) studied the factors that affected the utilisation of renewable energy in four Southeast Asian countries. They used the data from 1990 to 2016. They examined the relationship between trade openness, GDP, CO2 emissions, foreign direct investment, urbanisation, governance values, and the use of renewable energy. In this research, the FMOLS and DOLS approaches have been applied. The results show that urbanisation has a powerful impact on renewable energy, and good governance is a significant contributor to the long-term growth of

renewable energy. On the other hand, GDP and trade openness indicate substantial negative impacts on renewable energy development.

Nath and Liu (2017)examined the correlation between the increase in renewable energy sources and non-renewable sources, as well as the impacts of trade, sustainability, and financial complexity on the expansion of the economy. They deployed a panel quantile regression model and successfully retrieved data from 1995 to 2014. Their findings showed that the consumption of non-renewable energy had non-homogeneous effects across all quantiles. In contrast, the use of renewable energy has a more positive impact on economic growth, particularly in association with non-renewable sources.

In theory, the EKC suggests that environmental destruction increases at the initial stages of economic growth, characterised by peaks, and thereafter decreases as income levels rise. This argues that ecological deterioration follows a predetermined pattern as an economy expands. The hypothesis that economic expansion initially causes adverse environmental effects due to mechanisation and increased consumption is supported by the inverted U-shaped relationship between income per capita and environmental deterioration. However, after a certain economic level is reached, societies place a higher priority on environmental quality, which reduces pollution and increases spending on greener technologies, such as clean energy (Dinda, 2004).

Data & Methodology

This section outlines the approach used to achieve specific study objectives. The primary objectives are to examine the relationship between the use of clean energy and economic expansion in the BRICS countries, as well as the impact of foreign direct investment (FDI) on sustainable energy consumption.

Data Sources

This research reveals a correlation between the BRICS states' GDP, FDI, trade, population growth, industrialisation, and the adoption of sustainable energy. This study uses dynamic panel data from 2001 to 2020 to determine the dependent variable, which is the fraction of total final energy consumption (REC). GDP stands for Gross Domestic Product, FDI is expressed as a percentage of GDP, trade GDP is expressed in metric tons per capita, and PT stands for the yearly total population increase. The "World Bank Development Indicators" for Brazil, Russia, China, India, and South Africa provided the data for this study.

Table 1: Variables and data sources

Sr #	RE	Variables	Source of data
1	FDI	Foreign direct investment	World development indicator
2	POP T	Population Total	World development Indicator
3	GDP	Gross Domestic product	World development indicator
4	TRA	Trade of GDP	World development indicator
5	IND	Industry	World development indicator
6	FD	Financial Development	World development indicator

Methodology

The following model describes the connection among renewable energy (RE), economic growth (Y), trade of GDP (TRA), industry (IND), population total (POP), and wide money to reserve ratio (FD);

RE_{it} = F (FDI, GDP, TP, IND, FD, T)

Model Explanation and Panel Data Estimation

$RE_{it} = \beta 0+\beta 1(FDIit)+\beta 2(GDPit)+\beta 3(Tit)+\beta 4(TPit)+\beta 5(FDit)+\beta 6(INDit)+\mu it(2)$

Where the residual is denoted by μ and the coefficients are β1, β2, and β3. The definitions of TP (total population), FDI (foreign direct investment), T (trade openness), REC (renewable energy consumption), GDP (gross domestic product), and IND (industry) are explained. Additionally, it implies that the use of cointegration panel testing is restricted to particular facets of assessing the connections between variables.

Panel Unit Root Tests

Panel unit root tests are statistical methods used to assess whether a set of time series data exhibit a unit root, indicating non-stationarity. Independence means that the data does not have a fixed mean and variance, but it varies over time so it can be very tricky to analyze classically.

The idea of testing unit roots became more ubiquitous among economists through the 1980s as proposed by Robert Engle and Clive Granger. They have come up with tests like the Augmented Dickey-Fuller (ADF) test on whether a time series contains a unit root which implies the series is in fact not-stationary.

Panel unit root tests are extensions to panel data, that is, data with observations on the multiple entities (e.g., individuals, countries, firms) and time periods. They are especially effective in economics, finance, and other social sciences: data in those fields are frequently recorded in panel form or longitudinal form.

The most frequently used panel unit root tests are Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS) test and Fisher-type test. These tests take into consideration the possibility that cross-sectional dependence and individual units may be heterogeneous.

Root tests of panel units can play a critical role in establishing the validity of the time series analysis because a number of economic models are based on stationarity. If unit roots are present, it can lead to spurious regression results and misleading conclusions. Therefore, these tests play a crucial role in empirical research and policy analysis.

To evaluate the merging and stability of variables in panel co-integration, various tests for panel unit roots have been conducted. One of these tests, the LLC test (Levin, Lin, and Chu, 2002), is dynamic on the ADF (Augmented Dickey-Fuller) approach and is based on the assumption that the dynamic panel of auto regression is uniform over all panel units. The PP, Fisher-ADF, and Im, Pesaran, and Shin (2003) tests all allow for individual unit root processes.

Pooled Mean Group (PMG) estimation Method

The ARDL model, which stands for Autoregressive Distributed Lag model, was initially introduced by Pesaran and Shin in the early 1990s. It's designed to capture both short-run and long-run dynamics in a time series setting, accommodating for potential endogeneity and serial correlation issues.

Traditional panel data analysis techniques involve either pooling (assuming all units have a common slope) or fixed effects (allowing for unit-specific slopes). However, these approaches have limitations, especially when facing heterogeneous coefficients across individuals or entities in the panel. The concept of applying the group mean techniques where the group mean techniques include Mean Group (MG) and Dynamic Fixed Effects (DFE) models was developed with a view to contending with the heterogeneity concern. In G models the average coefficient over cross-sectional units is estimated, whereas in DFE models unit-specific time trends models are included to address individual effects.

PMG model is proposed by Pesaran et al. (1999), which is a special model of ARDL applied to panel data. It is a mixture of the advantages of the ARDL and pooling of group mean approaches. There is the possibility to estimate the shared or common dynamics and individual heterogeneities with the ability of estimating the pooled coefficients and individual coefficients.

It also offers more effective estimates than the conventional pooling method because it considers individual disparity. It specifies a possible cross-sectional reciprocity and heterogeneity with regard to dynamics. It shares with the advantages of the ARDL method in gripping the short- and the long-run dynamics.

The Panel Autoregressive Distributed Lag (ARDL) model relieves the conventional ARDL model of the restriction of dealing with panel data incorporating autoregressive and distributed lag structures. The extended model is to an aptitude of analyzing both time-series and cross-sectional dimensions simultaneously. In particular, in panel data, the ARDL model can be used to study dynamic relations among variables, both long-term and short-term effects.

Results and Discussion

Here, the results are analyzed and interpreted in the context of existing literature and the research question or hypothesis. Researchers discuss the implications of their findings, potential limitations of the study, and recommendations for future research. This section should also address any unexpected results and explain possible reasons behind them. Overall, the "Results and Discussion" section serves to communicate the key findings of the study and their broader significance within the field of research.

Descriptive Statistics

The chosen variables go through a comprehensive statistical analysis before the panel data is statistically analyzed. The authors note (Table 2) that between 2000 and 2020, the maximum and smallest amounts of renewable energy in these nations were 50.05000 and 3.180000, respectively, with an average of 14.23500 and a standard deviation of 16.873558. Furthermore, the population's mean and standard deviation are 5.97E+08 and 5.78E+08, respectively, and its range is 1.41E+09 to 47229714. 3.927163 is the industry mean, and 5.02651 is the standard deviation. The average GDP stands at 4.397 with a standard deviation of 4.041. Within trade and financial development indicators, foreign direct investment (FDI) boasts the smallest standard deviation at 1.210. Notably, the financial development variable (FD) exhibits the widest range, spanning from 16.83777 to 182.8681, with the highest standard deviation of 42.82987.

Table 2: Descriptive Statistics

	RE	POP	IND	GDP	FDI	FD	TRA
Mean	22.48840	5.97E+0	3.92716	4.397	2.295	78.1833	44.43
Medi	14.23500	1.97E+0	4.04337	4.627	2.082	58.7814	46.81
Maxi	50.05000	1.41E+0	15.0507	14.23	5.368	182.868	65.97
Mini	3.180000	4722971	-12.450	7.799	0.205	16.8377	22.10
Std. De	16.87355	5.78E+0	5.02605	4.041	1.210	42.8298	11.71
Skew	0.328889	0.426519	-0.3689	0.485	0.267	0.479848	O.386
Kurt	1.429952	1.236133	3.548056	3.467	2.153	1.862798	2.034
Jar-Bera	12.07384	15.85491	3.520581	4.841941	173121	9.226018	6.378787
Prob	0.002389	0.000361	0.171995	0.088835	0.124113	0.009922	0.041197
Sum	2248.840	5.97E+10	392.7163	439.7260	229.5807	7818.332	4443.421
Sum. Dev	28187.04	3.30E+19	2500.857	2622.385	145.1564	181605.4	13577.46
Obs	100	100	100	100	100	100	100

Results of Panel Unit Root

Establishing the order in which to integrate particular variables is essential. There were three tests used: IPS, Fisher PP, and ADF. At a 5% significance level, these tests revealed that RE, IND, GDP, POP, T GDP, FD, and FDI are non-stationary. Table 3 presents comprehensive details regarding the Panel Unit Root Outcomes. However, when converted into their initial differences, all of the previously described variables become stationary at a 5% significance level. Using Johansen Fisher for cointegration may be appropriate because they are stationary in their first differences but nonstationary at the base level.

Table 3: Results of Panel unit root

	1(0)			1(1)		
Vari	**IPS**	**ADF**	**PP**	**IPS**	**ADF**	**PP**
RE	2.5370*	25.5670*	35.1760*	-0.6345	16.5158	36.4917*
	(0.0002)	0.0044	0.0001	O.2629	0.0858	0.0001
PT	-0.2441	18.4883**	321.726**	1.42824	8.04135	5.99817
	0.4036	0.0473	0.0000	0.9234	0.6248	0.8154
IND	-0.0664	10.0559	18.4350	-6.563*	56.1436*	215.799*
	0.4735	0.4356	0.0481**	0.0000	0.0000	0.0000
FDI	-1.2442	16.1554	28.9529	-5.872*	50.3965*	326.604
	0.1067	0.0953	0.0013**	0.0000	0.0000	0.0000
FD	0.20576	12.3476	8.05555	-2.1353	20.3772	30.5133**
	0.5815	0.2625	0.6234	0.0164	0.0259	0.007
TR	-0.3391	9.47368	13.5689	-3.27**	28.6323**	57.2611*
	0.3673	0.4878	0.1936	0.0005	0.0014	0.0000

We utilized various tests to determine if the series had a single root. These tests included both individual and combined effects. To determine the integration order, we employed the Levin, Lin, and Chu t-test in combination with the Im, Pesaran, and Shin unit root tests for a comprehensive assessment. Individual analysis utilized the Fisher-ADF test. The results, showcased in Table 3 for LLC and IPS tests with constant and trend components, and in Table 2 for constant and constant-

trend, reveal that all variables exhibit non-stationary characteristics at this level. However, upon taking the first differences, all series showed integration.

PMG Outcomes

The findings of the Pooled Mean Group ARDL Model are showed in Table 4, where the quantity of energy derived from renewable sources is the dependent variable. Population, GDP, financial development, and foreign direct investment (FDI) are statistically significant over the long term in all countries. In the near term, FDI shows a statistically significant positive association. Significantly, the constant term value is -2.208829, which denotes a statistically significant negative association.

Table 4: PMG outcomes

Long Run Results				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP	0.879187	0.303314	2.898605	0.0054
IND	-0.206706	0.159871	-1.292958	0.2015
FDI	1.169690	0.453454	2.579511	0.0126
FD	-0.161788	0.038939	-4.154909	0.0001
POP	-1.01E-07	1.59E-08	-6.354375	0.0000
TRA	-0.004214	0.031232	-0.134928	0.8932
Short Run Results				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
COINTEQ01	0.288373	0.093232	3.093070	0.0031
D(GDP)	-0.059218	0.110235	-0.537195	0.5933
D(IND)	0.066630	0.067083	0.993242	0.3250
D(FDI)	0.198951	0.070236	2.832608	0.0065
D(FD)	-0.054695	0.042785	-1.278379	0.2066
D(POP)	2.58E-06	2.14E-06	1.208671	0.2321
D(TRA)	-0.020499	0.064091	-0.319838	0.7503
C	-35.29578	15.97941	-2.208829	0.0315

Table 4 presents the outcomes of the ARDL model with pooled mean group estimation, where the amount of energy sourced from renewables serves as the dependent variable. Across all nations, enduring connections are statistically evident in terms of gross domestic product, population, financial development, and foreign direct investment. Notably, gross capital formation (GCF), real practical exchange rates (REER), foreign direct investment (FDI), and trade openness (TO) exhibit positive and statistically significant relationships in the short term. The noteworthy value (0.288373) of the error correction term (COINTE) signifies a meaningful shift from short-term dynamics to long-term equilibrium, implying a causal association between the independent and dependent variables. This suggests that trade openness increases economic growth. According to this, TO and FDI provide easier access to technology and the flow of products and services, which improves commerce, builds up foreign exchange reserves, and eventually raises GDP. Moreover, the facilitation of FDI is significantly shaped by the crucial involvement of trade openness, and the interconnected impact of these elements on one another is substantial. The study indicates that the impact on growth from FDI is most significant when considered in conjunction with other variables. The BRICS nations heavily rely on trade, and their openness to trade has led to an increase in trade-related activities. These countries boost their trade by implementing new,

more flexible international trade policies, aiming to stimulate import and export operations (Lin & Moubarak, 2014; Edame & Okoi 2015). The rise in trade openness contributes to economic growth. When a nation's GDP expands, it generates more demand for exports while also increasing the supply of imports (Bhagwati, 1988). This growth can influence the living standards of a nation, which is often measured as GDP per capita; it can consequently contribute to rising exports within a country as the production is being demanded more, and it can equally lead to a drop in exports as the consumption is propelled by the population pressures, as is evident in China and India. This finding aligns with the findings of Liu and Nath (2013), who suggest that xenophobia acts as a barrier to capital imports and that the ease of accessing technology and managing human capital, which stimulates economic growth, is reduced due to trade openness.

Conclusion

The paragraph probably describes how trade, FDI, economic growth, and long-term energy use interrelate in BRICS nations. This implies that such factors are interrelated and can influence one another. A good example is that as trade and FDI increase, the economy may grow as a result, and consequently, increase the demand for energy, including renewable energy. Additionally, trade and investment-related policies and incentives can influence the adoption and development of renewable energy technologies. The paragraph emphasises the importance of considering these complex relationships when analysing renewable energy trends in BRICS countries. The primary objective of this study was to assess the feasibility of introducing renewable energy in the BRICS countries. Using panel data and recent time series analysis covering the period 2001-2020, the paper examines the linkages between renewable power acceptance, economic progress, and the relationships between trading and FDI. In addition, we evaluated energy demand and also considered causal relationships between energy intensity and energy source.

The first chapter presents the plan and objectives of the research, describes the assignment, and justifies the reason for the research. The second chapter deepens the literature review by polishing the knowledge on the factors that have impacted the energy demand. This chapter lays the groundwork for several themes and ideas that will be explored throughout the research. It emphasises important facets of the BRICS countries, including population, industry, trade, industrialisation, economic growth, and the practice of RE and foreign direct investment. The methodological framework of the thesis, including data and econometric measures, is presented in Chapter 3, and the estimating techniques used are carefully covered in Chapter 4. The complex and multifaceted relationship among foreign direct investment (FDI), economic growth, and renewable energy usage is evident in the BRICS nations.

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