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The impact of green finance on environmental degradation in BRI region

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Abstract

The Belt and Road Initiative (BRI) is one of the largest infrastructure projects in the world, accounting for more than 30% of global GDP and 60% of world population. The economic growth of BRI member countries can be improved significantly, attributable to the successfulness of the infrastructure projects. The increased economic growth indirectly leads to higher energy consumption and environmental damage. In response to this, the BRI established a new concept and version of the project, namely green BRI. Thus, this study aims to examine if green finance plays a significant role in mitigating environmental degradation in the BRI region. Utilising a Generalised Method of Moments approach, we find green finance is negatively and significantly correlated with environmental degradation, suggesting green finance play an essential role to reduce the deterioration of environmental quality, while enhancing economic growth at the same time. In conclusion, BRI member states should continue promoting green finance by implementing incentive schemes, such as subsidising interest rates for the green loan, reducing corporate tax and establishing green credit guarantee scheme. Besides, in order simultaneously enhance economic growth, promote sustainability and achieve the 2030 Sustainable Development Goals, both governments and private sector should work hand in hand to promote green transformation of BRI.

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1 Introduction

The Belt and Road Initiative (BRI), formerly known as One Belt One Road, was initiated by the President of China, Xi Jinping, in 2013 (Chen et al., 2017). The BRI is one of the largest infrastructure projects in the world with the aim of connecting the 'Silk Road Economic Belt' with the 'Twenty-first Century Maritime Silk Road'. In short, it will connect China with South and Southeast Asia, Africa, the Middle East, as well as Europe (Thürera et al., 2020). Thus, this gigantic project accounts for more than 30% of the global GDP and 60% of the world's population (Islam, 2021). As of October 2021, 141 countries and 32 international organisations have signed up to collaborate on the BRI projects (Advisory Council of the Belt and Road Forum for International Cooperation in 2019 and 2020, 2020). Annual investment in the BRI project is estimated to be in the range of 2.9 trillion to 6.3 trillion dollars (OECD report, 2018).

Focusing on mega infrastructure development projects, the BRI affects the global environment directly and indirectly. According to Zhang et al. (2021a), BRI member countries, especially developing countries in Asia and Africa, are trying their best to take advantage of lucrative opportunities provided by the BRI by producing the agreed BRI project outcomes. However, according to Montalbano and Nenci (2019), due to heavy reliance on non-renewable energy resources for the infrastructure projects, the environment is negatively affected, worsening environmental degradation. Likewise, Akorede and Afroz (2020) signify that the heavy consumption of non-renewable energy will deteriorate the environment quality over time. Besides, Zhang et al. (2021a) find successful infrastructure projects can significantly improve economic growth of BRI member countries. However, higher level of economic growth and increase in standards of living indirectly lead to higher energy consumption and worsening environmental damage (Shahbaz et al., 2018). Likewise, according to The World Bank (2019), although some of the BRI projects such as transportation infrastructure projects have increased economic growth significantly, they are associated with complex and extensive environmental risks.

Table 1 illustrates World GDP and CO_2 emission data between 2010 and 2018. From Table 1, both GDP and CO_2 emissions, which proxy for economic performance and environmental degradation, respectively, demonstrate similar and steadily increasing trends. Overall, GDP and CO_2 emissions have increased by 27% and 10%, respectively, from 2010 to 2018. Thus, in line with prior literature, CO_2 emissions are positively associated with economic growth.

In accordance with UNDP (2022), the Sustainable Development Goals (SDGs) adopted by the United Nations' developing and developed member countries in 2015 are a universal call to ensure that by 2030, all people are able to enjoy peace and prosperity. The SDGs consist of 17 goals, comprising social, economic and environmental sustainability. Out of the 17 goals, SDG 7 covers affordable and clean energy, which is critical for environmental sustainability. Based on UNDP (2022), providing more efficient and clean energy in the world will eventually help to sustain the environment, which in turn will sustain economic growth in the future.

Table 1 GDP and CO$_2$ emission in the world during 2010–2018

Year	GDP (constant 2015 billion US$)	CO$_2$ emissions (million kt)
2010	64,703	31
2011	66,864	32
2012	68,651	32
2013	70,604	33
2014	72,805	33
2015	75,112	33
2016	77,234	33
2017	79,856	33
2018	82,467	34

Source: World Bank Indicator

The World Bank (2019) states that China and other BRI member countries are aware environmental degradation coexists with economic growth. Therefore, governments of these countries are now focusing on green economy and making infrastructure greener to mitigate the adverse effects of economic growth. To support and cover broad aspects of 2030 SDGs, China is proposing a holistic implementation of the BRI. China is determined to enhance green and low-carbon operation by adhering to environmental protection requirements in infrastructure construction standards (OECD, 2018). In addition, high-quality Belt and Road cooperation is set up to ensure one of the new BRI concepts, that is, cooperation among BRI member countries to develop green technology, green infrastructure, and green finance as well as addressing the challenges of environmental protection, will be achieved (Advisory Council of the Belt and Road Forum for International Cooperation in 2019 and 2020, 2020). In addition, under the umbrella of green BRI, China introduced the environmentally friendly feature of supply chain management system to deliver green products to consumer (Abbas et al., 2022b). Apart from the above-mentioned facts, the current robust supply chain network of BRI would sustain the perishable foods quality to prevent environmental degradation as the perished food would emit a large amount of CO$_2$ (Abbas et al., 2022a). In short, Green BRI is established to promote new BRI investment projects emphasising environmental friendliness, including utilisation of green financial instruments (The World Bank Group, 2019).

The nature and scale of BRI projects necessitate huge amounts of capital. Therefore, financing is imperative to ensure success of the projects. To enhance economic growth through the BRI projects without compromising environmental quality, green finance, such as green bonds and carbon market instruments, might be a powerful tool to promote green development of BRI. Based on ESCAP (2021), The Green Finance Task Force, established in 2017, is a special alliance for the promotion of green financing and investment in the BRI projects. It initiates pilot projects offering environmental, social and financial benefits. In fact, investments in the green economy via green finance can be profitable in the long term. However, ESCAP (2021) further noted that green finance is not yet attractive to traditional financing institutions.

Most BRI member countries are developing countries which enjoy economic growth at the expense of environmental quality and are not fully aware of green finance. To the best of our knowledge, there are no previous studies examining the impact of green finance on environmental degradation in BRI region. Thus, this study is an endeavour to study if

green finance plays a significant role in mitigating the environmental degradation in said region using a generalised method of moments (GMM) method. The findings of this study are imperative as it would fill in the knowledge gap by providing instrumental insight to the BRI region, whose members are mainly developing countries, on two key questions: Firstly, whether green finance can significantly reduce environmental degradation of the BRI region, and secondly, whether economic growth and environmental sustainability can go hand in hand. As such, the outcome of this study could serve as a reference to the BRI region in evaluating the success of new concepts and the new version of green BRI. Furthermore, it provides information to traditional financial institutions in reconsidering whether it is worth promoting and shifting their focus to green finance in BRI region specifically, and developing countries in general.

The rest of the paper is structured as follows: Sect. 2 provides a review on the green finance and environmental protection literature, Sect. 3 explains the data and methodology adopted for this study, Sect. 4 presents and discusses the empirical results while Sect. 5 concludes with policy implications.

2 Literature review on green finance and environmental protection

Green finance is seen as a key driver of environmental protection and sustainable development. Especially with regard to carbon emissions, textbook policies such as carbon taxes and emissions have been found problematic. On the one hand, emissions trading systems, especially certificates traded on the financial market, are subject to great volatility, exceeding that of the stock market (Kemfert et al., 2019), which induces high uncertainty for green investments. On the other hand, carbon taxes, while stable and easy to implement, are far too slow in initiating substitution processes and can be passed on to customers, thus reducing incentive for firms and businesses to switch to green technology (Kemfert et al., 2019). Furthermore, a very high tax is needed for the policy to be effective (Heal & Schlenker, 2019). From a global perspective, Zhang et al. (2021a) find pollution burden shifting among Belt and Road economies, occurring through foreign direct investment and preferential trade agreements. Furthermore, they find that environmental provisions in trade agreements do not have any binding effect on pollution burden shifting, with middle-income countries suffering the most from pollution burden shifting brought about by technological innovation.

Therefore, there is a need for a different approach to environmental protection, by directly stimulating investment in green technology. On the one hand, this could be done through government intervention. Xu et al. (2022) document financing and allocating schemes for the Chinese Green Climate Fund, which aims to support local governments in climate change mitigation and adaptation initiatives. They find large historical polluters should bear the largest chares of the financing costs, while less-developed regions would be the biggest beneficiaries. A free-market approach would be to stimulate green investment through the use of green finance.

By incorporating the twin goals of environmental protection and sustainable development into investment and financial decisions, green finance has a two-fold effect: Firstly, green finance affects both demand and supply for environmental protection and sustainable development. By guiding the flow of funds, it simultaneously guides businesses towards environmentally friendly and sustainable production and stimulates consumer interest in green consumption. Taufik (2016) provides an example of how non-compliance with

environmental standards can adversely affect cash flow and diminish market value, thus showing how a firm's sustainability performance can materially affect its financial position. Secondly, by focusing on sustainable development, green finance nudges the financial industry as a whole to avoid excessive speculation and increase focus on long-term interests (Chen, 2013). Volz (2018) explains further—under green finance, environmental screening and risk assessment to meet sustainability standards form the criteria determining investment and lending decisions. Furthermore, green finance includes insurance to cover environmental and climate risk.

Chen et al. (2017) study an interesting model of green finance that utilises emission right-based lending. Under this system, firms invest in green technology and pollution abatement, which frees up their emission rights. In turn, the emission rights are used as collateral to apply for loans. Their theoretical model finds that given reasonable levels of market demand, the emission right-based lending model is profitable to both firm and bank, as well as effective in stimulating investment in green technology. Thus, Chen et al. (2017) show that green finance is viable profit-wise.

The key issue facing investment in green technology is cost. Green investments involve large initial investments, but only produce returns in the long run. Furthermore, since new technology is inherently uncertain with regards to returns, credit ratings will naturally be lower. And since the returns to green technology are tied to carbon pricing, any volatility in the emissions market will affect the volatility of green investments (Tran et al., 2020). Collectively, these increase costs and reduce profitability of green investments. Thus, Kemfert et al. (2019) propose government-sponsored bonds as an effective tool to de-risk. By guaranteeing all or part of the service and repayment, the government can lower yield and capital costs of green investments. This also has the effect of enabling smaller companies to participate in the transition towards green technology, thus enabling a wider economic transformation, instead of one limited to large firms that face little credit constraints. In addition, due to their long terms, bonds are the perfect match for large-scale infrastructure projects needed for green technology, and with greater disclosure requirements than normal bonds, green bonds have lower risk, providing investors with returns and the sense of social responsibility (Wang & Zhi, 2016). Sachs et al. (2019) consider instead the role of green central banking, where central banks can support development of green finance models and enforce the pricing of environmental and carbon risk.

However, the question remains on how effective green finance is towards environmental protection, which is ultimately an empirical question. Using panel data drawn from the Global Footprint Network and the Asian Development Bank, Khan et al. (2021) consider the effect of climate mitigation finance (as a proxy for green finance) on the ecological footprint in 26 countries, controlling for GDP per capita, population, trade openness and energy consumption. They find green finance delivers, that is, it significantly refuses ecological footprint, even when accounting for country fixed effects. However, it is noted that this study suffers from a small sample, and whether self-selection exists—it may be possible that countries facing higher cost in reducing their ecological footprint also invest less in green finance as a result. Zakari and Khan (2021) perform a similar study with different datasets, but the results are largely the same. Notably, the authors caution against using either only public or only private sector-led green finance, as this ignores the joint influences.

In the same vein, Meo and Abd Karim (2022) examine the relationship between green finance and carbon dioxide emissions. Implementing a quantile-on-quality regression, the authors find a negative relationship between green finance and carbon dioxide emissions for the USA, Sweden, Hong Kong, the UK and Switzerland, while there are

weak relationships for New Zealand, Norway, Japan, Denmark and Canada. However, there are variations within each country. Using the USA as an example, the relationship is positive when green finance levels are low, and when carbon dioxide emission levels are high. In contrast, for New Zealand, there is a positive relationship between green finance and carbon dioxide emissions for high emission levels, suggesting when emissions peak, demand for green investments increases. Overall, while green finance is negatively associated with emissions, the effect is asymmetric and varies across emissions and green finance level, which may suggest a more complex interplay between green finance and emissions levels.

Using a sample of 40 European countries, Afzal et al. (2021) investigate the effect of financial development on environmental degradation. Using energy use, carbon dioxide emissions, greenhouse emissions and natural resource depletion as dependent variables, as well as three measures of financial development (domestic credit to the private sector, bank credit to the private sector, and foreign direct investment (FDI)), the authors find domestic credit and private credit have inverse relationships on all three variables proxying for environmental degradation, but it is noted that FDI is positively associated with carbon dioxide and greenhouse emissions, as well as energy use. These suggest the presence of endogeneity issues. For example, FDI depends on economic growth, which causes increased energy use and emissions.

Focusing on China, Muganyi et al. (2021) utilise data from 290 cities between 2011 and 2018 to consider whether China's green finance-related policies have significantly reduced industrial gas emissions. Using a difference-in-difference approach, they find green finance-related policies led to significant positive environmental outcomes, captured by a 38% decline in sulphur dioxide emissions, a 28% decline in industrial gas and smoke emissions, and a 20% decline in overall sulphur dioxide production. They also find fintech development aids in reducing emissions by facilitating China's transition to a green financial system. However, similar to Khan et al. (2021), the authors are unable to address endogeneity and simultaneity issues.

Likewise, Shen et al. (2021) study Chinese carbon emissions. Using a panel of 30 Chinese provinces from 1995 to 2017, the authors use the cross-sectionally augmented autoregressive distributed lags model to estimate both the long- and short-run effects of green investment on carbon emissions. Under this approach, the authors find a negative relationship between green investment and carbon emissions in both short- and long-run, but the magnitude of the long-run effect is noticeable smaller than the short-run effect. This suggests some form of diminishing returns over time for green investments, but the authors do not explore or explain this further, which may be a worthwhile exercise. However, it is worth noting that the effect of green investments is significant at a lower significance level as compared to other regressors, which the authors speculate is due to energy subsidies provided by the Chinese government to facilitate economic growth—when energy costs are low, companies have less incentive to invest in green technology.

Instead of environmental degradation in the form of pollution, Zhang and Wang (2021) study the effect of green finance on sustainable energy development in China from 2004 to 2017 for 25 provinces and municipalities. With the Pressure-State-Response (PSR) model as basis, the authors use a modified entropy weight method to construct their green finance development index, as this allows integration of various indicators that is scientific and approximates reality. Employing static and dynamic panel models, the authors find green finance is associated with both decreased coal consumption and increased sustainable energy development. However, the positive correlation between GDP and coal consumption indicates a tradeoff between economic growth and environmental sustainability.

Narrowing their focus to green credit policy in China, Zhang et al. (2021b) investigate the effect of the aforementioned policy on investment and financing behaviour of high energy consumption and high pollution companies (known as "two high" enterprises). Using a difference-in-difference approach, the authors find that the green credit policy has a positive short run effect, but a negative long-run effect on liabilities. They also note that the policy effect is larger on state-owned enterprises, but has no significant effect on small-medium enterprises. In terms of investment, the green credit policy significantly inhibits corporate investment, especially for nonstate-owned companies. This is attributed to local government intervention in allocation of resources, which distorts incentives to invest. Overall, green credit is seen as effective in promoting environmental quality, especially by affecting investment and financing decisions of polluting enterprises.

From the perspective of green economic growth, Zhang et al. (2021a) study the effect of public R&D spending on green economic growth and energy efficiency. They find R&D fiscal expenditure and education have a significant positive effect on green economic performance. Crucially, the authors argue that sole reliance on public spending is sufficient in attaining green development goals. As such, there is a need to bring in private sector green finance, for example, through tax refunds and de-risking tools.

Looking at special spillovers, Li and Gan (2021) study the effects of green finance on the ecological environment, where they construct a comprehensive index combining both positive indicators such as wastewater discharge, desertification and industrial waste, and negative indicators, such as investment in environmental pollution treatment. Based on their results, not only does green finance have a significant positive effect on environmental quality of the province or city concerned, but also of surrounding areas. These suggest green finance has important spillover benefits, but if these positive externalities are not adequately internalised, free rider problems may result.

Based on the above-mentioned facts, overall, green finance is expected to reduce environmental degradation by diverting resources away from polluting enterprises and production processes, and towards environmentally friendly enterprises and the development of sustainable technology. However, there is still heterogeneity in the effects of green finance, especially at different levels of emissions, at different time horizons and across different types and sizes of firms. Empirically, most studies have used panel methods to estimate the effects of green finance on environmental health, but it is noted few studies account for endogeneity, for example, simultaneous causality between green finance and the state of the environment. Also, based on our best knowledge, no prior studies investigate the impact of green finance on environmental degradation in BRI region as a whole by using GMM method.

Besides green finance, there are other factors affecting the environmental degradation. Past literature documented that income would act as a financial constraint on environmental protection (Nordhaus,2015). Almost all works control for income in the form of GDP per capita, GNP, and in one case GDP per land area (see Afzal et al., 2021; Muganyi et al., 2021; Zhang and Wang, 2021; Zhang et al., 2021a; Li and Gan, 2021). Higher-income countries or provinces may also show greater awareness and demand for environmental sustainability. By the same logic, some works also control for urbanisation (Afzal et al., 2021; Zhang et al., 2021a). To capture economic activity, variables such as trade openness or export volume are used (Khan et al., 2021; Muganyi et al., 2021; Zhang and Wang, 2021). Lastly, to control for factors that directly influence environmental protection efforts, works generally use investment (Zhang et al., 2021b), research and development (R&D) (Zhang et al., 2021b), technology level (Afzal et al., 2021), governance as well as government expenditure (Afzal et al., 2021; Zhang and Wang, 2021). Lastly, to capture factors that directly contribute to environmental

degradation, energy consumption, electricity usage, power generation are commonly used (Khan et al., 2021; Li and Gan, 2021).

3 Methodology

3.1 Conceptual model

According to Nordhaus (2015), environmental protection is a public goods game, as the benefits from investing in emissions abatement are non-excludable. Thus, the dominant strategy is for firms to free ride on the investments of others and not abate, giving rise to a Prisoner's dilemma situation, where the Nash equilibrium is necessarily socially suboptimal. Therefore, to deal with the free riding problem, Nordhaus (2015) proposed a climate club, where club members are required to invest in abatement technology, but trade sanctions will be imposed on non-members. Thus, countries that join the climate club will be those having low levels of emissions and face low abatement costs. In contrast, countries with high emission levels and abatement costs will bear the sanctions rather than abate, and therefore not join the club.

Assuming the existence of some pollution penalty, we can assume firms as analogous to countries. Firms that face lower abatement costs will join the club, while firms with high emission levels and abatement costs will choose to bear the penalty instead of abating. Therefore, whether a firm abates instead of paying the penalty depends on the cost of abatement and investing in abatement technology. To promote green BRI, China and other member countries can induce more firms to join the club and abate by reducing the cost of investing in abatement technology. One way of doing so is by lowering financing costs through green finance in green projects. As a result, in line with Nordhaus (2015), green finance indirectly helps in reducing abatement cost. Therefore, it stands to predict that green finance will have a positive effect on environmental quality and a corresponding negative effect on environmental degradation.

3.2 Empirical model

Green finance is likely to reduce the costs of abatement and thus has a negative relationship with environmental degradation. Given the expected negative relationship, we aim to test the following hypothesis in alternative form:

H_1: There is a negative relationship between green finance and environmental degradation.

To test the relationship between green finance and environmental degradation in line with hypothesis H_1, we formulate our model as below:

$$CO_2 \text{ emissions}_{it} = \alpha + \phi CO_2 \text{ emissions}_{it-1} + \beta_1 \text{Green finance}_{it} + \beta_2 \text{ Income}_{it}$$
$$+ \beta_3 \text{ Population}_{it} + \beta_4 \text{ Urbanisation}_{it} + \beta_5 \text{ Trade openness}_{it} + \varepsilon_{it}$$
$$(1)$$

where α stands for the intercept term; ϕ and β indicate the coefficients; i represents the index for cross-section; t indicates the index for time-variation; and ε is the error term. In this study, carbon dioxide emissions ($CO_2 \text{ emissions}_{it}$) are taken as the dependent variable, reflecting environmental degradation. The independence variable, green finance (Green finance$_{it}$), is measured using public investment in multiple renewable energy technologies. In addition, to avoid issues from omitted variables, income level (Income$_{it}$), population (Population$_{it}$), urbanisation (Urbanisation$_{it}$) and trade openness (Trade openness$_{it}$) appear as control variables. A lagged dependent variable is included to allow for the partial

adjustment of CO_2 emissions to its long run equilibrium value. If β_1 is negative and significant, then it implies CO_2 emissions are reduced when green finance is enhanced.

Equation (1) is estimated using the generalised method-of-moments (GMMs) estimator provided by Arellano and Bond (1991). The dynamic panel GMM estimator is more efficient than static panel estimator as its lagged dependent variable can counter the endogeneity problem of all the explanatory variables. Then, following Arellano and Bond (1991), two specification tests, namely the Sargan test and Arellano and Bond's test for zero autocorrelation, are conducted to check the consistency of the GMM estimator. The Sargan test is conducted to check the over-identifying restrictions while Arellano and Bond's test for zero autocorrelation is conducted to check if the first differenced residuals are free from second-order serial correlation.

3.3 Data

In order to analyse the relationship between green finance and environmental degradation in BRI countries, panel data of green finance and environmental degradation from 2000 to 2019 are selected. Table 2 summarises the dataset by providing the definition and source of all variables.

We filter the sample to exclude missing values. After filtering, the balanced panel dataset contains 620 country-year observations, which account for 31 BRI countries (Armenia, Bangladesh, Bosnia and Herzegovina, China, Democratic Republic of the Congo, Ecuador, Egypt, Ghana, Guinea, Indonesia, Kenya, Kyrgyzstan, Malaysia, Mali, Mongolia, Morocco, Mozambique, Namibia, Nepal, Pakistan, Philippines, Senegal, Serbia, South Africa, Sri Lanka, Thailand, Tunisia, Turkey, Uganda, Uruguay and Vietnam).

4 Empirical results and discussion

Table 3 presents the summary statistics for the variables. On the one hand, the mean value of CO_2 emissions is 2.19 metric tons per capita. This value is lower than the average worldwide carbon dioxide emissions per capita during the period 1960 to 2020 (between 3 and 5 metric tons per capita) (Statista, 2022). Across the sample, the minimum and the maximum CO_2 emissions countries are Congo in 2001 and South Africa in 2008, respectively. This might be positively correlated with the level of economic development in the respective

Table 2 Description of variables

	Variable	Measure
Environment degradation	CO_2 emissions	CO_2 emissions (metric tons per capita)[a]
Green finance	Green finance	Public Investments on Renewable Energy (2019 million USD)[b]
Controls	Income	GDP per capita (current USD)[a]
	Population	Population density (people per sq. km of land area)[a]
	Urbanisation	Urban population (% of total population)[a]
	Trade openness	Imports + exports of goods and services (% of GDP)[a]

Source: [a]World Development Indicator; [b]The international Renewable Energy Agency (IRENA) Public Finance Database

countries. Congo also has the lowest income among the sample countries as of 2001. Conversely, Uruguay has the highest income in 2019. This country also registered as the most urbanised country among the sample country in 2019. On the other hand, the mean value of green finance is USD29.61 million, with values ranging between USD 0 and USD 965.16 million. This shows many countries did not provide any green finance in the early years of the sample, including Egypt, Ghana, Philippines and Tunisia. On the contrary, Turkey provided the most amount of green finance in 2018. Besides, the mean value of population and trade openness are 135.56 people per sq. km of land area and 73.71% of GDP, respectively. From Table 2, it is noticeable both least and most population countries are Asian countries, namely Mongolia in 2000 and Bangladesh in 2019. The statistics also revealed that Malaysia is the most open country in terms of international trade in 2000. Currently, Malaysia participates in many free trade agreements such as RCEP. Conversely, Serbia is a comparatively closed economy as it is least open for trade in 2000 among the sample countries.

Table 4 presents the correlation matrix for the variables chosen. The estimated results show that CO_2 emissions are positively associated with all other variables except population. Meanwhile, green finance and income exhibit similar trends as both are positively correlated with all other variables except for one variable, namely trade openness and population, respectively. On the contrary, population is inversely correlated with both urbanisation and trade openness while urbanisation is positively correlated with trade openness.

In general, the GMM estimation can be estimated in one- and two-step forms (Arellano & Bond, 1991). The main difference between one- and two-step GMM estimator is their weighting matrices. The weighting matrices of the one-step GMM estimators are independent of estimated parameters, while the weighting matrices of the two-step GMM estimators are weighted by a consistent estimate of the covariance matrix (Azman-Saini et al., 2010). The two-step GMM estimator is widely recognised as more efficient than the one step, and it can improve the power of associated tests.

The empirical results of Eq. (1) for one- and two-step GMM estimators are reported in Tables 5 and 6, respectively. The Sargan test for one-step GMM estimators shows that the model is not well specified. However, both diagnostic tests for two-step GMM estimators show that the model is well specified. The Sargan test does not reject the over-identification restrictions. Besides, based on Arellano and Bond's test, the absence of serial correlation is rejected at first level but not rejected at second level, indicating the model is free of autocorrelation. These support the appropriateness of the two-step GMM estimation for this study. Also, the lagged dependent variable (CO_2 Emissions Lag) is statistically significant

Table 3 Summary statistics

	Mean	Minimum (country, year)	Maximum (country, year)	Standard deviation
CO_2 emissions	2.19	0.02 (Congo, 2001)	8.57 (South Africa, 2008)	2.28
Green finance	29.61	0 (Egypt, 2001, 2006; Ghana, 2019; Philippines, 2003; Tunisia, 2013)	965.16 (Turkey, 2018)	92.05
Income	3013.00	153.59 (Congo, 2001)	18,703.86 (Uruguay, 2018)	3114.48
Population	135.56	1.54 (Mongolia, 2000)	1252.56 (Bangladesh, 2019)	200.54
Urbanisation	45.99	13.40 (Nepal, 2000)	95.43 (Uruguay, 2019)	17.79
Trade openness	73.71	22.49 (Serbia, 2000)	220.41 (Malaysia, 2000)	35.35

Table 4 Correlation matrix

	CO_2 emissions	Green finance	Income	Population	Urbanisation	Trade openness
CO_2 emissions	1					
Green finance	0.1856	1				
Income	0.6173	0.2977	1			
Population	−0.2026	0.0131	−0.1693	1		
Urbanisation	0.5502	0.1734	0.7204	−0.3054	1	
Trade openness	0.2964	−0.1115	0.0981	−0.1815	0.1570	1

at the 1% significance level, proving that the dynamic GMM application is appropriate for this model. As a result, the estimated results reported in Table 6 are robust and reliable.

As expected, Table 6 shows green finance has a negative impact on environmental degradation, with a statistically significant coefficient at the 1% significance level. This is in line with the findings of Meo and Karim (2022); Rasoulinezhad and Taghizadeh-Hesary (2022); Zhang and Wang (2021); Li and Jia (2017) and Sachs (2014) in different

Table 5 Results of dynamic panel one-step GMM estimations

Variables	Dependent variable: CO_2 emissions
Constant	−0.245 (0.186)
CO_2 emissions lag	0.743 (0.031)*
Green finance	-7.44×10^{-5} (1.03×10^{-4})
Income	2.43×10^{-5} (7.74×10^{-6})*
Population	-6.78×10^{-5} (8.45×10^{-4})
Urbanisation	0.012 (5.11×10^{-3})**
Trade openness	0.003 (1.01×10^{-3})*
Sargan test (p value)	383.93 (0.00)*

Figures in the parentheses are t-statistics

** and * indicate significance at the 5% and 1% levels, respectively

Table 6 Results of dynamic panel two-step GMM estimations

Variables	Dependent variable: CO_2 emissions
Constant	−0.235 (0.018)*
CO_2 emissions lag	0.744 (0.008)*
Green finance	-7.34×10^{-5} (5.41×10^{-6})*
Income	2.42×10^{-5} (1.50×10^{-6})*
Population	-3.04×10^{-4} (3.79×10^{-4})
Urbanisation	0.013 (8.42×10^{-4})*
Trade openness	0.003 (1.63×10^{-4})*
Sargan test (p value)	29.08 (1.0)
Autocorrelation of order 1 (p value)	0.045**
Autocorrelation of order 2 (p value)	0.610

Figures in the parentheses are t-statistics

** and * indicate significance at the 5% and 1% levels, respectively

countries. The importance of this result is that it shows green financial instruments are capable of aiding a region in achieving a greener environment (Sachs, 2014), and is considered one of the best measures to mitigate environment degradation (Li & Jia, 2017). In turn, a green environment will improve sustainable growth of the region by enhancing sustainable energy development. This result also indicates efforts of governments of BRI member countries and the Green Finance Task Force in promoting green finance are successful. Through green loans, firms are able to procure and use environmentally friendly raw materials and green technology for green projects, both of which reduce environmental damage and preserve environmental quality. The results prove that although green finance is new and yet to be well accepted by mainstream financial institution, it plays an essential and significant role in reducing the environmental degradation in the BRI region. However, according to Rasoulinezhad and Taghizadeh-Hesary (2022), the COVID-19 pandemic has led to capital shortages for green projects, contributing to the global economic recession. Since the empirical results indicate green finance mitigates environment degradation and in turn enhances sustainable growth, it is worthwhile for governments of BRI member countries to increase the volume of green bonds, as they serve as an important instrument of green finance to support green projects. In turn, this will help restore economic growth in the BRI region.

In contrast, income, urbanisation and trade openness show positive and significant effects on environmental degradation in BRI region. These results are consistent with past literature such as Adzal et al., (2021). Among the three above-mentioned variables, the adverse impact of urbanisation on environment degradation is the greatest. Aligning with the findings of Azam and Khan (2016) and Katircioğlua and Katircioğlub (2019), urbanisation results in environmental degradation, as urban population growth increases usage of infrastructure and energy, which contributes to CO_2 emissions. In addition, urbanisation will cause sectoral change in economic activity from agricultural to industrial. To capture economic growth, we proxy for income using GDP per capita. According to Adediyan et al. (2020), per capita income growth has a long-term negative impact on environmental quality. This may be due to excessive usage of non-renewable energy and overaggressive development projects Similarly, trade openness is also positive and significantly correlated with the environmental degradation in line with Jun et al. (2020)—trade openness increases domestic production to accommodate the surge in exports, which increases pollution and worsens environmental quality if green technology is not being adopted.

The estimated results show a positive but statistically insignificant coefficient for population, suggesting population growth does not adversely affect environmental quality in BRI region. This is corroborated by Bradshaw and Brook (2014). Using scenario projection, Bradshaw and Brook (2014) find changes in population do not significantly affect environmental quality. Cropper and Griffiths (1994), although population growth is viewed as one of the major contributors of environment degradation, due to its contribution to air and water pollution; among others, Cropper and Griffiths (1994) argue that the impact of population on environmental degradation can be mitigated by technology. Therefore, the estimated results not only indicate green finance reduces environment degradation directly through the channels of pollution and emissions, it also implies that green finance might mitigate the impact of environment degradation occurring indirectly through other channels such as trade and economic growth. Thus, to ensure both the sustainability of economic growth and the environment, promoting and developing green projects via green finance are imperative.

5 Conclusion

The past literature and data show economic growth has been happening at the expense of environmental quality, giving rise to public fear that environment may not be sustained for future generations. The BRI, with its large-scale projects, is a contributor to this problem of environmental degradation, with significant spillover costs to the rest of the world. In response, China and other BRI member countries are aware and have responded by coming up with an improved version of the BRI, namely the Green BRI. In this, they have pledged to ensure open and green cooperation in developing green infrastructure and green projects (Advisory Council of the Belt and Road Forum for International Cooperation in 2019 and 2020, 2020). Owing to the high capital required for the BRI-linked projects, green finance becomes one of the most essential tools to ensure success of green BRI-linked projects. Arising from the above, this study investigates the impact of green finance on environmental degradation in BRI region using the GMM method.

The empirical results indicate green finance significantly reduces environmental degradation in the BRI region. As such, the government of BRI member countries should continue to undertake appropriate strategies to promote green finance. To curb environmental degradation effectively, governments should consider to implement incentive schemes for green finance such as subsidising interest rates of green loans. Apart from government effort, private and conventional financial institutions should play an active part in promoting green finance. To motivate the involvement of private sector, governments should provide significant incentives such as significant corporate tax reductions to private financial institutions which promote and offer green finance. Besides, profits from the green industry are relatively uncertain as compared to mature and well-established traditional industries, implying greater risk (Cai & Zhang, 2014). As a result, private financial institutions will evaluate green loans more meticulously. Thus, to increase access to green loans, governments may consider developing green credit guarantee schemes (Taghizadeh-Hesary & Yoshino, 2019, 2020). Besides green finance, to avoid the environmental degradation, BRI member countries are urged to take into consideration environmental factors in urban planning and increasing domestic production for export due to trade openness.

Nevertheless, according to Tang et al. (2018), management plays the role of a catalyst in transforming green innovation into firms' performance. Past studies show that there is a positive relationship between the reduction in CO2 emissions and financial performance of the firms (see Fujii et al., 2013). However, the key factor underpinning this relationship is the management's concern for the environment. If the management is concerned about the state of the environment, they will devote more attention, resources and efforts to support green products and adopt appropriate strategies to ensure green products improve firms' performance. As a result, managers should be aware and recognise that green processes and green products stemming from green finance will eventually sustain the firm's performance in the long run.

To conclude, in order to enhance the continuous economic growth, promote environmental sustainability. As well as to achieve the 2030 SDGs, both governments and private sector should work hand in hand to promote green transformation of BRI.

6 Limitations and future research

This study has certain limitations. First of all, the empirical model of this study limited to a few independent variables. To investigate the green finance of BRI member countries in detail, the variable of interest should be segregated based on usage motive, for instance, green finance for manufacturing processes and for construction development, respectively. In addition, environment degradation may be divided into different forms of pollution, instead of solely focusing on CO_2 emission. However, these limitations should serve as future research topics as complete data are currently unavailable.

Nonetheless, this study adopts secondary data and the scope is limited to macroeconomics. Hence, it would be of interest for future research to investigate the impact of green finance on environment degradation using firm-level data by adopting a different methodology.

Declarations

References

Abbas, H., Zhao, L., Faiz, N., Ullah, H., Gong, J., & Jiang, W. (2022a). One belt one road influence on perishable food supply chain robustness. *Environment, Development and Sustainability, 24*, 9447–9463. https://doi.org/10.1007/s10668-021-01833-y

Abbas, H., Zhao, L., Gong, X., Jiang, M., & Faiz, N. (2022b). Environmental effects on perishable product quality and trading under OBOR supply chain different route scenarios. *Environmental Science and Pollution Research, 29*(45), 68016–68034. https://doi.org/10.1007/s11356-022-20486-6

Adediyan, A. R., Chigozie, U. K., & Ehisuoria, O. T. G. (2020). The empirics of per capita income growth, resources rents and environmental quality in Nigeria. *Academic Journal of Economic Studies, 6*(3), 72–80.

Advisory Council of the Belt and Road Forum for International Cooperation in 2019 and 2020. (2020). *High-quality belt and road cooperation: Partnership on connectivity*. Advisory Council of the Belt and Road Forum for International Cooperation.

Afzal, A., Rasoulinezhad, E., & Malik, Z. (2021). Green finance and sustainable development in Europe. *Economic Research-Ekonomska Istraživanja*. https://doi.org/10.1080/1331677X.2021.2024081

Akorede, Y. F., & Afroz, R. (2020). The relationship between urbanization, CO_2 emissions, economic growth and energy consumption in Nigeria. *International Journal of Energy Economics and Policy, 10*(6), 491–501. https://doi.org/10.32479/ijeep.9355

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies, 58*(2), 277–297. https://doi.org/10.2307/2297968

Azam, M., & Khan, A. Q. (2016). Urbanization and environmental degradation: Evidence from four SAARC Countries-Bangladesh, India, Pakistan, and Sri Lanka. *Environmental Progress & Sustainable Energy, 35*(3), 823–832. https://doi.org/10.1002/ep.12282

Azman-Saini, W. N. W., Baharumshah, A. Z., & Law, S. H. (2010). Foreign direct investment, economic freedom and economic growth: International evidence. *Economic Modelling, 27*(5), 1079–1089. https://doi.org/10.1016/j.econmod.2010.04.001

Bradshaw, C. J. A., & Brook, B. W. (2014). Human population reduction is not a quick fix for environmental problems. *Proceedings of the National Academy of Sciences of the United States of America, 111*(46), 16610–21661. https://doi.org/10.1073/pnas.1410465111

Cai, Y. P., & Zhang, Y. P. (2014). Green financial system construction: Problems and solutions. *Finance Theory & Practice, 9*, 66–70.

Chen, S. (2013). Green finance and development of low carbon economy. In *LTLGB 2012* (pp. 457–461). Springer.

Chen, X., Zhu, Q., Zhou, X., & Wong, Y. D. (2017). Game-theoretic comparison approach for intercontinental container transportation: A case between China and Europe with the B&R initiative. *Journal of Advanced Transportation*. https://doi.org/10.1155/2017/3128372

Cropper, M., & Griffiths, C. (1994). The interaction of population growth and environmental quality. *American Economic Review, 84*(2), 250–254.

ESCAP. (2021). *The belt and road initiative for seamless connectivity and sustainable development in the Asia-Pacific Region.* The Economic and Social Commission for Asia and the Pacific.

Fujii, H., Iwata, K., Kaneko, S. & Managi, S. (2013). Corporate environmental and economic performance of japanese manufacturing firms: empirical study for sustainable development. *Business Strategy and the Environment, 22*(3), 187–201. https://doi.org/10.1002/bse.1747

Heal, G., & Schlenker, W. (2019). *Coase, hotelling and pigou: The incidence of a carbon tax and CO_2 emissions (No. w26086).* National Bureau of Economic Research.

Islam, M. (2021). Financial development and FDI nexus evidence from one belt one road economies. *International Journal of Management, Accounting and Economics, 8*(7), 499–516. https://doi.org/10.5281/zenodo.5218894

Jun, W., Mahmood, H., & Zakaria, M. (2020). Impact of trade openness on environment in China. *Journal of Business Economics and Management, 21*(4), 1185–1202. https://doi.org/10.3846/jbem.2020.12050

Katircioğlua, S., & Katircioğlub, S. (2019). Testing the role of urban development in the conventional environmental Kuznets curve: Evidence from Turkey. *Applied Economics Letters, 25*(11), 741–746. https://doi.org/10.1080/13504851.2017.1361004

Kemfert, C., Schäfer, D., Semmler, W., & Zaklan, A. (2019). Green finance: The macro perspective. *Vierteljahrshefte Zur Wirtschaftsforschung, 88*(2), 5–9.

Khan, M. A., Riaz, H., Ahmed, M., & Saeed, A. (2021). Does green finance really deliver what is expected? An empirical perspective. *Borsa Istanbul Review*. https://doi.org/10.1016/j.bir.2021.07.006

Li, W., & Jia, Z. (2017). Carbon tax, emission trading, or the mixed policy: Which is the most effective strategy for climate change mitigation in China? *Mitigation and Adaptation Strategies for Global Change, 22*(6), 973–992. https://doi.org/10.1007/s11027-016-9710-3

Li, C. & Gan, Y. (2021). The spatial spillover effects of green finance on ecological environment—empirical research based on spatial econometric mode. *Environmental Science and Pollution Research*, *28*, 5651–5665. https://doi.org/10.1007/s11356-020-10961-3

Meo, M. S., & Abd Karim, M. Z. (2022). The role of green finance in reducing CO_2 emissions: An empirical analysis. *Borsa Istanbul Review, 22*(1), 169–178. https://doi.org/10.1016/j.bir.2021.03.002

Montalbano, P., & Nenci, S. (2019). Energy efficiency, productivity and exporting firm-level evidence in Latin America. *Energy Economics, 79*, 97–110. https://doi.org/10.1016/j.eneco.2018.03.033

Muganyi, T., Yan, L., & Sun, H. P. (2021). Green finance, fintech and environmental protection: Evidence from China. *Environmental Science and Ecotechnology, 7*, 100–107. https://doi.org/10.1016/j.ese.2021.100107

Nordhaus, W. (2015). Climate clubs: overcoming free-riding in international climate policy. *American Economic Review*, *105*(4), 1339-70.https://doi.org/10.1257/aer.15000001.

OECD. (2018). *The belt and road initiative in the global trade, investment and finance landscape: OECD business and finance outlook 2018.* OECD Publishing.

Rasoulinezhad, E., & Taghizadeh-Hesary, F. (2022). Role of green finance in improving energy efficiency and renewable energy development. *Energy Efficiency*. https://doi.org/10.1007/s12053-022-10021-4

Sachs, A. (2014). Completeness, interconnectedness and distribution of interbank exposures—A parameterized analysis of the stability of financial networks. *Quantitative Finance, 14*(9), 1677–1692. https://doi.org/10.1080/14697688.2012.749421

Sachs, J. D., Woo, W. T., Yoshino, N., & Taghizadeh-Hesary, F. (2019). *Why is green finance important? (No. 917)*. Asian Development Bank Institute.

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics, 74*, 843–857. https://doi.org/10.1016/j.eneco.2018.07.020

Shen, Y., Su, Z. W., Malik, M. Y., Umar, M., Khan, Z., & Khan, M. (2021). Does green investment, financial development and natural resources rent limit carbon emissions? A provincial panel analysis of China. *Science of the Total Environment, 755*, 142538. https://doi.org/10.1016/j.scitotenv.2020.142538

Statistia. (2022). *Average per capita carbon dioxide emissions worldwide from 1960 to 2020 (in metric tons)*. Retrieved from https://www.statista.com/statistics/268753/co2-emissions-per-capita-worldwide-since-1990/

Tang, G., Chen, Y., Jiang, Y., Paillé, P. & Jia, J. (2018). Green human resource management practices: scale development and validity. *Asia Pacific Journal of Human Resources*, *56*(1), 31–55. https://doi.org/10.1111/1744-7941.12147

Taghizadeh-Hesary, F., & Yoshino, N. (2019). The way to induce private participation in green finance and investment. *Finance Res. Lett., 31*, 98–103. https://doi.org/10.1016/j.frl.2019.04.016

Taghizadeh-Hesary, F., & Yoshino, N. (2020). Sustainable solutions for green financing and investment in renewable energy projects. *Energies, 13*, 788. https://doi.org/10.3390/en13040788

Taufik, K. (2016). Unilever palm oil supplier must suspend all plantation expansion to save reputation. *The Guardian*, *9*.

The World Bank Group (2019). *Belt and road economics: Opportunities and risks of transport corridors*. The World Bank Group.

Thürera, M., Tomaševicb, I., Stevensonc, M., Blomed, C., Melnykf, S., Chang, H. K., & Huang, G. Q. (2020). A systematic review of China's belt and road initiative: Implications for global supply chain management. *International Journal of Production Research, 58*(8), 2436–2453. https://doi.org/10.1080/00207543.2019.1605225

Tran, T., Do, H., Vu, T., & Do, N. (2020). The factors affecting green investment for sustainable development. *Decision Science Letters, 9*(3), 365–386. https://doi.org/10.5267/j.dsl.2020.4.002

UNDP (2022). *The SDGs in action. United Nations Development Programme*. Retrieved from https://www.undp.org/sustainable-development-goals.

Volz, U. (2018). Fostering green finance for sustainable development in Asia. In *Routledge handbook of banking and finance in Asia* (pp. 488–504). Routledge.

Wang, Y., & Zhi, Q. (2016). The role of green finance in environmental protection: Two aspects of market mechanism and policies. *Energy Procedia, 104*, 311–316. https://doi.org/10.1016/j.egypro.2016.12.053

Xu, M., Qin, Z. & Wei, Y. (2022). Exploring the financing and allocating schemes for the Chinese Green Climate Fund. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02137-5

Zakari, A., & Khan, I. (2021). The introduction of green finance: A curse or a benefit to environmental sustainability? *Energy Research Letters, 3*, 29977. https://doi.org/10.46557/001c.29977

Zhang, B., & Wang, Y. (2021). The effect of green finance on energy sustainable development: A case study in China. *Emerging Markets Finance and Trade, 57*(12), 3435–3454. https://doi.org/10.1080/1540496X.2019.1695595

Zhang, D., Mohsin, M., Rasheed, A. K., Chang, Y., & Taghizadeh-Hesary, F. (2021a). Public spending and green economic growth in BRI region: Mediating role of green finance. *Energy Policy, 153*, 112256. https://doi.org/10.1016/j.enpol.2021.112256

Zhang, S., Wu, Z., Wang, Y., & Hao, Y. (2021b). Fostering green development with green finance: An empirical study on the environmental effect of green credit policy in China. *Journal of Environmental Management, 296*, 113159. https://doi.org/10.1016/j.jenvman.2021.113159