Energy Consumption, Economic Growth And Environmental Sustainability Challenges For Belt And Road Countries: A Fresh Insight From "Chinese Going Global Strategy"

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Research Article

Keywords: Energy consumption, Economy, Environment, Belt and Road Initiative, Sustainable development, Carbon Dioxide

Posted Date: June 15th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-573704/v1

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on July 29th, 2021. See the published version at https://doi.org/10.1007/s11356-021-15549-z.

Energy consumption, Economic growth and Environmental Sustainability Challenges for Belt and Road Countries: A Fresh Insight from "Chinese Going Global Strategy"

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Abstract

The present study investigated impact of energy and economy related variables on CO_2 emissions in 49 countries of belt and road initiative from 1995-2018. The robust type of cross-section dependence and heterogeneity methods were adopted to analyze data set of countries. Energy consumption, foreign direct investment, medium and high-tech industry, and GDP has been found highly unfavorable for the ecological health (CO_2 emissions) in 49 nations on BRI panel. However, renewable energy consumption has been found in positive correlation with environmental quality (CO_2). Financial development indicator has no significant impact on CO_2 emissions in present study. The present outcomes clearly claim strong relationship of economic growth and energy with increased CO_2 emissions in 49 nations. Therefore, it is important for policy makers, experts and governments to incentivize and appreciate portfolio investors for sustainable green investments to transform the economic growth into a sustainable and energy efficient development.

Keywords: Energy consumption; Economy; Environment; Belt and Road Initiative; Sustainable development; Carbon Dioxide

Declaration

Ethics approval and consent to participate: Not Applicable

Consent for publication: Not Applicable

Availability of data and materials: The datasets generated and/or analysed during the current study are available in the [World Bank] repository, [https://databank.worldbank.org/source/world-development-indicators#]

Competing interest: The authors declare that they have no competing interest.

Funding: “The study is supported by Startup foundation for introducing Foreign Talent (Changwang high level talents) for Binjiang college of Nanjing University of Information Science and Technology, (NUIST), P.R.China (EMP#100003); startup foundation for introducing Talent of Nanjing University of Information Science and Technology, (NUIST), P.R.China (EMP#003203)”.

Authors’ contributions: Conceptualization from Abdul Jalil and Abdul Rauf; Data curation done by Waqas sikander and Abdul Rauf; Formal analysis completed by Waqas Sikander and Wang Tiebang; Methodology done by Abdul Jalil, Abdul Rauf, Waqas Sikander and Wang Tiebang; Project administration, Zhang Yonghong; Resources, Zhang Yonghong; Software, Abdul Rauf and Wang Tiebang; Supervision, Zhang Yonghong; Writing – original draft done by Abdul Jalil and Waqas Sikander; Writing – review & editing, Abdul Rauf and Wang Tiebang. All authors read and approved the final manuscript.

Acknowledgments: The authors wish to thank to the responsible editor and reviewers for their constructive and valuable comments for enhancing the quality of our manuscript.

1. Introduction

In the current era of development and modernization, climate change is the biggest threat particularly to the human beings and earth ecosystem in total. Global emissions of Greenhouse gases (GHGs), Carbon dioxide, and rise in atmospheric temperature are being considered as the core reasons of the global climate change (IPCC 2014). The 21st Conference of Parties (December 2015) held in Paris reached at an agreement called "Paris agreement" which emphasis on the limiting of global warming to well below 2 ℃ and working on developing strategies for long term reduction of greenhouse gases to achieve long term goals of Paris agreement (UNFCCC. 2018). The international trade has implications on the environment, which ultimately plays its role in global climate change (Cai et al. 2018).

The "Belt and Road (BRI)" is an initiative taken by Chinese government to develop international cooperation and economic strategy (Chen 2016, Rauf et al. 2020). This initiative has main goals to cover international trade, infrastructural and financial connectivity among partner countries, policies integration and coordination, sharing technologies for the development and economic advancement of partner countries around the globe (Finance 2021, Intelligence 2017). BRI has potential to develop a unified world trade partnership along with a strong geopolitical coalition, which will bring a common future for all partner nations (Ho 2017). The projects under BRI will have strong impact on the economic development of the partner economies (Yii et al. 2018), through trade extension, access to advanced markets, shared skills, technologies and manpower, and inflow of funds towards the under developed, developing and emerging countries (Economy 2017). The Ministry of Ecology and Environment of China issued guidelines in 2017 for promoting "Green Belt and Road". Later on, mentioned Chinese ministry initiated "BRI International Green Development Coalition" focusing on green initiative (finance, transport, innovation, urbanization and standards). They are mainly addressing the five goals of BRI initiative with the green development concept (Finance 2021). Along with advancement in infrastructure, economic and trade cooperation with developing and developed countries (Du &Zhang 2018), the climate change related issues and energy cooperation are major concerns of China while expanding BRI projects range (Zhang et al. 2017b). European Union (EU) and China in this regard showed strong commitment on clean energy (Zhang 2021) and climate change(Torney &Gippner 2018) through intensifying economic, political and technical cooperation (Liu &Hao 2018).

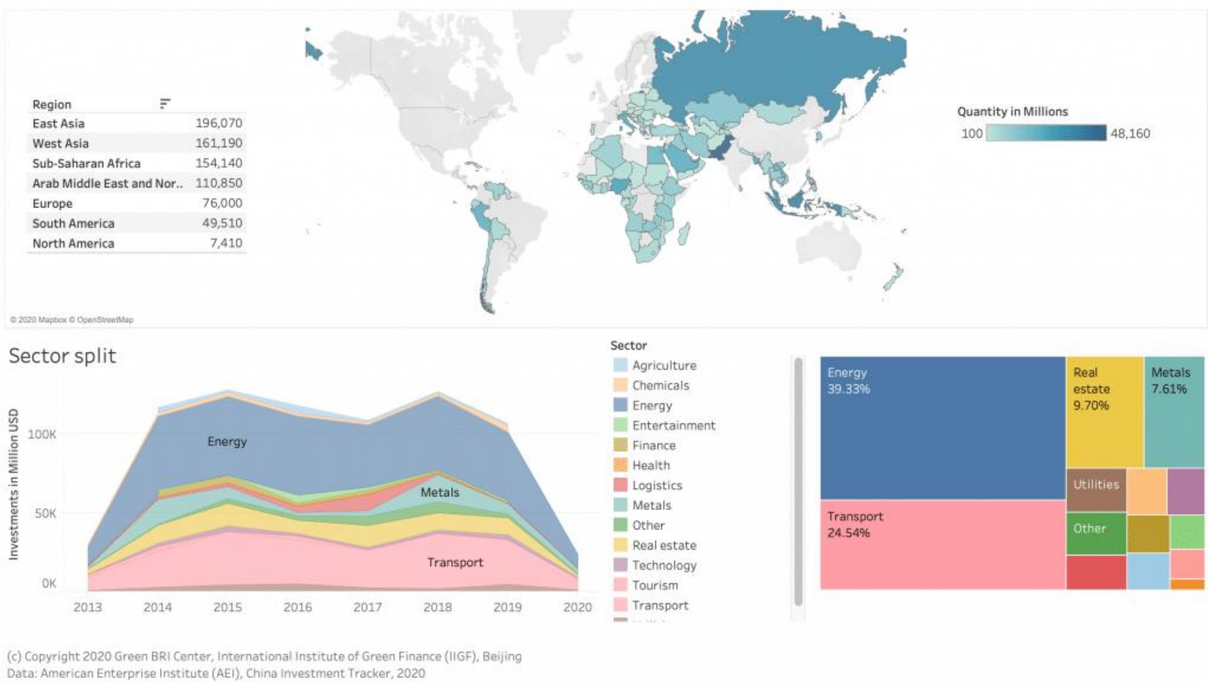
The energy growth has strong correlation with financial development (here in the sense of economic growth) and environmental change which can be found in literature. As, Grossman and Krueger (Grossman &Krueger 1995) testified the three stages of Environmental Kuznet curve (EKC) (Kuznets 1955) where first phase focusses on evolution of economy along with policy formulations while neglecting the ecological impacts of the development. Second phase shows the intensified emissions of CO_2 due to economic evolution while third phase is about realization of damage and adaptation of environment friendly policies and technologies to minimize the environmental impact. Many researchers around the globe tested EKC hypothesis and found a strong liaison between economic development and emissions of CO_2. Toman andJemelkova (2003) tested 25 OECD countries, Musolesi et al. (2010) tested 106 countries, Jaunky (2011) tested 36 high income countries; Apergis andOzturk (2015) tested 14 Asian countries. All aforementioned studies approved EKC hypothesis and found that emissions of CO_2 have strong long-term relationship with economic growth. Balsalobre-Lorente et al. (2018) also investigated the economic advancement relationship with emissions of CO_2 that was N-shaped nexus between them in 5 European countries.

Ayeche et al. (2016) investigated 40 European economies and found a strong linkage between GDP, financial development, trade openness and emissions of CO_2. In case of China, Xu andLin (2016a, b) found that rapid industrialization and economic development are the key factors behind CO_2 emissions in China. But Dombrowski (2017) warned that BRI projects will transfer the CO_2 emitting industries and businesses to other BRI partner countries, relieving china in a better state without having severe environmental impacts on it. The Statistical review by British Petroleum (Petroleum 2017) showed that BRI partner countries are contributing around 61.4% of CO_2 emissions among which 80% is energy consumption based emissions, that leading to global ecological deterioration impacts. Rauf et al. (2018a) also mentioned that BRI host countries might face severe natural resources deterioration effects along with stern impacts on their culture and ecology. Figure 1 shows the investments of china in BRI partner nations and 39.3% of those investments belongs to the energy sector.

The BRI projects can have impacts of accelerated global warming due to increased infrastructural, energy generation and trade activities (Fan et al. 2017, Zhao et al. 2016). On the other hand, it could also be an opportunity to minimize the global CO_2 emissions and to improve the quality of environment while implementing BRI in the partner countries (Zhang et al. 2017a). It is possible especially through empowering developing countries having abundant renewable resources but do not have sufficient technological and financial equipment to utilize those resources (Schwerhoff &Sy 2017). The BRI could also serve as a platform for the partner countries to take joint action against CO_2 emissions (Zhang et al. 2018). There has been highly sophisticated research been done on the economic, trade and international cooperation impacts of BRI on partner countries in particular and on the world in general. But it is a dire need to do the research on the long-term climate change related impacts of BRI in the partner countries and also on the global warming. Therefore, the present study objectives are; to investigate the impacts of energy consumption, economic growth and other developmental parameters on the emissions of CO_2 in BRI partner countries; and to evaluate the linkages between economic growth, environmental sustainability and energy growth factors in BRI countries.

Figure 1: Investments of China in BRI countries from 2013-H12020 (million USD) [1]

2. Materials and Methods



2.1. Data and Variables

This study contemplates BRI-associated nations in the terrestrial locations of Europe, East Asia, Pacific, Central Asia, South Asia, Middle East and North Africa. There were 49

[1] Source: https://green-bri.org/wp-content/uploads/2020/09/Investments-in-the-Belt-and-Road-Initiative-BRI-2020-1024x614.png

countries selected from those regions based on the data available (Please see list of countries in Table 1A).

The present study used CO_2 as dependent variable and other variables mentioned in Table 1 considered independent variables. The dataset has been log-transformed for the purpose of standardization. This standardization will minimize the robustness from data and will minimize the enlargement of coefficients, multi-correlations and autocorrelations related problems. The description and sources of all the variables have been stated in Table 1.

Table.1 Data Description and Symbolization

Variables	**Description**
Energy consumption (EC)	Litres to kilograms energy usage per capita
Carbon emission (CO_2)	Metric tones of CO_2 atmospheric release per capita
Foreign Direct Investment (FDI)	Percent of GDP (total inflow of foreign direct investment)
Trade friendliness/openness (TOP)	Trade (% of GDP)
Financial development (FD)	Percent of GDP (private sector domestic credit)
Industry (medium and high-tech) (MHI)	MHI as percent of value added manufacturing
Renewable energy consumption (REC)	REC as percent of total final energy consumption
Gross domestic product (GDP)	GDP per capita with a constant o 2010 US dollars

[2]

2.2. Steps for Econometric analyses

[2] Source: https://data.worldbank.org/

To test the hypothesis for the underlying variables, i.e., CO_2, ECON, FD, GDP, FDI, MHI, TOP, and REC a primary equation is formed (Equation-1). Based on several recent studies e.g. (Al-Mulali et al. 2015, Behera &Dash 2017, Doğan et al. 2021, Gulistan et al. 2020, Haseeb &Azam 2020, Khan et al. 2020, Khan et al. 2019, Rauf et al. 2020, Saboori &Sulaiman 2013) the following relationship among variables under investigation in this study has been developed;

$$\mathrm{CO_2} = f(EPC, FD, GDP, \mathrm{FDI}, MHI, TOP, REC,) \qquad (1)$$

Here in Eq. 1, Carbon dioxide as mentioned earlier is the dependent variable and relationship will be estimated as "CO_2 is equal to the function of independent variables". The econometric analysis for this study comprises the following steps. (i) Analysis of the descriptive statistics such as correlation analysis for the selected variables for this study. (ii) Testing the dependence (cross-sectional) of the countries data to confirm that the estimate drawn from the dataset is reliable. Afterwards, co-integration checkup based on the results can verify long-run integrated forms amongst the variables (Al-Mulali et al. 2013). (iii) Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) models for equilibrium relationships. Finally, (iv) The Panel Heterogeneous Granger causality test will be used to detect interconnectivity as used by Rauf et al. (2018a).

Equation 1 is an appropriate representation of the base model. The base model is rewritten with the natural log form of data and equation 2 is formed.

$$\begin{aligned}\mathrm{CO_2}_{\mathrm{i,t}} = \alpha &+ \beta_1 \mathrm{lnECON_{i,t}} + \beta_2 \mathrm{lnFD_{i,t}} + \beta_3 \mathrm{lnGDP_{i,t}} + \beta_4 \mathrm{lnFDI_{i,t}} + \beta_5 \mathrm{lnMHI_{i,t}} + \beta_6 \mathrm{lnTOP_{i,t}} \\ &+ \beta_7 \mathrm{lnREC_{i,t}} + \varepsilon_{\mathrm{i,t}} \qquad (2)\end{aligned}$$

Whereas, i = number of countries, t = time, ln = natural logarithm, α = intercept, β = slope to the parameters, and εi,t = error terms for the equation.

2.2.1. Dependency test (Cross-sectional)

Testing cross-sectional dependency of variables is critical to form any econometric model. Cross-sectional dependence (CD) is an important test in large data econometric modeling. It should be checked by investigators before evaluating investigation of any group. The existence or not of such a violation will correct the auxiliary path, which must be followed later. If the information in the dataset has a cross-sectional dependency, the other phases of the analysis should retain tests that are consistent with the cross-sectional dependency.

In structured variables, the cross dependence based on residuals can be examined by LM test (Breusch &Pagan 1980), scaled LM test (bias-corrected) (Baltagi et al. 2012) and CD test (Pesaran 2004). “No” cross-sectional dependence among that residual based dataset is the Null hypothesis.

Therefore, both the CD and LM test are structured in the following ways:

$$LM = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)\frac{(T-k)\hat{\rho}_{ij}^{2}-E(T-k)\hat{\rho}_{ij}^{2}}{Var(T-k)\hat{\rho}_{ij}^{2}} \qquad (3)$$

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \sim N(0,1) i,j = 1,2,3 \ldots 65 \ldots N \qquad (4)$$

Whereas, $\hat{\rho}_{ij}^{2}$ is residuals correlation, which was valued by using Ordinary Least Square equation. The results of the above given equations are given below in Table 2 with 1% level of significance for Null hypothesis (H^{o}).

Table.2 Results of (CD) Test

Test	Statistic
LM of Breusch-Pagan	11392.35***
LM of Pesaran scaled	210.6577***
Bias-corrected scaled LM	209.6777***
CD by using Pesaran	73.54330***

[1]Note: "***" represent 1% level of significance.

The cross dependence of the dynamic panels for residuals of dataset has been investigated by using CD tests of Frees (Frees 1995, 2004) Friedman (1937) and Pesaran (2004). The short term and large cross-sectional residual dependence for given dataset (time and number of countries) gave a clear understanding about the relationship between the countries over the given time period. The results (Table 3) of these tests rejected Null hypothesis of cross-section independence.

Table.3 Results of (CD) test of the residuals

Test	Statistic
Pesaran CD test	73.54330***
Friedman test	265.9161***
Frees test	7.504881***

[1]Note: "***" represent 1% level of significance.

2.2.2. Unit Root Tests

The unit root tests are of two types. First type considers the self-determining power of CD of target countries. The 2nd type/generation test allows the CD of the countries. The current study used both types of unit root tests to provide strong justification of stability in the results. The current panel's data acknowledges that there are longer-term events, which could increase the degree of independence (d.f) and exacerbate the multidimensional crisis to assess the equation of OLS. Therefore, panel data can withstand more compelling scientific techniques and asymptomatic statistics, which follow a general distribution rather than a noise distribution.

Choi(Choi 2006) deviced the panel unit root test with opposite assumption/hypothesis like Hadri (2000). Levin et al. (2002) used restricting type of panel unit root test for samples of the finite properties while Im et al. (2003) also advised heterogenous panel unit root test.

Therefore, this study applies the LLC, IPS, and ADF Fisher Chi-square test for testing the unit root (Table 10) to hold the order of cointegration among the variables under this study. In this connection, the panel unit root test of IPS is depicted with the following equation:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} \sum_{j=1}^{pi} \rho_{ij}\, \Delta y_{i,t-j} + \varepsilon_{i,t} \qquad i = 1, \dots \;\; t = 1, \dots T \qquad (5)$$

Equation 5 above depicts $y_{i,t}$ as the dataset containing i countries for t time but the lag operators are denoted with "Δ". Here, $\varepsilon_{i,t}$ stands for the error term for the normally distributed sample BRI countries.

The results (Table 2 and Table 3) show the cross dependence in the dataset. Therefore, we need to apply 2nd type of CD tests to justify the hitch of cross-dependence. Pesaran(Pesaran

2007) defined the process of cross-sectional Im, Pesaran, and Shin (CIPS) and cross-sectional augmented Dickey-Fuller (CADF). The country to county cross-sectional dependence, reliability and steadfastness will be the outcomes of these two methods with their natural heterogeneity.

Therefore, the test may further be built as follows:

$$\Delta y_{i,t} = c_i + \alpha_i y_{i,t-1} + \beta_i \bar{y}_{t-1} + \sum_{j=0}^{p} \gamma_{ij}\, \Delta \bar{y}_{i,t-j} + \sum_{j=1}^{p} \delta_{ij}\, \Delta \bar{y}_{i,t-j} + \eta_{i,t} \qquad i = 1, \ldots n \quad (6)$$

Whereas; c_i = constant, $\bar{y}$ = mean of cross-section at "t" period, and p = lag operator.

Supposing t_i (N, TM) same as the time ratio of α_i, the mean of t-ratios (time ratios) will be as follows;

$$CIPS\,(N, T_m) = \frac{\sum_{i=1}^{N} t_{i,}\left(N, T_{m,}\right)}{N} \qquad (7)$$

Here, $t_{i,}\left(N, T_{m,}\right)$ is Augmented Dickey-Fuller (CADF) indicators for the i^{th} cross-sections.

2.2.3. Co-integration Tests

The results of both types of unit root tests approved the stability of dataset. Co-integration tests by Pedroni (1999), (Pedroni 2004) can further validate the level of co-integration. Robustness can be confirmed by using Wetserlund co-integration test (Westerlund 2007) to get dependency of cross sections. The base of co-integration test is Engle-Granger (a typical unit root test) which has been further expanded by Westerlund et al. (2015). Also see (Al-Mulali et al. 2012, Ciarreta &Zarraga 2010 (Khan et al. 2017, Rauf et al. 2018a) for the purpose of determining long-run connectivity between candidate variables. Therefore, it has been verified that all given variables together formulated into first order (Equation 1).

Likewise, The Pedroni cointegration test augmented the following equation:

$$CO2_{i,t} = \alpha + \delta_i t + \beta_1 lnECON_{i,t} + \beta_3 lnFD_{i,t} + \beta_2 lnGDP_{i,t} + \beta_4 lnFDI_{i,t} + \beta_5 lnMHI_{i,t} + $$

$$+\beta_5 lnTOP_{i,t} + \beta_5 lnREC_{i,t} + \varepsilon_{i,t} \qquad (8)$$

$$i = 1, \dots \quad t = 1, \dots T$$

Whereas, $\boldsymbol{\alpha_i}$ is constant for each country, and $\boldsymbol{\delta_i t}$ is the full panel deterministic trends of the particular country. There were eleven statistical results of the Pedroni co-integration test while investigating both hypotheses. $\boldsymbol{\beta_1}$ is homogenous for null hypothesis and its heterogeneous for alternative hypothesis. The co-integration among variables can be seen in Table 9. The uniformity between the target variables has been found normally distributed, which verifies the Pedroni co-integration test. This relationship could be written as following equation;

$$\sqrt{\frac{N'_{N,T} - \mu\sqrt{N}}{\sqrt{V}}} \rightarrow N\ (0,1) \qquad (9)$$

In equation 9, μ and V stand for the Monte Carlo oriented adjustment measures.

The first four results of Panels (v, rho, PP, and ADF statistics) in the Table 9 are within-dimension statistics and latter three Groups (rho, PP and ADF) are between the dimension statistics. Therefore, we have at least 4 statistics out of 7 fulfills the lowest criterion for long-run linear co-integration approval within target variables.

After the approval of cross dependence between the target variables, the co-integration test by Westerlund (2007) has the ability to produce stable and vigorous results for the approval of the co-integration level. The results of (Westerlund 2007) are present in the form of two groups/forms. The first group is called cluster based group (Gt and Ga), whereas, other group is called panel statistics group (Pt and pa) (Rauf et al. 2018a, Saud et al. 2019) as shown in Table 8. The results show that co-integration exists among CO_2 and all other independent variables for all the 49 countries of the study regions.

2.2.4. The Dynamic Panel Data Estimation

The FMOLS valuation proposed by Pedroni(Pedroni 2001) and the DOLS valuation proposed by (Kao &Chiang 2001) and (Stock &Watson 1993) that have been used in this recent study to explore the long-run co-integration amongst variables.

Meanwhile, the following FMOLS and DOLS equations are presented to test the hypotheses:

$$\hat{\beta}_{NT} = \left[\frac{\sum_{i=1}^{N} \sum_{t=1}^{T} (x_{it} - \bar{x}_i)(y_{it} - \bar{y}_i) - T\hat{\gamma}_i}{\sum_{t=1}^{T} (x_{it} - \hat{x}_i)^2} \right] \quad (10)$$

Where $\hat{\gamma}_i = \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^{0} - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{21i}} \left(\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^{2} \right)$

And $\hat{\Omega}_i = \hat{\Omega}_i^0 + \hat{\Gamma}_i + \hat{\Gamma}'_i$

Whereas, $\hat{\Omega}_i$ = long-run matrix of stationarity, $\hat{\Omega}_{21i}^{0}$ = term to reject the covariance b/w errors terms of stationarity, and $\hat{\Gamma}_i$ = modified covariance between independent variables.

2.2.5. Heterogeneous Panel Causality test

At the last stage of econometric analysis, the panel Granger causality test has been used to find the instrumental correlation between target variables under investigation in the study.

3. Results and Discussions

The present study used a series of correlational and cross-sectional dependence tests to develop understanding about the effects of energy growth, financial development, GDP, medium and high-tech industries, trade openness and renewable energy consumption on the emissions of Carbon Dioxide (CO_2). The results presented in the form of series of Tables to clearly represent the outcomes of the present study for the regions and countries of the study. The empirical results obtained through current investigation can help the policy makers to achieve "Green BRI" goals in regional panels.

3.1. Descriptive Statistics

The summary of statistics has been presented in Table 4 comprising 49 countries and 1274 observations dataset. The variables data has been standardized by using natural logarithm to avoid heteroscedasticity. The consumption of energy was a trending variable with the mean of 1945.1240 and a standard deviation of 2698.9130. The mean emissions of CO_2 were lower (5.0492) in million tons but it was highly variable in the different countries of the different regions. This type of variation indicates the different level of advancement in individual countries. Similarly, mean GDP of the overall countries in the panel was higher (2698.9130) with lower standard deviation indicating the improved state of economy of the countries of the regions under investigation. The mean value of FD and MHI had similar outcomes (38.2041 and 24.4740 respectively) indicating their strong dependence on each other. Similarly, TOP and FDI shows similar trends in the given time span.

Table 4. Descriptive Statistics

Variable→	**CO_2**	**EC**	**FD**	**FDI**	**GDP**	**MHI**	**REC**	**TOP**
Mean	5.0492	1945.1240	38.2041	4.0261	2698.9130	24.4740	17.6670	88.0877

Median	2.9844	899.8239	33.4432	2.7452	4456.3600	24.0068	6.0378	81.1580
Maximum	35.9158	12406.7500	165.3904	54.2391	64864.7200	88.0370	92.3802	437.3267
Minimum	0.0000	0.0000	0.0000	-40.4143	0.0000	0.0000	0.0000	0.0000
Std. Dev.	6.4352	2698.9130	34.1423	5.5015	11334.0600	17.0908	23.1835	58.3168
Skewness	2.1786	2.2411	1.0170	2.3774	2.4375	0.6725	1.4498	2.0877
Kurtosis	7.9716	7.7552	3.8979	26.4151	9.4368	3.6670	4.2063	11.1954
Jarque-Bera	2319.8320	2266.6950	262.4066	30303.8600	3460.9280	119.6407	523.5765	4490.7950
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	6432.74	2478088	48672.04	5129.211	11037057	31179.84	22507.74	112223.7
Observations	1274	1274	1274	1274	1274	1274	1274	1274

3.2. Correlation Analyses

The present study correlation analyses results show the highly significant positive correlation between CO_2 and GDP (0.7153 ***) MHI (0.2564***), EC (0.8063***), FD (0.08291***) and TOP (0.2080***) respectively. There was highly significant negative correlation found between CO_2 and REC (-0.3956***) and as shown in Table 5. There was no significant correlation found between CO_2 and financial development (FDI). The results of strong association between GDP, MHI, and EC and CO_2 has also been observed by Rauf et al. (2020). But current study result contradicts the weak correlation results of CO_2 and FD with (Rauf et al. 2020). Therefore, it can be easily observed that CO_2 emissions are mainly connected with the GDP of the countries, medium and high-tech industries, and energy consumption as correlation statistics indicated clearly about it. These indicators are main drivers of the atmospheric CO_2 emissions and controls the atmospheric conditions through increased greenhouse gas emissions in the countries under current investigation. Therefore, the two-way correlation estimated provides a good insight into series of datasets. However, it is important to further validate the results and develop cross sectional relationships to cross validate the established preposition.

Table 5. Correlation Statistics

Variable	**CO_2**	**EC**	**FD**	**FDI**	**GDP**	**MHI**	**REC**	**TOP**
CO_2	1.0000							
EC	0.8063***	1.0000						
FD	0.08291***	0.0577**	1.0000					
FDI	0.02907	0.0815***	0.1795***	1.0000				
GDP	0.7153***	0.5745***	0.2331***	0.1343***	1.0000			
MHI	0.2564***	0.2280***	0.3897**	0.0835**	0.4267***	1.0000		
REC	-0.3956***	-0.3394***	-0.2230***	-0.1180***	-0.3904***	-0.2234***	1.0000	
TOP	0.2080***	0.2283***	0.3752***	0.4265**	0.4050***	0.4427***	-0.2271***	1.0000

[1] *, **, *** shows statistical significance at the 10%, 5% and 1% respectively.

3.2.1. Unit Root tests and Slope Homogeinity

This study used first-generation/type LLC, IPS and ADF (Table 6) and second-generation/type CIPS and CADF (Table 7) of unit root tests for data stationarity checking. The stationarity of individual variables examined and results indicated the difference between variables in panels of study regions. Some of the unit roots tests discarded the null hypothesis at their level, the stationarity at 1st order has been supported by most of the tests. The results of CD test showed strong cross dependence between variables. Further, study examined the slope heterogeneity test for heterogenous panels in Table 8. The Pedroni and Kao based tests (1st type /generation co-integration tests) might face the issue of lower co-integration between the variables. To avoid this problem with Pedroni and Kao based co-integration tests, the (Westerlund 2007) has been used to estimate the level of co-integration between study variables, (see (Yasmeen et al. 2018). The Pedroni co-integration test gave strong evidence of rejecting null hypothesis through 4 out of 7 values having higher significance level "p". The results of Westerlund co-integration test under the cross-dependence situation proved to be the best choice as shown in Table 9 which validates the long-run co-integration between variables. The results of Pedroni (Table 10) and Kao (Table 11) shows the high level of co-integration among all variables in long-run. Further investigations using FMOLS and DOLS models will give insight into the long-run co-integration in full and regional panels.

Table 6. Panel Unit Root test results (LLC, IPS and ADF)

At level								
Methods	**CO_2**	**EC**	**FD**	**FDI**	**GDP**	**MHI**	**REC**	**TOP**
Levin, Lin & Chu t*	6.25758	9.08305	0.31537	-7.19735***	2.78617	31.3982	4.92016	-20.2496***
Im, Pesaran and Shin	6.12583	7.99440	1.90677	-8.43596***	5.79338	5.98244	6.23507	-13.0170***
ADF - Fisher Chi-square	45.2075	13.9201	75.9352	256.125***	65.7046	48.2701	51.0456	174.249***

At first Difference								
Methods	**CO_2**	**EC**	**FD**	**FDI**	**GDP**	**MHI**	**REC**	**TOP**
Levin, Lin & Chu t*	-16.7716***	-18.4180***	-4.36735***	-16.7018***	-301.090***	186.936	-28.8923***	-117.817***
Im, Pesaran and Shin	-14.2569***	-13.9978***	-12.6790***	-21.9851***	-80.3471***	0.88611	-24.5213***	-54.9800***
ADF - Fisher Chi-square	383.619***	374.265***	362.666***	614.258***	395.857***	136.909***	651.300***	751.821***

[1] *, **, *** shows statistical significance at the 10%, 5% and 1% respectively.

Table 7. Results of CIPS and CADF (Panel unit root tests)

At Level								
Methods	**CO_2**	**EC**	**FD**	**FDI**	**GDP**	**MHI**	**REC**	**TOP**
CIPS	-2.679**	-6.093***	-2.169	-3.825***	-3.049***	-2.202	-2.696**	-2.401
CADF	-2.256	-1.633	-3.033***	-3.131***	-2.539**	-2.179	-1.929	-1.923
1st Deference								
Methods	**CO_2**	**EC**	**FD**	**FDI**	**GDP**	**MHI**	**REC**	**TOP**
CIPS	-2.679***	-6.320***	-4.939***	-5.793***	-4.616***	-4.459***	-4.732***	-4.419***
CADF	-3.896***	-3.638***	-3.491***	-4.580***	-3.411***	-3.352***	-3.168***	-3.373***

[1] *, **, *** shows statistical significance at the 10%, 5% and 1% respectively.

Table 8. Testing for slope heterogeneity

	Delta	P-value
	17.394***	0.000
Adj.	21.512***	0.000

[1] *, **, *** shows statistical significance at the 10%, 5% and 1% respectively.

Table 9. Westerlund test of Cointegration

Statistic	Value	Z-value	P-value
Gt	-13.126***	-49.216	0.0000
Ga	-19.064*	11.516	0.058
Pt	-56.338***	-4.123	0.0000
Pa	-24.097***	8.456	0.0000

[1] *, **, *** shows statistical significance at the 10%, 5% and 1% respectively.

Table 10. Pedroni test of Cointegration

			Weighted	
Panel and Group statistics	**Statistic**	**Probability**	**Statistic**	**Probability.**
v-Statistic (Panel)	2.5574***	0.0053	-0.0548	0.5219
rho-Statistic (Panel)	1.8471	0.9676	1.2252	0.8898
PP-Statistic (Panel)	-2.7401***	0.0031	-5.6625***	0.0000
ADF-Statistic (Panel)	-7.7309***	0.0000	-8.2642***	0.0000
rho-Statistic (Group)	4.2118***	1.0000		
PP-Statistic (Group)	-5.3655***	0.0000		
ADF-Statistic (Group)	-7.7040***	0.0000		

[1] *** shows statistical significance at 1% significance level.

The Kao co-integration test employed to validate the results of Pedroni co-integration tests. The result of Kao test showed -13.18381*** (Table 11), which clearly indicates that the previously applied integration tests were efficient and Kao test results are authenticating those previously obtained outcomes of co-integration. The similar results found in the study by (Rauf et al. 2018b) where their results of Pedroni co-integration tests were validated by Kao co-integration test.

Table 11. Kao test of Cointegration

	t-Statistic	Prob.
ADF	-13.18381***	0.0000
Residual variance	0.126030	
HAC variance	0.111819	

[1] *** shows statistical significance at 1% significance level.

3.2.2. Dynamic Panel data models

The estimations obtained from co-integration test validated the long term relationship among variables which gave strong reason to apply FMOLS and DOLS to get stable outcomes(Pedroni 2001); (Pedroni 2004). Both DOLS and FMOLS has been used to establish the expected relationship between the regressor and the regressed. The results shown in Table 12 clearly reveals that EC, FDI, GDP, and MHI found unfavorably influencing the environmental quality through carbon dioxide emissions. These results can be validated by results obtained from (Rauf et al. 2020). Renewable energy consumption (REC), and trade openness (TOP) have favorable effect on the environment. (Rauf et al. 2018b) also found that trade openness do not have negative effects on the environment in BRI partner countries.

Table 12. Results for FMOLS and DOLS for countries undder investigation

Regressor: CO_2 Emissions		
Panel-49 BRI countries		
Variables	**Coefficients**	
	FMOLS	**DOLS**
LNEC	0.173604***	0.282734***
LNFD	0.000992	0.031297
LNFDI	0.044221**	0.054350
LNGDP	0.438718***	0.467377***
LNMHI	0.170090***	-0.155954
LNREC	-0.306305***	-0.482432***
LNTOP	-0.002527	0.015257
R-squared	0.869660	0.999602
Adjusted R-squared	0.862954	0.989165

[1] *, **, *** shows statistical significance at the 10%, 5% and 1% respectively.

Precisely, it can be observed from the results of FMOLS that 1% increase in energy consumption EC, FDI, GDP and MHI leads to the degradation of environment (CO_2 emissions) having strong relationship of 0.173604***, 0.044221**,0.438718***,and 0.170090***respectively. The results of both models (DOLS and FMOLS) found to have been similar in terms of developing relationship between regressor and the regressed ones. We can summarize from the results of both models that the 49 countries studied need to understand that economic growth, medium and high-tech industries and foreign direct investments should transform their sources of energy generation from fossil fuel based to renewable energy generation sources. These findings reveal that level of emissions of CO_2 in the BRI partner countries is dependent on the consumption of energy. The increased magnitude of the energy consumption will cause the increased impact on the environment. It further leads the researchers to emphasis mainly on the innovation-based advancements. The adaptation of energy efficient technologies can reduce the burden on energy generation sector (Choi et al. 2012), which will ultimately have reduced impact on the ecological health of the countries. Therefore, it is strongly recommended to promote renewable energy generation and sharing of environment friendly technologies among the BRI partner countries for sustainable economic growth with minimum impact on the ecological health of the partner countries. In this regard, the Green BRI initiative is the good step to promote the environment friendly technologies and options for sustainable energy, economy and environmental growth in BRI partner countries. The current study results infers similar outcomes to (Apergis &Ozturk 2015, Arouri et al. 2012, Atici 2009, Bekhet &Othman 2017, Hafeez et al. 2018, Jalil &Mahmud 2009, Khan et al. 2017, Nasir &Rehman 2011, Omri 2013, Rauf et al. 2018b, Xu &Lin 2016b). The option of carbon free technologies such as nuclear, biomass based, wind turbines, hydropower, and solar energy and their associated technologies can transform the growth patterns of BRI partner countries with improved environmental quality. (Javid &Sharif 2016) found similar findings for Pakistan, (Zhang &Gao 2016) and (Xu &Lin 2016b) for China, (Kasman &Duman 2015) for European Union members, ((Rauf et al. 2018a); (Rauf et al. 2020); (Rauf et al. 2018b) for BRI member countries.

3.2.3. The Panel granger causality analysis

The causality between CO_2 and independent variables has been investigated using Granger panel causality analysis. (Dumitrescu &Hurlin 2012) developed the causality test, which also addresses the problem of heterogeneity among variables. Therefore, the causality test by (Dumitrescu &Hurlin 2012) has been used in the present study for the selected BRI countries. The divergent results of causality test found for the 49 BRI partner countries in the present study. The results of Granger causality test are presented in Table 12. The results are showing quite clear causal relationship of CO_2 with other variables. Energy consumption has unidirectional (one way) relationship with CO_2 emissions, while financial development, GDP, MHI and REC showed bidirectional (feedback type) relationship with CO_2. Foreign direct investment (FDI), and TOP has inverse unidirectional relationship with CO_2. The resultant pathways of relationship of independent variable with environmental health will help the policymakers to let them develop sustainable and environment friendly strategies in BRI partner countries.

Table 13. Dumitrescu Hurlin Panel Causality analysis

Null Hypothesis:	***Zbar-Stat.***	***Prob.***	***Relationship directions***
LNEC ≠ LNCO₂	*46.9575****	*0.0000*	*LNEC → LNCO₂*
LNCO₂ ≠ LNEC	*0.56576*	*0.5716*	
LNFD ≠ LNCO₂	*40.5894****	*0.0000*	*LNFD ↔ LNCO₂*
LNCO₂ ≠ LNFD	*21.5626****	*0.0000*	
LNFDI ≠ LNCO₂	*-0.44992*	*0.6528*	*LNFDI ← LNCO₂*
LNCO₂ ≠ LNFDI	*4.27438****	*0.0000*	
LNGDP ≠ LNCO₂	*2.21961***	*0.0264*	*LNGDP ↔ LNCO₂*
LNCO₂ ≠ LNGDP	*8.40507****	*0.0000*	
LNMHI ≠ LNCO₂	*-2.6427****	*0.0082*	*LNMHI ↔ LNCO₂*
LNCO₂ ≠ LNMHI	*181.943****	*0.0000*	
LNTOP ≠ LNCO₂	*1.28659*	*0.1982*	*LNTOPG ← LNCO₂*
LNCO₂ ≠ LNTOP	*23.939****	*0.0000*	
LNREC ≠ LNCO₂	*80.8119****	*0.0000*	*LNREC ↔ LNCO₂*
LNCO₂ ≠ LNREC	*2.2346***	*0.0254*	

This causal relationship between target variables clearly justifies the high rate of CO_2 emissions connectedness with the economic advancement (Table 13). It conclusively defines the influence of economic growth on the environmental health in the BRI partner countries. Carrying on these kind of economic development activities may lead to the increased global warming along with unprecedented type of human health effects. The possible solution of such negative thrust back of economic growth is the adaption of technologically advanced and green solutions. These type of causal relationships are also found in studies by (Al-Mulali et al. 2015, Katircioglu 2017); (Rauf et al. 2020, Saud et al. 2019)).

3.3. Checking regression robustness

The results of DOLS and FMOLS presented to see robustness (Table 11), this study applies the Dynamic Seemingly Unrelated Regression (DSUR). The purpose of applying DSUR is to check the robustness in the oucomes obtained from FMOLS and DOLS tests. The results presented in Table 14 shows that there was medium to high impact of indicators under investigation on emissions of Carbon dioxide (R^2 = 0.60) in the countries under investigation in the present study.

Table 14. Dynamic seemingly unrelated regression results

Panel	Variable	Coefficient	z-Statistic	Prob.
	LNEC	0.1559787***	24.67	0.0000
	LNFD	-0.0285969**	-2.51	0.0120
	LNFDI	0.0584332***	3.96	0.0000
	LNGDP	0.3897101***	21.37	0.0000
49 BRI countries	LNMHI	0.1741924***	9.93	0.0000

LNREC	-0.243571***	-21.03	0.0000
LNTOP	0.0600654***	3.76	0.0000
CONSTANT	-3.481891***	-23.78	0.0000
R-squared	0.7559		
Chi Square	3944.86***		

The results of DSUR endorse the results obtained by using FMOLS and DOLS, where EC, FDI, GDP and MHI are major drivers of the environmental degradation (Table 14). Trade openness and renewable energy consumption favored the environment as also found in FMOLS and DOLS test results. The indicator of FD has not been found with significant relationship with the emissions of CO_2, having similar results as previously used both models.

4. Conclusions

The present study conducted to examine the impacts of energy consumption, GDP, financial development, renewable energy consumption, foreign direct investment, and medium and high-tech industry on the emissions of Carbon dioxide (CO_2) in 49 nations on the panel of Belt and Road initiative. The duration of investigation expands from 1994 to 2019. The robust type of panel cross-section dependence and slope heterogeneity and other methods were adopted to analyze the dataset of BRI countries under investigation. The standardized (log-transformed) data has been used to employ slope heterogeneity, cross-sectional dependency of the panel data to confirm that the estimate drawn from the dataset is reliable.

Afterwards, panel tests (co-integration tests) used to verify the long-term integrated forms amongst the variables and, FMOLS and DOLS models used for long-term equilibrium relationship among the variables. Finally, The Panel Heterogeneous Granger causality test applied to detect the interconnectivity between variables at causal bases (mainly CO_2 emissions with other independent variables). The consumption of energy (EC) along with foreign direct investment (FDI), medium and high-tech industry (MHI) and GDP has been found highly unfavorable for the ecological health (CO_2 emissions) in 49 nations on BRI panel. However, renewable energy consumption (REC) has been found a favorable impact on the environment quality parameter (CO_2). There was no significant impact of financial development (FD) indicator on CO_2 emissions has been observed in the present study.

More precisely, the energy consumption, medium and high-tech industries and GDP has been the major variables found in all analytical outcomes, those having highly significant impacts on the environmental quality/health (CO_2 emissions). However, the adaptation of renewable energy sources has been found in significantly obliging impacts (favorable) in all analytical outcomes with ecological health of the countries in BRI panel. The present outcomes clearly claim the strong relationship of economic growth with increased CO_2 emissions in all 49 nations under investigation of Belt and Road initiative.

Therefore, it can be concluded that the huge investments of Chinese government under BRI projects on energy sector (mainly based on fossil fuel-based energy generation) along with industrial sector development are driving factors behind the environmental deterioration in those countries. However, the impacts of BRI projects on environment can be minimized using renewable energy generation sources especially those of carbon free energy generation technologies. Further, the industrial pollution can also be minimized through regulating them according to the environmental standards. The governments of BRI listed countries can formulate sustainable options of green energy, green transport, green innovation and green standards, which are in line with the initiative taken by Ministry of Ecology and Environment of

China. Present study can provide a strong justification of sustainable economic growth for the policy makers of BRI partner countries while keeping in mind the environmental implications. The transfer of technology between the partner countries can also help to transform the economic growth into an energy efficient and sustainable development.

The estimates of recent study suggest some essential policy implications for lawmakers and environmental experts. They must allocate economic resources based on the results of the study to maximize productivity, but wisely. As a result, researchers will take short- and long-term approaches to environmental issues, in particular the involvement of greenhouse gases (GHGs) and the BRI economy's climate change sensitivity. This shows that continued economic expansion is the key to improving the quality of the environment. Thus, for all regions tested to reduce CO_2 emissions, more practical and stringent policies / strategies are needed from decision makers and stakeholders. In addition, the various estimates of the current study are a useful tool for developing renewable energy supply strategies to avoid the risk of (GHG) emissions not only for the BRI partnered nations but it will be great gadget for larger countries of the world. It is also important to anticipate demand and supply of energy to achieve the development of BRI projects. In addition, improved GDP per capita (income) will allow the general public with the provision of more dynamic and environment friendly services. Therefore, it is also important for policy makers to incentivize and appreciate investors for green investment and inform them about its benefits.

Additionally, researchers can modify variables that may produce points that can further help to improve the understanding about the impacts of BRI projects investments on Environment in general and on the regional climate in particular. In addition, we could measure the relationship of energy and economic growth indicators with many other climate change and environment related indicators, like natural disasters, global warming, oxides of nitrogen, oxides of sulfur, Carbon Monoxide, industrial pollution and health effects, in order to obtain an overall environmental impression.

Appendix A

Table A1: List of Selected BRI countries

S.No	Countries	S.No	Countries
1	Albania	26	North Macedonia
2	Armenia	27	Mongolia
3	Azerbaijan	28	Moldova
4	Bahrain	29	Maldives
5	Bangladesh	30	Malaysia
6	Belarus	31	Myanmar
7	Bosnia and Herzegovina	32	Nepal
8	Bulgaria	33	Oman
9	Cambodia	34	Pakistan
10	Colombia	35	Philippines
11	Croatia	36	Romania
12	China	37	Russian Federation
13	Czech Republic	38	Poland
14	Egypt, Arab Rep.	39	Saudi Arabia
15	Georgia	40	Singapore
16	Hungary	41	Slovak Republic
17	India	42	Sri Lanka
18	Indonesia	43	Thailand

19	Iran, Islamic Rep.	44	Turkey
20	Israel	45	Tajikistan
21	Jordan	46	Ukraine
22	Kazakhstan	47	Yemen, Rep.
23	Kyrgyz Republic	48	United Arab Emirates
24	Kuwait	49	Vietnam
25	Lebanon		

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Figures

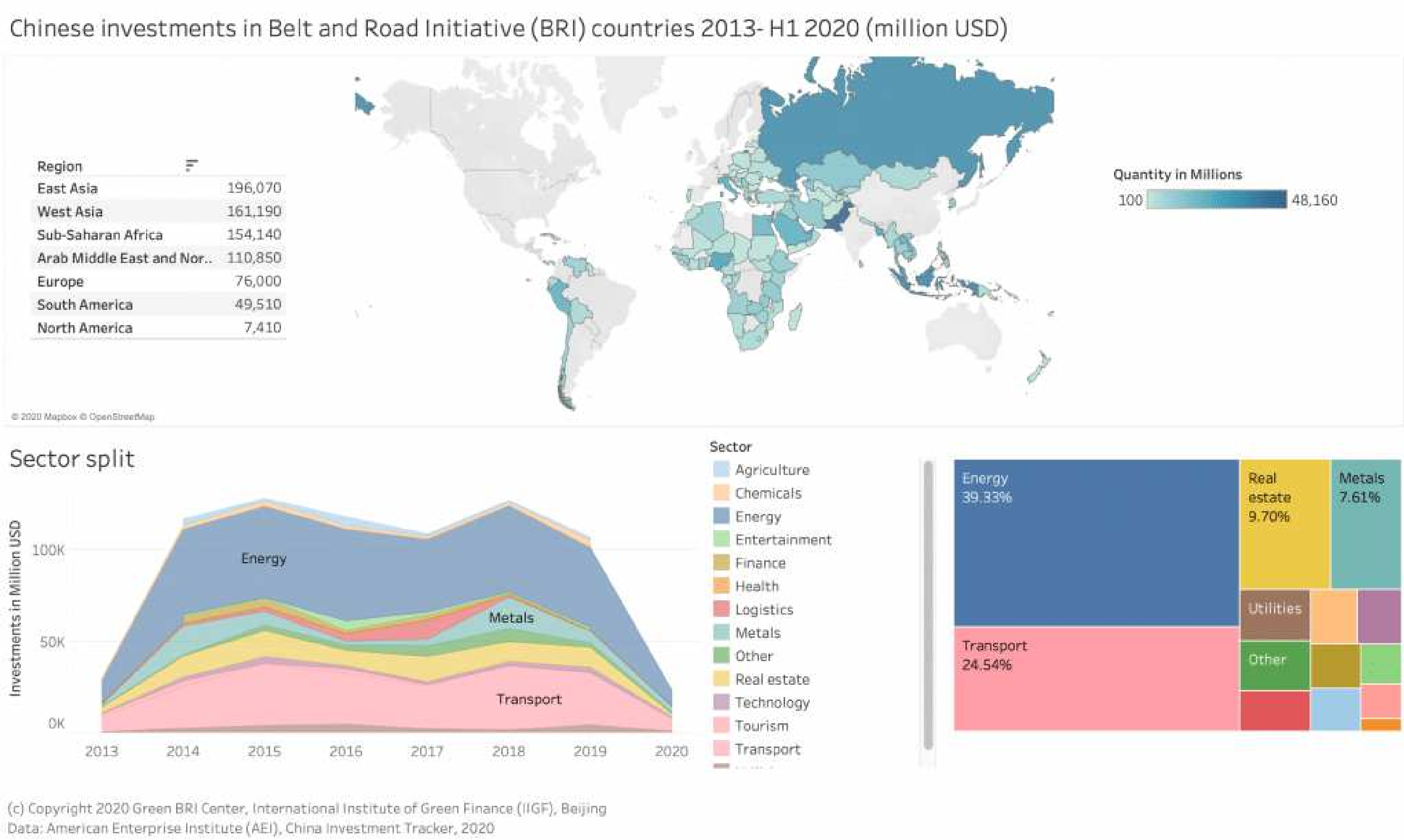

Figure 1

Investments of China in BRI countries from 2013-H12020 (million USD) 1 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.