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Transitioning to Green Economic Growth in China: Green Finance and the Mediator of Industrial Structure Upgrading

Wei Deng, Saira Kharuddin, Zariyawati Mohd Ashhari, Somod Dapo Olohunlana

School of Business and Economics, Universiti Putra Malaysia, Serdang 43400, Malaysia

Corresponding Author Email: saira@upm.edu.my

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Abstract

Green finance is expected to decrease environmental pollution and the depletion of fossil energy, ultimately contributing to green economic growth (GEG). The panel data from 31 Chinese provinces between 2010 and 2020 is used to investigate the role of green finance on GEG and the mediating effect of industrial structure upgrading (ISU). This study newly creates the GEG index with 17 indicators based on the entropy-weighted TOPSIS method and performs empirical analysis using fixed effect and panel quantile regression models. The two-stage least squares (2SLS) and system generalized method of moments (GMM) are also adopted to conduct the endogeneity test. It is found that the information presented by the GEG index accurately reflects the state of affairs in China's provinces, indicating that this index is valid. Green finance enhances GEG, and this boost increases as the level of GEG rises. The findings also imply that ISU positively mediates the impact of green finance on GEG, accounting for 28.4% of the total impact. The COVID-19 pandemic overall shows a promotion of GEG, although it hampers economic growth.

Keywords: Green Economic Growth, Green Finance, Industrial Structure Upgrading, Environmental Pollution.

Introduction

Urbanization and industrialization have raised living standards worldwide, but they have also drastically reduced resource availability and caused environmental degradation, particularly in China, the world's largest developing nation (Ajibade et al., 2021). From Fig. 1, China's total CO_2 emissions have been growing aggressively since 1998, and this value is 2.3 times that of the USA and equivalent to OECD countries by 2022. The continuous growth of CO_2 emissions inevitably has a detrimental influence on human living conditions, such as climate change and the greenhouse effect (Mikhaylov et al., 2020; Stollery, 1998), a health risk associated with the rising temperature brought along by carbon emissions (Tan et al., 2022). The ozone layer has gotten worse due to CO_2 emissions, which has led to a decrease in human and ocean life expectancy (Dermawan et al., 2022). More seriously, there is a substantial danger to the sustainable use of resources, especially given the depletion of fossil fuels. As a non-renewable energy source, fossil energy occupies most of China's total energy consumption (Pata & Caglar, 2021). However, the impact of these problems can be minimized if the seriousness of the problem is acknowledged and effective action is taken promptly.

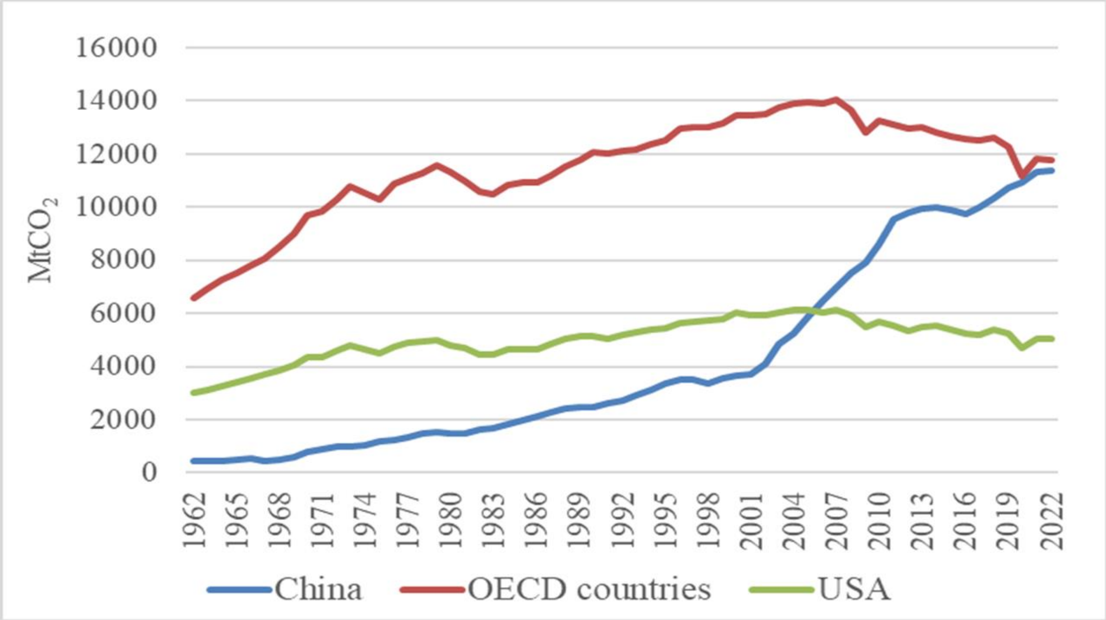

Fig. 1: CO_2 emissions of China, OECD countries, USA from 1962 to 2022.
Source: http://www.globalcarbonatlas.org

Over the previous several decades, governments have attempted to foster sustainability through policy and regulation modifications in order to advance economic growth while preserving the natural world (Khan et al., 2022). A new path of economic development is selected by China in light of severe ecological issues, switching from the crude model to the green economic growth (GEG) model (Gu et al., 2021). In 2005, GEG was first created to look into the possibility of creating a model of eco-friendly development for Asia's emerging nations (ESCAP, 2005). It has sparked widespread concern throughout the world and is perceived as an effective method of preventing environmental deterioration (Musango et al., 2014). GEG refers to fostering economic development while preserving the natural resources and environment that form the basis of services vital to human well-being (OECD, 2018). The objectives of GEG emphasise the need to address issues related to the environment, particularly climate change (Dong & Ullah, 2023). However, the shift in economic growth strategy will not be self-fulfilling, for example, through market mechanisms for self-recovery. Therefore, this critical issue needs to be researched and resolved.

The Chinese government emphasises the necessity of creating an attractive country and offers green financial assistance to implement China’s GEG target with a wide range of opportunities and enormous expansion space (Tan et al., 2023). China puts forth a green finance development strategy to support green development (Qu et al., 2023). It is estimated that China has to invest hundreds of billions of dollars in green projects to achieve carbon reduction (Yu et al., 2020). Green finance is crucial to maintaining environmental sustainability, and it has gained broad acceptance worldwide (Cheung & Hong, 2021). Compared with traditional finance, green finance gives environmental concerns more consideration as well as resource utilization (Zhou et al., 2020). Green development can be greatly impacted by green finance; strengthening green finance is the key strategy for expanding China's green economies (D'Orazio & Popoyan, 2019; Yang et al., 2021). Hence, China's GEG is anticipated to be realized through green finance.

Industrial structure upgrading (ISU) is the foundation for modifying China's rough economic development model, which benefits the environment and GEG. ISU refers to the process of transforming the whole industry from a low-level structure to a high-level structure (Y. Song et al., 2021). More specifically, it can be well presented in the trend of changes in three sectors seen at the national level. The primary sector gradually decreases as the industrial structure is upgraded and will gradually shift to the secondary sector, then the tertiary sector. ISU means higher added value and less pollution. In economic development, the level of resource consumption varies between different industries; the secondary industry consumes resources the most and causes the greatest damage to the ecological environment, while the tertiary industry, including software and service sectors, has the highest added value and the least pollution (Jing et al., 2021).

The upgrading from primary and secondary to tertiary industry promotes GEG efficiency (Zhu et al., 2019). ISU has been found to facilitate GEG through direct effects and spatial spillover effects in China (Xu & Zhou, 2023). The previous research mainly emphasizes the driving forces of GEG, such as environmental regulation, green finance, foreign investment and trade, ISU, and technology innovation (Ayayi & Wijesiri, 2022; Caetano et al., 2022; Ding et al., 2022; W. Hu et al., 2021; Peng, 2020; Sharma et al., 2021). Several studies have also been conducted between these component factors. For instance, green finance assists in the development of ISU in Indonesia through various strategies, such as green bonds and green loans (Nur Utomo et al., 2020). Green finance efficiently transfers money from polluted to environmentally beneficial industries (Lv et al., 2021). Nevertheless, few studies have jointly investigated the relationship between green finance, ISU, and GEG. Hence, collaborative research on the aforementioned factors for GG is currently lacking.

Additionally, as green finance provides financial support to improve ISU (Nur Utomo et al., 2020) and fostering changes to industrial structure effectively decreases carbon emissions (Ma et al., 2019), green finance not only has a direct impact on GEG but may also work through the mediator of ISU. Further investigation is necessary to understand whether ISU plays a mediating role in the relationship between green finance and GEG. Therefore, this paper aims to form a theoretical framework and investigate the enhancing role of green finance on GEG and the mediating effect of ISU by using 31 Chinese provinces between 2010 and 2020. Considering the COVID-19 pandemic is global and deeply affects politics, economy, and society, especially China, this study selects it as a dummy variable to portray its shock to GEG.

The contributions are as follows: (1) This article jointly explores the relationship between green finance, ISU, and GEG, as few studies have investigated those variables together. (2) GEG may be positively affected not only by green finance but also by the mediator, ISU. Further investigations should be conducted on the mediating role of ISU in the relationship between green finance and GEG, which contributes to building a theoretical framework. (3) With the lack of a globally harmonised GEG index, this study constructs a new index with 17 indicators to accurately represent China's achievements and shortcomings. The entropy-weighted TOPSIS method is adopted to measure the GEG index rather than a single index or production efficiency method. (4) Panel quantile regression is also added to complement the panel model with a fixed effect as it fully captures the conditional distribution of the explained variable, not just its mean value. The results not only reaffirm the contribution of green finance to GEG but also show that, in comparison to regions with low levels of GEG, regions with high levels of GEG benefit more from green finance's promotion. This article's remaining portions are arranged as follows: Section 2 covers the literature review and hypotheses development. The GEG index is created in Section 3. This is followed by the research methodology in Section 4. In Section 5, the article analyses and discusses the findings. Finally, Section 6 contains the conclusions.

Literature Review and Hypotheses Development

Literature Review

Green Economic Growth (GEG)

Measuring GEG is essential for a region to objectively assess the overall state of economic and ecological development. There are three different ways to evaluate this new concept. The single indicator comes first: Green GDP is used as a metric in academia, as it subtracts the costs associated with the environment from GDP and represents the exchange that occurs between ecological and economic systems (Cheung & Hong, 2021). Secondly, followed by the process performance of input and output, relevant studies believe that the goal of GEG is to produce more desirable output while requiring less input (Lin et al., 2013; X. Zhao et al., 2022). For instance, Zhao et al (2022) selected five indicators of GEG, including the desirable output GDP and four undesirable outputs highly related to environmental pollution. Thirdly, the framework includes three categories: production, consumption, and environment, which are submitted by the OECD, and the list of indicators in the framework has been kept flexible so that countries can adapt it to their particular contexts (OECD, 2017).

Meanwhile, the elements driving GEG have been the subject of numerous studies by scholars. Environmental regulation enhances sustainable growth through green technology innovation, which is a characteristic aspect of local government conduct in China (Peng, 2020). Governments can transfer money for environmental programs owing to an improved financial system (Ayayi & Wijesiri, 2022). Financial agglomeration can effectively improve urban green growth through the effects of scale economies and technical advancement (Tian et al., 2021). FDI enhances GEG through the mediation of energy consumption (Caetano et al., 2022). Trade openness has proven to be an important factor in improving green total factors, as it can facilitate the cross-country exchange of knowledge, technology, and finance (Ding et al., 2022). Intense industries boost the ratio of high-value-added items produced, which ultimately raises GDP (Yuan et al., 2020). ISU is an important driver of GEG, as it is characterized by the continuous flow of production factors to high-added-value and low-consumption industrial segments (Zhu et al., 2019). GEG benefits a lot from the achievement of eco-industrial structures (Hu et al., 2021). Developing countries have significant potential for economic growth due to technical innovation and its ripple effects (Ilkay et al., 2021; Seck, 2012; Tientao et al., 2016). Innovation in green technology ensures that technical growth can have a minimum environmental impact (Liu et al., 2021). Green technology innovation lessens pollution and damage to the environment through the eco-friendly behavior of companies (Sharma et al., 2021).

In summary, previous studies found that the driving forces stimulating GEG mostly concentrated on political factors, financial factors, foreign investment factors, industrial factors, and technological factors. Hence, this article is dedicated to exploring the enhancing role of green finance on GEG and the mediating effect of ISU.

Green Finance

With the release and implementation of relevant guiding documents such as "Agenda 21" in 1992 (Barcena, 1992), green finance gradually gained attention from the public. This concept refers to the financing of projects aimed at the establishment of a circular economy, including promoting clean energy, reducing greenhouse gas emissions, and financial operations for other environmental objectives (Banga, 2019). So far, there has been a large amount of relevant research on green finance from different perspectives. In terms of driving factors, green finance is influenced by government policy and technology. The allocation of green finance can be effectively improved by implementing environmental policies (Xia & Li, 2019). There is a need for government economic policies that will drive a green shift in the financial sector (Batrancea et al., 2020). Fintech can be a major force in the provision of green finance and encourage a shift to sustainability among individuals and SMEs by using big data analytics and intelligent technology (Duchêne, 2020).

Besides, green finance has impacts on industry, the circular economy, and individual behavior. The tertiary sector in China is most affected by green finance and grows quickly, followed by the primary and secondary sectors, which contribute to ISU (Wang & Wang, 2021). As a finance-based environmental instrument, green finance is designed to foster the circular economy, including encouraging renewable energy and reducing the release of greenhouse gases and pollution. Green credit has been shown to increase non-state-owned banks' profitability and lower their risks in China, but state-owned banks will see their earnings decline (Yin et al., 2021). For businesses that generate a great deal of pollution, green credit certainly has negative effects on financing and investment, and the promotion effect on the business performance of enterprises is relatively weak (Xie & Zhang, 2021).

Hypotheses Development

Green Finance and GEG

As the government attaches importance to environmental conservation and GEG, numerous studies have focused on the role of green finance in promoting GEG. From a theoretical standpoint, the policy guidance mechanism is crucial. Green finance allocates financial resource flow to green businesses, and the increase in green activities of firms contributes to GEG. It mainly aims to encourage the growth of a circular economy by supporting projects that promote sustainable development, environmental protection, and pollution reduction. The green credit program shifts funds from high polluters to environmental industries (Al-Qudah et al., 2022); this also increases productivity as well as environmental quality (Baloch et al., 2020). By using carbon financing, the financial sector can encourage green investments and strive to establish an economy that values the environment (L. Zhao et al., 2022). Using a variety of creative and unique financial arrangements, green finance offers financial services for GEG (Geng et al., 2023). Additionally, the risk diversification mechanism also makes a difference. Green finance diversifies green industrial risks and environmental risks, enhancing society’s ability to resist risk, which promotes GEG. The return on investment is relatively sluggish since green finance places more emphasis on the project's environment and ecological benefits (Anh Tu et al., 2020). Hence, for comprehensive risk management of green projects, banks mainly rely on qualified risk identification and management skills (Chen & Chen, 2021). Green finance can give businesses access to more effective technology and investment management channels, increase capital usage effectiveness, lower the risk associated with the green industry, and promote GEG (Dang, 2019).

In regards to empirical findings, it has been shown that green finance significantly lowers CO_2 emissions in the BRICS countries (Wang et al., 2021). China's increased green finance has resulted in a notable reduction in carbon emissions. (Zahan & Chuanmin, 2021). It confirms that green finance decreases carbon emissions and the environmental footprint in OECD nations (Habib et al., 2024; Umar & Safi, 2023). Green finance has revolutionised GEG in developed countries, but it should be noted that emerging nations also struggle with a lack of green funding and should reconcile economic development with environmental damage (Deng et al., 2024). Therefore, hypotheses 1 is proposed on this basis.

H1. Green finance positively affects GEG.

The Mediating Effect of Industrial Structure Upgrading (ISU)

Theoretically, there are two basic ways that ISU might mediate the relationship between green finance and GEG. First, green finance restricts pollution industries and stimulates eco-friendly industries, thereby benefiting the environment for GEG through ISU. Green finance provides financial support to eco-friendly projects; it guides financial institutions to distinguish between pollution sectors and green sectors through green financial policies, focusing on financing green industry initiatives like ecological protection. Most energy use and carbon emissions come from secondary industry, so encouraging ISU is capable of lowering carbon emissions (Ma et al., 2019). Therefore, green finance regulates and limits funding of pollution industries and improves the availability of eco-friendly industries, which finally improves GEG through ISU.

Second, green finance is beneficial to promote the tertiary industry with the highest added value and lowest pollution and decrease the secondary industry with the highest pollution, contributing to the improvement of GEG. The secondary sector has China's highest energy usage and carbon emission levels, making it the country's biggest source of pollution (Fang & Yu, 2021). Therefore, green finance can guide financial resources away from the secondary sectors with high pollution and towards the tertiary sector, which is mostly software, digital automation technologies, and service industries. Since the tertiary sector can easily meet green policy requirements, which make it grow fast, there will be an increase in the share of the service in all sectors. To some extent, the generation of pollutants can be effectively reduced by the tertiary industry's rising share (Jing et al., 2021). Specifically, digital automation technologies improve the recycling of resources and waste products through modern production systems (Awan et al., 2022), which is conducive to ecological conservation and GEG.

In terms of empirical findings, numerous studies on the role of green finance in promoting ISU have been conducted. Green finance assists in the development of ISU through various strategies, such as green loans (Nur Utomo et al., 2020). It has been found that China's tertiary industry is more significantly affected by green finance than the primary or secondary industries, which benefits ISU (Wang & Wang, 2021). Additionally, related studies have also focused on the impact of ISU on GEG. Since energy consumption and carbon emissions are mostly the responsibility of the secondary sector, encouraging changes to ISU efficiently reduces carbon emissions in China (Ma et al., 2019). In China, ISU has been demonstrated to improve GEG in 30 provinces between 2013 and 2019 (Su & Fan, 2022). Pakistan's carbon intensity decreased with the transformation of the green industry between 1975 and 2020 (Mehmood et al., 2024). Hence, this study puts forward hypotheses 2.

H2. ISU may positively mediate the relationship between green finance and GEG.

Overall, green finance guides funds flow to green businesses while restricting polluting projects, and the increase in green activities of enterprises will bring environmental benefits to GEG. At the same time, green finance diversifies the investment risk of the green sector through extensive risk management by banks, thus fostering GEG. Furthermore, ISU has a significant mediating function. Changes in the industrial structure contribute to the environment since green finance restricts polluting sectors and encourages eco-friendly industries. As the tertiary sector has high value-added and minimal pollution, it is easier to satisfy the requirements of the green fund. Ultimately, the development of the tertiary sector and the shrinkage of the industrial scale would facilitate the achievement of GEG. The theoretical framework of this study is shown in Fig. 2.

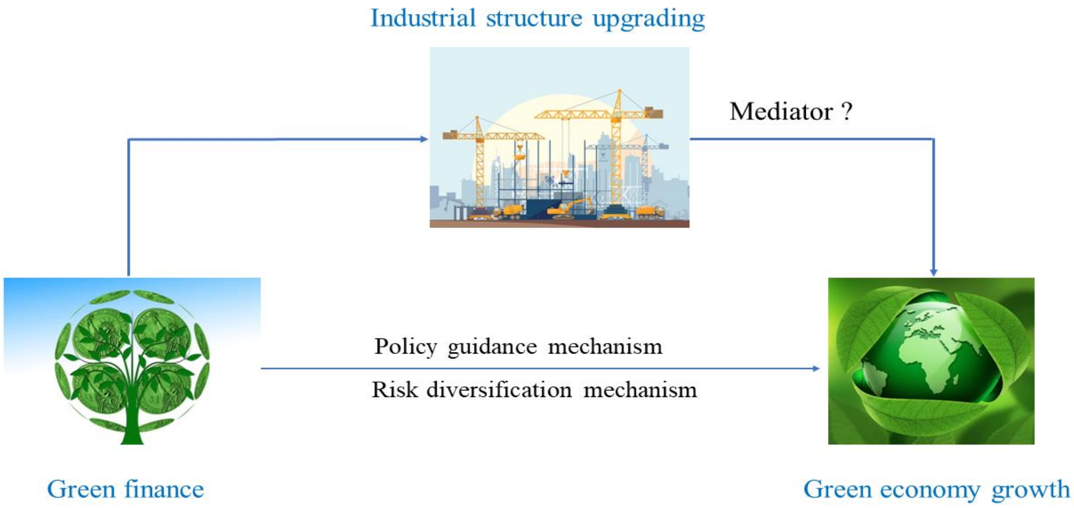

Fig 2: Theoretical framework

Construction of the GEG index

Dimensional Subdivision

GEG index is essential to accurately depicting a region's state of green development. Currently, the main types of GEG index include one single indicator (Cheung & Hong, 2021), the production efficiency of input and output (Lin et al., 2013; X. Zhao et al., 2022). Considering that there isn't currently a globally unified method, this study develops this index to truly reflect China's achievements and shortcomings. China had adopted a new path of economic development, concentrating on growth quality, social progress, resource saving, and pollution reduction (Wu & Zhou, 2019). This index is separated into three categories by this study: economic development, social progress, resource and environment.

Selection of Indicators

This index consists of 17 indicators in line with the notion of GEG and previous works (Lin & Zhou, 2022; Wang et al., 2022; J. Zhao et al., 2022), as seen in Table 1. Economic development mainly reflects the speed and quality of economic development. Social progress mainly includes human development, social justice, and social security. Resource and environment mainly include ecological resources and pollution reduction.

Table 1
Indicator System of China's GEG

Dimensions	**Sub-index**	**Basic indicators**	**Attribute**
Economic development	Economic growth rate	Per capita GDP growth rate	+
	Economic growth quality	The proportion of tertiary industry in the GDP	+
		The proportion of R&D expenditure to GDP	+
		The proportion of total import and export to GDP	+
Social progress	Human develop	The proportion of education expenditure in fiscal expenditure	+
		The average number of higher education students per 100,000 population	+
	Social justice	Proportion of per capita disposable income in rural and urban regions	+
		The proportion of per capita consumption expenditure in rural and urban regions	+
	Social security	The proportion of basic pension insurance fund expenditure to GDP	+
		The proportion of basic medical insurance fund expenditure to GDP	+
Resource and environment	Ecological resources	Forest coverage rate	+
		The green coverage rate of built-up area	+
		The proportion of energy consumption to GDP	-
	Pollution reduction	The proportion of industrial wastewater to GDP	-
		The proportion of industrial SO_2 to GDP	-
		The proportion of industrial waste solid to GDP	-
		Harmless disposal rate of household garbage	+

Entropy-Weighted TOPSIS Method

After choosing the dimensions and basic indicators, the choice of a measurement method for the GEG index is also critical. The evaluation method needs to ensure the objectivity of the weights and reflect the sharp differences (Sun et al., 2017). Hence, the entropy-weighted TOPSIS method is employed to evaluate this index. According to TOPSIS, the best option is that which is closest to the perfect solution in the positive case and the furthest from the ideal solution in the negative case (Kumar & Kaur, 2019). By allocating weight based on the index's fluctuation, the entropy weight method decreases interference from subjective elements (Lin & Zhou, 2022). Following is the calculation procedure.

1. Construction of an evaluation matrix
   $(X_{t,j})_{n*m}$ is constrtcted as indicating the value of the j indicator in year t.
2. Forward or reverse processing of data by the entropy weight method

The normalized method is used to get the standardized evaluation matrix. when indicator is positive, $X_{t,j}^{-}$=($X_{t,j}$-min $X_{t,j}$) /($maxX_{t,j}$- $minX_{t,j}$); when indicator is negative, $X_{t,j}^{-}$=(max$X_{t,j}$-$X_{i,j}$) /($maxX_{t,j}$- $minX_{t,j}$).

3. Compute the ratio of the j indicator in year t.

$Y_{t,j}$=$X_{t,j}^{-}$ / $\sum_{t=1}^{n} X_{t,j}^{-}$ (1)

4. Calculating the information entropy value E_j and information utility value d_j of indicator j.

E_j=-$\frac{1}{\ln m}$ /($\sum_{t=1}^{n} Y_{t,j}$* ln$Y_{t,j}$) (2)

d_j=1-E_j (3)

5. Calculating the weight of indicator j.

W_j=$\frac{d_j}{\sum_{t=1}^{n} d_j}$ (4)

6. Calculate the weights for each criterion.

$R_{t,j}$=$W_j X_{t,j}^{-}$ (5)

7. Determining the positive and negative solutions based on TOPSIS.

S_t^{+}=Max ($R_{t,i}$) (6)

S_t^{-}=Min ($R_{t,i}$) (7)

8. The distance between each solution with the ideal positive solution and negative ideal solution should be calculated and recorded as d_i^{-} and d_i^{+}, respectively.

d_t^{+}=$\sqrt{\sum_{t=1}^{n}(S_t^{+} - R_{t,j})^2}$ (8)

d_t^{-}=$\sqrt{\sum_{t=1}^{n}(S_t^{-} - R_{t,j})^2}$ (9)

9. Calculate the proximity of GEG index.

C_t=$\frac{d_t^{-}}{(d_t^{-}+d_t^{+})}$, $C_i \subset (0,1)$ (10)

Methodology

Variables

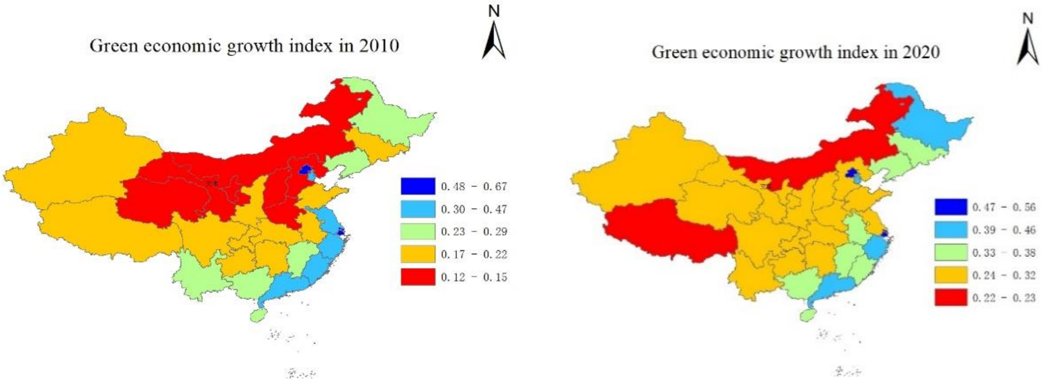

Fig. 3. GEG index in 2010, 2020

Dependent variable: GEG index; its indicators are shown in Table 1, measured by the entropy-weighted TOPSIS method. The GEG indexes of various provinces exhibit substantial regional differences, with eastern China performing significantly better than the central and western provinces, as presented in Fig. 3. It is consistent with reality, as the eastern provinces in China are economically developed and more environmentally conscious (M. Song et al., 2021; Sun et al., 2022).

Independent variable: green finance index, which consists of green credit, green security, green investment, and green insurance, according to the Chinese Green Finance Professional Committee. Chinese traditional commercial banks occupy a key position, and green credit is a major component in fostering green projects. This study uses a proportion of the liabilities of listed environmental protection companies (Yang et al., 2021). The proportion of the stock market value of listed environmental protection companies is adopted to measure green securities (Chen & Chen, 2021). The proportion of environmental pollution expenditure in total fiscal expenditure is used to measure green investment (Zhou et al., 2020), and the proportion of agricultural insurance expenditure in total insurance expenditure is calculated to measure green insurance (Chen & Chen, 2021). This study gives weight to the four dimensions using the entropy weight method and figures out the green finance index.

Mediating variables: ISU; the ratio of the tertiary to secondary sectors is adopted (Jiang et al., 2020).

Dummy Variable: COVID-19 started on December 29, 2019, and was recognized as a worldwide epidemic by WHO in 2020 (Ciotti et al., 2020), therefore, the dummy variable is set to “0” in 2019 and before, and “1” in 2020.

Control variables: this article selects control variables affecting green economy growth based on the existing study, including government intervention, openness, and labor (Caetano et al., 2022; Huang et al., 2022; Uzonwanne et al., 2015).

Sampel and Data Sources

The sample in this study comes from 31 inter-provincial regions in China from 2010 to 2020. Green finance data comes from the Wind database. The dummy variable data of COVID-19 is based on WHO. The Chinese Provincial Statistical Yearbook provides the GEG, ISU, and control variables data. Table 2 shows the detailed variables and data sources.

Table 2
Variables and data sources

Variables	Definition	Sources
GEG	GEG index	Chinese Provincial Statistical Yearbook (CPSY)
Green finance	Green finance index	Wind database
ISU	Ratio of the tertiary to secondary sectors	CPSY
COVID -19	"0" or "1"	WHO
Government intervention	Ratio of fiscal expenditure to GDP	CPSY
Openness	Ratio of total foreign investment to GDP	CPSY
Labor	Urban unemployment rate	CPSY

Econometric Models
Benchmark Model

To clarify the impact of green finance on GEG, a basic form of panel regression model Eq. (i) is developed from the prior work (Raharjo et al., 2014).

$$GEG_{it} = \alpha_0 + \beta_1 GF_{it} + \beta_2 DV_{it} + \sum \beta CV_{it} + \varepsilon_{it} \qquad \text{(i)}$$

Where i refers to the 31 inter-provinces in China, t refers to t year. $\mathrm{GEG_{it}}$ refers to the dependent variable of GEG index, $\mathrm{GF_{it}}$ represents the independent variable of the green finance index, $\mathrm{DV_{it}}$ refers to dummy variables, $\mathrm{CV_{it}}$ represents the vector of control variables. Eq. (i) will examine the positive effect of green finance on GEG, which corresponds to hypotheses H1.

Panel Quantile Model

Considering the model Eq. (i) is based on the mean value method, an additional model of panel quantile regression is added to capture the conditional distribution of GEG, as seen in Eq. (ii) (Xu et al., 2023). $Q_\tau(GEG_{it})$ represents τ quantile of GEG.

$$Q_\tau(GEG_{it}) = \alpha_0 + \beta_{1\tau} GF_{it} + \beta_{2\tau} DV_{it} + \sum \beta_\tau CV_{it} + \varepsilon_{it} \qquad \text{(ii)}$$

Mediation Model

Furthermore, this study also constructs additional Eq. (ia) and Eq. (ib) to mine the mediating effect of ISU which is set as ISU_{it}.

$$ISU_{it} = \alpha_0 + \beta_1 GF_{it} + \sum \beta CV_{it} + \varepsilon_{it} \qquad \text{(ia)}$$

$$GEG_{it} = \alpha_0 + \beta_1 GF_{it} + \beta_2 DV_{it} + \beta_3 ISU_{it} + \sum \beta CV_{it} + \varepsilon_{it} \qquad \text{(ib)}$$

The recursive Eq.(i), (ia), and (ib) are designed to examine whether there is a mediating effect (Lee et al., 2023), which corresponds to hypotheses H2.

Results and Discussion
Descriptive Statistics Analysis

As seen in Table 3, GEG has a mean value of 0.294 and a range of 0.123 to 0.678, indicating that the majority of provinces exhibit low GEG values. The averages of green finance, ISU, government intervention (GI), and openness are closer to the minimum, while the distribution of labor is more balanced. ISU shows a large standard deviation (0.677) and a huge gap between the largest (5.310) and smallest values (0.499).

Table 3
Statistical analysis results

Variable	Obs	Mean	Std.Dev.	Min	Max
GEG	341	0.294	0.112	0.123	0.678
Green finance	341	0.005	0.004	0.001	0.022
ISU	341	1.196	0.677	0.499	5.310
Labor	341	0.033	0.006	0.012	0.046
GI	341	0.280	0.208	0.106	1.379
Openness	341	0.383	0.378	0.050	1.843
COVID-19	341	0.091	0.288	0	1

Stationarity Test

This study uses short panel data, which is suitable for the HT test (Chen et al., 2022). Table 4 demonstrates that variables of labor (P=0.004) and GI (P=0.001) pass the unit root test, while there is a unit root in GEG, green fiance, ISU, and openness. So this study continues to perform the HT test of the latter variables after the measurement of the first-order difference; eventually, they all become stationary after this measurement.

Table 4
Stationarity for variables

Variable	Test method		Stationarity	
	HT test	P-value	No treatment	First-order difference
GEG	0.939	1.000		Stationarity
Green finance	0.840	0.976		Stationarity
ISU	1.010	1.000		Stationarity
Labor	0.628	0.004	Stationarity	
GI	0.604	0.001	Stationarity	
Openness	1.041	1.000		Stationarity

Cointegration Test

The cointegration test is employed to figure out whether the variables are in long-term equilibrium. As seen in Table 5, the results of the three methods in Eqs. (i), (ia), and (ib) all pass the 1% significance level. Regression analysis could be performed on the data, as all models satisfy the Pedroni cointegration test.

Table 5
Cointegration test results

Models	Pedroni test			
	Modified	Phillips-	Phillips-Perron t	Augmented Dickey-Fuller t
Eq. (i)	7.298 ***		-5.488 ***	-5.916 ***
Eq. (ia)	4.631 ***		4.272 ***	3.873***
Eq. (ib)	8.446 ***		-4.992***	-8.230***

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Hausmann Test

Before conducting a panel regression analysis, the Hausmann test is always employed to examine the appropriate model with an individual fixed or random effect. This paper carries out the random effect test, followed by the fixed effect test. Finally, the two models are compared so that the more suitable one can be selected. As presented in Table 6, the statistical value of the Hausmann test is 53 (P<0.01), indicating that the latter is better suited to this study.

Table 6
Results of hausmann test

Model selection	Statistics	Statistical value	Prob.
Fixed effect	F-statistics	42.52	0.000
Random effect	Chi-square-statistics	222.73	0.000
Hausmann test	Chi-square-statistics	53.00	0.000

Regression Results

Direct Effect

This study adopts the approach of stepwise regression through Models 1 and 2, as shown in Table 7. Controlling the variables of labor, government intervention, and openness, there remains a beneficial impact of green finance on GEG after adding the dummy variable of COVID-19, R^2 increases from 0.403 to 0.454. Labor (urban unemployment rate) negatively affects GEG at a significant level. Government invention and openness all have a positive effect. This study further supplements the panel quantile regression and finds that green finance enhances GEG at the 0.25, 0.5, and 0.75 quartiles, while this boosting effect accelerates as the levels of GEG increase, with the impact coefficient rising from 2.154 to 3.212, indicating that green finance has a greater influence with higher levels of GEG. Since all results show that green finance positively affects GEG, it is assumed that H1 is supported.

Table 7
Results of panel fixed effect and quantile regression

Variable	Model (i)		Q25	Q50	Q75
	GEG	GEG	GEG	GEG	GEG
Green finance	2.388**	2.215**	1.301	2.154**	3.212**
	(0.957)	(0.917)	(0.946)	(0.866)	(1.502)
COVID-19		0.036***	0.038***	0.036***	0.035**
		(0.007)	(0.009)	(0.009)	(0.015)
Labor	-3.879***	-4.022***	-4.222***	-4.035***	-3.803***
	(0.605)	(0.580)	(0.814)	(0.742)	(1.292)
Government intervention	0.338***	0.343***	0.365***	0.344***	0.318**
	(0.067)	(0.064)	(0.095)	(0.087)	(0.151)
Openness	0.056***	0.027**	0.018	0.027*	0.037
	(0.011)	(0.012)	(0.017)	(0.015)	(0.027)
_cons	0.294***	0.306***			
	(0.031)	(0.030)			
R^2	0.403	0.454			
N	341	341	341	341	341

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

This study finds that green finance is proven to contribute to GEG in China, confirming that China could significantly enhance GEG through green finance policy. There are some similar research. For example, green finance considers more about the environmental benefit and strengthens environmental protection through channelling green funds (Al-Qudah et al., 2022; Zhou et al., 2020). Financial restrictions imposed by green credit regulation on polluting businesses might encourage enterprises' innovation in green technology, leading to the shift of emerging economies to a sustainable economy (G. Hu et al., 2021). In fact, as early as 2020, China proposes to achieve a carbon peak and carbon neutrality. It is estimated that China has to invest hundreds of billions of dollars in green projects to achieve carbon reduction (Yu et al., 2020). According to official statistics, China's green credit balance was 22.03 trillion yuan in 2022, an increase of 92% from 2020. In terms of the investment direction of the funds, the infrastructure green industry, renewable energy industry, and industry for ecological protection and energy efficiency contributed 44.6%, 25.8%, and 14%, respectively. There is no doubt that China's green finance investments in clean energy, green industries, and other areas contribute to improving environmental quality and GEG.

Additionally, there is a new finding that regions with higher levels of GEG can benefit more from green finance. One reason lies in the fact that the regions with higher levels of GEG are located mostly in the developed eastern coastal regions, as can be seen from Fig. 3, where environmental awareness is stronger and investment in green innovation and green industries for emission reduction is greater, so the effect of GEG is more evident. Another possible explanation is that developed regions have stricter environmental regulatory systems, leading to more effective use of green finance, as evidenced by its greater contribution to GEG. This discovery will provide new insights into the formulation of policies in different provinces.

The dummy variable of COVID-19 also exhibits a positive effect on GEG. This could be attributed to the epidemic's limitations on population mobility and consumption, especially offline contact-based consumption, as well as businesses' decreased orders and production demands, which have enhanced environmental preservation even though they have hampered economic expansion.

Mediating Effect of ISU

In terms of the mediating effect of ISU in models (ia) and (ib), green finance significantly affects ISU (beta =15.893, P<0.05) in Table 8. Green finance and ISU all have significant effects on GEG; the coefficients are 1.586 (P<0.1) and 0.040 (P<0.01), respectively. Since the results show that ISU positively mediates the relationship between green finance and GEG, it is assumed that H2 is accepted. Furthermore, the results of the modified Sobel test confirm the mediating effect of ISU, which accounts for 28.4% of the total effect. In summary, all of the findings demonstrate that green finance promotes eco-friendly industries and the tertiary industry through financial support, and the improvement of ISU facilitates the achievement of GEG in China.

Table 8
Results of the mediating role of ISU

Variable	Model (i)	Model (ia)	Model (ib)
	GEG	ISU	GEG
Green finance	2.215**	15.893**	1.586*
	(0.917)	(7.967)	(0.894)
ISU			0.040***
			(0.008)
COVID-19	0.036***	0.156***	0.030***
	(0.007)	(0.046)	(0.007)
Labor	-4.022***	-10.268***	-3.616***
	(0.580)	(3.929)	(0.566)
Government intervention	0.343***	1.940***	0.266***
	(0.064)	(0.435)	(0.064)
Openness	0.027**	0.863**	-.007
	(0.012)	(0.0812)	(0.013)
_cons	0.306***	0.571***	0.283***
	(0.030)	(0.202)	(0.029)
R^2	0.454	0.557	0.484
N	341	341	341
Sobel test (Indirect effect)		Z-value =2.262**	
Proportion of total effect that is mediated		28.4%	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The findings confirm the facilitating effect of green finance on ISU as well as the economic and environmental benefits of GEG brought by ISU, which correspond with earlier research (Jing et al., 2021; Wang & Wang, 2021). Furthermore, ISU also mediates the relationship between green finance and GEG. In actuality, China's national economy has long been based primarily on the secondary sector, which is the biggest source of pollution due to its high levels of energy consumption and pollution (Fang & Yu, 2021). Utilising green funding policies, green finance distinguishes between high-pollution, high-consumption industries and green sectors, thereby upgrading the industrial structure. China's ISU (the ratio of tertiary to secondary sectors) has grown by 43% between 2010 and 2022, from 0.92 to 1.32. Consequently, the limitation of polluting activities and the increase of green business initiatives update the industrial structure, which in turn will benefit the environment and GEG. Nevertheless, the ratio of tertiary to secondary sectors in China has been gradually enhanced to 1.32 in 2022, but it still lags behind developed nations like Germany (2.68) and the United Kingdom (4.95) because the tertiary sector, which includes financial services, digital automation technologies, software, and so on, has the lowest pollution and the highest added value. Therefore, China needs to accelerate the upgrading of industry structures to carry out economic structural transformation and realize green development.

The mediating role of ISU has also been verified in similar literature. For example, ISU acts as a mediator in the negative link between financial development and carbon emissions; that is, financial development improves ISU, which in turn reduces carbon emissions (Chu et al., 2022). Compared with this study, the following highlights the significant distinctions in this study: (1) Green finance places a greater emphasis on environmental preservation than financial development does; (2) GEG reflects a comprehensive index that encompasses more than just environmental protection. This suggests that the research has been carried out more thoroughly than previous studies.

Endogeneity Test

Green financing and GEG might have a reverse causal connection since green finance is an outcome of the advancement of a green economy over time (Deng, 2008), and the state of green finance varies greatly due to variations in environmental laws, ecological circumstances, and goals for economic growth (Li et al., 2021). Hence, this study uses the two methods of 2SLS and System GMM to alleviate the potential endogeneity problem.

First, the first-order and second-order lagged variables are chosen as the instrumental variables to replace green finance based on the 2SLS model. Second, replace the static model with the dynamic System GMM model. As seen in Table 9, the fitted green finance still has a positive effect (beta=3.696, $P<0.01$) in the 2SLS model, as well as the results in System GMM (beta =1.303, $P<0.05$). Both methods pass the relevant tests, indicating the robustness of the findings in this paper.

Table 9
Endogeneity test

Variable	2SLS	System GMM
	GEG	GEG
L.GEG		1.046***
		(0.059)
Green finance	3.696***	1.303**
	(1.276)	(0.605)
Control variables	Yes	Yes
_cons		0.047***
		(0.011)
N	279	310
Sargan test	P = 0.704	P = 0.213
AR(1)		P = 0.001
AR(2)		P = 0.809

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Conclusions

This study first newly constructs the GEG index with a 3-dimension and 17-indicator to objectively reflect the real development status of each province in China. Based on the theoretical framework and hypotheses of this study, the fixed effect and panel quantile regression models are adopted to examine the enhancing role of green finance on GEG as well as the mediating effect of ISU.

The overall results show that: (1) The GEG index constructed in this study accurately reflects and distinguishes from the actual situation in 31 Chinese provinces, indicating that the index is valid. (2) Green finance positively affects GEG, and this boost will increase as the level of GEG rises. (3) ISU plays a mediating role in the effect of green finance on GEG, which makes up 28.4% of the total impact. (4) Despite undermining the economy, COVID-19 exhibits an active effect on GEG.

There are also some suggestions for policymakers and investors. First, local policymakers should create a green financial system and provide enough green funds for green projects, as this fundamentally contributes to fostering GEG. Second, they also need to realize that the higher the level of GEG, the greater the role of green finance in promoting GEG. Low-level provinces could catch up with high-level provinces by improving 17 indicators to accelerate local GEG. Third, policymakers might focus on the intermediary function of ISU so as to transform the economic growth model through the development of green industry and the tertiary sector. Fourth, investors could shift their attention to green investment projects for long-term investment returns, as they have broad market, consumer, and government backing due to their ability to balance economic and environmental benefits.

The shortcomings of this paper are as follows: First, the findings of this study indicate that green finance promotes GEG, and this boost is also regulated by different levels of GEG. Hence, more research should be performed to determine the possibility of a heterogeneous effect of green finance on GEG in the eastern, central, and western regions. Second, the GEG index's stratified map (Fig. 3) has distinct regional aggregation features, suggesting that the influence of green finance on GEG may have a spatial spillover effect. Further regional or spatial analysis can be performed in future research.

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