The Nexus between Green Finance and Environmental Quality in China

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Abstract

Sustainable development maintains a balance between economic growth, environment, and standard of living. Many countries worldwide are facing environmental degradation, which has become a major obstacle to economic growth. Thefinancial sector has played an important role in developing economic sectors by providing quick necessary funds, and the environmental sector is no exception.Therefore, this study aims to investigate the nexus between green finance and financial innovation and their impact on the environmental quality situation in China from 1995 to 2021. To investigate the financial and environmental nexus, we have applied the ARDL model. The results confirm that the long-term projection associated with green finance significantly affects CO2 emissions.Similarly, the financial innovation long-run estimation is significant and positive in the CO2 emission models.This result shows that CO2 emission is reduced in China when green finance increases. Therefore, the environmental quality is improved. Green finance is positive and significant in the shortrun with CO2 emission. The results suggest some important policy implications.

Keywords: Green Finance, Financial Innovation, And Environmental Quality

China is a country in the developing nations that have witnessed a great industrial upswing, due to which considerable emission has been reported (Hammoudeh et al., 2020). As per the statistics of the world resource institute, China has been leading the world in CO2 emissions since 2005 (Q. Yang et al., 2022). In China in 2020, CO2 emissions accounted for around 98.94 billion tons, making China the first emitter of CO2 due to environmental degradation and affecting the Chinese carbon neutrality goals (Lee and Lee, 2022). International Energy Agency (IEA) reported that CO2 emissions from global industrial processes and energy consumption would increase by 6 percent yearly; in 2021, it reached 36.3 billion tons. China emits more than 11.9 billion tons of CO2 emissions, accounting for 33 per cent of the total globe annually. Environmental degradation due to high CO2 emissions is imagined to be a severe threat to Chinese economic growth and carbon emission neutrality goals (D.-X. Yang et al., 2021). Moreover, it has been highlighted that China will achieve the world's largest reduction in the intensity of CO_2 emission, reaching the peak of carbon emissions and achieving carbon emission neutrality in the shortest possible time. To achieve CO_2 emission neutrality goals, The Chinese government needs a comprehensive green revolution transformation of the society and economy through comprehensive green innovation (Singh et al., 2020). Financial innovation, renewable energy use and green finance are mostly considered an implacable solution for CO_2 emissions reduction, as it contributes to cleaner production and improves energy efficiency (Balsalobre-Lorente, 2022). In this regard, renewable energy, financial innovation, and green finance are effective tools for tackling environmental crises. Recent research in green finance has endorsed a remarkable reduction in greenhouse gases (Jian and Afshan, 2022). Green financing and renewable energy projects are very helpful in dealing with environmental challenges(Ozturk and Ullah, 2022). One of the basic reasons for green finance is its contribution to the natural environment (Madaleno et al., 2022). In the last few years, the financial sectors of the developed nations have endorsed that green financial instruments play a role in sustainable growth that counters the challenges of the environment confronted by numerous nations (Irfan et al., 2022).Many studies have identified the relationship between green finance and environmental quality. Green finance measured both the cost and benefit of economic growth (Rannou et al., 2021). The origination system of green finance supports technological innovation in the renewable energy sector (Liu et al., 2017).Hence, green finance is an important tool for solving environmental issues and promoting human welfare. Therefore, environmental quality is a key problem developing countries face worldwide(Sharma et al., 2020). It is important to explore how green finance can promote environmental quality. Some studies have explained the concept of green finance from a micro perspective(Acheampong et al., 2020). In contrast, few studies have accurately measured green finance development or quantitative measures for exploring environmental issues and green finance. As a key course for future financial development worldwide, green finance development is a major advance in environmental quality and human welfare(Falcone and Sica, 2019). Green finance, renewable energy, and financial innovation positively impact environmental quality(Dong et al., 2022). Green finance specifies financial institutions should incorporate environmental assessment into their investment activities and financing (Sachs et al., 2019).A prominent feature of green finance is that it emphasizesthe environmental benefits of society, such as health and well-being.It considers the consumption of resources as an important criterion for determining the effectiveness of its achievements, so it can validate its socioeconomic,and environmental development by considering the welfare and health outcomes of the society. The association between green finance and environmental quality suggested the environmental problems could be addressed through financial instruments (Z. Li et al., 2022). For example, the world's leading should give practical considerations to the expansion of green finance to promote environmental and economic development. Relevant literature of (Z. Li et al., 2022; Muhammad et al. 2019; Azam et al., 2022), (Naiwen et al., 2020), and (Wang et al., 2020) pointed out that green finance promotes environmental quality with the help of monetary funds.It is worth noting how important financial development is for a country's economy (Singh et al., 2020; Naseem et al. 2023). Also, it is impossible to ignore the prominence of financial inclusion as an element of financial development. At the turn of the millennium, a study that recognized financial exclusion as a root cause of poverty illuminated the concept of financial inclusion in poor living conditions(Luo et al., 2021; Naseem et al., 2019). Financial inclusion means that everyone in a country, including businesses and individuals, should have easy access to a wide range of financial goods and services in an appropriate, affordable, and suitable manner(World Bank, 2018).Although several studies have explored the association between economic development and environmental quality, research on the impact of financial inclusion on CO_2 emission is just beginning. CO_2 emission can be positively or negatively affected by financial inclusion. As stated earlier, investment is clean technology is made more possible through access to and utilization of financial services. The optimistic effects of a more climate financial system can be realized through the sector's increased affordability, accessibility and adoption of high-population (Wei Li and Hu, 2014).Better financial inclusion is helpful for economic disadvantages, who frequently lack the resources to invest in clean technology that emits low-carbon emissions (Ren et al., 2020).This result suggests that increasing access to financial services can help green technology get on the ground by raising money for environmental initiatives.On the other side, the financial inclusion positive change can increase industrial and manufacturing activities, which in turn can lead to increased CO2 emission and environmental degradation (Orman, 2015; Naiwen et al., 2022).Similarly, consumer buyers may buy more energy-concentrated goods due to cheaper access to finance and credits, significantly increasing carbon pollution. Financial innovation is envisioned as a tool for funding environmental creativities. In this regard, (Wei Li and Hu, 2014)confirmed the financial innovation's positive role in the clean water Implementation Act in the USA. (W. Li et al., 2021)found that green innovation encourages financial innovation in the context of strict environmental regulation and relatively low levels of banking opposition. According to(Jones, 2015),green finance is an important component of financial innovation in China's modern macro-environment. It is understood to be the main reason for the country's reduction in carbon intensity. (Unsal et al., 2021) noted that financial innovation in Asian economies has successfully curbed environmental damages. This is the key to realizing the transformation of the industry energy and achieving the carbon double standard and the basis for green growth and social changes (Huang and Zhang, 2021). However, financial innovation has a research and development R&D cycle, low profitability, and a high risk of failure, leading to insufficient incentives for green R&D and a low level of financial innovation in China.Given the above discussion, it is clear that the literature on the influence of green finance, energy consumption, and financial innovation on the environment is scarce. Furthermore, the present literature gives assorted evidence on the environmental quality. Thus, the nexus between green finance, energy use, financial innovation, and the environment need to be explored to gain clarity. Existing studies have utilized outdated approaches, which is another drawback of the available literature.The above arguments confirm that financial innovation and green finance significant roles in improving and conservation of environmental quality. Pragmatic evidence exploring the effects of green finance and financial innovation on carbon emissions in case of China is lacking.On the other hand, a handful of research has investigated the linkage between green finance, financial innovation, energy use and environmental quality, particularly the primary transmission channels. Unfortunately, there is no specific research on the impact of green finance policies and perspectives on internal transmission mechanisms on financial innovation or the long-term shock of green finance, and energy use on environmental quality.Thus, to fill this gap, this present study claim, to pragmatically examine the effects of green finance, energy use and financial innovation on the environmental quality of China. Moreover, China ranks second largest economy in terms of GDP which is the cause of emitting CO2, where the finance sector is developing that provide essential and future guideline for related stakeholders. This study's novelty lies in the following aspects. The main objectives of green finance to confirm sustainable environment through energy use and financial innovation. Thus, an important part of this study is to integrate green finance, financial innovation, and renewable energy projects use on environmental quality. Majority of the studies in this literature use green finance index. However, to examine the dynamics of green finance and financial innovation on carbon emission, we applied the ARDL approach. ARDL approach has best feature it provide short and long-run empirical relationship between the variables.

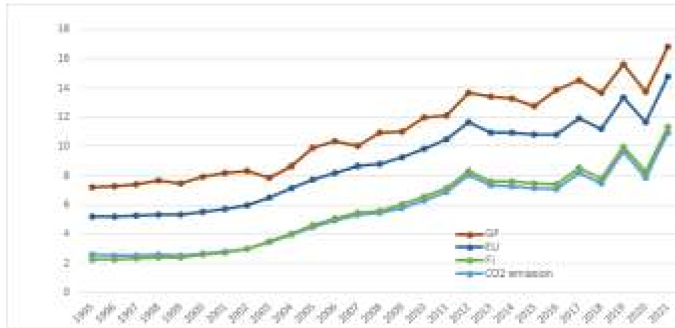

Fig: No.1 Graphically Representation of Variables

Methodology

Research Design

Green finance dynamically promote green innovation, economic development, and improves environmental quality (Yu et al., 2021). Green finance instruments are green bonds andgreen credits(Rannou et al., 2021). Green finance handover funds from the surplus segment to the shortfall segment and remove difficulties in the transformation of funds (Z. Chen et al., 2022). The climate financial theory indicates that green finance can be keyto gaining carbon neutrality goals (Qian et al., 2020). Similarly, green finance is an important innovative instrument that encourages economic activities which help in CO2 emissions reduction (He et al., 2019); (X. Chen and Chen, 2021).improves the financial innovation process and reduces financial risks and obstacles that help improve green innovation investment for environmental quality (Su et al., 2022). The causes of ideological research that green financial innovation can also play a vital role in environmental quality through many economic and social channels. (Meo and Abd Karim, 2022)Revealed that green finance, direct and indirect, effect CO2 emissions in the longterm. While green finance innovation also plays a lasting role in technological innovation and environmental quality (Sachs et al., 2019). Therefore, according to(Isbat Alam et al., 2020), we employed the following econometric model:

Model

CO2 = f (GF, EU, FI) UT

Whereas,

CO2 = CO2 emissions

GF= Green Finance

EU= Energy Use

FI= Financial Innovation

Estimation Technique and Data Collection

The purpose of the study is to explore the nexus between carbon emissions (CO2 emission), Green Finance (GF), Energy Use (EU), and financial innovations (FI). We collected data from different sources, which aredetailed in Table 1. We utilize Chinese data set covering the period from 1995-2021.The data period is selected based on data availability. We collect these variables' data to analyses the hypothesis testing empirically. China is the developing second-largest industrialized and fastest-growing economy in the world; Ffurthermore,it has become the largest CO2-emitting economy in the rest of the world due to the largest industrialization and manufacturing.Consequently, the country contributes greatly to the global climate and threatens the environmental sustainability of its own country. We used a variable to proxy environmental concerns, i.e. CO2 emissions, measured in metric tons.Green finance isused as a green finance proxy in renewable energy worth millions of USD. Research and development expenditure (R&D) as a % of GDP is used to measure financial innovation. Energy consumption as a proxy of energy use in kg of oil equivalent per capita. In conclusion, considering a small figure of data in mind, this study further utilises time series Chinese data for 1995-2021. Tie series data has been edited to the following general specification:

$$(CO_{2t}) = f(GF_t, (EU_t), (FI_t), \ldots .(1)$$

CO2 is carbon emission, GF is green finance, EU is energy use, and FI is financial innovation, while Tdenotes time. CO2 emissions are used as the dependent variable, while green finance (GF), energy use (EU), and financial innovation (FI) are independent variables.There is a positive impact on the Green finance model. We employed Autoregressive Distributed Lagged (ARDL) method model withCo-integrated approach (H. H. Pesaran and Shin, 1998); (M. H. Pesaran et al., 2001). The ARDL model has generally been utilized in recent empirical research according to some desired structure. Co-integration approaches, on the other hand, have some serious drawbacks: often, effective variable, large sample, and pre-test integration order for large sample and some pre-conditions (Engle and Granger, 1987); (Søren Johansen, 1995); (Soren Johansen and Juselius, 1990). However,the ARDL model provides long-term approachable valuations, corresponding to a limited sample size. ARDL model Structure is,for example, below:

$$(LNCO_{2t}) = a_0 + \beta 1LNEDU_t + \beta 2LNREC_t + \beta 3LNEMP_t + \varepsilon_t \ldots .(2)$$

All of these variables are transformed into logarithmic. The main purpose of the log using to avoidance from a complication of the estimated results; after transforming the variables into the natural log, below is the regression form in equation 2

$$\Delta CO_2 = a_0 + \sum_{t-1}^{a} a_1\, i\Delta GF + \sum_{t-1}^{a} a_2\, i\Delta EU + \sum_{t-1}^{a} a_3\, i\Delta FI + a_4 LNCO_{2t-i} + a_5 LNGF_{t-i} + a_6 LNEU_{t-i} + a_7 LNFI_{t-i} + \mu_t \ldots.(3)$$

A1, a2, and a3 represent the coefficient of variables, which estimated the short-run explanation, and a4, a5, and a6 assessed long-run coefficient estimation. In the third step process, the long-term coefficient (a3…a7) does not utilize the analysis with the dependent variable; therefore, it is utilized to become F-statistics restricted values. According to previous researchers, we also follow the ARDL three-stepin the first stage, equation (01), estimates are made, and the long-term coefficient is subsequently re-distributed to obtain the limitation of F-statistics. But, in the next stage, the F-statistics restricted value is examined, and the Co-integration among the variables is checked. We formulate the null hypothesis for the hierarchical model.

H0: a1 = a3, = 0 (long-term association between the variablesdoes not exist)

H1: α4= α7, ≠ 0 (long-term associationbetween the variables exist)

The subsequent limitation is mandatory for the particular boundaries of equation 3. The analysis procedure forthe null hypothesis is done based on F-statistics, or Wald Test, and ifthe null hypothesis is rejected, we can remove long-term estimation. We can move further towards long-term estimation.

$$CO_2 = \beta_0 + \sum_{t-1}^{d} \beta_1\, GF_{t-1} + \sum_{t-1}^{e} \beta_2\, EU_{t-1} + \sum_{t-1}^{f} \beta_3\, EU_{t-1} + e_t \ldots\ldots(4)$$

Where d, e, and f denote the upper bounds of the summary. Equation (4)measures long-term elasticity, but there may be short-term deviations from long-term stability; we then turn to an error correction model (ECM) to estimation these dynamic forces. It can be measured in the following way.

$$\Delta CO_2 = \lambda_0 + \sum_{t-1}^{j} \lambda_1\, i\Delta GF + \sum_{t-1}^{k} \lambda_2 i\Delta EU + \sum_{t-1}^{L} \lambda_3\, i\Delta FI + 1 + \varphi EC\, T_{t-1} + e_t \ldots\ldots(5)$$

The j, k, and L indication the upper limits of summation. The ECTt-1 is the error correction term and measures the coefficient of ECTt-1 speed of model adjustments. A negative sign of φwould suggest an assimilating property of the model, while a positive φ would indicate a divergence from equilibrium. The data period for Carbon emission (CO2), green finance (GF), energy use (EU), and financial innovation (FI) is taken from the different sources database (1995-2021). The detail of the variables and their abbreviation, definitions, and sources are given below in table 1. And descriptive statistics are shown in table 2; the mean value of CO2, GF, EU, andFI is 0.20, 1.61, 1.53, and 2.01, respectively.

Table 1 Variable Sources

Variable	Description	Sources
CO2	CO2 emissions (metric tons per capita)	www.worldbank.org
GF	Green finance in renewable energy projects (million USD at 2019 prices)	www.irena.org
EU	Energy use (kg of oil equivalent per capita)	www.iea.org
FI	Research and development expenditure (% of GDP)	www.worldbank.org

Table 3 Descriptive Statistic

	lnCO2	lnEU	lnFI	lnGF
Mean	0.207402	1.616163	1.537423	2.013328
Median	0.138915	1651.538	1.55536	138.1897
Maximum	0.565927	2564.873	2.50093	1245.184

	lnCO2	lnEU	lnFI	lnGF
Minimum	-0.147786	244.3352	0.56324	22.51020
Std. Dev.	0.212748	6.674330	0.590583	23.37755
Skewness	0.224842	-0.189220	-0.12955	0.570804
Kurtosis	1.876045	1.803787	1.769669	1.661682

Table 3 Unit root test

	DF-GLS			PP		
Variables	**I(0)**	**I(1)**	**Decision**	**I(0)**	**I(1)**	**Decision**
lnCO2	-2.17009	-5.59925***	I(1)	-2.35435	-5.46534***	I(1)
lnFI	0.376589	-4.55682***	I(1)	-0.27272	-4.55741***	I(1)
lnEU	-1.1317	-5.48911***	I(1)	-1.17489	-7.87008***	I(1)
lnGF	-4.21989***	-8.31661***	I(0)	-4.2093***	-13.605***	I(0)
Note: ***p < 0.01;**p < 0.05; *p<0.1.						

Empirical Analysis and Results

This study investigates the influence of green finance and financial innovation on environmental quality in China. This study practises time-series data, and volatility mainly arises in time-series data.Thus, confirming the stationarity of the data before using any essential regressions technique. We use DF-GLS and Phillips and Perron (PP) (Phillips and Perron, 1988) unit root tests to implement this task. The stationarity results of both unit rootsare present in table 3.After implementing the unit root test, the DF-GLS test reveals that green finance is stationary at the level, and the rest of the variables are stationary at first difference. The PP test outcomes illustrate that green finance is stationary at this level. And rest of the variablesare stationary at first difference. But, one of the requirements includes no variable must be at order 2. According to these findings, we employed the ARDL model for further investigation.

Baseline ARDL Estimation

This section shows the results of the ARDL model estimations. In this part, we apply the ARDL model in three basic phases. First, we estimate the equation; second, we select lag values In F-statistics to calculate the bound test. Therefore, once the bound test confirms and verifies the long-term association between the variables. Then, in the final phase, we will continue with long-term assessments and an error correction model (ECM). The bound test outcomes reveal that the F-values of the upper bound above show long-term association (see table 4). Table 5 represents the short- and long-run CO2 emission model coefficient estimates.

Table 4 Bound test

H0: No long-run relationships exist

Test Statistic	Value	K
F-statistic	5.236287	3
Critical Value Bounds		
Significance	Lower Bound	Upper bound
10%	2.37	3.2
5%	2.79	3.67
2.50%	3.15	4.08
1%	3.65	4.66

Table 5 ARDL Co-integrating and Long Run Form

Short Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNEU)	-0.02029	0.068846	-1.03828	0.0399
D(LNFI)	-0.03418	0.010433	-3.27604	0.0045
D(LNGF)	0.01888	0.010279	1.836827	0.0038
CointEq(-1)*	-1.77449	0.185072	-9.58812	0.0000
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNEU	1.02144	0.074009	13.80156	0.0000
LNFI	0.122532	0.069059	1.774308	0.092
LNGF	-0.03069	0.011321	-2.71119	0.0139
C	-2.50815	0.238483	-10.5171	0.0000

Table 5 representsour model's long and short-run estimation; the short-term co-efficient is under the error correction model (ECM). Usually, variables that achieve long-term equilibrium may diverge from long-term equilibrium; consequently, we use an error correction term to capture short-term deviation ECT (-1). Our short-term results recommend that green finance positively and significantly affects CO2 emissions. Each year, a 1% increase in green finance increases CO2 emissions by 0.7%. Similarly, energy use has a negative and significant relationship with CO2 emissions; a 1% decrease in EU leads to o.20% decrease in CO2 emissions. The same situation with FI has a significant negative association if FI 1% decreases CO2 emissions by 0.34%, respectively.The negative and significant coefficient error correction term reveals that our model has a converge property and shows that the ECT (-1) shifts towards the long-run equilibrium by 1% each year. Long-term results are not similar to the short-term coefficients; green finance significantly and negatively influences CO2 emissions. It shows that a 1% increase in green finance leads to a decrease in CO2 emissions by o.36% in short-term respectively.Similarly energy use and financial innovation have a positive and significant association with CO2 emissions; if both increase by 1% leads to an increase in CO2 emissions of 10% and .12% increases in the short-term,respectively. We also find that the short-run coefficient shows a higher value thanthe long-term coefficient, which reveals that CO2 emissions are a comparatively higher impact in the shortrun. Our results confirm that green finance significantly affects environmental quality. A similar association is reported by(Isbat Alam et al., 2020); (Meo and Abd Karim, 2022).

Diagnostic Test

Table 6 Diagnostic Test

Diagnostic Test	Problem	(P-Value)	Decision
LM	Serial Correlation	0.3092	No serial correlation exists
Breusch-Pagan-Godfrey	Heteroskedasticity	0.0802	No Heteroskedasticity exist
Ramsey Reset test	Model	0.0425	The model is correctly specified
VIF	Multicollinearity		No multicollinearity exists

Table 6confirms previous results and categorizes any error in our results; for example, the Autocorrelation problem that occurs in most time-series studies. Model stability that further strengthens our analysis, a correlation test is applied to detect the autocorrelation problem in our present model using the LM test. The autocorrelation outcomes recommend there is no problem with autocorrelation. Breusch Pagan-Godfrey represents that there is no heteroscedasticity in the model. Ramsey Reset suggests that the model is properly stated. VIF indicates that there is no multicollinearity. All diagnostic tests indicate that our empirical outcomes provide a valid approximation and the model has no serious flaws.

Robustness Test

Further confirming the estimates of the baseline ARDL model, this study applied the Granger Causality test (Granger, 1969). Table 5 shows the Granger Causality outcomes, and we infer a unidirectional causality between the CO2 emissions and LNEU, CO2 emissions and LNFI as the F-statistics are insignificant in one case. There is a unidirectional causality between CO2 emissions and LNGF. Also found unidirectional causality running from LNEU to LNFI. According tothe results, no causality was found between LNEU and LNGF. And between LNFI and LNGF because the F-statistics are insignificant in both Cases.

Table 7: Granger Causality Test

Null Hypothesis:	Obs	F-Statistic	Prob.
LNEU → LNCO2	23	6.08822	0.0047
LNCO2 → LNEU		0.85301	0.5152
LNFI → LNCO2	23	5.29574	0.0105
LNCO2 →LNFI		0.7409	0.5797
LNGF → LNCO2	23	0.29575	0.8759
LNCO2 →LNGF		4.05165	0.0402
LNFI →LNEU	23	2.70734	0.0734
LNEU → LNFI		0.51369	0.7269
LNGF → LNEU	23	0.52042	0.7223
LNEU → LNGF		1.59734	0.2298
LNGF → LNFI	23	1.22035	0.3462
LNFI →LNGF		0.39925	0.806

Conclusion and Policy Recommendation

The concept of Green finance, renewable energy and financial innovation theories have flourished in the finance literature. This conceptis related to the development of financial institutions, which played an important role in the development of each department by providingnecessary funds. The field of the environmental quality sector is no exception. However, no pragmatic evidence has examined the impact of financial development on environmental quality. Therefore, we aim to examine the impact of green finance, energy use, and financial innovation on China's environment. Before conducting the empirical analysis, we check the variable's stationarity.For this purpose, we have used pp and DF-GLS as unit root tests for the stationarity of variables. The outcomes of both tests show that variables are stationary at level I (0) and the first difference I (1). Based on the outcomes, we applied the ARDL model for different integration orders of variables. The outcomes confirm that green finance is positively significant in the short-run estimation.Likewise, financial innovation and energy use are both significant and negative in the short-run estimation. This means increased financial innovation and energy use are environmentally friendly in China. In the long-run estimation, green finance is negatively significant to CO2 emissions in China. But, financial innovation and energy use are both positive and significant in the long run. Furthermore, the causality outcomes a unidirectional causality between the CO2 emissions and energy use, CO2 emissions and financial innovation. There is a unidirectional causality between CO2 emissions and green finance. And also found unidirectional causality running from energy use to financial innovation. According to the results, no causality was found between energy use and green finance and financial innovation and green finance.According to these outcomes, we have suggested some optional policies for stakeholders. First, policymakers should direct the flow of green finance to green production activities, green technology, and renewable energy sources projects that can improve and preserve the environment in China.Second, policymakers can encourage financial institutions to provide credit to stakeholders and manufacturers to upgrade their machinery and shift the structure towards renewable energy in China. Third, the conclusion is that environmental quality improvement and environmental and financial policies must be integrated to achieve the carbon neutrality goal. Last, governments should direct the institutions to provide essential funding at a concessional rate for green infrastructure investment. And also provide interest-free loans for green innovation. Green and low-carbon production technology must be adopted to reap the maximum benefits of green finance. Therefore, enterprises should expand traditional production techniques and shift them towards green technology and renewable energy projects. As well, financial institutions should provide financial support to enterprises.This study explores the impact of financial innovation and green finance at the comprehensive level in China. It does not cover effects at the heterogeneous level due to data limitations. In upcoming studies, an investigation should be conducted for the contrast level to provide proper policy recommendations at the proportional level in China. Coming studies should also redirect other factors that affect environmental quality. Inconsistencies in associations may weaken deeper links between selected variables; therefore, asymmetric associations can overcome this problem.

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