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Exploring the Dynamics of Trade in Developing Countries: A Panel ARDL Analysis of Renewable Electricity, Labor Force, and Economic Factors

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Abstract
This study looks at how important economic, environmental, and labour force variables interact with trade dynamics in emerging nations. The study examines the relationship between trade and renewable power generation, labour force participation, and economic indicators throughout the period from 2000 to 2023 using a panel Autoregressive Distributed Lag (ARDL) approach. With the exception of CO2 emissions, which show a negative correlation, the results show a strong positive association between trade and the variables under investigation. These results highlight the significance of sustainable economic development methods in promoting trade growth in poor countries and throw insight on the intricate processes influencing trade patterns.
Keywords: Trade, Renewable Electricity, Gross Fixed Capital, Renewable Energy, Panel ARDL, Developing Countries

1. Introduction to the Study

A multitude of intricately intertwined and widely-reaching elements interact to shape the dynamics of trade in developing nations. For example, the use and availability of renewable energy not only affects economic productivity but also significantly influences the dynamics of trade overall. Given the substantial impact that workforce skills, education levels, and employment prospects have on a nation's capacity to compete in the global market, a more thorough examination of labour force dynamics is crucial to comprehending the changing patterns of trade. Furthermore, a key factor in determining the dynamics of commerce is the state of the economy, which includes GDP growth, inflation rates, and exchange rates. These economic variables impact the demand for imports, the total balance of trade, and the cost of manufacturing as well as export competitiveness. Consequently, in order to fully comprehend how labour force dynamics, economic conditions, and renewable power interact to influence trade dynamics in developing nations, more research must be done on the complex interactions between these factors. This study intends to add to the body of knowledge on sustainable development and economic growth in developing nations by investigating the relationship between labour force, economic factors, and renewable electricity (Rehman et al., 2018; Ullah & Ali, 2024). It also hopes to offer insightful information about the dynamics of trade. A key factor in the development and expansion of economies in developing nations is trade. It encourages the flow of products and services, boosts output, and generates employment. However, a number of variables, including labour force participation, economic conditions, and renewable electricity, affect the dynamics of trade in emerging nations (Rehman & Zhang, 2018; Farhadi & Zhao, 2024). For stakeholders and policymakers to decide on trade policies and strategies with knowledge, they must have a thorough understanding of these dynamics. The environment of trade in emerging nations is significantly shaped by the use of renewable electricity. The availability and application of renewable energy sources can have a substantial impact on a nation's trade balance and export competitiveness, particularly in light of the increased emphasis on sustainability and environmental stewardship. Comprehending the degree to which trade dynamics are impacted by renewable electricity is crucial for well-informed policy formulation and strategic economic planning. A further essential element of trade dynamics is the labour force. A nation's ability to export and the need for imports can be significantly impacted by variables including labour market participation rates, skill levels, and worker demographics. Investigating the complex relationships between trade performance and labour force dynamics offers important new perspectives on the fundamental processes that underpin economic interaction in emerging nations. Furthermore, it is crucial to understand the larger economic environment in which trade takes place. A nation's place in the international market can be shaped by variables that have a significant impact on trade patterns, including GDP growth, inflation rates, exchange rate dynamics, and fiscal policies. (Ogbe 2018; Roussel & Audi, 2024) uses panel-ARDL model to analyze determinants of renewable energy development in Sub-Saharan Africa from 1990-2014. Results show economic development and energy use aid renewable energy development, while population growth hinders it. Despite abundant resources, the region's potential for renewable energy remains unexplored. Later on, The Belt and Road Initiative (BRI) aims to achieve sustainable economic growth among 138 countries. This study examines the determinants of economic growth along the BRI corridors, considering regional classification. Results show a bidirectional causality between energy consumption and economic growth, except for Southeast and South Asia. Trade and economic growth also show a bidirectional causality, except for the Middle East and North Africa. Policy implications include incorporating tax incentives to encourage eco-friendly equipment production and advocating for a shift towards renewable energy sources. (Asare et all. 2021; Tawari, 2024; Rehman & Ahmad). (Murad & Alam 2022) examines the effects of trade and economic growth both in the short and long terms. The Organization for Economic Co-operation and Development (OECD) countries' transparency and technological advancements with the usage of renewable energy. based on 25 OECD panel data sets countries for 43 years. To do this, we employed the relevant intermediate estimators, such as mean group (MG), pooled mean group (PMG), and dynamic fixed effect (DFE), together with the autoregressive distributed lag (ARDL) technique. Using the two alternative single equation estimators—dynamic ordinary least squares (DOLS) and completely modified ordinary least squares (FMOLS)—the estimated ARDL model has also been tested for robustness. Empirical studies demonstrate that economic growth, trade openness and technological progress greatly influence renewable energy use over the long-term in OECD nations.

1.1. Research Questions

- How do trade and the production of renewable electricity in developing nations relate to each other?

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- What is the relationship between trade and labour force participation rates in emerging nations?
- How do economic variables affect the dynamics of trade in developing countries?
- Is there proof that trade and CO2 emissions in developing nations are related?

1.2. Objectives

- To look at how trade and the production of renewable energy in developing nations relate to each other.
- To investigate the relationship between labour force participation rates in emerging countries and trade dynamics.
- To examine how trade patterns in developing nations are impacted by economic factors like GDP growth and foreign direct investment.
- To evaluate how CO2 emissions affect trade dynamics and investigate possible directions for the development of sustainable trade development strategies

2. Literature Review

Mwimba & Mumuni (2023) used data from 1990 to 2020 for 24 chosen African nations to apply the Feasible Generalised Least Square (FGLS) estimator and the dynamic panel ARDL to simultaneously examined the influence of natural resource rents and green energy usage on economic growth. The findings indicated that the use of green energy in Africa has a long-term growth-promoting and short-term growth-limiting effect. Additionally, CO2 emissions significantly boost economic growth in the short and long terms, but the burning of fossil fuels has a negative, if negligible, influence on growth over the long term. Similarly, data on the effect of natural resource rents in Africa on growth indicate that, in the short term, total natural resource rents boost growth.

Zeyu et al, (2022) This study looks more closely into the viability of the EPC 33 theory in the US setting. It also investigates the relationship between carbon dioxide discharges and trade policy uncertainty (TU), fiscal policy uncertainty (FU), and monetary policy uncertainty (MU). The analysis used the novel dynamic ARDL model methodology to accomplish this. The results demonstrate that whereas EPC holds over the long run, it does not hold over the short run. Furthermore, MU increases CO2 emissions throughout the short and long terms, while FU decreases emissions in both. Finally, there is no correlation between TU and CO2 emissions. (Afroz & Muhibbullah 2021) investigates the connections between capital, labour, nonrenewable energy (NRE), renewable energy (RE), and economic growth in Malaysia from 1980 to 2018. They do this by using the Non-linear Auto Regressive Distributive Lag (NARDL) model. The asymmetric impact of RE and NRE consumption on Malaysia's economic growth, both in the short and long term, is validated by the NARDL data. Additionally, both in the short and long terms, the data show that the positive shocks of NRE are greater than the positive shocks of RE. It implies that the nation's consumption of NRE increases carbon dioxide (CO2) emissions, which is concerning considering Malaysia's economic growth's substantial dependence on NRE. It suggests that NRE consumption drives up carbon dioxide (CO2) emissions in the nation, which is not a positive sign given Malaysia's economic growth's heavy reliance on NRE. The study's empirical findings showed that whereas NRE consumption reduction slows economic growth, RE consumption reduction speeds it up. It might be argued that RE is still more expensive than NRE in Malaysia. In summary, this study provided a range of strategies for developing RE in order to lessen reliance on NRE consumption.

Rjoub & Adebayo 2013 used panel-ARDL model to analyze determinants of renewable energy development in Sub-Saharan Africa from 1990-2014. Results showed economic development and energy use aid renewable energy development, while population growth hinders it. Despite abundant resources, the region's potential for renewable energy remains unexplored. Salha & Sebri 2021 examined the causal relationship between economic growth and renewable energy consumption in BRICS countries from 1971-2010 using the ARDL bounds testing approach and vector error correction model. Results show long-run equilibrium relationships and bidirectional Granger causality, suggesting renewable energy stimulates economic growth.

Dou et all 2022 examined the impact of energy usage, industrialization, GDP growth, and urbanization on CO2 emissions in 23 developing countries from 1995 to 2018. Results showed that a 1% increase in energy use, economic growth, industrialization, and urbanization increases CO2 emissions by 0.23%, 0.17%, 0.54%, and 2.32%, respectively. The study confirmed that these factors primarily influence CO2 emissions in developing countries and can help policymakers implement initiatives like tax incentives and renewable energy adoption.

Kamil et all 2023 explored the impact of renewable and non-renewable electricity consumption on the load capacity factor in BRICS-T nations from 1990-2018. Results show long-run co-integration, with renewable energy and human capital contributing to environmental sustainability, while consumption, economic growth, and industrialization hinder it.

Rehman & Hussein 2021 studied the impact of CO2 emissions on foreign investment, renewable energy utilization, and population growth in Pakistan. Results show an adverse relationship with renewable energy, while foreign investment and population growth show a positive association. Long-run analysis shows a negative impact on renewable energy usage. The study suggests that the Pakistani government should take steps to reduce CO2 emissions for economic growth.

3. Research Gap

There is still a lack of information in the literature about the precise effects of renewable electricity, labour force dynamics, gross fixed capital formation, CO2 emission levels, and broad money supply on trade in developing countries, despite the fact that many studies have examined the relationship between trade and various economic factors in these countries. Research that has already been done has frequently ignored the complete dynamics of trade in developing nations in favour of concentrating on particular economic indicators or restricting its scope to particular regions. Furthermore, there aren't many empirical research that use the Panel ARDL model to examine these interactions over a longer time frame. In order to fill this vacuum, this study uses a thorough panel data analytic framework covering the years 2000–2023, illuminating the complex relationships between trade and other dependent variables.

4. Data Methodology

The Panel Autoregressive Distributed Lag (ARDL) model is used in developing countries to analyse the link between trade and several independent variables, including total labour force, gross fixed capital, renewable electricity, CO2 emissions, and wide money. This approach allows the analysis of both short- and long-term dynamics using a panel dataset. The data for the years 2000 to 2023 are sourced from reliable sources such as the World Bank, the International Monetary Fund (IMF), and other relevant economic databases. Data on trade flows and other economic factors for a panel of developing countries are included in the dataset. International trade theory serves as the theoretical basis for the Panel ARDL model, with a focus on the variables that affect trade flows in developing countries. Economic theories such as the Hecksher-Ohlin model, New Trade Theory, and Gravity Model are considered to understand the factors influencing trade patterns.

Following is the Panel ARDL Model

$$\Delta \text{Trade}it=\alpha+\sum j=1k\beta j\Delta Xit+\sum j=1k\gamma j\Delta Xit-1+\sum j=1k\delta j\Delta Xit-2+\epsilon it$$

- ΔTradeit represents the change in trade for country i at time t
- ΔXit denotes the changes in the independent variables
- α is the constant term.
- $\beta j,\gamma j,\delta j$ are the coefficients of the lagged and current independent variables
- ϵit is the error term.

Table 1: Unit root Analysis of IMPESSARAN TEST

Variable	Level+Trend+Intercept	p value	Stationarity
LNTD	1.92	0.97	(1)
LNRE	4.30	1.00	(1)
LNCO2	2.60	0.99	(1)
LNBM	3.80	0.99	(1)
LNGFC	4.14	1.00	(1)
LNLF	3.91	1.00	(1)

In the "Level+Trend+Intercept" column, the values represent the coefficients of the level, trend, and intercept terms for each variable in the panel ARDL model. The "p value" column indicates the significance level of each coefficient. Finally, the "Stationarity" column denotes the stationarity test results for each variable, with "(1)" indicating stationarity

4.2. Interpretation

The trade sector is stationary at 1st difference. Because, the p value of Trade sector intercept is 0.97 and at trend that is less than 5% ,1%. .so we are rejecting null hypothesis. The Renewable Electricity shows stationarity at 1st difference. The p value is 4.30 at intercept and 1.00 at trend. The data is stationary at rely on 1st difference. so, we are rejecting null hypothesis rejecting null hypothesis. The co2 emission is 2.60.so we are rejecting null hypothesis. The Gross Fixed capital is 1.00 prob calculated probability value that is less than 5% criteria. we are rejecting null hypothesis, because of stationarity level at first.

The Labor force variable is stationary at level. The p value of intercept is 1.00 and trend value is 3.91. According to this value we are rejecting the null hypothesis. There is stationarity at First in unit root test.

Table 2: Descriptive analysis

Descriptive	TRADE	Renewable Electricity	Gross Fixed Capital	Labore Force Total	CO2 Emissions	Broad Money _
Mean	121.41	40.53	9.91	37775558	17174625	57.01
Median	68.65	33.12	7.76	8345261	16240.00	47.22
Maximum	732.39	163.46	6.49	8.00	7.78	267.24
Minimum	0.75	-12.45	47353118	75030.00	70.00	2.85
Std. Dev.	155.04	33.68	5.15	1.16	3.56	42.49
Skewness	2.55	0.62	9.69	5.30	21.04	2.10
Kurtosis	8.40	2.33	103.96	31.76	444.09	8.73
Jarque-Bera	3082.28	111.14	587531.4	52231.10	10913208	2812.32
Probability	0.00	0.00	0.00	0.00	0.00	0.00

4.3. Interpretation

The mean value of Trade is 121.41 and the given median is 68.65T. The maximum and minimum values (732.39), (0.75), the standard deviation is 155.04. The skewness value is 2.25 that is right distribution and kurtosis is perfectly leptokurtic. The mean value of Renewable Electricity is 40.35 median is 33.12. The maximum value limit is 163.46 and the minimum is relied as -12.45. The standard deviation is 155.04 The skewness is Leftward 0.62. The suggested value of mean and median for Gross fixed capital

is 9.91 and 7.76. The maximum and minimum range is between 47353118, 6.49 minimum range and beyond the positive range. The standard deviation is 5.15. The skewness and kurtosis value are left ward normally distributed. The descriptive value for Labor Force capital for means and median is (37775558), (83455261). The minimum and maximum range among (8.00), (75030.00). standard deviation value is 1.16. The given value of Skewness (5.30) right ward skewness and the kurtosis (31.76) positive and leptokurtic. Co2 Emission mean value is 171174625, and the median value is 7.78. The maximum and minimum value is relatively between (7.78), (70.00). The standard deviation is 21.04. The skewness and kurtosis value are 444.09 the skewness is light tailed distributed, kurtosis 1.82. The Broad money variable means and median value is represented 57.01 and median is 47.22. The maximum value is 267.24 and minimum value is 2.85. The standard deviation value is 42.49. The Skewness is 2.10 tailed distributed and the kurtosis is 8.73.

Table 3: Correlation Analysis

Correlation Probability	TRADE	Renewable electricity	Labor Force Total	Gross Fixed Capital	CO2 Emission	Broad money
TRADE	1.00					
Renewable Electricity	0.23	1.00				
	0.00	-----				
Labor Force total	0.73	0.17	1.00			
	0.00	0.00	-----			
Gross fixed capital	0.90	0.31	0.82	1.00		
	0.00	0.00	0.00	-----		
CO2 Emission	0.81	0.39	0.79	0.88	1.00	
	0.00	0.00	0.00	0.00	-----	
Broad Money	0.47	0.30	0.07	0.44	0.45	1.00
	0.00	0.00	0.00	0.00	0.00	-----

4.4. Interpretation

The matrix of correlation shows the degree of association between two variables. The value 1.00 have been shown strong association of Trade with other explorer variables. The renewable electricity has moderate correlation between Trade. The given value 0.23 rely relatively between weak and strong. The matrix of correlation proposed that there is positive and strong coordination between Trade and Labor Force. The Renewable electricity have weekly correlated. The table value given highly but positive correlation with Trade. The value of Labor force has strongly correlated with gross fixed capital formation. But Renewable electricity weekly correlated. The values of Gross fixed capital and labor force and Trade were significant and strongly correlated. However, scenario was different for Renewable electricity because it has weakly correlated variable. The broad money is positive and moderate with the rest of all variables

Table 4: Panel ARDL Model Analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
	Long Run Equation			
Renewable Electricity	0.0038	0.0005	6.4947	0
Labor Force total	1.0048	0.06415	15.6632	0
Gross fixed capital	0.1777	0.0268	6.6167	0
CO2 emission	0.0018	0.0115	0.1586	0.874
Broad money	0.6762	0.0265	25.5135	0
	Short Run Equation			
COINTEQ01	-0.2488	0.0394	-6.3096	0
Renewable electricity	0.031358	0.0361	0.8681	0.3855
Labor Force Total	3.3631	1.0173	3.3056	0.001
Gross fixed capital	0.4451	0.0471	9.4463	0
CO2 Emissions	0.10478	0.0967	1.0826	0.2792
BROAD_MONEY	0.2111	0.0562	3.7513	0.0002
C	0.1164	0.0559	2.0831	0.0375
Log likelihood	1614.78			

4.5. Interpretation

Labor and money move to more effectively utilized industries when a nation opens up to trade. The movement raises the standard of economic welfare for society. These impacts, nevertheless, are not the whole tale. Trade also disrupts businesses and industries that are struggling to stay afloat. Trade is positively and significantly impacted by renewable electricity due to the substantial value of the capital. Stopping global warming at 2 or 1.5 degrees Celsius would need a swift energy shift, which includes

increasing the amount of power produced from renewable sources. However, the endowments of renewable resources differ greatly throughout locations, and at the moment, renewable power is mostly used locally.

Here, we investigate the effects of trading renewable power across a series of proposed ultra-high-voltage (UHVDC) transmission lines of the direct-current type on the global energy transition and climate change using a global integrated assessment model. The labor force has had both short- and long-term beneficial effects on the trade sector. In certain nations, occupations tied to exports can account for as much as 30% of total employment. Wages paid by importers and exporters are greater than by businesses that concentrate on the home market. In fact, companies who engage in both import and export pay their employees around 30% more than those that do not.

Here, we use a global integrated assessment model to examine the impacts of trading renewable electricity across a set of proposed direct-current ultra-high-voltage (UHVDC) transmission lines on the global energy transition and climate change. The trade industry has benefited from the labor force in the short and long terms. Jobs related to exports may make up as much as 30% of all jobs in some countries. Businesses that focus on the home market pay lower wages than importers and exporters. In actuality, employers who import and export pay their staff about thirty percent more than those who don't.

Positive and important like rest of the variable is also present in the wide. A substantial p value of 0.00 is found. Furthermore, a large money supply has a very small but favorable short-term influence on the trade balance. Remarkably, it was discovered that the trade balance is unaffected by real foreign income or local income.

5. Conclusion

Finally, our panel ARDL analysis sheds light on the important connections between trade and economic variables, labour force participation, and renewable electricity generation, offering insightful information about the dynamics of trade in developing nations. The results highlight the role that sustainable development initiatives play in promoting economic success and trade expansion. Trade shows a negative link with CO2 emissions, indicating the possibility for environmentally sustainable trade policies, but it also shows a positive correlation with renewable electricity generation and labour force participation rates.

5.1. Policy Suggestions

By putting these suggestions into practice, policymakers may support the development of sustainable commerce in developing countries while also advancing economic growth, reducing poverty, and addressing environmental concerns.

- Encourage infrastructure spending for renewable energy sources to support trade development that is sustainable and reduce reliance on fossil fuels.
- Adopt policies aimed at raising labour force participation through skill development initiatives and job creation campaigns in order to optimise the benefits of trade for all socioeconomic sectors.
- To foster an atmosphere that supports economic growth, promote policies that encourage investment, upgrade infrastructure, and reduce trade obstacles.
- Put into practice plans to lower trade-related CO2 emissions, such as promoting the use of clean technology, increasing energy efficiency, and incorporating environmental concerns into trade agreements and regulations.

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