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Short Paper

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Abstract

Green innovation plays a pivotal role in fostering the harmonious development of economic growth and environmental preservation. This article employs a panel regression model using data from Chinese A-share listed companies spanning from 2011 to 2020 to investigate the influence of digital finance on corporate green innovation and its underlying mechanisms. The findings reveal that digital finance effectively facilitates green innovation by mitigating corporate financing constraints and reducing business risks. Furthermore, the study highlights the moderating role of government subsidies. Additionally, a heterogeneity analysis indicates that digital finance exerts a more pronounced impact on green innovation in the east-central region compared to the western region. The breadth and depth of coverage are significant factors influencing corporate green innovation, while the level of digitization exhibits no substantial effect. Consequently, this study contributes to establishing a theoretical foundation for leveraging digital finance to advance enterprises' transition towards sustainability.

Keywords: digital finance; corporate green innovation; government subsidies

Introduction

Emerging economies, including China, face significant pressure to mitigate carbon emissions and achieve the target of limiting global temperature rise to 1.5 degrees Celsius, as stipulated by the Paris Agreement. Promoting green innovation stands as a viable approach to ensure sustainable economic growth while effectively managing carbon emissions (Kong et al., 2022). Green innovation encompasses hardware or software advancements that specifically relate to green products or processes, including technologies aimed at energy-saving, pollution prevention, waste recycling, green product designs, and corporate

environmental management (Chen et al., 2006). Long-term and stable capital investment is a fundamental requirement for enterprises to engage in green innovation endeavors (Yu et al., 2021). On one hand, the long payback period, high investment risks, and information asymmetry between investors and enterprises make it challenging for enterprises to secure long-term and stable financial supports. On the other hand, the externalities associated with green innovation create a lack of motivation for enterprises to engage in green innovation activities. As for the long-term and stable capital investment of green innovation, traditional financial services face challenges in meeting the capital requirements of numerous enterprises engaged in green innovation due to high thresholds, elevated costs, and limited efficiency. As a result, digital finance, driven by the continuous advancement of digital technology, has garnered increasing attention across different sectors. Digital finance offers potential solutions to the capital constraints in the realm of green innovation through measures such as lowering thresholds, enhancing resource allocation, mitigating information asymmetry, reducing transaction costs etc. Based on the research of Ozili (2018), digital finance encompasses the full range of products, services, technologies, and infrastructure that enable individuals and companies to access payment systems, savings accounts, and credit facilities via the internet, eliminating the need for physical visits to a bank branch or direct interaction with financial service providers. As for the externalities of green innovation, existing scholars suggest that government subsidies can motivate enterprises to increase investment in green innovation.

Many recent works have explored various factors influencing green innovation, such as institutional quality (Sun et al., 2019), government subsidy (Huang et al., 2019), green finance (Irfan M et al., 2022). However, few studies have discussed the impact of digital finance on green innovation. In the limited number of empirical studies, the majority of existing research has explored the impact of digital finance on green finance from a regional perspective (Lin and Ma, 2022).From the perspective of firm-level research, existing scholars have reached inconsistent conclusions regarding the impact of digital finance on green innovation. Some scholars argue that digital finance can drive green innovation by alleviating financing constraints and resolving information asymmetry (Li et al., 2022). However, others believe that digital finance may disrupt the stability of the financial system and corporate operations, thereby hindering the improvement of corporate green innovation (Ozili, 2018). This paper argues that the explanation of its inconsistent conclusions may lie in the role of government subsidies. Firstly, government subsidies enable enterprises to sustain investments in green research and development (R&D) and maintain path dependence (Huergo et al., 2016). Secondly, government subsidies serve as interventions to address market failures, mitigate the externalities associated with green innovation, and incentivize enterprises to enhance both the quantity and quality of green output (Xiang et al., 2022). Therefore, this paper proposes these questions: as a new way of financial services, can digital finance drive corporate green innovation to achieve sustainable development? Is digital finance affected by government subsidies in the process of influencing corporate green innovation?

Research Hypotheses

Green innovation investment distinguishes itself from other types of investments through several key characteristics. Firstly, green innovation investment yields lower returns compared to other forms of investment due to its inherent high risk of failure. Moreover, the unpredictable nature of innovation hinders investors from accurately forecasting investment outcomes. Secondly, Adjustment costs are a pivotal element of green innovation in enterprises, requiring extensive knowledge accumulation and technological expertise. Consequently, enterprises must consistently invest in green innovation to prevent the attrition of R&D personnel. Thirdly, Insufficient financial support and incentives in the context of green innovation can lead to double externalities.

Given the aforementioned characteristics of green innovation and the absence of a robust risk transfer financial system, external sources are unlikely to provide enterprises with the necessary financial support. First, digital finance significantly enhances financial coverage by efficiently collecting massive data at low risk and cost, facilitating the absorption and integration of additional funds to meet the continuous and stable capital demand of the long tail group during green technology R&D (Nie et al., 2021). Moreover, as a powerful convergence of the financial and technological revolutions, digital finance profoundly impacts traditional financial institutions (Demertzis et al., 2018), improving the transformative vitality of existing financial sectors and promoting resource allocation efficiency. Through digital financial platforms, institutions can offer diversified green financial products, supported by access to millions of mobile

terminals via big data platforms and the Internet, employing digital technologies like artificial intelligence to expedite information matching, simplify lending processes, and reduce financing costs. Meeting the substantial funding needs for green innovation activities often triggers enterprises to proactively engage in corresponding green innovation efforts, ultimately elevating their level of green innovation. Thus, this paper propose the following hypothesis:

H1: Digital finance can promote green innovation in enterprises.

Due to the dual externalities associated with green innovation, enterprises are unlikely to fully capitalize on the benefits it offers. Government subsidies can serve as a remedy for the profit loss resulting from innovation externalities by providing direct financial support in the green technology R&D stage. Enterprises that receive government subsidies are more motivated to utilize digital finance to acquire additional external funding in order to fulfill government green projects and secure future subsidies for continuous investment in green R&D (Cin et al., 2017). Moreover, a higher level of government subsidies during the technology transformation stage indicates that the green projects undertaken by enterprises align with the national strategic development direction. The utilization of digital finance can reduce the risk associated with technology transfer, thereby enhancing both the quantity and quality of green innovation. In summary, this paper proposes the following assumptions:

H2: Government subsidies can strengthen digital finance's role in promoting enterprises' green innovation.

Research Design and Data Description

Model Construction

In order to test H1 and H2, as Xue and Zhang (2022) indicated, this paper sets the following regression model to be tested:

$$GI_{i,t} = \alpha_1 + \beta_1 DIF_{j,t} + \gamma_1 X_{i,t} + \sum Year + \sum Industry + \sum City + \varepsilon_{i,j,t} \quad (1)$$

$$GI_{i,t} = \alpha_1 + \beta_1 DIF_{j,t} + \delta_1 Sub_{i,t} + \theta_1 Z_{i,t} + \gamma_1 X_{i,t} + \sum Year + \sum Industry + \sum City + \varepsilon_{i,j,t} \quad (2)$$

Among them, i represents the enterprise, t represents the year, and j represents the city where the enterprise is located. GI represents enterprise green innovation; DIF is the level of digital financial development in the city; Sub represents government subsidies; Zi,t represents the intersection of digital finance and government subsidies; X is the control variable of other dependent variables. The year is the time-fixed effect, Industry is the industry-fixed effect, and City is the city-fixed effect; εi, j, t represents the random error term.

Variable Selection

Dependent Variable

Green innovation (GI): In 2010, the World Intellectual Property Organization (WIPO) launched the "Green List of International Patent Classifications". This paper uses the patent classification number in the China Research Data Service Platform (CNRDS) to retrieve and count the green patents of listed companies and uses the natural logarithm of (green patent application number + 1) to measure the green innovation level of listed companies (Hu et al., 2020). At the same time, to further investigate the heterogeneity of green innovation, the number of green invention patent applications (GI1) and the number of green utility model patent applications (GI2) represent the quality of green innovation and the number of green innovation, respectively.

Independent Variable

Digital Finance (DIF): Based on the practice of Guo et al. (2020), this paper draws on the "Peking University Digital Inclusive Finance Index" compiled by Peking University Digital Finance Research Center. The index constructs a digital inclusive financial index system from three dimensions: the breadth of digital financial coverage, the depth of digital financial use, and the degree of digitization of inclusive finance, including China's provincial level, city level, and county level. In the benchmark regression model, the digital inclusive

financial index at the municipal level is adopted, and the index is divided by 100 to solve the dimensional problem.

Moderating Variables

Government subsidies (Sub): The government subsidy data is derived from the details of government subsidies in the company's annual report, which is measured by the logarithm of the total amount of government subsidies in the year.

Control Variables

Many factors affect the green innovation of enterprises. This paper selects the following control variables: enterprise scale, asset-liability ratio, return on assets, TobinQ, capital expenditure, the proportion of independent directors, duality, nature of property rights, and audit opinions.

Intermediary Variable

Financing constraint (FC): Based on the research of Zhang et al. (2019), this paper takes the absolute value of the SA index as the measure of corporate financing constraints. The larger the value, the more serious the financing constraints of enterprises.

Business risk (Risk): Based on the research of Wang et al. (2017), this paper uses the cumulative distribution probability of the standard deviation of profit rate before interest tax depreciation and amortization from year t-4 to year t-1 (4 years) to calculate the business risk. The higher the value, the higher the business risk of the enterprise.

Data Sources and Descriptive Statistics

This paper takes China's A-share listed companies as research samples. The starting year of the digital finance index is 2011, so the panel data set for 2011-2020 is constructed. The descriptive statistical results of the variables are shown in Table 1.

Variable	Obs	Mean	SD	Min	Max
GI	20357	0.890	1.190	0	4.700
GI1	20357	0.610	0.980	0	4.250
GI2	20357	0.590	0.940	0	3.870
DIF	20357	2.190	0.680	0.560	3.220
Sub	20357	16.43	1.76	11.00	20.62
Size	20357	22.44	1.300	19.74	26.33
Lev	20357	0.460	0.210	0.0700	0.920
Roa	20357	0.0300	0.0700	-0.290	0.210
TobinQ	20357	2.080	1.460	0.840	9.550
Expend	20357	0.0400	0.0400	0	0.200
Ind	20357	0.380	0.0500	0.330	0.570
Dual	20357	0.230	0.420	0	1
Soe	20357	0.430	0.500	0	1
Opin	20357	0.0400	0.200	0	1

Table 1. Descriptive statistics

Empirical Analysis

Benchmark Model Estimation Results

This paper first examines the impact of digital finance on corporate green innovation, and the benchmark regression results are presented in Table 2. In column (1), the coefficient of the digital finance level is significantly positive at the 1% confidence level (coefficient=0.553), indicating that digital finance effectively promotes green innovation in enterprises and supports H1. Furthermore, the results in columns (2) and (3) demonstrate that digital finance enhances both the quality and quantity of green innovation (coefficient=0.577 and 0.238, both at 1% confidence level). By reducing financing costs and expanding financing channels, digital finance provides financial support for enterprises to implement green innovation. Simultaneously, it mitigates business risks and encourages proactive engagement in green innovation. Column (4) reveals that government subsidies positively moderate the role of digital finance in promoting enterprises' green innovation (coefficient=0.073, at 1% confidence level), thereby confirming H2.

	(1)	(2)	(3)	（4）
Variable	GI	GI1	GI2	GI
DIF	0.553***	0.577***	0.238***	0.519***
	(6.87)	(8.37)	(3.62)	(6.36)
Sub				0.100***
				(19.42)
Z				0.073***
				(13.48)
Size	0.406***	0.347***	0.277***	0.326***
	(54.54)	(54.30)	(45.47)	(36.36)
Lever	0.011	-0.090**	0.128***	0.015
	(0.26)	(-2.44)	(3.62)	(0.34)
Roa	-0.113	-0.187*	-0.065	-0.208*
	(-1.00)	(-1.92)	(-0.70)	(-1.80)
TobinQ	0.045***	0.054***	0.026***	0.038***
	(7.77)	(10.92)	(5.54)	(6.01)
Expend	0.945***	0.763***	0.763***	0.783***
	(5.47)	(5.15)	(5.40)	(4.46)
Ind	-0.091	0.123	0.012	-0.064
	(-0.74)	(1.16)	(0.12)	(-0.52)
Dual	-0.030*	-0.009	-0.039***	-0.028*
	(-1.81)	(-0.62)	(-2.93)	(-1.72)
Soe	0.068***	0.089***	0.024*	0.077***
	(4.17)	(6.39)	(1.83)	(4.66)
Opin	-0.157***	-0.078***	-0.126***	-0.163***
	(-4.52)	(-2.63)	(-4.45)	(-4.53)
Constant	-8.152***	-6.939***	-6.022***	-8.005***
	(-19.04)	(-18.91)	(-17.19)	(-18.67)
Year, Industry, City FE	YES	YES	YES	YES
N	20,357	20,357	20,357	20,357

R^2	0.428	0.383	0.387	0.443

Table 2. Estimated results of the benchmark model

Robustness Test

Replace the Tobit Model

Since the green innovation of the explained variable has an obvious left-tailed phenomenon with zero as the critical value, it is replaced with the Tobit model for robustness test. Columns (1) - (3) in Table 3 are the results of the replacement with the Tobit model. The development level of digital finance still significantly improves the green innovation of enterprises at the level of 1 %.

Replacement of Explanatory Variable Measures

In the robustness test, this paper will select the provincial digital financial development index for regression test according to the province where the enterprise is registered. Columns (4) - (6) in Table 3 are the regression results of replacing explanatory variables. It is clear that the level of digital financial development still significantly promotes corporate green innovation.

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	GI	GI1	GI2	GI	GI1	GI2
DIF	0.557***	0.572***	0.384***	0.139**	0.219***	0.002
	(22.81)	(22.21)	(15.40)	(2.25)	(4.19)	(0.04)
Constant	-14.389***	-15.856***	-12.635***	-7.680***	-6.526***	-5.560***
	(-41.41)	(-43.50)	(-35.60)	(-21.89)	(-21.91)	(-19.51)
Control variables	YES	YES	YES	YES	YES	YES
Year, Industry, City FE	YES	YES	YES	YES	YES	YES
N	20,357	20,357	20,357	25,970	25,970	25,970
R^2	0.059	0.067	0.056	0.406	0.360	0.370

Table 3. Robustness test

Influence Mechanism Analysis

According to the above research, the development level of digital finance significantly promotes the green innovation of enterprises. Then, can digital finance enhance the green innovation of enterprises by alleviating the financing constraints of enterprises and reducing the business risks of enterprises? Based on the method of Wen and Fan (2015), the following model is constructed, in which $M_{i,t}$ is the intermediary variable.

$$M_{i,t} = \alpha_2 + \beta_2 DIF_{j,t} + \gamma_2 X_{i,t} + \sum Year + \sum Industry + \sum City + \varepsilon_{i,j,t} \quad (3)$$

$$GI_{i,t} = \alpha_3 + \beta_3 DIF_{j,t} + \gamma_3 X_{i,t} + \delta_4 M_{i,t} + \sum Year + \sum Industry + \sum City + \varepsilon_{i,j,t} \quad (4)$$

(1) Financing constraints (FC). As listed in Table 4 (1), the level of digital financial development can significantly alleviate the financing constraints faced by enterprises. After adding the variable of financing constraints to the econometric model, the estimated coefficient of the digital inclusive financial index is significant at the statistical level of 1 %, indicating that financing constraints play a partial intermediary role.

(2) Business risk (Risk). It can be seen from Column (3) of Table 4 that digital finance can reduce the business risk of enterprises. It can be seen from Column (4) that the estimated coefficient of business risk is significantly negative, and the estimated coefficient of digital finance is still significant after adding the

variable of business risk, indicating that business risk plays a partial mediating effect in the process of digital finance promoting green innovation of enterprises.

	（1）	（2）	（3）	（4）
Variable	FC	GI	Risk	GI
DIF	-0.030*	0.545***	-0.056**	0.550***
	(-1.71)	(6.78)	(-2.38)	(6.84)
FC		-0.281***		
		(-8.58)		
Risk				-0.051**
				(-2.10)
Constant	4.851***	-6.789***	0.306**	-8.136***
	(52.67)	(-14.89)	(2.44)	(-19.00)
Control variables	YES	YES	YES	YES
Year, Industry, City FE	YES	YES	YES	YES
N	20,357	20,357	20,357	20,357
R^2	0.329	0.430	0.141	0.428

Table 4. Analysis of influencing mechanism

Heterogeneity Analysis

Regional heterogeneity

Because of the great differences in economy, technology and natural resources among different regions, this paper examines the differences in the impact of digital financial development level on enterprise green innovation in different regions. Through the results of table 5, it can be seen that digital finance in the eastern, central and western regions has played a significant role in promoting corporate green innovation; Compared with the eastern and central regions, the impact of digital finance in the western region on corporate green innovation is slightly weaker. The popularity of digital finance in most areas of western China is low and the development of big data, blockchain and other technologies lags behind; and the green innovation policy maturity and green innovation market environment in the western region have a certain gap compared with the eastern and central regions. Therefore, in the western region, digital finance is difficult to play an equal role in corporate green innovation compared with the eastern and central regions.

Variable	East China			Central China			South China		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GI	GI1	GI2	GI	GI1	GI2	GI	GI1	GI2
DIF	0.490***	0.544***	0.228**	1.108***	1.155***	0.489***	0.699**	0.633***	0.437*
	(3.83)	(4.91)	(2.20)	(6.21)	(7.71)	(3.24)	(2.57)	(2.81)	(1.94)
Constant	-9.008***	-8.023***	-6.284***	-9.097***	-7.256***	-7.105***	-7.680***	-6.446***	-5.625***
	(-31.09)	(-32.03)	(-26.74)	(-15.44)	(-14.67)	(-14.26)	(-11.27)	(-11.44)	(-10.01)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year, Industry, City FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	13,986	13,986	13,986	3,808	3,808	3,808	2,255	2,255	2,255
R^2	0.443	0.402	0.407	0.471	0.424	0.411	0.462	0.408	0.419

Table 5. Heterogeneity Analysis1

Digital finance dimension test

According to the research of Guo et al. (2020), the coverage breadth of digital finance reflects the audience's scope of digital finance. The depth of use of digital finance refers to the type of financial services used by users; Digitization improves the convenience of financial services and eliminates information asymmetry between borrowers and lenders. Based on the above, this paper studies the impact of different levels of digital finance on corporate green innovation. According to columns (1) - (6) of Table 6, digital finance can significantly affect corporate green innovation through coverage and depth of use. The degree of digitization has no significant effect on the promotion of green innovation, but it can significantly promote the quality of green innovation.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GI	GI1	GI2	GI	GI1	GI2	GI	GI1	GI2
Coverage	0.456***	0.426***	0.231***						
	(6.61)	(7.19)	(4.09)						
Usage				0.417***	0.430***	0.172***			
				(6.74)	(8.12)	(3.39)			
Digitization							0.048	0.095***	-0.014
							(1.17)	(2.70)	(-0.41)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year, Industry, City FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	20,357	20,357	20,357	20,357	20,357	20,357	20,357	20,357	20,357
R^2	0.428	0.383	0.387	0.428	0.383	0.387	0.427	0.381	0.386

Table 6. Heterogeneity Analysis2

Conclusion

Based on data from A-share listed companies between 2011 and 2020, this study employs a fixed-effect model, robustness tests, mechanism impact analysis, and heterogeneity analysis. The findings reveal the following: (1) Digital finance significantly promotes green innovation in enterprises, leading to a substantial enhancement in both the quality and quantity of green innovation. (2) Government subsidies strengthen the role of digital finance in driving corporate green innovation. (3) The impact of digital finance on corporate green innovation exhibits heterogeneity. Specifically, in terms of regional differences, the influence of digital finance on corporate green innovation is significantly more pronounced in the eastern and central regions compared to the western regions, which aligns with prior research outcomes (Lin and Ma, 2022). Decomposing digital finance further indicates that the breadth and depth of coverage have a significant impact on corporate green innovation, whereas the level of digitization does not exhibit a significant effect.

Based on the aforementioned research findings, this paper proposes the following policy recommendations. Firstly, to enhance the integration of digital technology and traditional finance, it is imperative to leverage the advantages offered by digital technology, including big data and cloud computing. This can be accomplished by expanding the breadth of financial coverage, deepening its utilization, and embracing digitization. By doing so, a conducive market environment can be established to facilitate enterprise green innovation activities. Secondly, the government should synergize digital finance with government subsidies to provide support for research and development as well as the commercialization of green innovation projects undertaken by enterprises. Lastly, in consideration of regional equilibrium, the government should enhance infrastructure development in the western region to foster the growth of digital finance. This paper acknowledges several research limitations. Firstly, the sample used in this study consists solely of listed companies in China, potentially overlooking the potential effectiveness of digital finance for green innovation in small and medium-sized enterprises (SMEs). Future research will explore the impact of digital finance on green innovation in technology-based SMEs. Secondly, this paper does not differentiate between government subsidies in the stages of green innovation research and development (R&D) and achievement transformation. Subsequent investigations can expand our understanding of the role of government subsidies at different stages in the association between digital finance and green innovation.

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References

Chen, Y. S., Lai, S. B., & Wen, C. T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of business ethics*, *67*, 331-339.

Cin, B. C., Kim, Y. J., & Vonortas, N. S. (2017). The impact of public R&D subsidy on small firm productivity: Evidence from Korean SMEs. *Small Business Economics*, *48* (2), 345–360.

Demertzis, M., Merler, S., & Wolff, G. B. (2018). Capital Markets Union and the fintech opportunity. *Journal of financial regulation*, *4*(1), 157-165.

Guo, F., Wang, J., Wang, F., Cheng, Z., Kong, T., & Zhang, X. (2020). Measuring China's Digital Financial Inclusion: Index Compilation and Spatial Characteristics. *China Economic Quarterly*, *19*(04), 1401-1418.

Hu, J., Pan, X., & Huang, Q. (2020). Quantity or quality? The impacts of environmental regulation on firms' innovation–Quasi-natural experiment based on China's carbon emissions trading pilot. *Technological Forecasting and Social Change*, *158*, 120122.

Huang, Z., Liao, G., & Li, Z. (2019). Loaning scale and government subsidy for promoting green innovation. *Technological Forecasting and Social Change*, *144*, 148-156.

Huergo, E., Trenado, M., & Ubierna, A. (2016). The impact of public support on firm propensity to engage in R&D: Spanish experience. *Technological Forecasting and Social Change*, *113*, 206-219.

Irfan, M., Razzaq, A., Sharif, A., & Yang, X. (2022). Influence mechanism between green finance and green innovation: Exploring regional policy intervention effects in China. *Technological Forecasting and Social Change*, *182*, 121882.

Kong, T., Sun, R., Sun, G., & Song, Y. (2022). Effects of digital finance on green innovation considering information asymmetry: An empirical study based on Chinese listed firms. *Emerging Markets Finance and Trade*, *58*(15), 4399-4411.

Li, X., Shao, X., Chang, T., & Albu, L. L. (2022). Does digital finance promote the green innovation of China's listed companies?. *Energy Economics*, *114*, 106254.

Nie, X., Jiang, P., Zhang, X., & Wu, Q. (2021). Research on Digital Finance and Regional Technology Innovation. *Journal of Financial Research, 489*(03), 132-150.

Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Review*, *18*(4), 329-340.

Sun, H., Edziah, B. K., Sun, C., & Kporsu, A. K. (2019). Institutional quality, green innovation and energy efficiency. *Energy policy*, *135*, 111002.

Wang, Z., Wang, Z., & Li, J. (2017). Business risks and working fund financing decisions. *Accounting Research*, *355*(5), 60-67.

Wen, Z., & Fan, X. (2015). Monotonicity of effect sizes: Questioning kappa-squared as mediation effect size measure. *Psychological methods*, *20*(2), 193.

Xiang, X., Liu, C., & Yang, M. (2022). Who is financing corporate green innovation?. International *Review of Economics & Finance*, *78*, 321-337.

Xue, L., & Zhang, X. (2022). Can digital financial inclusion promote green innovation in heavily polluting companies?. *International Journal of Environmental Research and Public Health*, *19*(12), 7323.

Yu, C. H., Wu, X., Zhang, D., Chen, S., & Zhao, J. (2021). Demand for green finance: Resolving financing constraints on green innovation in China. *Energy Policy*, *153*, 112255.

Zhang, X., Li, Z. J., & Li, C. T. (2019). Bank competition, Financial constraints, and corporate innovation: evidence from industrial firms in China. *Journal of Financial Research*, *472*(10), 98-116.