Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

Does sustainable financial inclusion and energy efficiency ensure green environment? Evidence from B.R.I.C.S. countries

Dandan Dou & Liying Li

To cite this article: Dandan Dou & Liying Li (2022) Does sustainable financial inclusion and energy efficiency ensure green environment? Evidence from B.R.I.C.S. countries, Economic Research-Ekonomska Istraživanja, 35:1, 5599-5614, DOI: 10.1080/1331677X.2022.2032785

To link to this article: https://doi.org/10.1080/1331677X.2022.2032785

Published online: 21 Feb 2022.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2022, VOL. 35, NO. 1, 5599–5614
https://doi.org/10.1080/1331677X.2022.2032785

Does sustainable financial inclusion and energy efficiency ensure green environment? Evidence from B.R.I.C.S. countries

Dandan Dou and Liying Li

Department of Management, Henan University of Technology, Zhengzhou, China

ABSTRACT

Continuous rise in a global economy with a 3–4% annual growth rate poses a severe risk to environmental sustainability due to high energy demand. Since the Paris climate accord, countries worldwide have implemented numerous strategies to attain the target of carbon neutrality. With the rising environmental challenges, it is important to consider global financial inclusion (F.I.) policies. This study uses panel data for the B.R.I.C.S. countries to investigate the impact of F.I. and energy efficiency in limiting trade adjusted emissions (T.A.E.) taking technological innovation and trade as control variables. This study uses panel data consisting small sample size and large time period; therefore, keeping in mind the potential econometric problems, this study uses AMG method, which can efficiently deal with endogeneity problems and small sample bias. We find a positive impact of F.I. and energy efficiency on CO_2 emissions. Moreover, we find that technological innovation, exports and output amplify CO_2 emissions.

ARTICLE HISTORY
Received 1 December 2021
Accepted 19 January 2022

KEYWORDS
sustainable financial inclusion (F.I.); energy efficiency; low emissions; B.R.I.C.S

JEL CODES
F3; F6; P5

1. Introduction

To address environmental concerns, a well-known climate pact was signed in 2015, with the goal of limiting increasing temperatures. Despite the agreement, CO_2 emissions have been increasing throughout the years, posing a constant threat to human lives on Earth. Countries are enacting measures to give low-cost access to clean and green energy. The primary means of achieving the desired aim of considerably lowering global greenhouse gas (G.H.G.) emissions is the utilisation of renewable energy sources. Renewable energies are key components in facilitating the transition to a low-carbon energy system (Ji et al., 2021). However, transitioning to a sustainable energy system will be impossible without an effective finance structure (Wang et al., 2020).

Financial inclusion (F.I.), an integral part of financial system, is a key enabler to foster the deepening of financial system by helping the households and entrepreneurs

CONTACT Dandan Dou Dandandou01@hotmail.com

to access to low-cost financial products and services. Moreover, F.I. is considered as a key enabler for achieving 7 out of 19 Sustainable Development Goals (S.D.G.s). F.I. could have both positive and negative influence on environmental performance. The theoretical justification for the positive effect is that F.I. increases the accessibility to low-cost pure energy, which facilitate the transition towards carbon neutrality. Hence, F.I. impedes CO_2 emissions. On the contrary, improved access to financial products poses a severe risk to the environmental sustainability due to high energy demand. At micro level, individuals who have more access to financial products are abler to purchase energy intensive electric appliances commodities, which in turn increase energy consumption, which is considered as a severe threat for eco system and environmental sustainability (Shahzad et al., 2022). At a macro level, improved financial system facilitates economic activities, which causing the temperature to rise. Hence, improvement in F.I. and financial system poses a severe risk to the environmental sustainability. Given the ambiguous impact of F.I. on CO_2 emissions, it is imperative to examine the linkage between F.I. and environmental performance.

This study makes use of panel data for the B.R.I.C.S. countries, to estimate the impact of F.I. and energy efficiency in limiting trade adjusted emissions (T.A.E.s). The B.R.I.C.S. countries are vital to study based on the following evidences: First, the B.R.I.C.S. countries have large share in world's output. As of 2018, represents 42% of the world's population, 18% of the world's total exports and 23.2% of the world's output, i.e., US$19.6 trillion. The new global powers like China and India, which in combination with Russia, Brazil, and South Africa, could have an economy size larger than G-6 countries by 2041 (Wilson & Purushothaman, 2003). Second, B.R.I.C.S. countries are among the greatest carbon emitters and at the same time victims of climate change. The carbon emissions in these five countries have been increasing over the years. With the increased investment in infrastructure and industries, the energy consumption of these countries has been increasing over the years. Owing to high energy consumption, rapid urbanisation and increasing trade flows, the B.R.I.C.S. countries have been confronting with rising G.H.G. emissions and hence, face massive environmental challenges. However, the countries particularly, China and Russia have sufficient resources to address the environmental issues. The B.R.I.C.S. countries are keen to ensure energy efficiency to eliminate energy waste and abate carbon emissions. The performance of B.R.I.C.S. countries in achieving energy efficiency is decent. The energy efficiency in these five countries ranges from 23.5% in Russia to 99.9% in Brazil. However, the F.I. in B.R.I.C.S. countries is not outstanding. F.I. is recognised as a vital strategy to attain carbon neutrality. The F.I. index for B.R.I.C.S. countries and found that the score of F.I. index in these five countries ranges from 0.67 in China to 0.18 in South Africa.

Carbon emissions have been measured using two methodologies in the extant literature on the drivers of environmental performance: the production-based approach (P.B.A.) and the consumption-based approach (C.B.A.). The majority of the study took P.B.A. into account when examining the potential factors of environmental performance. Nonetheless, scholars have recently shifted their focus to C.B.A. because this method considers the final destination of products and services (Ali et al., 2020). Table 1 shows the B.R.I.C.S. countries' consumption-based carbon emissions (CCO_2)

Table 1. Average ratios of CCO_2 to TCO_2 of sample countries.

Countries	CCO_2/TCO_2	CCO_2–TCO_2	Decision
China	0.872633	−800.198	Emission Exporter
India	0.941664	−88.2027	Emission Exporter
South Africa	1.1388	56.77792	Emission Importer
Russian Federation	0.839677	−260.681	Emission Exporter
Brazil	1.08753	30.4703	Emission Importer

Source: drawn by authors.

to territory-based carbon emissions (TCO_2). It is evident that among B.R.I.C.S. countries, China, India and Russia are net exporter of carbon emissions as the ratio of CCO_2 to TCO_2 is less than one. Brazil and South Africa on the other hand, are net imports of carbon emissions.

From the above discussion, we can infer that on one hand, most of B.R.I.C.S. countries are net exporter of carbon emissions. Moreover, B.R.I.C.S. economies are growing at a remarkable level and their contribution to world's output has been significantly increasing over the years. On, the other hand, these countries are continuously improving their energy efficiency to attain carbon neutrality. However, the performance of B.R.I.C.S. countries in term of F.I. is not impressive. Hence, the linkage between energy efficiency and F.I. are vital aspects to study the complex low carbon economic model and sustainable development. This study examines the impact of F.I. on environmental performance of B.R.I.C.S. countries. With the rising environmental challenges, it is important to consider global F.I. policies. Especially, how F.I. is linked with carbon emissions? How F.I. help households to purchase energy-efficient products? To what extend improvement in energy efficiency is important to deal with environmental challenges. These are the main concerns of the study. Moreover, this study includes energy efficiency, technology, G.D.P., exports and imports to examines their impact on environmental performance of B.R.I.C.S. countries.

2. Literature review

The literature on the responsible factors of environmental degradation is quite rich. Income is the most discussed factor of environmental degradation (Magazzino et al., 2022). The impact of income on environment is empirically tested by the E.K.C. hypothesis, which demonstrates an inverted U shape relationship between the level of income and CO_2 emissions (Acaravci & Ozturk, 2010; Balsalobre-Lorente et al., 2018; Song et al., 2020). The E.K.C. hypothesis is extensively validated by majority of empirical studies (Ali et al., 2014; Al-Mulali & Ozturk, 2016; Sushmita et al., 2002). However, these studies use incomplete model specification and incomprehensive proxies used for environmental degradation. Hence, researchers included other important variables while testing the E.K.C. hypothesis. In the literature, several determinants of environmental performance have been highlighted. The most widely identified determinants of environmental degradation are income, industrialisation, international trade, urbanisation, deforestation, population, energy consumption etc. (Baek, 2016; Bosupeng, 2016; Costantini et al., 2017; Erdoğan et al., 2020; Hasanov et al., 2018; Meng et al., 2015; Rafique et al., 2021; Zhang et al., 2017; Zhao et al., 2022;). Moreover, energy efficiency is acknowledged to be important factors for improving environmental quality (Dan, 2002; Ji et al., 2021; Wu & Shao, 2016; Zhao & Lin, 2019). The importance of renewable energy in achieving carbon neutrality is highly discussed in the literature. Recently, researchers such as Abid (2016), Baloch et al. (2018), Jiang and Ma (2019), Safi et al. (2021), Wang et al. (2020) and Bayar et al. (2020) included financial development as important factor of environmental degradation.

In the literature, the role of financial system in affecting economic growth, poverty reduction and income inequality is extensively studies. Moreover, the importance of financial development in affecting CO_2 emissions has attained more importance in recent years. F.I., an integral part of financial system is the subject of ongoing debate. A bulk of studies have investigated the effects of F.I. on poverty, macroeconomic stability, financial efficiency, capital accumulation, inequality and economic growth (Cabeza-García et al., 2019; Ji et al., 2021; Kim et al., 2018; Le et al., 2019; Makina & Walle, 2019; Naqvi et al., 2021; Park & Mercado, 2015; Rojas-Suarez & Amado, 2014; Sahay et al., 2015; Salazar-Cantú et al., 2015; Schmied & Marr, 2016; Umar et al., 2021a, 2021b). Van et al. (2021) in case of emerging markets, Kim et al. (2018) in case of O.I.C. countries, Makina and Walle (2019) in case of African countries and Hajilee et al. (2017) in case of emerging economies confirm positive influence of F.I.N.C. on growth. However, the linkage between F.I.N.C. and environmental performance has not received immense importance from researchers until recent year. Although, F.I.N.C. has theoretically been recognised to have negative impact on environmental performance. However, there is limited empirical evidence to prove it, especially for B.R.I.C.S. countries. Few authors have investigated the impact of F.I.N.C. on CO_2 emissions (Le et al., 2020; Usman et al., 2021). Increased access to financial products poses a severe risk to the environmental sustainability due to high energy demand. Moreover, Le et al. (2020) in case of Asian countries found no evidence to confirm the nexus between F.I.N.C. and CO_2 emissions. Usman et al. (2021) in case of top 15 emitter countries confirms the negative influence of F.I.N.C. on CO_2 emissions. Nevertheless, the major limitation of the study lies in using incomprehensive proxy used for F.I.N.C. For example, Usman et al. (2021) used financial development to represent F.I.N.C., which can be greatly criticised.

To sum up, F.I. is an integral part of financial system, the measurement and dimensions of both financial development and F.I.N.C. are different. Moreover, the existing studies investigate the relationship between F.I. and CO_2 emission without taking into account the important variables such as energy efficiency, trade and technological innovation. This study contributes to the literature by investigating the impact of F.I.N.C. on CO_2 emission by taking technological innovation and trade as control variables. Moreover, we use trade adjusted CO_2 emissions to represent environmental performance. Previous studies make use of production bases accounting system to measure CO_2 emissions, which overlook the environmental impacts of consumption and does not take into account the effect of global trade on these emissions. Trade adjusted CO_2 emissions takes into account the environmental impacts of consumption and considers the country's total emission levels by including imports and excluding exports. Third, as B.R.I.C.S. countries are more integrated with each other, there is more likely cross-sectional dependency. A shock in one country may spillovers to other countries affect the macroeconomic performance in other countries. Hence, we make use of second-generation econometric methods to estimate the nexus between F.I.N.C., energy efficiency and CO_2 emissions.

Our results show positive effect of F.I.N.C., exports and output on CO_2 emissions in the B.R.I.C.S. countries. Moreover, improved energy efficiency and imports lead to fewer CO_2 emissions in B.R.I.C.S. countries. This study suggests that F.I.N.C. must be considered in policymaking process. However, steps must be taken to regulate and monitor the financial system. Green financing must be expanded in order to help deprived regions within the country to cope with environmental challenges.

3. Methodology

3.1. Model

This study analyses the role of F.I. and energy efficiency in determining the trade adjusted CO_2 emissions in B.R.I.C.S. countries over the period of 2004 to 2019. The empirical equation is modelled as:

$$CO_{2it} = \beta_0 + \beta_1 FI_{it} + \beta_2 TI_{it} + \beta_3 ENEF_{it} + \beta_4 EX_{it} + \beta_5 IM_{it} + v_{it} \quad (1)$$

$$CO_{2it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 TI_{it} + \beta_3 ENEF_{it} + \beta_4 EX_{it} + \beta_5 IM_{it} + v_{it} \quad (2)$$

where, CO_2 represents trade adjusted carbon emissions, F.I. stands for financial inclusion, G.D.P. represents gross domestic product, TI represents technology (patents from world bank), E.N.E.F. represents energy efficiency, measured by G.D.P. per unit of energy use (constant 2017 PPP $per kg of oil equivalent), E.X. and I.M. represent exports and imports.

In the existing literature, production-based emissions (P.B.E.) and T.A.E. are the two accounting methods to measure carbon emission (Afionis et al., 2017; Khan et al., 2020; Yasmeen et al., 2019). Most of the previous literature has used P.B.E. approach, which considers the country's total emission levels, including exports (Bhattacharya et al., 2020). Nevertheless, the P.B.W. approach provides an incomplete picture of key factors of emissions and ignore the environmental impacts of consumption. Moreover, the P.B.E. approach does not take into account the impact of global trade on these emissions. Since, the product producing country may not be the product consuming country, T.A.E. approach is a closer proxy to measure CO_2 emissions. The T.A.E. approach considers the country's total emission levels by including imports and excluding exports. Hence, T.A.E. system takes into account the environmental impacts of consumption. Countries having a higher T.A.E. should be more ethically responsible and exert more efforts for mitigation (Ali et al., 2021).

3.2. Analytical techniques

3.2.1. Cross sectional dependency (C.S.D.)

Since, B.R.I.C.S. countries are more integrated with each other, they are more likely to be dependent cross-sectionally. A shock in one country may affect the macroeconomic performance in other countries. Ignoring C.S.D. may lead to biased and spurious results (Chudik & Pesaran, 2013, 2015; Pesaran, 2004; Song et al., 2022). Hence, before estimation of model, we check the C.S.D. by implying Pesaran (2015) C.D. test. The test equation is given as:

$$CD_{Adjusted\quad one} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{k=i+1}^{N}\hat{\tau}_{ik}\right)\frac{(T-j)\hat{\tau}_{ik}{}^{2} - E(\mathrm{T}-j)\hat{\tau}_{ik}{}^{2}}{V(T-j)\hat{\tau}_{ik}{}^{2}} \tag{3}$$

$$CD = 1, 2, 3, 4 \ldots\ldots.15\ldots\ldots.N \tag{4}$$

$$CD_{Pesaran\quad(2004),\quad i} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{k=i+1}^{N}\hat{\tau}_{ik}\right) \tag{5}$$

where, $\hat{\tau}_{ik}$ indicates the residual pairwise correlation coefficient.

3.2.2. Pesaran and Yamagata (*2008*) slope heterogeneity

Keeping in mind the possibility of C.S.D., this study uses Pesaran and Yamagata (2008) slope heterogeneity test, which does not allow for C.S.D., as suggested by Atasoy (2017). Furthermore, this test lacks in dealing with panels consisting ($T > N$). The test performs well when it comes to the case of small sample size. The regular dispersion statistic for testing slope homogeneity is given by the following equations.

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \tag{6}$$

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \tag{7}$$

$\tilde{\Delta}_{SH}$ and $\tilde{\Delta}_{ASH}$ represent delta tilde and adjusted delta tilde, respectively.

3.2.3. Unit root tests

This study uses the Cross Sectionally Augmented I.P.S. (C.I.P.S.) statistics, popularised by Pesaran (2007). The C.I.P.S. test deals with C.S.D. and slope heterogeneity. The general form for the regression is given below as:

$$\Delta W_{i,t} = \varphi_i + \varphi_i Z_{i,t-1} + \varphi_i \overline{W}_{t-1} + \sum_{l=0}^{p}\varphi_{il}\Delta\overline{W_{t\bar{l}}} + \sum_{l=1}^{p}\varphi_{il}\Delta W_{i,t-l} + \mu_{it} \tag{8}$$

where, $\overline{W}_{t-1}$ and $\Delta\overline{W_{t\bar{l}}}$ present the cross-section averages. The CIPS statistic is given below as:

$$\widehat{\mathrm{CIPS}} = \mathrm{N}^{-1}\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{CDF}_{\mathrm{I}} \tag{9}$$

Whereas, C.D.F. statistic obtained from the t-ratio of the parameter φ_i in equation (8).

3.2.4. Westerlund cointegration

This study make use of Westerlund's cointegration test, which takes into account structural dynamics instead of residual dynamics, thus, eliminating any common factor restriction. This test deals with C.S.D. and slope heterogeneity (Ali et al., 2021). This test ensures normal distribution, deals with C.S.D.

The test statistics are specified as:

$$G_t = \frac{1}{N}\sum\nolimits_{i=1}^{N} \frac{\alpha_i^{'}}{SE(\alpha_i^{'})} \tag{10.1}$$

$$G_a = \frac{1}{N}\sum\nolimits_{i=1}^{N} \frac{T\alpha_i^{'}}{\alpha_i^{'}(1)} \tag{10.2}$$

$$P_t = \frac{\alpha'}{SE(\alpha')} \tag{10.3}$$

$$\alpha' = \frac{P_a}{T} \tag{10.4}$$

where, the pair Gt and Ga represent the group statistics and the pair Pa and Pt represent panel statistics. The error correction parameter, denoted by 'α' and its standard error by using $\Delta\widetilde{y}_{it}$ and $\widetilde{y}_{i,t-1}$ is calculated as:

$$\hat{\alpha} = \left(\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{y}_{i,t-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{t=2}^{T}\frac{1}{\hat{\alpha}(1)}\widetilde{y}_{i,t-1}\Delta\widetilde{y}_{it} \tag{11}$$

$$SE(\hat{\alpha}) = ((\hat{S}_N^2)^{-1}\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{y}_{i,t-1}^{2})^{-1/2} \tag{12}$$

3.2.5. Augmented mean group method

Tackling endogeneity problems is another important issue in in regression models. To deal with endogeneity problems efficiently and utilising the suitable estimation method are crucial for publication in many academic journals. The A.M.G. method estimates two equations: First, the equation is estimated by entering the first-difference of variables via O.L.S. method, as shown in equation (14).

Table 2. Diagnostic tests.

Slope heterogeneity		
Statistic	Model-1	Model-2
$\tilde{\Delta}$	4.677***	4.821***
$\tilde{\Delta}$ Adjusted	6.236***	6.429***
Cross-section dependence test		
CO_2	*FI*	*TI*
8.759***	3.012***	6.351***
GDP	*ENEF*	*EX*
11.877***	4.526***	6.975***
IM	–	–
6.09***	–	–

Note: Significance is denoted by ***, ** and * for 1%, 5% and 10%.
Source: drawn by authors.

$$\Delta CO_2 = \alpha_1 \Delta FINC_{it} + \alpha_2 \Delta TI + \alpha_3 \Delta ENEF_{it} + \alpha_4 \Delta EX_{it} + \alpha_5 \Delta IM_{it} + \sum\nolimits_{t=2}^{T} c_t \Delta D_t \tag{14}$$

4. Results and discussions

Before estimation of model, we test for the presence of interdependence between data series. The presence of C.S.D. is confirmed for all data series. Moreover, we test for the presence of another potential problem in models with panel data, i.e., slope heterogeneity. The significant test statistics enable us to confirm slope heterogeneity in model 1 & 2 (Table 2). The presence of C.S.D. for all series and S.H. in both models call for the use of suitable cointegration approaches to avoid biased estimation. In the empirical analysis, if these problems are not taken into account, the estimation test may produce spurious estimation.

We test for the presence of a unit root using C.I.P.S. test. It is evident that all variables, such as CO_2, F.I., G.D.P., T.I., E.N.E.F., E.X. and I.M., follow a unit-root process (Table 3).

After findings a unit root process for all variables, the next step is to check the long run relationship among all integrated series. The results of Westerlund's test are reported in Table 4. The significant group and panel statistics confirm the assumption of stable cointegration among variables. This implies that CO_2, F.I., G.D.P., T.I., E.N.E.F., E.X. and I.M. are co-integrated over the long run. Additionally, the cointegration among variables is also confirmed for model 2.

The results of A.M.G. are shown in Table 5. The results indicate positive impact of F.I. and imports on trade adjusted CO_2 emissions. Moreover, we observe negative impact of energy efficiency, T.I. and exports on CO_2 emissions. In model 2, we substitute the variable F.I. by G.D.P. to estimate the effect of output on CO_2 emissions. It is interesting that similar to the results of model 1, the coefficients of energy efficiency, technological innovation and exports are negative while the coefficient is positive in the case of I.M. The sign and size of parameters in model 1 are consistent with the that of model 2. Hence, we can infer that A.M.G. estimator is robust to various empirical models.

Specifically, F.I. augments CO_2 emissions in B.R.I.C.S. countries. A 1% change in F.I.N.C. results in a 0.195 unit change in carbon emissions. These results are aligned

Table 3. Unit root testing.

	Level and trend	
Variable(s)	I(0)	I(1)
CO_2	−2.463	−4.114***
FI	−0.842	−2.891*
GDP	−1.714	−2.877*
TI	−1.722	−3.246***
ENEF	−2.682	−3.341***
EX	−1.852	−3.109***
IM	−1.882	−2.939**

Note: Significance is denoted by ***, ** and * for 1%, 5% and 10%.
Source: drawn by authors.

Table 4. Cointegration testing.

Models	G_t	G_a	P_t	P_a
Model-1	−7.890***	−10.931***	−8.231***	−12.314***
Model-2	−7.930***	−9.741***	−10.715***	−11.381***

Note: Significance is denoted by ***, ** and * for 1%, 5% and 10%.
Source: drawn by authors.

Table 5. Long-run empirical testing.

Variable(s)	Model-1 Coefficients (p-values)	Model-2 Coefficients (p-values)
FI	0.195***	–
	(0.000)	
GDP	–	0.441***
		(0.000)
TI	−0.120*	−0.052***
	(0.081)	(0.000)
ENEF	−0.747***	−0.722**
	(0.000)	(0.049)
EX	−0.320***	−0.359***
	(0.000)	(0.000)
IM	0.164***	0.259***
	(0.000)	(0.000)
Constant	−1.534***	−1.532***
	(0.000)	(0.000)
Wald-Stats	171.00***	40.61***
	(0.000)	(0.000)
RMSE	0.0077	0.0079

Note: Significance is denoted by ***, ** and * for 1%, 5% and 10%. RMSE is for root mean squared errors.
Source: drawn by authors.

with the earlier findings of Le et al. (2020). However, our results contradict the findings of Usman et al. (2021). We argue that improvement in F.I. over the years, the growing consumerism is observed in B.R.I.C.S. countries. The consumers are more inclined to purchase energy intensive products, which increase energy demand and hence, cause increase in CO_2 emissions. Moreover, the due to increase F.I., the use of domestic fossil-fuel increases, which in turn deteriorates the environmental quality in the B.R.I.C.S. countries. Additionally, improvement in F.I. represents the deepness of financial system, which poses a severe risk to the environmental sustainability due to high energy demand.

The results further indicate negative effect of energy efficiency on CO_2 emissions. Numerically, a 1 unit change in E.N.E.F. brings 0.747 unit change in carbon

Table 6. Robustness check (D.O.L.S.).

Variable(s)	Model-1 Coefficients	Model-2 Coefficients
FI	0.171***	–
GDP	–	1.097***
TI	−0.161*	−0.409***
ENEF	−0.631***	−0.561***
EX	−0.681**	−0.573***
IM	0.676**	0.431***
Constant	1.0092***	1.264***

Note: Significance is denoted by ***, ** and * for 1%, 5% and 10%.
Source: drawn by authors.

emissions. In both models, the coefficient of E.N.E.F. is negative, which specifies improved energy efficiency in the B.R.I.C.S. countries. The energy efficiency in these five countries is appreciable and has been increasing over the years. Our results are aligned with the earlier findings of Shahzad et al. (2021) and Bashir et al. (2020). Since energy efficiency (E.N.E.F.) indicates same output produced with fewer energy use and hence, reduce energy-related CO_2 emissions. An improvement in E.N.E.F. may reduce direct emissions from fossil fuel consumption, and indirectly from electricity generation. Hence, targeting E.N.E.F. is an important way to achieve carbon neutrality. If energy efficiency is ensured, B.R.I.C.S. countries would be more able to eliminate energy waste and abate carbon emissions.

The results further indicate negative influence of innovation on carbon emissions. Numerically, a 1 unit change in TI brings 0.120 unit change in carbon emissions. Since, eco-innovation denotes to the development of procedures that are more sustainable, it is more helpful to achieve environmental targets. Through eco-innovation, B.R.I.C.S. countries are more inclined to transfer their economies to sustainable energies. These results match the earlier findings of Guo et al. (2021) and Zhao et al. (2015).

The results suggest that export decreases carbon emissions, while import increases carbon emission. In the literature, exports growth is strongly associated with environmental degradation; however, it is negatively related with environmental degradation in case of countries where the energy mix has more share of renewable energy. The present study uses trade adjusted carbon emission, which takes into account the environmental impacts of consumption. Since, a product producing country may not be the product consuming country, an increase in net exports implies relocation of emissions to other countries. While, an increase in net imports would imply a country is net importer of carbon emissions. Hence, increase in exports is negatively related with CO_2 emissions and imports are positively related with CO_2 emissions. These results match the findings of Hasanov et al. (2018), Salman et al. (2019) and Sato (2014).

The robustness of A.M.G. results is reconfirmed through D.O.L.S. approach (Table 6). The empirical results of D.O.L.S. estimator are consistent with the findings of A.M.G. estimator. Hence, we can infer that our empirical models are robust to various econometric approaches.

The causal nexus among the variables is checked via Dumitrescu Hurlin causality test (Table 7). The empirical results of D.H. test show that except for the variables F.I.N.C. and T.I., the bi-directional causal nexus is observed between the remaining

Table 7. Causality test.

H^0	$W - Stat$	$\bar{Z}_{Stat}$	$p - values$
FINC-CO_2	3.962***	3.103	0.001
CO_2–FINC	2.232	1.159	0.246
GDP–CO_2	3.852***	2.981	0.002
CO_2–GDP	4.233***	3.408	0.000
ENEF–CO_2	4.159***	3.325	0.000
CO_2–ENEF	2.821*	1.821	0.068
TI–CO_2	4.395***	3.342	0.000
CO_2–TI	2.504	1.465	0.142
IM–CO_2	5.066***	3.973	0.000
CO_2–IM	3.702***	2.812	0.004
EX–CO_2	4.712***	3.947	0.000
CO_2–EX	3.224**	2.274	0.022

Note: Significance is denoted by ***, ** and * for 1%, 5% and 10%.
Source: drawn by authors.

variables. It is evident that any policy change in variables such as F.I., G.D.P., E.N.E.F., T.I., I.M. and E.X. has implications for trade adjusted CO_2 emissions. However, an improvement in environmental performance has implications for G.D.P., E.N.E.F., I.M. and E.X.

5. Concluding remarks

A debate regarding the nexus between F.I. and environmental performance has mainly been based on theoretical argument, while less inspired by empirical evidence. Few authors provide empirical findings but their analyses are based on week measurement of F.I. and failed to consider other essential variables. This study expands the horizon of this debate by considering the evidence of B.R.I.C.S. countries because of their economic growth potential and diversity in emission levels. Unlike previous studies, this study uses trade adjusted CO_2 emissions to represent environmental performance. The econometric tests offer robust results that match the previous literature; (1) the presence of C.S.D. is confirmed for all data series; (2) ample evidences are observed for slope heterogeneity in both models; (3) All variables, such as CO_2, F.I.N.C., G.D.P., T.I., E.N.E.F., E.X. and I.M., follow a unit-root process; (4) We confirm the assumption of stable cointegration among variables; (5) we find positive impact of F.I. and imports on trade adjusted CO_2 emissions; (6) we observe negative impact of energy efficiency, technological innovation and exports on CO_2 emissions; (7) F.I. augments CO_2 emissions in B.R.I.C.S. countries; (8) there is evidence for emission embodied in trade, where import enhances, and export reduces emission; (9) the empirical results of D.O.L.S. estimator are consistent with the findings of A.M.G. estimator; and (10) Except for the variables F.I.N.C. and T.I., the bi-directional causal nexus is observed between the remaining variables (CO_2, E.N.E.F., G.D.P., E.X. and I.M.).

This study suggests that B.R.I.C.S. countries should improve their level of energy efficiency, which has the potential to reduces carbon emission. Moreover, to reduce CO_2 emissions, B.R.I.C.S. countries need to diversify their overall energy mix towards by increasing the share of renewable energy. F.I. must be considered in policymaking process. However, steps must be taken to regulate and monitor the financial system.

Green financing must be expanded in order to help deprived regions within the country to cope with environmental challenges. Through improved F.I., individuals must be facilitated in importing products with lower carbon footprint. A huge amount of green investment is required for transition to a low carbon green economy.

One of the major limitations of the current study is that it analyses the impact of F.I. on trade adjusted CO_2 emissions in case of B.R.I.C.S. countries. We explored that F.I. along with G.D.P., technology, energy efficiency, exports and imports are important determinants of environmental performance in case of B.R.I.C.S. countries. Nevertheless, one of the limitations of using F.I. is that it does not truly represent the financial development of the countries. Hence, in future, studies may be carried out to gauge financial development by more close proxies such as domestic credit. Moreover, the results of this study can be generalised to other group of countries.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Abid, M. (2016). Impact of economic, financial, and institutional factors on CO_2 emissions: Evidence from sub-Saharan Africa economies. *Utilities Policy*, *41*, 85–94. https://doi.org/10.1016/j.jup.2016.06.009

Acaravci, A., & Ozturk, I. (2010). On the relationship between energy consumption, CO_2, emissions and economic growth in Europe. *Energy*, *35*(12), 5412–5420. https://doi.org/10.1016/j.energy.2010.07.009

Afionis, S., Sakai, M., Scott, K., Barrett, J., & Gouldson, A. (2017). Consumption-based carbon accounting: does it have a future?. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(1), e438.

Ali, S., Babi, M., & Rabbi, F. (2014). A new economic dimension to the environmental Kuznets curve: Estimation of environmental efficiency in case of Pakistan. *Asian Economic and Financial Review*, *4*(1), 68–79.

Ali, S., Dogan, E., Chen, F., & Khan, Z. (2021). International trade and environmental performance in top ten-emitters countries: The role of eco-innovation and renewable energy consumption. *Sustainable Development*, *29*(2), 378–387. https://doi.org/10.1002/sd.2153

Al-Mulali, U., & Ozturk, I. (2016). The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. *Renewable and Sustainable Energy Reviews*, *54*, 1622–1631. https://doi.org/10.1016/j.rser.2015.10.131

Atasoy, B. S. (2017). Testing the environmental Kuznets curve hypothesis across the U.S: Evidence from panel mean group estimators. *Renewable and Sustainable Energy Review*, *77*, 731–747.

Baek, J. (2016). Do nuclear and renewable energy improve the environment? Empirical evidence from the United States. *Ecological Indicators*, *66*, 352–356. https://doi.org/10.1016/j.ecolind.2016.01.05

Baloch, M. A., Meng, F., Zhang, J., & Xu, Z. (2018). Financial instability and CO_2 emissions: The case of Saudi Arabia. *Environmental Science and Pollution Research*, *25*(26), 26030–26045. https://doi.org/10.1007/s11356-018-2654-2

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO_2 emissions? *Energy Policy*, *113*, 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Bashir, M. A., Sheng, B., Doğan, B., Sarwar, S., & Shahzad, U. (2020). Export product diversification and energy efficiency: Empirical evidence from OECD countries. *Structural Change and Economic Dynamics*, *55*, 232–243. https://doi.org/10.1016/j.strueco.2020.09.002

Bayar, Y., Diaconu, L., & Maxim, A. (2020). Financial development and CO_2 emissions in post-transition European Union countries. *Sustainability*, *12*(7), 2640. https://doi.org/10.3390/su12072640

Bhattacharya, M., Inekwe, J. N., & Sadorsky, P. (2020). Consumption-based and territory-based carbon emissions intensity: Determinants and forecasting using club convergence across countries. *Energy Economics*, *86*, 104632. https://doi.org/10.1016/j.eneco.2019.104632

Bosupeng, M. (2016). The effect of exports on carbon dioxide emissions: Policy implications. *International Journal of Management and Economics*, *51*(1), 20–32. https://doi.org/10.1515/ijme-2016-0017

Cabeza-García, L., Del Brio, E. B., & Oscanoa-Victorio, M. L. (2019). Female financial inclusion and its impacts on inclusive economic development. *Women's Studies International Forum*, *77*, 102300. https://doi.org/10.1016/j.wsif.2019.102300

Chudik, A., & Pesaran, M. H. (2013). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics*, *188*(2), 393–420.

Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics*, *188*(2), 393–420. https://doi.org/10.1016/j.jeconom.2015.03.007

Costantini, V., Crespi, F., Marin, G., & Paglialunga, E. (2017). Eco-innovation, sustainable supply chains and environmental performance in European industries. *Journal of Cleaner Production*, *155*, 141–154. https://doi.org/10.1016/j.jclepro.2016.09.038

Dan, S. (2002). The improvement of energy consumption efficiency in China's economic growth. *Economic Research Journal*, *9*, 49–56.

Erdoğan, S., Yıldırım, S., Yıldırım, D. Ç., & Gedikli, A. (2020). The effects of innovation on sectoral carbon emissions: Evidence from G20 countries. *Journal of Environmental Management*, *267*, 110637. https://doi.org/10.1016/j.jenvman.2020.110637

Guo, J., Zhou, Y., Ali, S., Shahzad, U., & Cui, L. (2021). Exploring the role of green innovation and investment in energy for environmental quality: An empirical appraisal from provincial data of China. *Journal of Environmental Management*, *292*(May), 112779. https://doi.org/10.1016/j.jenvman.2021.112779

Hajilee, M., Stringer, D. Y., & Metghalchi, M. (2017). Financial market inclusion, shadow economy and economic growth: New evidence from emerging economies. *The Quarterly Review of Economics and Finance*, *66*, 149–158. https://doi.org/10.1016/j.qref.2017.07.015

Hasanov, F. J., Liddle, B., & Mikayilov, J. I. (2018). The impact of international trade on CO_2 emissions in oil exporting countries: Territory vs consumption emissions accounting. *Energy Economics*, *74*, 343–350. https://doi.org/10.1016/j.eneco.2018.06.004

Ji, X., Umar, M., Ali, S., Ali, W., Tang, K., & Khan, Z. (2021). Does fiscal decentralization and eco-innovation promote sustainable environment? A case study of selected fiscally decentralized countries. *Sustainable Development*, *29*(1), 79–88. https://doi.org/10.1002/sd.2132

Ji, X., Zhang, Y., Mirza, N., Umar, M., & Rizvi, S. K. A. (2021). The impact of carbon neutrality on the investment performance: Evidence from the equity mutual funds in BRICS. *Journal of Environmental Management*, *297*, 113228. https://doi.org/10.1016/j.jenvman.2021.113228

Jiang, C., & Ma, X. (2019). The impact of financial development on carbon emissions: A global perspective. *Sustainability*, *11*(19), 5241. https://doi.org/10.3390/su11195241

Khan, Z., Ali, S., Umar, M., Kirikkaleli, D., & Jiao, Z. (2020). Consumption-based carbon emissions and international trade in G7 countries: The role of environmental innovation and renewable energy. *The Science of the Total Environment*, *730*, 138945. https://doi.org/10.1016/j.scitotenv.2020.138945

Kim, D. W., Yu, J. S., & Hassan, M. K. (2018). Financial inclusion and economic growth in OIC countries. *Research in International Business and Finance*, *43*, 1–14. https://doi.org/10.1016/j.ribaf.2017.07.178

Le, T. H., Chuc, A. T., & Taghizadeh-Hesary, F. (2019). Financial inclusion and its impact on financial efficiency and sustainability: Empirical evidence from Asia. *Borsa İstanbul Review*, *19*(4), 310–322. https://doi.org/10.1016/j.bir.2019.07.002.

Le, T. H., Le, H. C., & Taghizadeh-Hesary, F. (2020). Does financial inclusion impact CO_2 emissions? Evidence from Asia. *Finance Research Letters*, *34*, 101451. https://doi.org/10.1016/j.frl.2020.101451

Li, J., Zhang, X., Ali, S., & Khan, Z. (2020). Eco-innovation and energy productivity: New determinants of renewable energy consumption. *Journal of Environmental Management*, *271*, 111028. https://doi.org/10.1016/j.jenvman.2020.111028

Magazzino, C., Mele, M., Schneider, N., & Shahzad, U. (2022). Does export product diversification spur energy demand in the APEC region? Application of a new neural networks experiment and a decision tree model. *Energy and Buildings*, *258*, 111820. https://doi.org/10.1016/j.enbuild.2021.111820

Makina, D., & Walle, Y. M. (2019). Financial inclusion and economic growth: Evidence from a panel of selected African Countries. In *Extending financial inclusion in Africa* (pp. 193–210). Academic Press. https://doi.org/10.1016/B978-0-12-814164-9.00009-8

Meng, J., Liu, J., Guo, S., Huang, Y., & Tao, S. (2015). The impact of domestic and foreign trade on energy-related PM emissions in Beijing. *Applied Energy*, *184*, 853–862. https://doi.org/10.1016/j.apenergy.2015.09.082

Naqvi, B., Mirza, N., Rizvi, S. K. A., Porada-Rochoń, M., & Itani, R. (2021). Is there a green fund premium? Evidence from twenty-seven emerging markets. *Global Finance Journal*, *50*, 100656. https://doi.org/10.1016/j.gfj.2021.100656

Park, C., & Mercado, R. V. (2015). *Financial inclusion, poverty, and income inequality in developing Asia* [ADB Economics Working Paper Series 426/2015]. https://www.adb.org/sites/default/files/publication/153143/ewp-426.pdf

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *Empirical Economics*, *60*, 13–50.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, *34*(6–10), 1089–1117.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50–93. https://doi.org/10.1016/j.jeconom.2007.05.010

Rafique, M. Z., Doğan, B., Husain, S., Huang, S., & Shahzad, U. (2021). Role of economic complexity to induce renewable energy: Contextual evidence from G7 and E7 countries. *International Journal of Green Energy*, *18*(7), 745–754. https://doi.org/10.1080/15435075.2021.1880912

Rojas-Suarez, L., & Amado, M. A. (2014). *Understanding Latin America's financial inclusion gap* [Center for Global Development Working Paper 367]. http://www.cgdev.org/sites/default/files/latin-american-financial-inclusion-gap.pdf

Safi, A., Chen, C., Wahab, S., Ali, S., Yi, X., & Imran, M. (2021). Financial instability and consumption-based carbon emission in E-7 countries: The role of trade and economic growth. *Sustainable Production and Consumption*, *27*, 383–391. https://doi.org/10.1016/j.spc.2020.10.034

Sahay, R., Cihak, M., N'Diaye, P. M., Barajas, A., Mitra, S., Kyobe, A., Mooi, Y. N., & Yousefi, S. R. (2015). *Financial inclusion: Can it meet multiple macroeconomic goals?* [IMF Staff Discussion Notes 15/17]. International Monetary Fund. https://www.imf.org/external/pubs/ft/sdn/2015/sdn1517.pdf https://doi.org/10.5089/9781513585154.006

Salazar-Cantú, J., Jaramillo-Garza, J., & Rosa, B. Á. (2015). Financial inclusion and income inequality in Mexican municipalities. *Open Journal of Social Sciences*, *03*(12), 29–43. https://doi.org/10.4236/jss.2015.312004

Salman, M., Long, X., Dauda, L., Mensah, C. N., & Muhammad, S. (2019). Different impacts of export and import on carbon emissions across 7 ASEAN countries: A panel quantile regression approach. *The Science of the Total Environment*, *686*, 1019–1029. https://doi.org/10.1016/j.scitotenv.2019.06.019

Sato, M. (2014). Embodied carbon in trade: A survey of the empirical literature. *Journal of Economic Surveys*, *28*(5), 831–861. https://doi.org/10.1111/joes.1202

Schmied, J., & Marr, A. (2016). Financial inclusion and poverty: The case of Peru. *Regional and Sectoral Economic Studies*, *16*(2), 29–43.

Shahzad, U., Ferraz, D., Nguyen, H., & Cui, L. (2022). Investigating the spill overs and connectedness between financial globalization, high-tech industries and environmental footprints: Fresh evidence in context of China. *Technological Forecasting and Social Change*, *174*(2), 121205. https://doi.org/10.1016/j.techfore.2021.121205

Shahzad, U., Schneider, N., Ben, M., & Panth, P. (2021). How coal and geothermal energies interact with industrial development and carbon emissions? An autoregressive distributed lags approach to the Philippines. *Resources Policy*, *74*(March), 102342. https://doi.org/10.1016/j.resourpol.2021.102342

Song, M., Peng, L., Shang, Y., & Zhao, X. (2022). Green technology progress and total factor productivity of resource-based enterprises: A perspective of technical compensation of environmental regulation. *Technological Forecasting and Social Change*, *174*, 121276. https://doi.org/10.1016/j.techfore.2021.121276

Song, M., Zhao, X., & Shang, Y. (2020). The impact of low-carbon city construction on ecological efficiency: Empirical evidence from quasi-natural experiments. *Resources, Conservation, & Recycling*, *157*, 104777. https://doi.org/10.1016/j.resconrec.2020.104777

Sushmita, D., Benoit, L., Hua, W., & David, W. (2002). Confronting the environmental Kuznets curve. *Journal of Economic Perspectives*, *16* (1), 147–168.

Umar, M., Ji, X., Mirza, N., & Naqvi, B. (2021a). Carbon neutrality, bank lending, and credit risk: Evidence from the Eurozone. *Journal of Environmental Management*, *296*, 113156. https://doi.org/10.1016/j.jenvman.2021.113156

Umar, M., Ji, X., Mirza, N., & Rahat, B. (2021b). The impact of resource curse on banking efficiency: Evidence from twelve oil producing countries. *Resources Policy*, *72*, 102080. https://doi.org/10.1016/j.resourpol.2021.1020

Usman, M., Makhdum, M. S. A., & Kousar, R. (2021). Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries. *Sustainable Cities and Society*, *65*, 102590. https://doi.org/10.1016/j.scs.2020.102590

Van, L. T., Vo, A. T., Nguyen, N. T., & Vo, D. H. (2021). Financial inclusion and economic growth: An international evidence. *Emerging Markets Finance and Trade*, *57*(1), 239–263. https://doi.org/10.1080/1540496X.2019.1697672

Wang, L., Su, C. W., Ali, S., & Chang, H. L. (2020). How China is fostering sustainable growth: The interplay of green investment and production-based emission. *Environmental Science and Pollution Research International*, *27*(31), 39607–39618. https://doi.org/10.1007/s11356-020-09933-4

Wilson, D., & Purushothaman, R. (2003). Dreaming with BRICs: The path to 2050. *Goldman Sachs Global Economics Paper*, *99*, 1–24.

Wu, X., & Shao, J. (2016). The influence of import openness on manufacturing energy efficiency in China – An empirical study based on Tariff reduction. *Finance & Trade Economics*, *6*, 82–96.

Yasmeen, R., Li, Y., & Hafeez, M. (2019). Tracing the trade-pollution nexus in global value chains: Evidence from air pollution indicators. *Environmental Science and Pollution Research International*, *26*(5), 5221–5233. https://doi.org/10.1007/s11356-018-3956-0

Zhang, Y. J., Peng, Y. L., Ma, C. Q., & Shen, B. (2017). Can environmental innovation facilitate carbon emissions reduction? Evidence from China. *Energy Policy*, *100*, 18–28. https://doi.org/10.1016/j.enpol.2016.10.005

Zhao, H., & Lin, B. (2019). Will agglomeration improve the energy efficiency in China's textile industry: Evidence and policy implications. *Applied Energy*, *237*, 326–337. https://doi.org/10.1016/j.apenergy.2018.12.068

Zhao, X., Ma, X., Chen, B., Shang, Y., & Song, M. (2022). Challenges toward carbon neutrality in China: Strategies and countermeasures. *Resources, Conservation and Recycling*, *176*, 105959. https://doi.org/10.1016/j.resconrec.2021.105959

Zhao, X. L., Yin, H. T., & Zhao, Y. (2015). Impact of environmental regulations on the efficiency and CO_2 emissions of power plants in China. *Applied Energy*, *149*, 238–247. https://doi.org/10.1016/j.apenergy.2015.03.112