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Green finance and mining development: evidence from China

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Abstract

Based on panel data from Chinese provinces (2014-2021), we employ a fixed-effects model incorporating composite indices of green finance, regional disparities, and mining development. The results demonstrate that green financial development significantly constrains mining sector growth, particularly in regions heavily dependent on polluting fuels and related industries, while showing notable regional heterogeneity. Mechanism analysis reveals that while green finance initially hampers traditional mining operations, it ultimately enhances air quality and reduces pollution by promoting cleaner production methods. These findings suggest that green finance, despite its short-term growth-inhibiting effects, fosters a more sustainable and efficient mining sector in the long run. This nonlinear relationship warrants further investigation in future research.

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1. Introduction

Since 2014, China's mining industry has transitioned from resource dependence to sustainable upgrading amid increasing global sustainability demands. Despite enhancements noted in the "China Mining Development Report," challenges in productivity and technology persist, compounded by significant ecological damage and environmental quality issues (Wang & Lu, 2022; Wu et al., 2023; Wu, 2024). Resource-based industries' reliance on external capital and technology has driven the adoption of green financial instruments, crucial for fostering sustainable mining through technological and environmental investments (Wang and Lu, 2022; Wang et al., 2023).

Green financial policies are key in mitigating mining's environmental impacts, enhancing resource efficiency, and balancing environmental and economic goals (Zhou et al. 2020; Wu, 2024). Studies have also highlighted green finance's role in promoting technological and environmental improvements (Wang et al., 2022; Yu et al., 2023; Chu et al., 2024). However, research on their specific mechanisms and varied effects within the mining sector remains limited.

Most existing literature focuses on the overall effect of green finance on mining development, and shows a significant role it plays in promoting mining growth (Chu et al., 2024; Ge et al., 2024; Xue et al., 2024). Nonetheless, most of these studies fail to provide a detailed examination of how green finance affects mining development across different regions. For example, the research of Wang et al. (2022) and Chu et al. (2024) shows that green finance can further improve technological level and resource efficiency to enhance mining development, However, these studies do not examine regional differences, even though scale effects across different regions likely exist. This study aims to explore the regional differences, especially between economically developed and undeveloped areas.

Moreover, previous researches also pointed out that the differences in regional green finance implementation to promote mining development vary among regions (Asr et al., 2019; Cole and Broadhurst, 2022; Wu, 2024). But because these studies have not explored other factors due to the limitations of their illustrative method, such as regional differences in economic structure and the degree of financial system maturation, this model has insufficient interpretability for green finance impact on mining development. This paper will elucidate how these factors work together to produce different affects from green finance in each country by a more detailed data analysis, including stratified regression.

Last, although some researches (Wang and Lu, 2022) have started to examine this topic for certain sectors such as resource-intensive industry there is still no analysis on the heterogeneity of these impacts within sub-sectors like mining. A natural corollary to this is the extent to which green finance may impact traditional high eye-popping pollution industries such as coal, oil and gas differently than it does their possibly somewhat cleaner energy mining sectors. With this, the research objective of our article is to contribute towards filling in a gap by looking at different sub-sectors more detailed through granular data and exploring for differential impacts on green finance within the mining industry sector.

In conclusion, this paper will explore the impact of green finance on mining development from multiple dimensions, including regional heterogeneity, industry heterogeneity, and impact mechanisms, thereby addressing the gaps in the existing research.

2. Research design

The following panel model is constructed to investigate the impact of green finance on mining development:

$$\begin{aligned} MiningDev_{it} = \alpha &+ \beta_1 GreenFinance_{it} + \beta_2 Industrialize_{it} + \beta_3 GDPpcGrowth_{it} \\ &+ \beta_4 Urbanization_{it} + \beta_5 Education_{it} + \beta_6 RnD_{it} + \beta_7 FDI_{it} \\ &+ \beta_8 EnergyStruct_{it} + \gamma_i + \lambda_t + \varepsilon_{it} \end{aligned}$$

The variables in the model are defined as follows:

$MiningDev_{it}$: The level of mining development in province *i* at time *t*, represented as the growth rate of the mining industry. $GreenFinance_{it}$: The level of green finance in province *i* at time *t*, represented as the growth rate of the green finance index. $Industrialize_{it}$: The level of industrialization in province *i* at time *t*, represented as the growth rate of the industrialization index (Perez and Claveria, 2020). $GDPpcGrowth_{it}$: The growth rate of GDP per capita in province *i* at time *t*, reflecting the impact of economic growth on mining development. $Urbanization_{it}$: The level of urbanization in province *i* at time *t*, represented as the growth rate of urbanization. $Education_{it}$: The level of education in province *i* at time *t*, represented as the growth rate of education levels. RnD_{it}: The level of research and development investment in province *i* at time *t*, represented as the growth rate of R&D investment. FDI_{it}: The level of foreign direct investment in province *i* at time *t*, represented as the growth rate of FDI (Fu, 2008; Wu et al., 2021). $EnergyStruct_{it}$: The energy consumption structure in province *i* at time *t*, represented as the growth rate of the energy consumption structure.

Green Finance is constructed as a composite index integrating four provincial-level indicators (green credit, green insurance, green bonds, and green funds). The Green Finance index is constructed as a composite measure integrating four equally weighted provincial-level indicators: green credit, green insurance, green bonds, and green funds. Following Wu and Yang (2021), we adopt the geometric mean (square root of the product) to aggregate these components, as it mitigates the influence of extreme values and better reflects the synergistic development of multi-dimensional green financial instruments. This approach is widely used in green finance literature (e.g., Zhou et al., 2020; Sun & Chen, 2022) and ensures both transparency and replicability. **Industrialization Level** is proxied by the average annual growth rates of petroleum, natural gas, and coal extraction, reflecting the intensity of resource-based industrial activities, which is supported by Perez and Claveria (2020). **Per Capita GDP Growth Rate** serves as a key indicator of economic growth, reflecting the economic development pace across provinces during the study period. **Urbanization Level** is measured by the urbanization rate of the population in each province, reflecting the impact of urbanization on economic and social development. **Education level**, as measured by the proportion of educational investment to GDP, shows relatively small variation among provinces, indicating limited regional differences in educational investment levels (Wang and Lu, 2022). **R&D Investment** reflects the technological innovation capacity of each province and is measured by the proportion of R&D investment to GDP (Fu, 2008). **Foreign Direct Investment (FDI)** captures the ability of regions to attract international capital, reflecting the degree of economic openness in a global context (Wu et al, 2021). **Energy Consumption Structure** primarily measured by the share of clean energy in total energy consumption.

These data are primarily sourced from the CEINET Statistics Database, as well as relevant national and provincial statistical yearbooks and databases, ensuring the accuracy and consistency of the research data. The data of all variables span the years 2014 to 2021, with annual statistical frequency. The description data resource, the descriptive statistics, and the VIF test of variables are shown in the Appendix 1. In the estimation process, the Hausman test is employed to determine whether a fixed effects model (FEM) or a random effects model (REM) should be used, as shown in Appendix 2.

3. Results

3.1 Benchmark regression

According to the Hausman test results, the fixed effects model is more appropriate than random effect model. Meanwhile, we also give the RE results as a comparison, as shown inTable 1.

Table 1: Benchmark regression

	(1)	(2)
	FE	RE
	MiningDev	MiningDev
GreenFinance	-0.1840***	-0.0244**
	(-6.02)	(-2.45)
Industrialize	-0.0779	-0.0807
	(-0.39)	(-0.72)
GDPpcGrowth	-0.358***	-0.406***
	(-3.32)	(-3.70)
Urbanization	-0.221***	-0.354***
	(-3.82)	(-6.76)
Education	-0.189	-0.155
	(-0.82)	(-0.72)
RnD	-0.152**	-0.199***
	(-2.02)	(-2.63)
FDI	-0.00660	-0.00787
	(-0.65)	(-0.74)
EnergyStruct	0.0539	0.00808
	(0.77)	(0.41)
Constant	0.354***	0.0705
	(3.12)	(1.55)
Year Fixed Effect	Control	Control
Province Fixed Effecgt	Control	Control
Observations	232	232
R^2	0.431	

t statistics in parentheses

** $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

The baseline regression in the fixed effects model shows that green finance negatively affects mining development with a significant coefficient of -0.184 at the 1% level, suggesting that as green finance increases, traditional mining investments decrease. The coefficient in the random effects model is also negative but smaller (-0.0244) and not significant at the 5% level, reinforcing that the fixed effects model more accurately captures the impact of green finance. Moreover, robustness tests excluding data from municipalities under central government and the COVID-19 period still show a significant negative impact of green finance, validating the credibility of the regression results (as shown in Appendix 3).

3.2 Heterogeneity analysis

Heterogeneity analysis was employed to investigate the varying effects of green finance on the development of the mining industry across different regions—specifically, the eastern, central, and western regions of China. This approach was necessary to understand how regional economic structures and resource dependencies influence the impact of green finance, as shown in Table 2.

Table 2: Heterogeneity analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	East	Middle	West	East	Middle	West
GreenFinance	-0.148***	-0.188**	-0.242***	-0.0954	-0.0695	-0.0989
	(-3.63)	(-2.54)	(-4.31)	(-1.12)	(-0.40)	(-0.81)
Industrialize	0.795*	0.0589	-0.666**	2.324***	-0.0343	-0.663
	(1.76)	(0.19)	(-2.05)	(2.86)	(-0.04)	(-1.10)
GDPpcGrowth	-0.381**	-0.248	-0.729***	-0.353**	-0.234	-0.646***
	(-2.11)	(-1.34)	(-3.46)	(-2.01)	(-1.24)	(-3.11)
Urbanization	-0.316**	-0.771***	-0.135	-0.304**	-0.669**	-0.131
	(-2.67)	(-2.94)	(-1.65)	(-2.52)	(-2.37)	(-1.63)
Education	-0.505	0.0119	-0.0614	-0.222	-0.0199	-0.270
	(-1.22)	(0.03)	(-0.16)	(-0.53)	(-0.04)	(-0.70)
RnD	-0.392**	-0.202*	-0.136	-0.336*	-0.189	-0.148
	(-2.11)	(-1.69)	(-1.08)	(-1.79)	(-1.56)	(-1.21)
FDI	-0.0450	-0.00157	-0.0168	-0.0674	0.0039	-0.0144
	(-1.09)	(-0.04)	(-1.47)	(-1.64)	(0.09)	(-1.29)
EnergyStruct	-0.244	0.0897	0.147	-0.702	0.383	0.405**
	(-0.88)	(0.94)	(1.16)	(-1.20)	(1.32)	(2.47)
GreenFinance×Industrialize				-0.725**	0.0415	0.198
				(-2.25)	(0.11)	(0.48)
GreenFinance×EnergyStruct				0.157	-0.133	-0.200**
				(1.07)	(-1.08)	(-2.40)
Constant	0.336	0.267	0.440**	0.371	-0.0100	0.161
	(1.03)	(1.30)	(2.38)	(0.74)	(-0.02)	(0.71)
Year Fixed Effect	Control	Control	Control	Control	Control	Control
Province Fixed Effect	Control	Control	Control	Control	Control	Control
Observations	72	72	88	72	72	88
R^2	0.582	0.467	0.636	0.625	0.480	0.668

t statistics in parentheses

** $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

First, column (1) – (3) in Table 2 show that the effect of green finance on mining industry development is uniformly negative in all three regions. The regression coefficients for green finance in the eastern, central, and western regions are -0.148, -0.188 and -0.242, respectively. This means that green finance has a restraining effect on the development of the mining industry with the greatest impact in the western region. This may result from the relatively high reliance on resource - based economies in the west, where implementation of green finance raises the bar even higher for high-pollution, high-energy industry.

Table 2 (Columns 4-6) examines the interaction effects between green finance and two key factors - industrialization and energy consumption structure - in influencing mining development. The results reveal distinct regional mechanisms: In eastern regions, green finance demonstrates a significant negative interaction with industrialization ($\beta = -0.725$), indicating that it effectively restrains industrial expansion and facilitates a structural shift toward less resource-intensive tertiary industries, thereby indirectly suppressing mining development. In western regions, green finance shows a statistically significant negative association with energy consumption structure ($\beta = -0.200$, $p < 0.05$), suggesting that financial instruments for green development help curb mining growth by reducing dependence on traditional, high-pollution energy sources.

In general, the findings analyse substantial regional variances in how green finance promotes allow industrial transformation. More than simply affecting the mining sector, green finance promotes a transition to tertiary industries in mining in the east of China and plays a role in reducing dependence on traditional energy sources for mines located at west areas.

3.3 Mechanism analysis

The goal of developing green finance is to reduce pollutant emissions, especially in the mining industry. Next, we have designed a mechanism analysis to discuss the causal relationships between green finance, air quality, and traditional mining. This will help us identify how green finance inhibits the development of traditional mining.

Table 3: Mechanism analysis

	(1)	(2)	(3)
	MiningDev	AQI	MiningDev
GreenFinance	-0.1210***	0.0696**	-0.1660***
	(-4.14)	(2.39)	(-5.24)
Industrialize	-0.253	-0.392*	-0.0073
	(-1.27)	(-1.96)	(-0.03)
GDPpcGrowth	-0.180*	0.299***	-0.342***
	(-1.68)	(2.80)	(-3.12)
Urbanization	-0.278***	-0.0148	-0.277***
	(-5.18)	(-0.28)	(-4.84)
Education	0.467**	0.877***	0.161
	(2.52)	(4.74)	(0.81)
RnD	-0.0645	0.173**	-0.155**
	(-0.85)	(2.27)	(-2.05)
FDI	-0.0080	-0.0168	-0.00234

	(-0.74)	(-1.55)	(-0.23)
EnergyStruct	-0.0364	-0.186***	0.0602
	(-0.51)	(-2.61)	(0.73)
L. AQI			-0.400***
			(-4.82)
Constant	0.411***	0.821***	0.541***
	(3.57)	(7.14)	(4.20)
Observations	232	232	203
R^2	0.320	0.393	0.436

L.AQI indicates the first-order lag of AQI, which avoids the endogeneity caused by potential reverse causality.

t statistics in parentheses

** p < 0.10, ** p < 0.05, *** p < 0.01*

Column (2) shows that green finance significantly improves the AQI compliance rate (coefficient = 0.0696, $p < 0.05$), indicating its positive environmental impact by promoting cleaner production. Meanwhile, column (3) reveals a strong negative effect of green finance on mining development (coefficient = -0.166, $p < 0.01$), suggesting it suppresses traditional mining activities. To address endogeneity, we include the lagged AQI compliance rate, finding that poorer past environmental quality further hinders mining development. This supports the conclusion that green finance restrains mining by improving environmental standards.

From the above mechanism analysis, this study digs deeply into how green finance achieves a negative relationship with mining development, and finds that the inhibitory effect of green finance on mining is not merely from cutting back traditional money to be invested in miners but comes from promoting the greening process for all sectors including mines. Our model reveals that green finance effectively ameliorates air quality, implying emissions reduction through pressuring mining companies to invest more on environmentally friendly technologies contributes to the adaptation of environmental transition for mining firms instead of merely stifling their development. So, although the relationship between green finance and mining development may seem negative at first glance, this relationship reflects the guiding and optimizing role of green finance in mining development.

4. Conclusion

The study reveals that green finance significantly influences China's mining industry, steering it towards sustainable practices. It shows that increased green finance leads to a decline in traditional mining, as investments shift to more sustainable technologies. This effect varies regionally, being more pronounced in economically advanced areas with superior financial systems and environmental governance. The analysis also demonstrates that green finance enhances air quality and reduces pollution by promoting cleaner production methods in mining. Although initially slowing traditional mining, green finance ultimately fosters a more sustainable and efficient sector. Policymakers are encouraged to strengthen green financial policies and adapt them regionally to enhance their effectiveness. The study acknowledges limitations, including a lack of detailed exploration into how green finance tools like green bonds affect the market, and insufficient analysis of regional impact disparities. It suggests future research could focus on supporting economic transformation in mining through green finance, enhancing environmental sustainability, and promoting technological innovation in the sector. Additionally, further studies could explore the role of green finance in sustainable development more broadly, possibly including international comparisons to assess the applicability of China's experiences elsewhere. Third, while this study focuses on economic and environmental mechanisms, it does not incorporate social indicators such as unemployment or income inequality, which could further elucidate the socio-economic implications of green finance transitions in mining-dependent regions. Future research could explore these social dimensions to provide a more holistic assessment of green finance's impact on sustainable development.

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