

# GREEN INVESTMENT, ENERGY EFFICIENCY, AND ECONOMIC GROWTH: DOES ECONOMIC FREEDOM MATTER? EVIDENCE FROM BRICS COUNTRIES

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**Abstract.** Sustainable development goals, particularly number 7, clearly urges economies over the globe to multiple their efforts in order to improve efficiency. Although witnesses stressed out the importance of energy efficiency and claimed that when it is improved drastically, it triggers economic growth, however, the reported evidences to support the claim are mixed. In BRICS scenario, economies are experiencing the change from high-speed growth to high quality growth, due to which it is equally important to look into green investment as it is an essential tool to build high quality economic growth. Although green investment targets energy conservation as well as ecological deficit as its main goal. However, limited literature claims that it affects economic growth as well. Thus, the present study aims to assess green investment, energy efficiency, and economic growth (EG) and their impact on economic freedom index of the BRICS countries. Methods of Moments-Quantile-Regression (MMQR) approach is applied to explore the association between the understudy constructs in the time span of 2001–2020. Interestingly, it is revealed that green investment, energy efficiency and renewable energy are positively related with economic freedom index of the BRICS countries. With the evidences, the study proposes a conclusive remark to spur development across the countries.

**Keywords:** green investment, energy efficiency, economic growth, sustainable development, economic freedom index.

**JEL Classification:** O13, F63, P18, Q20, Q28.

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## 1. Introduction

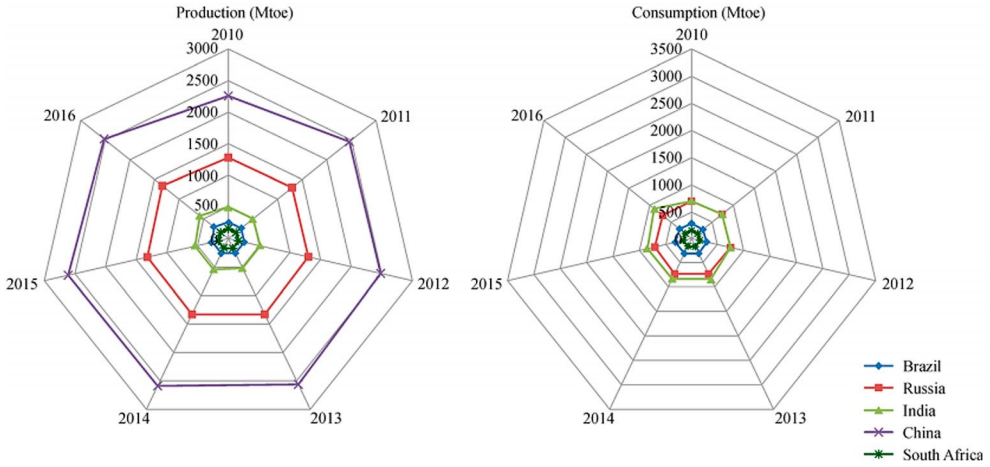
The world is facing a vicious economic circle over the past few decades. The countries are on the way to financial stability. The ultimate aim is to facilitate their people. Economic freedom ensures the safety of common people's human rights. As economic freedom is the basic human right to possess, manage, and dominate one's own property and labor. People in a free market are allowed to create, labor, invest, and consume in whatever way they want, can afford, or want as long as they do not infringe on the rights of others (Shahzad et al., 2022; Tiberius et al., 2021). Additionally, in such an economy, the government permits free movement of people, products, capital, and labor and refrains from restricting or restraining freedom for any longer than is necessary to uphold and defend that freedom. On the one hand, both direct and indirect impacts have been extensively studied in relation to the significance of economic freedom as a determinant in EG (Atkočiūnienė & Siudikienė, 2021;

Şenalp, 2019). Economic stability is a prime aim of any country and they invest their maximum efforts to achieve it. The reason for the economic development is to bring prosperity to the country's people by providing them freedom in every aspect of life, particularly in financial matters. A country with high economic freedom index results in a better standard of living for people. There is a number of factors that affect the economic freedom of the country like EG (Akadiri et al., 2021; Yodchai et al., 2022), renewable energy (Amoah et al., 2020; Streimikiene & Akberdina, 2021), population (Dat et al., 2022; Gouider, 2022), inflation (Alola et al., 2022; Assi et al., 2020; Matuszewska-Pierzynka, 2021).

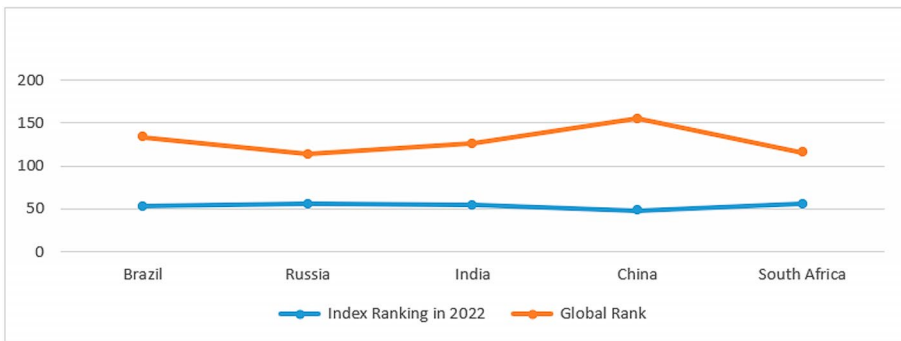
It is to be noted that energy security is crucial for socio-economic growth and in order to address energy crisis, advancement in renewable energy is quite an impressive way. BRICS economies are consisted of five emerging economies namely "Brazil, Russia, India, China and South Africa". These countries are included in top ranked countries who are highest energy consumers. BRICS countries are considered to be center of transformation and their economic growth is continuously flourishing (See Figure 2). Statistics shown in Figure 1 indicate that there exists a large difference between energy generation and energy requirement specifically when we look into China and India. We also can observe that Brazil and South Africa somehow able to maintain the balance, while, in case of Russia, it has a surplus energy production that is reasonable to fulfil the requirement. The variation is due to technological progress, population growth, and various other factors (BP, 2017; Yıldırım et al., 2019; Zaman et al., 2016).

BRICS nations are rich in mineral resources and they have low labour cost. For suppose, India which is consisted of high population growth, has high energy demands, thus, the country is able to manufacture goods with lower cost. Russia is also a resource-rich country and leads the manufacturing of commodities especially steel and iron. However, the country's main electricity source is natural gas (Pathak & Shah, 2019). Brazil is also rich in agricultural and mineral reserves along with hydroelectric resources that have the capacity to produce renewable energy. China, on the other hand, is the largest energy consumer. Interestingly, none of these economies are the member of energy institutions at international level (IEA). Although, BRICS economies are highly interested to increase energy efficiency in order to waive off energy waste and reduce carbon emission. BRICS economic performance in energy efficiency improvement is quite decent as recent statistics reveal that the energy efficiency in these economies ranges from 23.5% to 99.9%. however, the major issue in BRICS economies is lacking of financial channels particularly related renewable energy as well as investment shortages. However, these potential resources depict that BRICS could be the leader in renewable sector, but in order to achieve energy security and efficiency along with clean growth, these economies need to review the existing energy policies (Hailiang et al., 2023; Gu et al., 2018).

Besides, BRICS governments are encouraging economic freedom by establishing a sound financial system, a legal foundational structure and an impartial governance system that advocates rights of properties and contracts (Akadiri et al., 2021; Cera et al., 2022; Shafi et al., 2022). So that government institutions should not clenched property of people and interfere in their personal decisions. Moreover, government should also not seize the right of people or restrict them in voluntary exchanges. This is necessary to do so because by restricting their abilities in product markets they are snatching their economic freedom. In case of



**Figure 1.** Total Energy production and consumption in BRICS Countries (2010–2016) (source: Pathak & Shah, 2019)



**Figure 2.** Economic Freedom Index of BRICS (source: The Global Economy)

BRICS economies, the region makes restriction on economic freedom by replacing “individual choice, voluntary exchange, and market coordination with taxes, government spending, and restrictions” (Duan et al., 2022; Paraschiv et al., 2021; Yousaf et al., 2021). Hence, it is quite interesting to unearth the following question:

***Do these factors really affect economic freedom in BRICS case?***

With this background, it is quite interesting to study these economies in depth and explore the association of economic freedom index with green investment, REO and REC in BRICS countries with recent data. This way the present study signifies the usefulness of economic freedom index with the view to strengthen the economic stability, particularly in BRICS countries, and facilitates economy-related associates to restructure policies to uplift the country economic freedom index rating. Finally, the study sketches some deep-rooted analysis that facilitates future researchers to explore new avenues.

Structurally the overall introduction of the study is present in first section. The second chapter presents the evidence about the economic freedom index, green investment, REO, REC, EG, inflation and population growth in connection with prior evidences. The next section provides data technique and measurement of variable that are being used for data analysis. In next section, discussion of study has been presented where the evidences are being contrasted with preceding evidences. Lastly, implications and limitations are presented in the last section of study.

## 2. Literature review

In last few decades, the increasing energy consumption led to an increase the production. The countries having less renewable energy resources lead to increase production from traditional resources with not only impacts the environment but also hit the economy in negative manner (Hussain et al., 2022; Zeraibi et al., 2023). The promotion of renewable energy will lead to a prosperous economy which further leads to economic freedom, thus, green investment leads to economic freedom through prosperity in the economy. In this context: Assi et al. (2020) explored economic development and green investment in terms of RE in countries with high economic freedom. The study chose 28 countries as a sample study and covered the time period from 2006–2017. Findings showed that investment in renewable energy leads to betterment in the economic development of the selected countries. Renewable energy is one of the core points of sustainable development goals. Green investment i.e., renewable energy leads to top betterment in the economy which further affects economic freedom. In this context, Mushtaq, Ejaz, and Khan (2018) explored the similar constructs in the sample of 58 economies covering the period from 2000 to 2015. Evidences revealed that green investment i.e., renewable energy results in the betterment of economic freedom through economic prosperity. Moreover, Graafland (2019), explored whether green investment i.e. environmental responsibility has any association with economic freedom in the a sample of 41 economies in the time span of 2005–2014. Evidences stated that investment in renewable energy i.e., green investment leads to environmental stability as well as betterment in the economic freedom.

The rapid changes in the environment are one of the serious concerns of the world. The major issue which degrades environmental quality is the energy produced from conventional methods. The world is switching to renewable energy. Another concern is the high demand for energy but less production capacity. This demand-supply equation also has a strong effect on the country's economy through the business sector (Leitão et al., 2021; Yevdokimov et al., 2018). The EG of the country is a sign of economic freedom for the country's people. In this context: Adesina and Mwamba (2019), scrutinized the association between economic freedom and renewable energy through carbon emission in African context. Evidences proclaimed that there is an association between RE and economic freedom. More production of renewable energy will lead to less carbon emission which positively affects economic freedom. Additionally, Chen et al. (2019) and Wirsinna and Grega (2021) explored the relationship between REO and economic freedom through EG in China's economy in the time span of 1980–2014. Evidences showcase that RE has a strong association with economic freedom through EG. Moreover, Mahmood et al. (2022), checked whether renewable energy in both output and consumption has any association with economic freedom in 41 Asian Pacific regions. It is

revealed from the study that there is no bidirectional relationship between all the selected variables in the selected economies. Furthermore, the findings suggest significant structural changes together with a good regulatory environment. Our empirical study also suggests that the degree of economic freedom and energy intensity is influencing GDP growth rates in Asia-Pacific nations.

The world has become a global village. This transformation has revolutionized every aspect of life. The world is witnessing innovations at a rapid pace. The usage of technology has accelerated at a rapid pace. One of the factors which are needed for every aspect of life is energy. Even though the countries' economies are based on the energy sector (Azam, 2019; Santiago et al., 2020). In this context: Amoah et al. (2020), explored the association between REC and economic freedom in 32 African countries. Results showcase that as per the aggregated metrics of economic freedom, the energy consumption is lowered by both property rights and tax burden. On the other hand, more business and trade flexibility measures increase the % of REP in total energy. African regulators should aggressively promote trade freedom and business flexibility to enhance REC % if they want to achieve the 2030 SDG of fostering access to cheap, dependable, sustainable, and modern energy for everyone. Moreover, Shahnazi and Dehghan Shabani (2021), also explored RE effects on economic freedom in EU states. Findings points out that REC significantly influences the economic freedom of the country. It indicates the energy is important for all sort of economies. However, established economies extract more benefits by switching to renewable energy. As renewable energy conversion benefits both environment and the economy. In this context, Alola et al. (2022), also investigated the economic freedom and REC relationship in the G20 countries. Findings show that REC has a strong association with the economic freedom of the country.

The countries with a high rate of population growth usually face unemployment. This increase in population further results in economic instability due to an imbalance in government revenue and expenses, thus, the population growth results in effect economic freedom. The gulf cooperation council countries, which are regarded as the richest area in the Arab world, have gone through a significant socioeconomic and demographic transformation. Leitão et al. (2023) quoted that with an average annual population growth rate of 4.9% between 2000 and 2019, this area has one of the world's fastest expanding populations (Al-Gasaymeh, 2020; Dkhili & Dhiab, 2018; Niaz, 2021; Marin-Gracia et al., 2022). In this context: Guider (2022) explored the association between economic freedom and population growth through unemployment. The study was conducted in gulf cooperation council countries covering the time span of 2005–2019. Results point out that the lower the unemployment rate the greater the economic freedom score. Thus, for a better economic score, there is an urgent need to control population growth. The country's population is one of the considerable factors in the economy. Any change in the economy will affect the country's population's standard of living. In this context: Brkić et al. (2020) also explored whether economic freedom affects the EG of 43 developing countries in the time span of 2008–2009. Evidences pointed out that any change in economic freedom affects the EG of the country in Canada setting. Moreover, Dean and Geloso (2022), also explored the association between economic freedom and income mobility. The population growth of the country is one of the considerable factors which affect the country's income mobility. Results showed that economic freedom has an association with a population in terms of income mobility.

The countries invest their maximum efforts to bring stability to their economy with the view to providing ease to their people in every aspect of life. Only a financially stable country can provide a better standard of living to its people through economic freedom. In this context: Akadiri et al. (2021) checked whether economic freedom with EG in BRICS countries. Insights revealed that both economic freedom and EG are strongly associated with each other. Moreover, Malanski and Póvoa (2021) also explored the role of economic freedom in the relationship between EG and corruption in Latin America and Asian Pacific economies. Findings showed that Countries in Latin America with more economic freedom suffer from corruption, yet the region's economy benefits. Only in Asian nations with less economic freedom does corruption have a detrimental impact on economic progress. Even though both of these nation groupings are referred to be "emerging", it was found that when comparing this reality to that of Latin America, the countries on that continent are at an earlier level of development than the Asian ones. Similarly, Duan et al. (2022) also checked whether economic freedom along with human capital and governance affect EG in BRICS. Results pointed out that there is an inverted U-shaped link rather than a linear one between human capital and EG. Additionally, the impact of human capital on EG in the BRICS is positively moderated by strong governance performance and only lasts for a limited time. In continuation, Dkhili and Dhiab (2018) explored the nexus between economic freedom and EG in the gulf cooperation council from 1997 to 2015. It has showed that economic freedom positively and significantly affects the EG of the selected GCC economies.

The prime factor which causes economic freedom is economic stability. A country with an unstable economy can't secure a good rating in the economic freedom index as all the economic factors like inflation is equally important for the country (Jermsittiparsert, 2021; Ojogiwa, 2021). The economy is the combination of multiple factors like inflation, foreign direct investment, and exchange rate. In this context: Law and Soon (2020) investigated whether inflation causes economic inequality in 65 developed and developing countries with the help of the two-step SG method. Findings proposed that there is a strong negative association between inflation and income inequality. Institutional quality can lead to a balance in income inequality; thus, policymakers pay special attention to institutional quality. Similarly, Şenalp (2019) checked the association between economic freedom and inflation through EG in 83 developed as well as developing countries from 1970 to 2009. It has been extracted from the evidences that EG inclusive of inflation affects the economic freedom of the selected countries. The country with weak economy leads to a low economic freedom index score. The inflation rate in any country lead to economic stability and economic stability is the prime and core sign of a healthy economic freedom index. In this context, Rapsikevicius et al. (2021) explored the association between economic freedom and economic performance inclusive of inflation in selected European Union economies from 2005 to 2018. Evidences proposed that economic performance is directly associated with economic freedom. A country with better economic performance results in betterment in economic freedom. Thereby, we formulate following hypothesis:

- H1.** *There is a relationship between green investment and economic freedom.*
- H2.** *There is a relationship between energy efficiency and economic freedom.*
- H3.** *There is a relationship between economic growth and economic freedom.*

### 3. Research methodology

#### 3.1. Data

Green investment talks about GDP proportion which is recovered via investments that are related to environmental pollution control (Liao & Shi, 2018). In contrast to traditional investment, the prime difference is how these two concepts contribute to economic growth and environmental quality. The conventional investment model is linked to the "extensive production model" which only emphasizes on economic advantages, hence, neglect pollution discharge injected into nature (Pavlyk, 2020). Green investment, as a concept is viewed as a historic moment that aimed to shed light on the differences in the goals between investment models. In present research, green investment is measured through investment in environmentally friendly companies to total investment (Zhang et al., 2020).

Energy intensity is viewed as a key indicator of "energy efficiency", thus, countries are interested to minimize their energy intensity in order to improve their energy efficiency because when changes happen in energy intensity, energy efficiency numbers automatically change (Özcan & Özcan, 2018). Most of the studies used it as a proxy of energy efficiency, however, the present research used two indicators to gauge the efficiency of energy; renewable energy consumption and renewable energy output. These two indicators are also appropriate to justify the energy efficiency ratio because the more the economies are aiming to prioritize renewable energy goals, the more they get success to improve energy efficiency (Chen et al., 2019; Dzwigol et al., 2023). Besides, the study uses economic freedom as the dependent variable and two control variables named population growth and inflation. Table 1 shows the complete detail of variables.

**Table 1.** Variables Measurement

S#	Constructs	Measurement	Sources
01	Economic Freedom	Economic freedom index	The Global Economy
02	Green Investment	Investment in environmentally friendly companies to total investment	OECD
03	Energy Efficiency	REO (% of total energy output)	WDI
		REC (% of total energy consumption)	WDI
04	Economic Growth	GDP growth annual percentage	WDI
05	Control Variables	Population growth annual percentage	WDI
		Inflation, consumer price	WDI

#### 3.2. Econometric model

The study investigates the effectiveness of green investment, energy efficiency, EG, population growth, and inflation on the economic freedom index of the BRICS countries. The article has used secondary data taken from WDI, The Global Economy, and OECD from 2001 to 2020. The expression of proposed economic model is stated below:

$$EFI_{it} = \alpha_0 + \beta_1 GIN_{it} + \beta_2 REO_{it} + \beta_3 REC_{it} + \beta_4 EG_{it} + \beta_5 PG_{it} + \beta_6 INF_{it} + e_{it}, \quad (1)$$

where: *EFI* – Economic Freedom Index; *t* – Time Period; *i* – Counties; *GINV* – Green Investment; *REO* – Renewable Energy Output; *REC* – Renewable Energy Consumption; *EG* – Economic Growth; *INF* – Inflation; *PG* – Population Growth.

The article’s results provide the detail of all the variables used in the study using descriptive statistics. Additionally, the article’s results also provide the correlation between the constructs using a correlation matrix. Furthermore, the study also checks the issue of multicollinearity via variance inflation factor (VIF). The equations are mentioned below:

$$R_Y^2 \rightarrow Y_{it} = \alpha_0 + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + e_{it}; \tag{2}$$

$$j = R_Y^2, R_{X1}^2, R_{X2}^2, R_{X3}^2, R_{X4}^2, R_{X5}^2; \tag{3}$$

$$\text{Tolerance} = 1 - R_j^2, \text{VIF} = \frac{1}{\text{Tolerance}}. \tag{4}$$

Finally, the study results also show the association among the constructs through MMQR approach. It is a new method of examining the association among variables developed by Machado and Silva (2019). Moreover, this approach effectively deals with the outliers; thus, it has the qualities of being robust to outliers. In addition, this technique also allowed the “conditional heterogeneous covariance effects” of *EFI* to impact the whole distribution in variance to panel quantile regression, which allows shifting means (Adebayo et al., 2022a). Furthermore, it also has the quality of producing dynamic assessments in various conditions; even the model has the characteristic of being nonlinear (Adebayo et al., 2022b; Hartani et al., 2021). Hence, this technique is a suitable technique that includes nonlinear and asymmetric associations by monitoring heterogeneity and endogeneity (Ike et al., 2020; Shibli et al., 2021). Thus,  $Q\tau(\tau/X)$  represents the conditional quantile and the “locational-scale alternate model” is established as below:

$$A_{it} = \alpha_i + B_{it}\beta + (\delta_i + C_{it}\lambda)U_{it}. \tag{5}$$

In Eq. (5),  $P\{\delta_i + C_{it}\lambda > 0\} = 1$  represents the probability,  $\alpha$ ,  $\beta$ ,  $\lambda$  and  $\delta$  represents parameters that need to be estimated,  $\alpha_i$ ,  $\delta_i$ ,  $i = 1, \dots, n$  shows a specific fixed effect, while  $C$  shows the  $k$ -vector of component  $B$ , the components are transformed with component  $l$ , which is mentioned below:

$$Zl = Zl(Y), l = 1, \dots, k. \tag{6}$$

In Eq. (6),  $U_{it}$  shows orthogonal to  $B_{it}$  and consistent to achieve the moment conditions that do not include stringent heterogeneity. Hence, in the above Eq. (5), the conditional quantile of  $A$  is established as under:

$$Q\tau(\tau / B_{it}) = (\alpha_i + \delta_i q(\tau)) + B_{it}\beta + C_{it}\lambda q(\tau). \tag{7}$$

In Eq. (7),  $B_{it}$  represents the independent variables such as *GIN*, *REO*, *REC*, *EG*, *PG*, and *INF* and  $A_{it}$  is the dependent variable such as *EFI*, which is conditional as  $B_{it}$ . Due to time invariants, the heterogeneous effects are permissible for changes across the quantiles of the predictive construct  $B$ . Therefore,  $Q(\tau)$  is established as under:

$$\text{Min}_q = \sum_t \sum_i p\tau(R_{it} - (\delta_i + Z_{it}\lambda)q). \tag{8}$$



## 4. Research findings

The article's results provide the detail of all the study variables using descriptive statistics (see Table 2). It is shown in Table 2 that EFI mean value was 0.472%, GIN 0.349%, REO 26.975%, REC 22.685%, EG mean 4.379%, PG 0.833% and INF 5.905%.

**Table 2.** Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EFI	100	0.472	0.049	0.357	0.565
GIN	100	0.349	0.082	0.214	0.534
REO	100	26.975	28.461	0.418	88.996
REC	100	22.685	16.622	3.167	48.920
EG	100	4.379	4.086	-7.80	14.231
PG	100	0.833	0.583	-0.460	1.729
INF	100	5.905	3.809	-0.732	21.477

Moreover, the study also shows the country-wise details of all the variables used. The findings exposed that the highest EFI was reported in Russia (0.513), while the largest value of GIN was in China (0.469), and the highest REO was reported in Brazil (81.826). Moreover, the findings also exposed that the highest REC was reported in Brazil (45.347), the largest value of EG was in China (8.702), while the largest value of PG was in South Africa (1.384), and the highest INF was reported in Russia (9.543). Table 3 presents the results given below:

**Table 3.** Descriptive statistics (Country)

	EFI	GIN	REO	REC	EG	PG	INF
Brazil	0.475	0.348	81.826	45.347	2.005	0.978	6.165
Russia	0.513	0.391	16.654	3.384	3.124	-0.087	9.543
India	0.467	0.294	16.187	38.054	5.932	1.335	6.292
China	0.400	0.469	19.216	15.438	8.702	0.556	2.335
South Africa	0.503	0.245	0.993	11.201	2.131	1.384	5.192

The findings from Table 4 exposed that the highest EFI was reported in 2020 (0.519), while the largest value of GIN was in 2020 (0.387), and the highest REO was reported in 2009 (28.171). Additionally, the findings also exposed that the highest REC was reported in 2001 (27.208), the largest value of EG was in 2007 (8.364), while the largest value of PG was in 2001 (0.946), and the highest INF was reported in 2008 (8.828).

In addition, the article's results also provide the correlation between the constructs using a correlation matrix. The results from Table 5 revealed that green investment, REO, REC, EG, population growth, and inflation have a positive association with the economic freedom index of the BRICS countries. The results provide guidelines to the regulators in developing policies related to the achievement of economic freedom by improving green investment and energy efficiency.

**Table 4.** Descriptive statistics (Years)

	EFI	GIN	REO	REC	EG	PG	INF
2001	0.425	0.311	27.424	27.208	4.470	0.946	7.704
2002	0.429	0.318	26.976	26.588	4.878	0.895	7.460
2003	0.435	0.320	26.633	26.186	5.858	0.860	7.798
2004	0.440	0.324	27.240	25.222	7.110	0.845	4.877
2005	0.445	0.328	27.757	24.464	6.839	0.834	5.528
2006	0.450	0.332	27.728	24.088	7.710	0.826	4.908
2007	0.454	0.336	27.861	23.526	8.364	0.838	6.003
2008	0.459	0.340	27.003	23.082	5.245	0.852	8.828
2009	0.464	0.344	28.171	22.866	1.559	0.858	6.781
2010	0.469	0.347	27.292	22.068	6.840	0.854	6.229
2011	0.474	0.351	27.584	21.240	5.247	0.871	6.908
2012	0.479	0.355	26.863	20.722	4.332	0.911	5.660
2013	0.484	0.359	26.424	20.400	4.280	0.908	6.276
2014	0.489	0.363	25.961	20.130	3.498	0.887	5.774
2015	0.494	0.367	26.270	20.536	2.168	0.852	7.090
2016	0.499	0.371	26.604	20.986	2.537	0.826	5.860
2017	0.504	0.375	26.534	20.914	3.610	0.800	3.447
2018	0.509	0.379	26.464	21.370	3.856	0.728	3.415
2019	0.514	0.383	26.394	21.734	2.644	0.677	3.790
2020	0.519	0.387	26.324	20.366	-3.470	0.597	3.769

**Table 5.** Correlation matrix

Variables	EFI	GIN	REO	REC	EG	PG	INF
EFI	1.000						
GIN	0.336	1.000					
REO	0.068	0.170	1.000				
REC	0.219	-0.242	0.692	1.000			
EG	0.698	0.258	-0.181	-0.004	1.000		
PG	0.058	-0.696	0.001	0.537	-0.071	1.000	
INF	0.261	-0.190	0.049	-0.106	-0.201	-0.265	1.000

Furthermore, the study also checks the multicollinearity by applying VIF technique. The findings revealed that the VIF is  $<5$ , while the reciprocal of VIF values are  $>0.2$ . These figures indicated that no multicollinearity issue exists. Table 6 presents the results.

The results of MMQR revealed that green investment, REO, REC, EG, population growth, and inflation are positively associated with the economic freedom index in BRICS case. Table 7 exposed that GIN significantly impacted EFI in quantiles 1 to 7, while REO significantly impacted EFI in quantiles 1 to 7, and REC significantly impacted EFI in quantiles 1 to 8. Moreover, the results also exposed that the EG significantly impacted EFI in quantiles 1 to 5 and

9, while PG significantly impacted on EFI in quantiles 1 to 5, 7, and 9, and INF significantly impacted on EFI in quantiles 1 to 3, 5, and 8 to 9. Table 7 presents the results of MMQR and Table 8 presents the results of FMOLS and DMOLS.

**Table 6.** Variance inflation factor

	VIF	1/VIF
GIN	2.764	0.362
REO	2.657	0.376
REC	2.524	0.396
EG	2.429	0.412
PG	2.234	0.448
INF	1.902	0.526
Mean VIF	2.418	.

**Table 7.** Panel quartile estimation (MMQR)

Variables	Method of Moments Quantile Regression (MMQR)										
	Location	Scale	Quartiles grid								
			0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
GIN	0.542***	0.764*	0.643**	0.761**	0.664*	0.647**	0.655*	0.654*	0.664*	0.102	0.546
REO	0.654**	0.621*	0.519**	0.338*	0.310*	0.722***	0.556**	0.392**	0.519**	0.321	0.384
REC	0.763***	0.722**	0.812**	0.190**	0.288*	0.903*	0.908*	0.721*	0.472*	0.291*	0.211
EG	0.573*	0.439**	0.611*	0.362*	0.544**	0.664*	0.826*	0.029	0.211	0.129	0.646*
PG	0.647**	0.438**	0.372**	0.347**	0.378**	0.645*	0.763*	0.291	0.342*	0.029	0.243*
INF	0.554*	0.254**	0.243*	0.479**	0.855**	0.231	0.547*	0.133	0.201	0.893*	0.721*

**Table 8.** FMOLS and DMOLS results

Dependent	Independent	FMOLS Coefficient	Prob	DMOLS Coefficient	Prob
EFI	GIN	0.40	0.00	0.53	0.00
	REO	0.39	0.04	0.41	0.002
	REC	2.31	0.002	0.52	0.013
	EG	0.621	0.00	0.65	0.005
	PG	0.19	0.01	0.29	0.00
	INF	0.12	0.02	0.12	0.013

## 5. Discussions

The study explores the impact of green investment, energy efficiency, EG, population growth, and inflation on the economic freedom index in BRICS economies. Findings proclaim that green investment increases economic freedom. These results are supported by the past study of Ren, Hao, and Wu (2022). The past study states that when in the economy, the economic enterprises not only carry out the economic activities without considering the environmental impacts of these activities but invest in green practices, they show socially responsible behavior. These enterprises satisfy the government regulating authorities and achieve their favor and enjoy economic freedom. Liu et al. (2020) in this regard also posits that if business enterprises make a green investment, they carry out green practices like utilizing green infrastructure for buildings or lands, using the least polluting technologies for production processes, reducing the use of chemicals, and effective management of factory wastes, etc. In this situation, these enterprises are allowed to be free in economic practices. Hence, green investment leads enterprises to get economic freedom. Findings are consistent with Xie and Zhang (2021). According to this past study, getting freedom from government or regulators for certain production processes, trading of goods and services, or using a particular building depends on the impacts of the business practices on the surrounding. The enterprises which make an investment in green practices win the trust of authoritative persons and gain economic freedom.

The findings confirm that REO enhances economic freedom. Evidences are backed up by Shahnazi and Dehghan Shabani (2021). The past study implies that the environmental regulators have the duty to check whether the economic activities which are performed or going to be performed are safe for the environment and not damaging to natural resources and human health. When in an economy, the REO is large in amount, the use of fossil fuel for energy decreases automatically. The resultant energy efficiency assures environmental protection and motivates the environmental regulators to allow economic freedom. Thus, the increasing REO enhances economic freedom. Alola et al. (2022) also added the argument that if the output of RE is increasing at a fast rate, the use of clean energy will increase. As a result, there would be a less focus on fossil fuels. Because of the responsible economic behavior of businesses, regulators allow economic freedom. Assi et al. (2020), also highlights that in the areas where renewable energy is produced in significant quantity to encourage the clean energy usage within the country, there is economic freedom.

The study confirms that REC enhances economic freedom due to similar direction. Chai-kumbung (2021) also stated that the freedom of carrying on specific economic activities like construction, agriculture, manufacturing, tourism, transportation, etc., is granted by the government only when the firms show responsible behavior towards the environment. So, the individuals or firms engaged in any of the economic activities utilizing renewable energy instead of fossil fuels are free to perform these economic activities and apply for self-made roles in the contracts. These results are also in line with the study of Filimonova et al. (2021), which throws light on renewable energy's impacts on economic freedom. The study also claims that when firms apply renewable sources of energy and employ green marketing

practices, they have the freedom to trade in goods and services both at the national and international levels. Zhang et al. (2021) also claims that the use of RE is an effective tool to mitigate the negative environmental impacts of business practices like manufacturing, construction, maintenance of infrastructure, marketing, etc., show concern for the environment and social welfare. These firms gain public trust and regulators' satisfaction which leads to the grant of economic freedom.

The study confirms that EG increases economic freedom due to positive association. Mahmood et al. (2022) also stated that when a country is making rapid growth, individual businesses are making progress and have the intention to sustain their performance. The performance of sustainable development practices, which protect the environmental quality and gives a sense of protection to social people, are allowed to make contracts and perform practices of their choice. Thus, EG leads to economic freedom. Song et al. (2018) also stated that when a country has high EG and high financial development, green programs can be executed. In this situation, business firms are provided with economic freedom. Similarly, Sart et al. (2022) also tells that countries making higher EG have financial and technological development. So, energy-efficient technologies and economic processes can be employed in the economy, and thereby, economic freedom can be attained.

The study confirms that inflation and economic freedom are positively connected. These results are supported by the past study of Mushtaq et al. (2018), which shows that in case there is an inflationary period, investment is being made in developmental and environmentally-friendly projects which facilitate and regulate economic activities along with maintaining social welfare. Hence, economic freedom is possible as it would be fruitful. Findings are confined with Ahmed et al. (2022) that highlights that during an inflationary period, there is an increasing trend in production level, and marketing can also be raised. As a result, work for environmental sustainability and social welfare gets started, which motivates the authorities to allow economic freedom. Sandberg et al. (2019) also claims that the inflationary period is one of the key drivers of economic freedom. It means that when there is inflation, sustainable energy technologies like bioenergy, solar energy, wind power, hydropower, etc., are likely to be employed due to financial development. This leads the country towards freedom.

The findings showed that population growth in the economy and economic freedom share positive connection. Findings are backed up by Fahimipour et al. (2018), that show that high population growth within the country demands more resources. Moreover, in order to fulfill the increasing needs, it is required to increase economic activities. So, the government and regulatory authorities allow freedom. Similarly, Sworobowicz et al. (2020) also shed light on the green investment role in economic freedom. The study posits that high population growth facilitates country in the form of human capital. An economy where there is a high population, needs to become economically growing and, through trade openness and increasing economic development, must meet the needs of the increasing population. For this purpose, economic freedom is granted. Dodson et al. (2020), also proclaimed that high population growth demands more energy. Thereby, in order to fulfil the need, economic actors focus on the REP and REC

## 5.1. Implications of the study

Economic freedom is a significant step to attaining sustainable economic development, so it has considerable importance to all countries. The study serves as a guideline for the economist, government, and regulatory authorities indicating how to encourage economic freedom. The study guides them that they must form policies to encourage investment in green practices in order to promote economic freedom. The study conveys that effective policies must be formulated to facilitate REO so that economic freedom can be made possible. It also serves as a guideline that the policymakers must encourage REC for the social and economic purpose of promoting economic freedom. The paper suggests that policymakers must struggle to accelerate EG to create conditions that can encourage economic freedom. The study also conveys that the inflation period must be managed to contribute to EG for encouraging economic freedom. The results provide guidelines to the regulators in developing policies related to the achievement of economic freedom by improving green investment and energy efficiency. It is also recommended that the population growth rate must be managed properly to enhance economic freedom.

In order to remodel low carbon energy supply, a standardized low-carbon emission model should be designed at national level. Moreover, fossil fuels must be replaced so that energy efficiency of a country can be improved and energy security can be promoted. Also, BRICS economies must accelerate electrification of terminal energy and improve energy efficiency and quality, if they really want to bring change in energy consumption patterns. It is also meaningful to increase the focus towards novel technologies. Besides, energy system reforms must be in continuation to be implemented along with the improvement of modern markets systems of energy so that their capabilities can fully be utilized.

Furthermore, credible green policies have the potential to give boost to economic activities and reduce policy risk to the point, where economies are able to see green investment as a worthwhile opportunity to increase economic growth. Although private sector wishes to observe successful economic growth, however, a credible policy is required to kick-start the investment in energy efficiency and renewable resources.

In an environment where private sectors are commencing deleveraging in dramatic manner, in such scenarios, public sector leveraging with the help of credible policy design could increase various economic activities. It is quite alluring that crowding-in investment not only can generate income and increase employment ratio but also increase tax revenues through which public indebtedness can be address. Meanwhile, BRICS economies can also achieve toughest emission-related targets and quit a deep-rooted legacy via transitioning methods and become resource efficient and eco-friendly economy. Although, in current market, private money flow is there, however, due to lack of private sector opportunity, multiple opportunities at the same times are found to be rare, hence, should not be missed.

Moreover, as per findings, there is a need to adopt supportive policies that helps in green energy development and energy efficient projects. Also, policies related to energy efficiency must be prioritized in development procedures because it will not only provide climate benefits but also helps in generating long-term growth benefits. In this context, BRICS economies must give favour to those policies that aimed at changing long-term attitudes such as

“institution and implementation of EE policies and regulations, interventions to discourage the use of inefficient equipment, incentivize the use of energy-efficient equipment”. Government should also offer flexible and attractive financial schemes for such kind of investments. Interestingly, effort pertaining to energy efficiency can only be doubled when policies related to income inequality and living standard would be prioritized. Lastly, “tax holidays on basic energy-efficient appliances” which are normally adopted by lower income bracket people may improve energy efficiency as well.

## 6. Conclusions

The study evaluated green investment, REO, REC, and EG on economic freedom and also assessed inflation and population growth in view with economic freedom. A survey was conducted on BRICS economies to collect data for green investment, REO, REC, EG, inflation, population growth, and economic freedom. Findings confirm the positive connection between green investment, REO, REC, EG, inflation, and population growth to economic freedom. The results stated that when in an economy, the firms have the tendency to make the investment in green practices such as applying energy-efficient technologies, chemical-free raw material, water management, waste management, etc., they show a responsible attitude and behavior, thereby attaining economic freedom. The results indicated that when in the country, REP is at a high level, and consequently, the uses of clean energy increases, the firms can employ energy-efficient and ecological-friendly business processes. This socially responsible behavior helps attain economic freedom. The results revealed that increasing EG improves the country’s financial and technological development, which is significant for implementing environmentally friendly and socially favorable activities. These activities support to attainment of economic freedom. The results also showed that during inflation, the increasing financial position and the need to accelerate the marketing force the firms to achieve business sustainability which leads to economic development. The study concluded that high population growth demands more resources however it also provides excessive amount of human capital. The consequent sustainable business practices encourage economic freedom.

## Limitations

Some limitations are still found and these limitations must be overcome in further literature. Here, in this study, only the factors like green investment, REO, REC, and EG have been examined to check economic freedom. The significant factors, such as sharing economy, corporate governance, and technological advancements, in driving economic freedom have not been evaluated within a single framework. Hence, future authors must broaden the scope of the study by analyzing these factors along with green investment, REO, REC, and EG for determining economic freedom. Moreover, for this study, the evidential data for green investment, REO, REC, EG, inflation, population growth, and economic freedom from BRICS economies. The study validity is restricted to these BRICS countries or some other similar countries only. For a general study, the authors collect data from multiple diverse economies for the study.

## Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Competing interests

The author declare that they have no competing interests.

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