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Regenerating Sustainable energy and environmental solutions: Challenges and Opportunity in Belt and Road Initiative Countries.

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Abstract: This study examines financial development, economic growth, energy consumption, trade openness, urbanization, and environmental degradation in 47 Belt and Road Initiative (BRI) countries from 1980 to 2022. Panel unit root tests (IPS, LLC, PP, and ADF) ensured data correctness and stationarity. Three co-integration tests examined the variables' connections. Difference of means (DOLS) and functional moment (FMOLS) tests examined BRI economies' co-integration. A paired Granger causality test found bidirectional correlations between CO2 emissions, urbanization, financial development, economic growth, and the creation of gross fixed capital. Trade openness only correlated with ecological well-being. International study suggests regional, state, and federal policy implications. The empirical investigation used a panel causal heterogeneous test, dynamic ordinary least squares (DOLS), and fully modified ordinary least squares (MOLS) with fixed and random effects. Trade openness negatively affected CO2 emissions, but all other regressors positively affected environmental quality. Good governance and country-specific policies are needed to maximize BRI advantages. Despite conflicting energy statistics, the study found that economic development hurt the environment in all 47 countries. Industrialized nations generally use renewable energy, which minimizes ecological issues, hence their omission from the BRI full panel may explain the negative coefficient. Since most BRI economies are in emergent and growing countries, environmental preservation and renewable energy technologies need more time and money. Instead of coal, the Chinese government and other BRI nations are urged to invest in wind, hydro, solar, and biomass. Sharing green energy technology might help BRI economies. Cross-national urbanization strategy should incorporate eco-friendly solutions. The panel and governments may utilize the paper's substantial policy recommendations.
Keywords: Environmental sustainability, CO2 emissions, Economic Growth, Financial Development, Trade Openness,

1. Introduction:

A connection, the Belt and Road Initiative (BRI) includes 71 nations, or 65% of the world's population. The project aids nations in sharing resources, technology, and trained labor, modernizing industrial infrastructure and boosting economic development. 2020 (Tomasic). China's president, Xi Jinping, originally introduced the BRI to expand China's markets in Asia, Africa, and Europe. As a result, the region's industrial infrastructure will be strengthened, technology will progress, and commodities will be transported more conveniently. The International Energy Agency inferred that the finances connected to BRI projects range from US$ 4 to US$ 8 trillion (Holmberg & Erdemir, 2017).

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The majority of BRI money is allocated to underdeveloped nations to accelerate their rate of growth. The BRI has reportedly started more than 7000 projects, including the expansion of several businesses, power production facilities, road and rail infrastructure, poverty alleviation, etc., according to (Laurance, 2018). The importance of capital and labour for economic development has been highlighted by the Solow growth model. Later, Shahbaz et al. (2017) included energy variables in the Solow growth model, stating that energy is a critical component of business operations and long-term economic prosperity. Previous research ignores how the Belt and Road Initiative (BRI) projects in the 47 participating nations affect economic development, energy consumption patterns, and the integrity of the environment. This study objectives to explain the connections amid economic development, energy consumption, urbanization, gross fixed capital formation, trade openness, financial expansion and carbon dioxide emissions (a measure of environmental deterioration) in each of the 47 BRI economies between 1980 and 2022. The findings have the potential to provide significant policy insights for the group of countries as well as for individual countries, allowing them to identify opportunities and difficulties in their economies, energy, and environment. Moreover, the derived estimates provide succinct strategic advice and direction for policymakers and governing bodies, promoting efficient governance, environmentally friendly waste management practices, a move toward a reliance on renewable energy, and the execution of essential actions to restore the ecosystem.

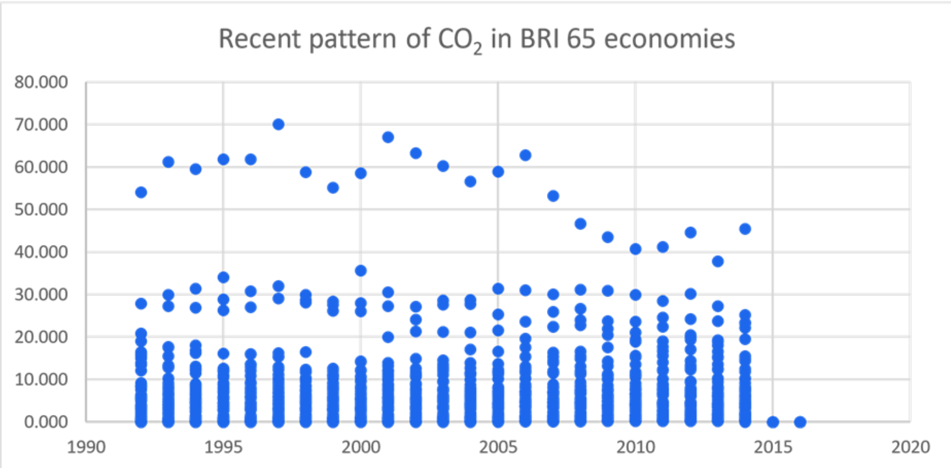

Figure 1.1: The BRI Countries Recent Pattern of CO2 emission

The BRI program has had a variety of direct and indirect effects on human activities. It is crucial to note that while this will benefit economies through globalization, there may be drawbacks as well, including environmental degradation caused by increased energy (Laurance, 2018). China has the highest energy consumption and CO2 emissions, accounting for around 30 percent of worldwide emissions. According to Cao et al. (2022), China's CO2 emissions are mostly caused by economic development and industrialization.

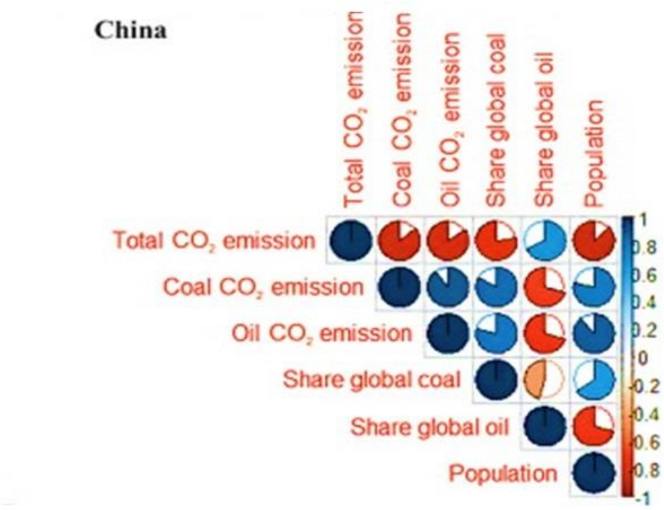

Figure 1.2: Coal emission trends in China (Mehmood et al., 2024).

As a result, China is rapidly developing its reliance on energy power production. In the meantime, as a result of the BRI plan, certain environmentally harmful power generation facilities and polluting industrial sectors are going overseas. In BRI projects, coal-based power plants get 65% of the funding allocated for energy production, whereas wind energy receives 1% of the overall investment. Between 2007 and 2013, China was the source of around 40 percent of all state spending on coal-based initiatives worldwide. It is important to note that China is constructing two hundred and forty coal-based energy plants with a combined installed capacity of 251 Gigawatts in 25 BRI nations. The proportion of global CO2 emissions attributable to BRI countries, excluding China, has risen to almost 61.4 percent (BP 2017). Additionally, the BRI economies account for nearly 80% of the world's energy-intensive CO2 emissions, highlighting the vital role the energy sector plays in accelerating environmental deterioration. Proceeding with this premise, it is difficult to avoid the decision that BRI schemes will benefit the economy while also harming the environment. A few academics additionally stated that the "global shifting tsunami" of BRI projects may harm local ecosystems and resources (Howard, 2017). As a result, it has grown to be one of the key problems influencing BRI project success in limited economies.

1.1 Hypothesis:

H1: There is a positive relationship between economic growth and environmental degradation in the 47 Belt and Road Initiative (BRI) countries.
H2: Energy consumption is positively associated with environmental degradation in the BRI countries.
H3: Financial development positively impacts environmental degradation in the BRI countries.
H4: Trade openness hurts CO2 emissions in the BRI countries.
H5: Urbanization is positively correlated with environmental degradation in the BRI countries.
H6: Gross fixed capital formation is positively related to environmental degradation in the BRI countries.

2. Literature Review

Numerous studies have looked into the connection between economic development, CO2 emissions, and energy usage. A comprehensive global analysis. Cerdeira et al., (2016); The interconnection between oil-driven economic growth and electricity usage posits that investments in the energy sector can reduce CO2 emissions, thereby positively impacting environmental quality and vice versa. However, the literature critiques this phenomenon. Vaona (2012); Dogan (2016) particularly scrutinizing the sensitivity of econometric methodologies and categorical country selection. Despite criticisms, their investigation highlights the potential impact of exogenous shocks on economies, influencing results and conclusions.

The Environmental Kuznets Curve (EKC) model has been modified in recent research to include elements such as financial development, urbanization, and technological innovation. Notably, researchers (Chen & Chen 2015; Xu & Lin 2016) demonstrate a strong positive correlation between energy usage and urbanization, which raises CO2 emissions. Urban areas, housing over 50 percent of the global population, are responsible for approximately 70 percent of greenhouse gas emissions, as reported by various researchers (Shi 2003; Bekhet & Othman 2017). Zhao (2018) evaluates the total factor energy efficiency of 35 countries involved in the Belt and Road Initiative (BRI) using three-data envelopment analysis; the results show that more emissions are produced by nations with lower energy efficiency. Similarly, Liu (2016) investigates the empirical relationship between energy consumption, income, CO2 emissions, capital formation, and labor. In recent works on mega projects like the BRI, the environmental impact is examined, considering a single-country method, and panel countries illustration (Ben et al. 2017; Rahman, 2017). Kraft & Kraft (1978) establishes the causal relationship between economic growth and energy utilization using data from 1947 to 1974. Short-run analyses confirm a direct and diverse interdependence of variables. Clement (2002) proposed policy implications regarding Bangladesh's environmental issues due to industrial modernization. Meng & Niu (2011) employs a linear regression model to analyze Chinese industries sector-wise, revealing unidirectional and bidirectional associations of electricity demand with industrial value-added amenities. Factors influencing CO2 emissions are determined (Banerjee & Rahman 2012), indicating positive associations with industrial growth and population size, while foreign direct investment (FDI) exhibits a negative relationship.

A study on Nigeria explores the impact of energy use, financial development economic growth , and trade openness on CO2 emissions from 1971 to 2010, using autoregressive distributive lag (ARDL). The study finds a long-term co-integration affiliation among these variables, with growth, financial development, and energy use showing positive impacts on CO2 emissions. Trade openness, however, exhibits a negative impact. The study recommends governmental enhancement of programs and strategies to reduce CO2 emissions (Ali et al. 2018).

3. Methodology

3.1 Data Sources and Variables

The panel dataset of the 47 economies was extracted from the WDI database. Going global
via bilateral ties is the motive of the BRI, which was started by the Chinese government (Du and Zhang, 2017; Cheng 2017). All sectors must engage in economic activity for an economy to flourish and be sustainable. Investment in fixed capital, trade openness, Urbanization, labor activities, gross domestic product (GDP), the health of the environment, and energy use are all important factors are a few examples of these contributions. Additionally, all of these must be done to speed economic development and attain sustainability. The BRI spans more than 68 nations, making it possible to comprehend the supply and demand for ecological quality, supportable growth, and commercial and occupational cooperation. Therefore, for the BRI to succeed across the board and in light of the debates discussed previously, it is crucial to evaluate the difficulties and prospects for the future. Therefore, CO2 emissions are included in the current research as a dependent variable to assess environmental sustainability. All variables as presented in Table 1 with the appropriate justification (Apergis & Ozturk, 2015; Dogan & Seker, 1979; Shahbaz et al., 2017; Jalil & Mahmud, 2009). In this study variables are used in the form of logarithms.

Table 3.1: Variables measurement

Variables	Elaboration	Data Source
Carbon emission (CO2)	CO2 equivalent (metric tonnes per person)	WDI
Energy consumption (ECON)	Energy consumption (k ilograms of oil equivalent per capita)	WDI
Gross domestic product (GDPPC)	GDP per capita (constant at 2010 US $)	WDI
Financial development (FDEV)	Domestic credit to private sector as percentage of GDP	WDI
Gross Fixed Capital Formation (GFC)	Gross Fixed Capital Formation% of GDP	WDI
Urbanization (URBN)	Urban population of the total population	WDI
Trade Openness (TROPS)	Total value of imports and exports imports% of GDP	WDI

3.2 Econometric Methodology

Typically, the individual time series dataset has a large number of unit root tests (ADF, PP, KPSS, and GLS, among others). It is acknowledged that the Dickey and Fuller (1979), and Phillips and Perron (1988) tests are ineffective when compared to the alternative stationary series condition, which is often utilized for tiny images. A larger number of points are available in the dataset to panel data, reducing multicollinearity and cumulative degrees of freedom between the forecaster regressors.

For the panel unit root, there are several tests available, including those in references (Levin et al., 2002; Pesaran, 2003; Hadri, 2000; Maddala & Wu, 1999; Dickey & Fuller, 1979; Phillip & Perron, 1988). Four distinct unit root tests, including Levin, Lin, and Chu (LLC) Levin et al. 2002, I'm, Pearson, and Shin (IPS) (Pesaran, 2003), were employed in this investigation. Additionally, this permits the Pedroni cointegration test cointegration examination between the predicted variables and regressors (Pedron, 2004).

3.3 Panel Co-integration Tests

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The panel unit root inquiry may observe the dataset series consistent at the level or the first difference, depending upon inference. Further, the co-integrating association between dependent variables and independent variables if the series is stationary at the first difference. Use typical OLS panel measures if the data set sequence is stationary at that level. Even though panel cointegration is fundamentally unstable, the linear-patterned stationarity of the order of cointegration (1, 1) as two variables suggests it happens. Panel cointegration tests (Al-Mulali et al. 2017; Ciarreta & Zarraga 2010) were used to determine variable stationarity. For co-integration testing, the variables continuously integrating at the first-order I (1) will be utilized successively. Seven residual-based statistical methods are used to examine panel cointegration for long-term links between data sequences. H0: No cointegration connection for all I and H1: A cointegration link for all I is the Pedroni cointegration test's hypothesis and null hypothesis. The predicted variables and regressors are associated over the long term if the panel data statistics show a larger positive weight than the statistics. According to the "H0" hypothesis, the two-dataset series are not cointegrated.
The following equation represents the Pedroni cointegration test:

$$CO2i,t = \alpha + \delta it + \beta 1lnECONi,t + \beta 3lnGDPi,t + \beta 2lnFDEVi,t + \beta 4lnGFCi,t + \beta 5lnTOPSi,t + \beta 5lnURBNi,t + \varepsilon i,t \quad (1)$$

Equation (4) illustrates the cointegration test's foundation, where I stand for a country-specific constant, and "it" stands for the corresponding single country's deterministic tendency in the whole panel of selected countries. The results obtained from the Pedroni cointegration test represent the standardized evidence in an asymptotic distribution. Consequently, the following is a possible formulation for the Pedroni equation:

$$\sqrt{}\, NN, T'\text{-}\mu \sqrt{}\, N \;\; \sqrt{}\, V \rightarrow N\,(0,1) \qquad (2)$$

Equation (5) reveals the Monte Carlo (MC)-shaped term and the variance term V, respectively.

3.4 Dynamic Panel Modeling

Fully modified OLS (FMOLS) and dynamic OLS (DOLS) panels were used in the research to examine the long-run cointegrating association between the independent and the dependent variable (CO2).
The correlational drawbacks among the panel intensive-error terms are the primary justification for using the DOLS and FMOLS.
To normalize the findings, all variables under study are turned into logarithms. The FMOLS and DOLS estimates during the research will be determined and measured using the following equations:

$$\hat{\beta}NT = [\Sigma\Sigma(xit - \bar{x}i)(yit - \bar{y}i)Tt = 1Ni = 1 - T\hat{\gamma}i\Sigma(xit - \hat{x}i)2Tt = 1] \qquad (4.6)$$

where

$$\hat{\gamma}i = \hat{\Gamma}21i + \hat{\Omega}21i0 - \hat{\Omega}21i\hat{\Omega}21i(\hat{\Gamma}22i + \hat{\Omega}22i2) \qquad (4.7)$$

And

$$\hat{\Omega}i = \hat{\Omega}$$
$$i0 + \hat{\Gamma}i + \hat{\Gamma}'i \qquad (4.8)$$

The long-run stationarities matrix is shown by the I term, which is followed by the i0 term, which deals with the covariance between stationary error terms. A further illustration of the corrected covariance term between the regressor variables is provided by the i.

3.5 Heterogeneous Panel Causality Test

The next step in establishing the relationships between the variables is to use Granger causality analysis to trace the chain of causative linkage. Here, the heterogeneous Granger causality test (Dumitrescu & Hurlin, 2012) will be used to find the estimators. Here, the heterogeneous Granger causality test (Dumitrescu & Hurlin, 2012) will be used to find the estimators and focus on Wald asymptotical values. This evaluation has the advantage of taking variation and dependence on particular economies into account. Additionally, it may work when time (T) is longer or shorter than cross-country distance (N).

4. Results

The FMOLS and DOLS models were used to derive the empirical values. To put light on the long-term estimates for policy choices and effects in each country, a total of 47 BRI economies were taken into consideration. Across the whole panel and in the cross-country studies, these countries were looked at in terms of the total energy, economic, and environmental sustainability problems and opportunities.

4.1 Descriptive Statistics

The overall data for all the factors that were looked into is constantly shown in Table 4-1. It includes 1719 observations throughout 37 time intervals and 47 cross-sections. To avoid unfavorable shocks, the variables were mostly translated into natural logarithms; nevertheless, these estimates may also have shown weaknesses in the present study's dependability. Table 4-1 shows the mean, median, maximum, and lowest values. These indicate the dataset's series and distribution.

Table 4.1: Descriptive statistics

	CO2	ECON	GDPPC	GFC	FDEV	TROPS	URBN
Mean	0.76	6.16	7.106	19.744	30.535	68.44	52.14
Median	0.68	6.811	7.874	21.254	24.208	67.489	54.345
Max	3.57	9.436	11.631	65.55	166.514	251.149	98.348
Min	-3.556	0	0	0	0	0	6.09
Std. Dev.	1.366	2.652	2.94	11.081	30.622	47.647	21.549
skewness	-0.262	-1.484	-1.532	-0.268	1.34	0.443	-0.033
Kurtosis	2.849	4.105	4.445	3.376	4.983	2.958	2.154
JB. Test	24.215	727.247	832.789	31.381	799.507	59.06	50.411
Prob.	0	0	0	0	0	0	0
Sum	1317	10512	12218	33941	52473	117666	91330
Sq. Dev.	3251	12171	14955	210972	16099	38986	79852
Obs.	1719	1719	1719	1719	1719	1719	1719

Author's Estimations.

4.2 Impact on Retention

The correlational statistics are presented in Table 4-2. In 47 BRI economies, it seems that there is a strong correlation between all factors and CO2 emissions. Urbanization and energy use had a greater than 50 percent impact on environmental excellence, while the trade openness, GDPC, and had corresponding impacts of 42.32, 36.52, 25.92, and 20.96%. This suggests that compared to other regressors, urbanization, and energy use have a substantially greater negative impact on the environment.

Table 4.2: Correlation Statistics

Probability	CO2	ECON	GDPC	GFC	FDEV	TROPS	URBN
CO2				1			
ECON			0.565358		1		
0.0000							
GDPPC		0.423292		0.504484		1	
0.0000			0.0000				
GFC		0.209665	0.325132		0.575475	1	
0.0000		0.0000		0.0000			
FDEV	0.259249		0.180134	0.408942	0.423395		1
0.0000		0.0000	0.0000		0.0000		
TROPS	0.365223	0.360227	0.542231		0.508871	0.45238	1
0.0000	0.0000		0.0000	0.0000	0.0000		
URBN	0.769096	0.30611	0.305279	0.043016	0.212563	0.286609	1

0.0000	0.0000	0.0000	0.0746	0.0000	0.0000

Note: Author's table where CO2 stands for carbon emissions, ECON for energy usage, GDPPC for gross domestic product per person, and FDEV for financial development. The abbreviations GFC, URBN, and TROPS stand for Gross Fixed Capital Formation, Urban Population, and Trade Openness, respectively. Statistics are 10%, 5%, or 1% significant, respectively, according to the symbols *, **, and ***.

4.3 Data Diagnostics

The stationarity of the study dataset was observed using the panel unit root tests (LLC, IPS, ADF, and PP). Table 4-4 presents the obtained estimates. All variables were stable and stationary at the first difference for the LLC, IPS, PP, and ADF tests. As a result, it is necessary to investigate the cointegration state between anticipated variables and regressors since this shows that all variables are stationary at the initial difference. However, the PP and ADF unit root tests revealed that commerce and urbanization both had substantial probabilities at 10%. However once the variables were transformed into the first difference, they all started to stabilize.
The amount of cointegration among the variables was established by the model's computation. Seven tests in Table 4-5 verified that the variables exhibit long-run cointegration at I (1, 1) and overturned the null hypothesis (H0). Additionally, the Pedroni-based panel cointegration results were verified and aligned using the Johansen and Fisher (JF) panel cointegration test, which is given in Table 4-6 According to Table 4-6's JF cointegration test findings, the null hypothesis (H0), which states that there is no cointegration between the variables, should be rejected. These two tests both confirm and guarantee that the variables have a long-term linear relationship, which serves as a sign of long-term panel cointegration. The findings for long-run cointegration are provided in Table 5.7 after the Kao-based residual cointegration test was employed as an extra accreditation. Using Kao-based statistics, we discovered a result of 5.952 ***, which shows that the two prior cointegration tests were successful and call for further verification.

Table 4.3: Unit root test

Regions	Methods	*CO2*	*ECON*	*GDPPC*	*GFC*	*FDEV*	*TROPS*	*URBN*
Full panel 47 countries	LLC	2.563	12.148	11.925	−4.340	7.842	−2.184 **	12.961
	IPS	2.801	4.242	6.416	−4.162	9.218	−0.966	−0.150
	ADF	80.662	60.327	60.133	146.992	38.392	104.548	122.581 **
	PP	73.656	34.617	117.395 *	128.598	38.693	115.163 *	380.958 ***
1st Difference								
Full panel 47 countries	LLC	−36.90 ***	−31.11 ***	−149.7 ***	−38.36 ***	−25.1 ***	−33.410 ***	−6.354 ***
	IPS	−31.31 ***	−22.44 ***	−52.55 ***	−32.15 ***	−25.4 ***	−33.010 ***	−4.671 ***
	ADF	957.30 ***	776.28 ***	706.47 ***	838.42 ***	761.33 ***	970.871 ***	310.124 ***
	PP	1031.750	884.77 ***	768.11 ***	979.89 ***	827.96 ***	1045.85 ***	546.27 ***

Note: *, **, *** indicates that statistics are significant at the 10%, 5%, and 1% level of significance, respectively.

Table 4.4: Pedroni panel cointegration test.

Alternative Hypothesis: Common Auto-Regressive (AR) coefficients				
Within-dimension Statistic		Prob.	Statistic	Prob.
Panel v-Statistic	1.96206	0.025 **	−3.8078	1.000
Panel rho-Statistic	3.7788	1.000	3.766	1.000
Panel PP-Statistic	−6.5950	0.000 ***	−6.4180	0.000 ***
Panel ADF-Statistic	−5.7340	0.000 ***	−6.4840	0.000 ***

Alternative hypothesis: Individual AR coefficients (between-dimension)		
Statistic		Prob.
Group rho-Statistic	5.3726	1.000
Group PP-Statistic	−9.1704	0.000 ***
Group ADF-Statistic	−4.3975	0.000 ***

Table 4.5: Johansen Fisher panel cointegration test cointegration rank test

Hypothesized	**Fisher Statistics**		**Fisher Statistics**	
No. of CE (s)	(from trace test)	Prob.	(max-eigen test)	Prob.
None	1863.000	0.001 ***	1997.00	0.005 ***
At most 1	1156.000	0.003 ***	706.00	0.006 ***
At most 2	628.8	0.000 ***	356.2	0.004 ***
At most 3	361.5	0.008 ***	189.1	0.003 ***
At most 4	235.4	0.005 ***	143.3	0.002 ***
At most 5	167.7	0.004 ***	133.7	0.004 ***
At most 6	172.6	0.002 ***	172.5	0.006 ***

Table 4.6: Kao test for residual cointegration.

Null Hypothesis	**No Cointegration**
Kao t-Statistic	Probability
−6.852	0.002

Note: *** indicates that statistics are significant at a 1% level of significance, respectively.

4.4 Dynamic Panel Modeling

Panel estimates from the cointegration tests supported the long-term cointegration of the variables. For consistent results, it also recommends using fully modified OLS (FMOLS) (Pedroni, 2000; Kao and Chiang 2000). To verify the intended linkages and evaluate the research hypothesis, DOLS and FMOLS were used. According to the empirical assessment in Table 4-7, urbanization, gross fixed capital formation, energy consumption, and gross domestic product, all have a positive and considerable impact on the ecological condition (rise in CO2 emissions). On the other side, in the 47 BRI economies, trade openness has no negative impact on the state of the environment. We discovered using FMOLS that changes in ecological degrading (CO2 emissions) are correlated with changes in financial development, energy consumption gross fixed capital formation, and urbanization, with correlation coefficients of (0.16259 ***), (0.040417 ***), (0.012342 ***), (0.005335 ***), and (0.030532 ***, respectively. The state of the environment is also negatively impacted by commercial openness. The FMOLS estimates imply that the 47 BRI nations may have implemented some measures to limit reciprocal trade openness and its detrimental impact on ecological sustainability, while other estimates show hazardously rising compressions on environmental degradation for the 47 BRI economies. Censured acts must be implemented, and governments must establish strong regulations to stop ecological damage, for the BRI to succeed. Overall, the findings of DOLS and FMOLS imply that the environmental sustainability of Energy consumption in 47 BRI nations is a challenge to BRI initiatives because it is largely reliant on non-renewable energy sources including gas, coal, and oil. Is a higher economic growth rate—regardless of how it is attained—really important for any country? The sustainability of the environment has lately been negatively impacted by countries that are developing, emerging, or low-developing achieving high GDP levels. The majority of the economies included by BRI rely on outlay, but not necessarily green-intensive savings. Green investments may stimulate economic development without harming the environment if people are more aware of them. Urbanization should be managed in the interim so as not to affect ecological sustainability or its position. Similar conclusions are reached by this research (Xu & Lin, 2016; Dogan & Seker, 2016; Jalil & Mahmud, 2009; Shahbaz et al. 2017; Apergis & Ozturk, 2018; Hafeez & Chunhui, 2018).

Table 4.7: DOLS and FMOLS estimation

Dependent Variable			**CO2 Emissions/Environmental Degradation**	
Panel-1			Panel-2 (DOLS)	
Independent	Coefficient	t-Statistic	Coefficient	t-Statistic

ECON	0.16259 ***	18.0931	0.112086 ***	6.7634
GDPPC	0.040417 ***	3.643503	0.038047 ***	2.67892
GFC	0.012342 ***	4.302308	0.015532 ***	4.59378
FDEV	0.005335 ***	4.18017	0.00362 ***	2.78995
TROPS	−0.00537 ***	−6.544434	−0.00553 ***	−5.47391
URBN	0.030532 ***	6.620429	0.039617 ***	7.17279
Observations	1669		1569	
R2	0.882718		0.987315	
Adjusted-R2	0.878944		0.970313	

Note: Author's estimates, where: FDEV stands for Financial Development; CO2 stands for Carbon Emissions; ECON is abbreviated for Energy Consumption; GDPPC stands for Gross Domestic Product Per Capita; The acronyms GFC stands for Gross Fixed Capital Formation, URBN for urban population, and TROPS for trade openness. The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

4.5 Dumitrescu Hurlin Panel Heterogeneous Causality Test

The fundamental relationships among the study's variables were determined using a panel Granger causality test based on heterogeneity (Dumtrescu & Hurlin, 2012). Table 4.9 displays the findings of the panel Granger causation test. Divergent findings are revealed by the heterogeneous causality test estimates for the 47 countries. Except for trade openness, which has a one-way relationship with environmental quality, the causal estimates point to bidirectional relationships between CO2 emissions (environmental quality) and independent variables. A rise in regressors also considerably worsens the quality of the environment, according to the heterogeneous panel test.

Table 4.9: Pairwise Dumitrescu–Hurlin panel causality tests.

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
ECON does not homogeneously cause CO2	2.5845	6.5894 ***	0.0000
CO2 does not homogeneously cause ECON	132.626	570.342 ***	0.0000
GDPPC does not homogeneously cause CO2	1.78912	3.14126 ***	0.0017
CO2 does not homogeneously cause GDPPC	17.4198	70.9029 ***	0.0000
GFC does not homogeneously cause CO2	2.16896	4.77437 ***	0.0000
CO2 does not homogeneously cause GFC	2.24507	5.10369 ***	0.0000
FDEV does not homogeneously cause CO2	1.79336	3.15877 ***	0.0016
CO2 does not homogeneously cause FDEV	4.65403	15.5583 ***	0.00000
TROPS does not homogeneously cause CO2	2.05119	4.27686 ***	0.0000

CO2 does not homogeneously cause TROPS	1.33402	1.16806	0.2428
URBN does not homogeneously cause CO2	2.0885	4.43914 ***	0.0000
CO2 does not homogeneously cause URBN	7.92282	29.7319 ***	0.0000
GDPPC does not homogeneously cause ECON	2.01748	4.13126 ***	0.0000
ECON does not homogeneously cause GDPPC	302.794	1308.05 ***	0.0000
GFC does not homogeneously cause ECON	2.0842	4.40761 ***	0.0000
ECON does not homogeneously cause GFC	5.09723	17.445 ***	0.0000
FDEV does not homogeneously cause ECON	2.3183	5.43411 ***	0.0000
ECON does not homogeneously cause FDEV	5.87297	20.8417 ***	0.0000
TROPS does not homogeneously cause ECON	2.01295	4.1111 ***	0.0000
ECON does not homogeneously cause TROPS	1.78924	3.14134 ***	0.0017
URBN does not homogeneously cause ECON	2.20207	4.93148 ***	0.0000
ECON does not homogeneously cause URBN	13.1911	52.5709 ***	0.0000
GFC does not homogeneously cause GDPPC	1.21968	0.66684	0.5049
GDPPC does not homogeneously cause GFC	4.4179	14.5056 ***	0.0000
FDEV does not homogeneously cause GDPPC	4.71034	15.8024 ***	0.0000
GDPPC does not homogeneously cause FDEV	2.31776	5.43178 ***	0.0000
TROPS does not homogeneously cause GDPPC	1.45646	1.69881 ***	0.0894
GDPPC does not homogeneously cause TROPS	3.0435	8.57836 ***	0.0000

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URBN does not homogeneously cause GDPPC	8.48795	32.1818 ***	0.0000
GDPPC does not homogeneously cause URBN	26.2417	109.147 ***	0.0000
FDEV does not homogeneously cause GFC	1.77286	3.05957 ***	0.0022
GFC does not homogeneously cause FDEV	4.0814	13.0471 ***	0.0000
TROPS does not homogeneously cause GFC	3.14244	8.98575 ***	0.0000
GFC does not homogeneously cause TROPS	2.80657	7.53253 ***	0.0000
URBN does not homogeneously cause GFC	2.02434	4.14861 ***	0.0000
GFC does not homogeneously cause URBN	11.4119	44.7685 ***	0.0000
TROPS does not homogeneously cause FDEV	4.31992	14.1088 ***	0.0000
FDEV does not homogeneously cause TROPS	1.24132	0.76571	0.4438
URBN does not homogeneously cause FDEV	2.9404	8.1306 ***	0.0000
FDEV does not homogeneously cause URBN	14.1335	56.6468 ***	0.0000
URBN does not homogeneously cause TROPS	2.54725	6.42721 ***	0.0000
TROPS does not homogeneously cause URBN	27.2547	113.53 ***	0.0000

Note: Author's estimates, where FDEV stands for Financial development, GDPPC displays gross domestic product per capita, and CO2 stands for carbon emissions. The acronyms GFC stands for Gross Fixed Capital Formation, URBN for urban population, and TROPS for trade openness. W-stat stands for the likelihood of Wald and Zbar statistics. Statistics are significant at the 10%, 5%, and 1% levels of significance, respectively, according to the symbols *, **, and ***.

4.6 Country-Wise Long-Run Estimations

The lists the statistical analyses of ecological deterioration over the long term that are focused on a certain economy. The results of every economy, from Yemen to Albania, demonstrate that economic expansion has a protective effect against environmental degradation (Bekhet & Othman, 2017; Khan et al., 2017). The BRI panel's participation by a few affluent economies has both positive and negative impacts on ecological quality, similar to the influence of energy consumption. Wealthier economies, predominantly relying on renewable energy, experience diminishing ecological concerns. Conversely, numerous BRI economies, predominantly in less-developed and developing stages, face challenges in allocating time and resources for environmental preservation and renewable energy initiatives. Enhanced trade among BRI nations has the potential to promote environmental sustainability through the transfer of green investments and technologies. Consequently, in transnational urbanization efforts, governments should prioritize environmental protection measures.

4.7 Robustness Examination of the Dynamic Panel Models

Pooled regression, fixed effect, and random effect models were used to counter-check the DOLS and FMOLS estimates' robustness, as shown in Appendix 5. A. These three methods were used to address the standard endogeneity and heterogeneity issues. Except trade openness, all factors under the DOLS and FMOLS approaches remained favorable and negatively impacted the environment's quality. For unbiased results from endogeneity and serial correlation, a cross-check utilizing pooled regression, random effect, and fixed effect models was suggested. Similar to the random effect models, which used the aforementioned DOLS and FMOLS methodologies to provide robust findings, the linear OLS model produced mixed results but with a fixed effect. The model fitness was consistent with the observed R-square. Based on the "Hausman test," the fixed effect model is the most appropriate match for the current study. Therefore, according to the study's estimates, CO_2 emissions are positively and significantly influenced by core explanatory variables, However, trade openness generally has a detrimental effect on ecological sustainability.

5. Conclusion:

The study was to examine the 47 economies that collectively made up the BRI from 1980 to 2022 to examine the relationships between financial development, economic growth, energy consumption, trade openness, urbanization, and environmental sustainability. After utilizing a series of four-unit root tests (LLC, ADF, IPS, and PP) to determine whether or not the dataset was stationary, we next utilized three cointegration tests to plot out the cointegration connections among the variables of interest. The DOLS and FMOLS tests were used to indicate the cointegration values for the entire panel of 47 BRI economies, and the pooled regression, fixed effect, and random effect were used to evaluate robustness. There were found to be bidirectional links between CO_2 emissions (environmental quality) and economic growth energy consumption, urbanization financial development, and gross fixed capital formation except trade openness. Which only had a one-way relationship with environmental quality. This was confirmed by a pairwise Granger causality test. Moreover, the cross-country research revealed multi-dimensional estimators, suggesting various policy implications at the regional, state, and federal levels.

The DOLS FMOLS and Husman test show that the regressors had positive and significant effects on environmental quality, except trade openness, which hurt CO_2 emissions. For this reason, it was proposed that countries improve their authority and implement country-specific policy recommendations to benefit from the BRI. Comparative, long-term studies also discovered that growing economies were contributing to environmental degradation in all 47 countries, despite varying levels of evidence for the impact of energy use. The negative coefficient can be explained by the fact that there are no industrialized countries within the 47 BRI full panel; these countries are more likely to rely on renewable energy sources. Most BRI economies, however, are located in LDCs and emerging markets, which require additional time and resources to invest heavily in environmental protection and the development of domestic renewable energy sources (such as hydropower, wind power, biomass power, solar power, waste-based renewable energy, etc.). As a result, in tandem with other BRI economies, the Chinese government should shift investment priorities away from coal-based facilities and towards renewable energy sources such as solar energy, hydropower, wind, biomass, etc. Trading green energy-based gadgets and technology might help the BRI economies expand ecological sustainability. Implementing options that will also lessen environmental damage should be done to govern cross-country urbanization. The report also offers unified policy implications for the whole panel and for particular nations.

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