How does digital finance affect firm environmental, social and governance (ESG) performance? — Evidence from Chinese listed firms

Liuyang Xue [a], Junan Dong [b,*], Yifan Zha [c]

[a] *Business School, Nankai University, Baidi Road, Nankai District, Tianjin, 300071, China*
[b] *School of Management, Shandong University, Licheng District, Jinan Shandong, 250100, China*
[c] *School of Business Administration, Dongbei University of Finance and Economics, Shahekou District, Dalian Liaoning, 116025, China*

A B S T R A C T

The use of digital finance to promote firm environmental, social, and governance (ESG) fulfill-
ment is the key to achieving sustainable development. This study uses the data of Chinese listed
firms from 2010 to 2019 and China Digital Financial Inclusion Index of Peking University to
empirically examine the impact and mechanism of digital finance on firm ESG performance.
Results show that digital finance significantly and positively impacts firm ESG performance.
Mechanism tests reveal that digital finance influences ESG performance by promoting firm green
innovation, improving firm goodwill and reducing agency costs. Moreover, political connections
negatively moderate the relationship between digital finance and firm ESG performance, while
regional institutional development positively moderates this relationship.. Subdivision of digital
finance dimension test shows that the main factors affecting ESG performance are the depth of use
and the degree of digitization, while the breadth of coverage is not significant. Digital finance can
also promote firm innovation by promoting ESG performance. This study integrates the value
effect of digital finance with the concept of sustainable development, which has important
theoretical and practical significance.

1. Introduction

At the end of 2021, the size of global environmental, social, and governance (ESG) funds, led by the European market, reached
$2.74 trillion, which was an increase of up to 58 % compared to the previous year. According to the Natixis 2022 Global Institutional
Survey, 75 % of institutional investors considered ESG factors important when selecting quality investments, compared with the 60 %
in 2017.[1] The majority of global ESG investments is currently made by Europe, the United States, and Canada, whereas China, which is
the world's second-largest economy, accounts for only a small percentage of global ESG investments despite its growth in such in-
vestments. With China's commitment to "carbon peaking" and "carbon neutrality," ESG investment has gradually become an "im-
mediate need" for firm investment, and ESG investment efforts have increased significantly. The ravages of COVID-19 highlighted the

---

interconnectedness of environmental (E), social (S) and governance (G) [1]. To promote firm ESG fulfillment, relevant Chinese government departments issued a series of policies to motivate listed firms to pay attention to ESG practices and vigorously develop sustainable concepts. ESG is an important indicator of the comprehensive development of firms and an important tool for implementing the "double carbon" goal.

In recent years, the "insufficient supply" of the real economy of traditional financial services largely restricted the ESG performance of firms. With the rapid development and extensive penetration of cutting-edge digital technologies, represented by big data, cloud computing, and artificial intelligence, a new type of financial service industry emerged, namely, digital finance. As a new financial industry innovation format and mode, digital finance, formed by combining finance and technology, is developing vigorously, especially policies such as the issuance of the "Financial Technology Development Plan (2022–2025)" by the People's Bank of China and "Guiding Opinions on the Digital Transformation of Banking and Insurance Industry" by the General Office of the China Banking and Insurance Regulatory Commission have been tremendously guiding. Financial technology is pushing China's financial industry toward deep integration with technology. China's digital financial inclusion business achieved leapfrog development between 2011 and 2020, with the median value of the provincial digital financial inclusion index reaching 33.6 in 2011, increasing to 214.6 in 2015, and further increasing to 334.8 in 2020. The median value of the provincial digital financial inclusion index in 2020 was 10 times that in 2011, with the index value increasing an average of 29.1 % per year, thereby showing the rapid development trend of digital financial inclusion in China.

Digital finance includes a series of new financial products, financial services, financial software, and customer communication and interaction forms provided by financial technology firms and innovative financial service providers [2]. Digital finance deeply integrates digital technology and financial services, mainly with three characteristics. First, digital finance uses artificial intelligence, big data, and cloud computing technologies to reduce transaction costs, enabling individuals and firms to avail of payments, savings, and credit services without visiting bank branches or directly trading with financial service providers [3]. Second, owing to the scarcity of financial market resources and credit discrimination by traditional financial institutions, some firms cannot obtain development funds with appropriate interest rates [4]. Thus, digital finance strives to reach all groups, offering financial services to firms that may be excluded by traditional financial institutions. It aims to enhance the accessibility and inclusiveness of financial services, broaden application scenarios, lower the service threshold, and extend its reach to underdeveloped areas that are not covered by traditional finance. Third, digital financing can provide financial products such as savings, loans, and settlements for individuals and firms. Digital finance can provide important financial support for the transformation and upgrading of firms based on aforementioned characteristics. In the process of accelerating the "dual carbon" goal, whether digital finance can provide convenient financial services to firms and promote their sustainable development is worth examining.

Based on the above discussion, to deeply explore the impact and mechanism of digital finance on firm ESG performance, this study constructs an econometric model using data from Shanghai and Shenzhen A-share listed firms from 2011 to 2019 and finds that digital finance can considerably promote firm ESG performance. From the perspective of impact mechanisms, this study determines that digital finance can affect firm ESG performance by promoting firm green innovation, improving firm goodwill and reducing agency costs. After conducting the endogenous test and substitution test with different indicators, this study concludes that the research conclusions hold. In addition, political connections negatively moderate the relationship between digital finance and firm ESG performance, while regional institutional development positively moderates the relationship. The test results of the division of the digital finance dimensions show that the main factors affecting ESG performance are the depth of use and the degree of digitization, while the breadth of coverage is not significant. We also find that digital finance can promote firm innovation by promoting ESG performance.

Overall, the contributions of this study are mainly reflected in the following aspects: First, the purpose of this study is not only to clarify the relationship between digital finance and ESG performance, but also to explore the mechanism of influence between the two. Although there have been more studies exploring the relationship between digital finance and ESG performance, the research on the mechanism of how digital finance affects ESG performance is fragmented and not comprehensive enough. Based on the three dimensions of ESG, our study proposes mechanisms by which digital finance affects the environmental dimension (green innovation), the social dimension (firm goodwill), and the governance dimension (agency costs). Our study is the first of its kind to explore the mechanisms by which digital finance affects ESG performance based on the three subdimensions of ESG. Moreover, the social dimension mechanism and the governance dimension mechanism that we propose are also newly discovered influence mechanisms compared to existing studies. In other words, this study extends the research on the impact path of digital finance on ESG performance and provides ideas for further improving the research on digital finance and ESG.

Second, we identify boundary conditions between digital finance and ESG performance from institutional theory, introducing two moderators that are important in the context of transitional China, namely political connections [5] and regional institutional development [6]. The extant literature argues that formal and informal institutions shape actors' behavior [7]. We therefore explore how political connections, an important informal institutional arrangement, and regional institutional development, an indicator of the level of formal institutional development, affect the relationship between digital finance and ESG performance. In doing so, we flesh out the mechanism that link digital finance to firm ESG performance and contribute to the understanding of ESG performance in developing countries with uneven institutional development, such as China.

Finally, this study reveals the importance of ESG performance in digital finance to promote firm innovation, and few scholars have further explored that digital finance can promote firm innovation by promoting the improvement of firm ESG performance and thus firm innovation. This study reveals ESG as an important mechanism between digital finance and firm innovation, deepens the

understanding of the role of ESG performance in promoting firm innovation under the value orientation of sustainable development, and provides empirical evidence for firms to emphasize and improve their ESG performance and innovation capabilities.

1.1. Hypothesis development

The impact of digital finance on ESG performance.

The purpose of this study is not only to clarify the relationship between firm ESG and digital finance, but also to explore the influence mechanism between the two. Mu et al. (2023) argues that digital finance enhances ESG performance by decreasing firm financing constraints and increasing firm ESG investments [8]. Ren et al. (2023) argues that digital finance influences firm ESG performance through green innovation and external regulation [9]. The roles of financing constraints, green innovation and external supervision in ESG performance research have been well documented by previous scholars [8–12]. Based on the existing studies, this study further innovatively proposes three possible mechanisms by which digital finance affects ESG performance based on the three dimensions of ESG: the environmental dimension (green innovation), the social dimension (firm goodwill), and the governance dimension (agency costs).

Digital finance and environmental performance. Digital finance is free from the constraints of traditional business outlets and can provide more efficient financial services and lower-cost financing funds for low-carbon development of firms. Combined with government subsidies for firm green development and lower loan taxes and fees, digital finance guides funds to flow better to green innovation firms and firms with real financing difficulties in green transformation [13], and encourages firms to incorporate production concepts, such as green production, quality management, and brand image, into the production process. On the one hand, the green innovation of firms can reduce the pollution of the environment and fulfil the environmental responsibility of firms. On the other hand, firm green innovation is also a responsibility to the society and employees [14]. Moreover, green technological innovation of firms can attract more financial investors and help firms to achieve long-term sustainable development [15]. By improving the efficiency of firms in handing pollutants and launching green products to attract potential consumers [16], it enhances competitiveness and achieves long-term firm value addition. Therefore, digital finance contributes to fostering firm green innovation, which ultimately affects their environmental (E) scores.

Digital finance and social performance. The application of digital technology also aids in reducing firm verification costs [17]. Digital finance provides a convenient channel for investor supervision and capital market regulation. On the one hand, driven by the profit-seeking nature of capital, the popularity of big data information access makes market investors actively participate in firm information mining and cross-validation, which strengthens the monitoring function of market investors; on the other hand, the application of digital technology in the field of financial regulation strengthens the real-time and effectiveness of capital market regulation. Such supervision strengthens firm internal governance, promotes stakeholders' trust in firms [18,19], improves stakeholder engagement, enables firms to engage in direct, two-way dialogue with stakeholders [20], and reduces verification costs in offline scenarios. The direct, two-way dialogue of mutual trust between firms and stakeholders also allows firms to better communicate their achievements in environmental protection, philanthropy, and poverty alleviation to communities and government agencies, resulting in better goodwill and higher social (S) scores.

Digital finance and governance performance. One of the most prominent costs in corporate governance is agency costs due to the separation of ownership and control in modern firms [21]. Agency costs mainly arise from information asymmetry between shareholders and managers [22]. Previous studies have found considerable heterogeneity in ESG performance across firms. When managers perceive that stakeholders value ESG fulfilment, they are likely to "comply and enforce" ESG standards [23]. When firms perceive limited pressure from influential stakeholders to fulfil ESG, there may be room for resistance, creating a dynamic game between firms and stakeholders. In China, it is difficult for ESG practices to become spontaneous, internally self-driven strategic behaviors of firms. Digital finance provides a convenient channel for investor monitoring and capital market regulation. The use of digital technology in the field of financial regulation strengthens the real-time and effectiveness of capital market regulation. The development of regulatory technology can not only reduce the cost of regulation, but also reduce the regulatory blind spots brought about by the application of digital technology. Under the joint supervision of the market and the government, on the one hand, it can effectively reduce corruption and commercial bribery in purchasing and sales departments [24], thus better protecting the interests of shareholders and creditors. On the other hand, it reduces the likelihood of corporate governance violations such as stock dilution, shareholder disenfranchisement [25], or violations of disclosure rules [26]. In summary, the development of digital finance contributes to the reduction of agency costs, enhancement of corporate governance, and ultimately results in increased corporate governance (G) scores.

Based on the theoretical analysis of the three mechanisms, we propose the following hypothesis.

Hypothesis 1. Digital finance will improve firm ESG performance.

1.2. Moderating effect of political connections

Given that ESG performance is a social phenomenon, it does not exist in an institutional context independent of the firm [27]. As pointed out by Jamali and Karam (2018), the uniqueness of CSR research in developing countries such as China lies in its exploration of the impact of both formal and informal institutions [28]. Institutional theory suggests that formal and informal institutions significantly influence actors' behavior [7]. Therefore, this study discusses how both aspects of institutions influence the relationship

between digital finance and firm ESG performance. In transitional China, a widely adopted practice among firms is to establish political connections with government officials, and political connections are regarded as an important informal institutional arrangement, with informal institutions being widespread and playing an important role [29]. The connections between firms and government officials (i.e., political connections) are an important part of the informal system and exert a substantial influence on actors' behavior [30].

First, firms can obtain preferential policies and lower financing costs by building relationships with government officials [31], which can increase firm value. Second, government officials protect politically connected firms from strict environmental regulations for their private interests. Xiao and Shen (2022) find that firms without political connections have better performance in terms of environmental ratings [32]. This study suggests that firms with political connections are protected by the government from being held accountable for environmental pollution and therefore lack incentives for better ESG performance. Therefore, politically connected firms are more likely to focus on non-ESG performance aspects, such as improving financial performance. Therefore, we propose the following hypothesis:

Hypothesis 2.   Political connections will negatively moderate the relationship between digital finance and firm ESG performance.

2. Moderating effect of regional institutional development

Institutions plays a fundamental role in long-term economic growth as they shape the investment incentives of economic agents [33]. First, it is only in regions with a high level of institutional development that firms can develop stable expectations and have incentives to invest in ESG for long-term returns. On the contrary, in regions with lower levels of institutional development, firms may have more incentives to invest in political connections or rent seeking for short-term returns. Second, well-developed infrastructures enable low-cost information dissemination and media access, which makes firm ESG performance highly visible in regions with high levels of institutional development. For example, legal system and market monitoring mechanisms are in place [34], which safeguard the entire process of ESG investments and information disclosure. In contrast, regions with lower institutional development often experience institutional gaps that lead to sticky messaging and localized 'rules of the game' to 'protect' local firms from penalties for poor ESG performance [34,35]. Finally, digital financial development requires large investments in digital technologies, and digital financial development may require a more stable and predictable institutional environment. Fan et al. (2021) find that the anti-corruption function of ICTs is more pronounced in countries with better institutional and political systems, and in countries with better property rights protection [24]. Therefore, we propose the following hypothesis :

Hypothesis 3.   Regional institutional development will positively moderate the relationship between digital finance and firm ESG performance (see Fig. 1).
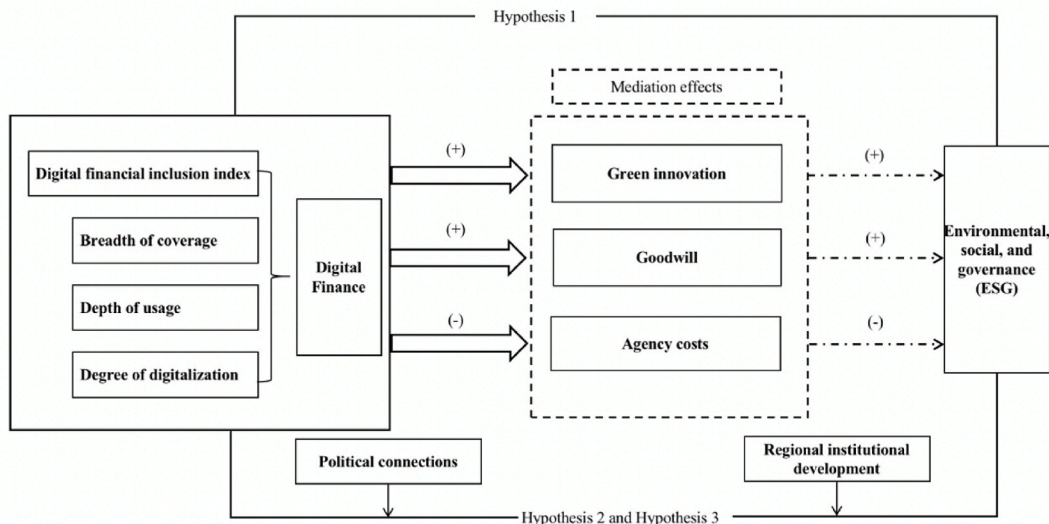

Fig. 1. The conceptual framework of digital finance on firm ESG.

3. Empirical strategy

3.1. Data source

The study's sample consists of A-share firms listed in Shanghai and Shenzhen, covering the period from 2010 to 2019. The ESG rating data is sourced from the Bloomberg database, the digital finance index is compiled by the Digital Finance Centre of Peking University, and the data used for the other variables are sourced mainly from the CSMAR and WIND databases. In this study, 2010 is chosen as the research starting year, which is determined based on the starting year of the digital financial data. To ensure the reliability of the findings, the sample is treated as follows: firms with missing key variables, firms in the financial and insurance sectors, ST and PT firms, insolvent firms, and firms listed for less than one year are excluded. In addition, continuous variables from the 1% and 99% levels are also winsorized. Following these treatments, the sample comprises a total of 7964 observations for regression analysis.

3.2. Econometric model

To empirically test the impact of digital finance on ESG performance, we employ a fixed-effects model for our baseline regression analysis. The baseline model is expressed as follows:

$$ESG_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \sum Control_{i,t} + Year + \mu + \epsilon_{i,t} \tag{1}$$

where $ESG_{i,t}$ is the ESG performance variable, $DF_{i,t}$ is the digital finance variable, $Control_{i,t}$ is the set of control variables, $Year$ is the time (year) fixed effect, μ is the individual(firm) fixed effect, and $\epsilon_{i,t}$ is the random error term.

3.3. Variables

The dependent variable is firm ESG performance (ESG). Many studies have used rating data from third-party agencies to measure ESG performance [36–38]. These organizations mainly construct indicator systems, assign varying weights to different indicators, and then aggregate them to derive ESG scores. In addition, some Chinese scholars have also used CSR reports to measure ESG performance [39,40], as the indicator is too one-dimensional for accurate measurement. Based on the analysis and data availability, most existing studies have used Bloomberg ESG scores and HuaZheng ESG ratings to measure ESG performance [41]. In this study, Bloomberg ESG data are used for testing, Bloomberg data has been widely used in the previous ESG/CSR literature [42,43], which covers three dimensions of ESG, namely environmental score, social score, and governance score, each assigned a weight of 1/3 for subdimension evaluation.[2] All ESG scores are divided by 100 to maintain consistency in magnitude with other variables.

The independent variable is digital finance (DF), which is measured with the Peking University Digital Inclusive Finance Index constructed by Guo et al. (2020) [44], forming an inclusive index system of digital finance at the provincial, municipal, and county levels. It comprises three dimensions and effectively captures the development trends of digital finance across various regions in China, offering satisfactory representativeness and authority. Many scholars have used this index to examine the impact of digital finance on firm innovation, bank competition, firm financing, and economic development [45,46]. This study uses the financial inclusion data at the municipal level for the measurement.[3] All digital inclusive finance indexes are divided by 100 to maintain consistency in magnitude with other variables.

In addition, to ensure robust estimation results, we control for a range of variables. Specifically, firm size (Size) is represented by the firm's total assets; profitability (ROE) is calculated as the firm's net profit divided by shareholders' equity; leverage (Lev) is the ratio of a firm's total liabilities to its total assets; state ownership (SOE) is measured as 1 when a firm's ultimate controlling shareholder is government and 0 otherwise; market performance (Tobin's Q) is measured as the ratio of a firm's market value to the book value of its total assets; the firm's year of establishment (Age) is calculated as the natural logarithm of the current year minus the year of establishment plus 1; equity balance (Balance) is determined by summing the shareholdings of the second to fifth largest shareholders and dividing it by the shareholding of the largest shareholder; board size (Board) is measured as the logarithm of the number of directors; cash holdings (Cash) is the ratio of cash and cash equivalents to total assets; institutional investor shareholding (INST) is the total number of shares held by the institutional investors divided by the total share capital.

3.4. Summary statistics

According to the descriptive statistical results in Table 1, the mean value of ESG is 0.204, with a standard deviation of 0.065. These statistics indicate significant variations in ESG among the listed firms. The mean value of DF is 2.013, with a standard deviation of 0.667. The values of other variables fall within reasonable ranges, with no extreme or abnormal values observed.

---

[2] Bloomberg, "Look beyond: Bloomberg for environmental, social and governance data". Available at: https://www.cfaboston.org/docs/ESG/BloombergLookBeyond2014.pdf.

[3] See the report "Peking University Digital Finance Index (2011–2019)" published by the Peking University Digital Finance Research Centre Group for details on the calculation.

Table 1
Summary statistics.

Variable	Obs	Mean	Std.Dev	Min	Median	Max
ESG	7964	0.204	0.065	0.091	0.198	0.434
DF	7964	2.013	0.667	0.526	2.128	3.086
Size	7964	0.003	0.006	0.000	0.001	0.046
ROE	7964	0.077	0.110	−0.506	0.082	0.331
Lev	7964	0.475	0.200	0.068	0.486	0.867
SOE	7964	0.495	0.500	0.000	0.000	1.000
Tobin's Q	7964	1.900	1.189	0.847	1.490	7.419
Age	7964	2.864	0.348	1.609	2.944	3.466
Balance	7964	0.659	0.588	0.027	0.466	2.629
Board	7964	2.180	0.201	1.609	2.197	2.708
Cash	7964	0.229	0.219	0.017	0.158	1.269
INST	7964	0.496	0.222	0.017	0.517	0.879

4. Results

4.1. Basic results

The regression results for DF and ESG are presented in Table 2. The control variables are not included in Model 1. Model 2 includes control variables but does not control for time and individual effects, while Model 3 incorporates control variables and controls for time and individual effects. According to the regression results in Model 1, the regression coefficient of DF is 0.031 and significantly positive at the 1 % level. In Model 2, the regression coefficient of DF is 0.018 and significantly positive at the 1 % level. In Model 3, the regression coefficient of DF is 0.029, which is also significantly positive at the 1 % level. These results demonstrate that digital finance can promote the ESG performance of firms, thus confirming the hypothesis 1.

Table 2
Basic results.

	Model 1	Model 2	Model 3
DF	0.031*** (3.913)	0.018*** (16.116)	0.029*** (3.646)
Size		1.225*** (10.859)	0.494*** (4.728)
ROE		0.003* (1.792)	0.001 (0.960)
Lev		−0.001 (−0.170)	−0.003 (−0.590)
SOE		0.015*** (9.346)	0.005 (1.624)
Tobin's Q		−0.005*** (−9.171)	0.000 (0.421)
Age		0.013*** (6.287)	−0.006 (−0.878)
Balance		0.006*** (5.163)	−0.002 (−1.564)
Board		0.010*** (2.757)	−0.001 (−0.158)
INST		0.040*** (11.900)	0.004 (1.109)
Cash		−0.009*** (−3.086)	0.003 (0.985)
Constant	0.150*** (25.669)	0.086*** (8.619)	0.165*** (7.657)
Firm FE	Yes	No	Yes
Year FE	Yes	No	Yes
N	7964	7964	7964
R^2	0.259	0.197	0.262

Note: t values in parentheses, *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$.

Table 3
Endogeneity test results.

	Model 1	Model 2	Model 3
L.DF	0.024*** (2.829)	0.354*** (34.394)	
DF			0.069*** (2.831)
Controls	Yes	Yes	Yes
Constant	0.215*** (8.474)	1.853*** (43.557)	0.092 (1.268)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	6607	6607	6607
R^2	0.236	0.995	0.236

Note: t values in parentheses, *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$.

4.2. Endogeneity tests

First, to address potential endogeneity issues caused by reverse causality, we introduced a lag period for DF, and the results are shown in Table 3. According to the test results in Model 1, the coefficient of L.DF is significantly positive at the 1 % level, which proves that the conclusions are valid. To further verify the robustness of these findings, we conducted tests with lag periods of two, three, and four periods for the explanatory variable. The results of these tests also confirm the robustness of our conclusions.

Second, following Li et al. (2020), we select the lagged period of digital finance development as an instrumental variable (IV). The results of the IV test are presented in Table 3, and the results of the first stage regression in Model 2 reveal that L.DF is significantly and positively related to DF. Moreover, the coefficient of DF in the second stage in Model 3 is significantly positive at the 1 % level, indicating that the findings of this study are robust.

5. Robustness tests

5.1. Substitution of independent variable

Provincial data is used to measure digital finance instead of municipal data, and the empirical results are reported in Model 1 of Table 4. In this model, the coefficient of PDF is significantly positive at the 5 % level, and the regression results are robust.

5.2. Substitution of dependent variable

This study further conducts the regression using the Huazheng ESG ratings. The ESG rating is divided into nine grades, ranging from low to high: C, CC, CCC, B, BB, BBB, A, AA, and AAA, each assigned a numerical value from 1 to 9. The scores are averaged four times a year to get the annual ESG performance. The regression results are shown in Model 2 of Table 4, where the coefficient of DF is significantly positive at the 5 % level, and the regression results are robust.

In addition, the direct method of Huazheng rating assignment is adopted to construct the dependent variable ESG_AD. Specifically, when the rating is C–CCC, ESG _ D = 1; when the rating is B–BBB, ESG _ D = 2; and when the rating is A–AAA, ESG_D = 3. The scores are averaged four times a year to get the ESG_AD. Model 3 of Table 4 shows that the regression coefficient of DF is significantly positive at the 10 % level, and the regression results are robust.

5.3. Exclusion of some influencing factors

The ESG performance of firms and digital finance development are closely related to the overall global economic development. Disregarding external economic development factors can introduce bias into regression results. The Chinese stock market crash in 2015 had a substantial impact on Chinese financial markets. The main force that powered the China stock market rollercoaster was the excessive increase of margin lending throughout 2010 to 2014. In the beginning, regulators allowed margin lending in private investment for a list of 90 stocks in 2010, and by 2014, this number had expanded to over 900.For those financial institutions that

Table 4
Substitution of variable measurement.

	Model 1	Model 2	Model 3
PDF	0.014** (2.114)		
DF		0.397** (2.559)	0.114* (1.662)
Controls	Yes	Yes	Yes
Constant	0.177*** (8.401)	7.084*** (16.799)	2.296*** (12.284)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	7964	7964	7964
R²	0.261	0.054	0.067

Note: t values in parentheses, *indicates p < 0.10, **indicates p < 0.05, ***indicates p < 0.01.

Table 5
Exclusion of influencing factors.

	Model 1	Model 2	Model 3
DF	0.028*** (3.344)	0.033*** (3.974)	0.022** (2.119)
Controls	Yes	Yes	Yes
Constant	0.168*** (7.372)	0.158*** (6.829)	0.172*** (5.784)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	7024	7315	4692
R²	0.273	0.264	0.300

Note: t values in parentheses, *indicates p < 0.10, **indicates p < 0.05, ***indicates p < 0.01.

granted loans, capital budgets suddenly tightened, which eventually had a ripple effect that led to the well-known market crash in 2015, sending a huge shock to financial markets [47,48]. Moreover, the stock market crashlikely had a potential impact on the ESG performance of listed firms. Based on this, this study excludes the sample of the year of the Chinese stock market crash (2015). The results are shown in Table 5. In Model 1, the regression coefficient of DF is significantly positive at the 1 % level.

Second, the approval and threshold requirements for enterprises listed on the Growth Enterprise Market (GEM) are relatively low, and these enterprises are in a high-growth phase, accompanied by higher risks. The presence of GEM-listed firms may potentially impact the research findings. In Model 2, the regression results, excluding the GEM-listed firms, show that the coefficient of DF remains significantly positive at the 1% level, demonstrating the robustness of the findings in this study.

Finally, the manufacturing industry is a cornerstone of the national economy's rapid development and plays a crucial role in promoting China's real economy. In this study, the non-manufacturing subsample has been excluded from the regression. In Model 3, the regression coefficient of DF is significantly positive at the 5 % level,indicating the robustness of the findings in this study.

5.3.1. Mediating mechanism test

In the baseline regression, we have found that digital finance can significantly improve firm ESG performance. In this section, we further explore three potential mechanisms through which digital finance affects ESG performance. To be specific, digital finance improves firm ESG performance by promoting firm green innovation, improving goodwill and reducing agency costs. We adopt the approach of Judd and Kenny (1981) and Baron and Kenny (1986) to test these mechanisms [49,50].

The mechanism test is carried out in three steps. The regression model of the first step is the same as Equation (1), the regression model of the second step is shown as Equation (2), and the regression model of the third step is presented as Equation (3). In Equation (2) and Equation (3), $Mediator_{i,t}$ represents the mediator variable, and the significance of coefficients α_1 and β_2 are tested.

$$Mediator_{i,t} = \alpha_0 + \alpha_1 DF_{i,t} + \sum Control_{i,t} + Year + \mu + \epsilon_{i,t} \tag{2}$$

$$ESG_{i,t} = \beta_0 + \beta_1 DF_{i,t} + \beta_2 Mediator_{i,t} + \sum Control_{i,t} + Year + \mu + \epsilon_{i,t} \tag{3}$$

5.4. Green innovation mechanism

Following previous studies [51], we used the number of annual green patent applications (Green) to measure firm green innovation. Models (2) and (3) were derived from model (1) to test the mediated effects. The effect of digital finance on ESG performance was confirmed above, and the regression coefficient of DF in Model 1 of Table 6 is significantly positive at the 10 % level, thus validating the conclusions of the second step. The coefficient of green innovation (Green) in Model 2 is 0.000, which is significantly positive at the 1 % level. Therefore, digital finance improves firm green innovation, thereby enhancing firm ESG performance.

5.5. Firm goodwill mechanism

Following recent literature [41], we use media exposure as a proxy for goodwill and construct a measure of media exposure. We use online financial news data from the China Financial News Database of Listed Companies (CFND). The database includes news coverage data from more than 400 important online media outlets in China. We want to know whether digital finance improves the exposure of positive news. Therefore, we define the variable Posinews as the natural logarithm of the number of positive news. The regression results are shown in Table 6. The regression coefficient of DF in Model 3 of Table 6 is significantly positive at the 1 % level; thus, the second step is verified. The coefficient of Goodwill in Model 4 is 0.005 and significantly positive at the 1 % level. Thus, the results prove that the mediating effect holds.

5.6. Agency costs mechanism

Following Ang et al. (2000), this study measures the agency costs between shareholders and management using the management

Table 6
Green innovation and goodwill mechanisms.

	Model 1	Model 2	Model 3	Model 4
	Green	ESG	Goodwill	ESG
DF	4.237* (1.751)	0.028*** (3.527)	0.345*** (2.798)	0.027*** (3.419)
Green		0.000*** (6.073)		
Goodwill				0.005*** (7.040)
Controls	Yes	Yes	Yes	Yes
Constant	−22.912*** (−3.482)	0.170*** (7.925)	4.768*** (14.211)	0.139*** (6.382)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	7964	7964	7964	7964
R^2	0.132	0.266	0.291	0.267

Note: t values in parentheses, *indicates p < 0.10, **indicates p < 0.05, ***indicates p < 0.01.

Table 7
Agency costs mechanism.

	Model 1	Model 2	Model 3	Model 4
	Agency One	ESG	Agency Two	ESG
DF	−0.019** (−2.145)	0.028*** (3.594)	0.002 (0.620)	0.029*** (3.694)
Agency One		−0.022** (−1.983)		
Agency Two				−0.120*** (−4.816)
Controls	Yes	Yes	Yes	Yes
Constant	0.203*** (8.564)	0.169*** (7.822)	0.002 (0.180)	0.165*** (7.693)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	7964	7964	7964	7964
R^2	0.131	0.262	0.035	0.265

Note: t values in parentheses, *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$.

expense ratio, which is calculated as management expense divided by total operating revenue [52]. A higher value of this indicator implies higher agency costs, denoted as "Agency one." Meanwhile, the relationship between controlling shareholder and other shareholders is measured with the capital occupation of the large shareholders (other receivables/total assets). A larger index indicates higher agency costs, denoted as "Agency two." The regression results are shown in Table 7. The regression coefficient of DF in Model 1 is significantly negative at the 5 % level; therefore, the second step is verified. The coefficient of agency costs (Agency one) in Model 2 is negative and significant at the 5 % level. These findings show that digital finance can mitigate the first type of agency costs and promote ESG performance. Therefore, the results prove that the mediating effect holds. Model 3 in Table 7 presents the empirical results for Agency two as the mediator variable. However, the regression coefficient of DF in Model 3 is not significant, indicating that digital finance does not mitigate the second type of agency costs.

6. Moderating effects test

6.1. Moderating effect of political connections

According to Hypothesis 2, we argue that political connections negatively moderate the positive impact of digital finance on ESG performance. To test this hypothesis, this study introduces a dummy variable for political connections, denoted as PC. PC equals 1 if the chairman or CEO of the firm has served or currently serves in the central and local governments at all levels, courts, procuratorates, or has served as a deputy to the National People's Congress at all levels and as a member of the Chinese People's Political Consultative Conference (CPPCC); otherwise, it equals 0. As shown in Model 1 of Table 8, the coefficient of DF*Political is significantly negative at the 1 % level. Therefore, the evidence supports Hypothesis 2.

6.2. Moderating effect of regional institutional development

According to Hypothesis 3, we argue that regional institutional development positively moderates the relationship between digital finance and ESG performance. We follow the mainstream literature in management by measuring the regional marketization level using the marketization index of each province in China [53]. The index provides a comprehensive assessment of province-level marketization level by evaluating the government-market relationship, the share of non-state-owned enterprises, the development of product (and service) and factor markets, and the development of market intermediaries and legal systems. The results are reported in Table 8. Model 2 presents the results of the interaction term test, with the coefficient of DF*Institutional significantly positive at the 5 % level. Therefore, the evidence supports Hypothesis 3.

Table 8
Moderating effects test.

	Model 1	Model 2
DF	0.030*** (3.830)	0.016 (1.552)
Political	0.010*** (3.318)	
DF* Political	−0.004*** (−3.240)	
Institutional		−0.004** (−2.550)
DF* Institutional		0.001** (2.165)
Controls	Yes	Yes
Constant	0.158*** (7.309)	0.198*** (7.916)
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	7964	7964
R^2	0.263	0.263

Note: t values in parentheses, *indicates $p < 0.10$, **indicates $p < 0.05$, ***indicates $p < 0.01$.

Table 9
Refinement of digital finance dimensions.

	Model 1	Model 2	Model 3
Cover	−0.003 (−0.349)		
Usage		0.025*** (4.824)	
Digit			0.007*** (2.867)
Controls	Yes	Yes	Yes
Constant	0.186*** (8.620)	0.165*** (7.773)	0.182*** (8.740)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	7964	7964	7964
R^2	0.261	0.263	0.261

Note: t values in parentheses, *indicates p < 0.10, **indicates p < 0.05, ***indicates p < 0.01.

6.3. Refinement of digital finance dimensions

As the development of digital financial inclusion encompasses many dimensions, each dimension may generate different effects on ESG performance. To further refine the influence of digital finance on firm ESG performance, this study examines the role of digital finance from three sub-indicators: breadth of coverage, depth of use and the level of digital support services, based on the digital finance sub-dimensions index data. The regression results are presented in Model 1, Model 2 and Model 3 of Table 9. The regression results show that the main factors affecting ESG performance are the depth of use and the degree of digitization, while the breadth of coverage is not significant. Therefore, government departments and financial institutions should accelerate the construction of digital infrastructure and create more application scenarios for digital finance.

6.4. Digital finance, ESG performance and innovation

Numerous studies have confirmed that digital finance can effectively address the structural issues of traditional finance and plays a pivotal role in promoting firm innovation [54,55]. Firm innovation is an activity with high investment and a high probability of failure, and digital finance can improve the financing environment for firms, alleviate their financing constraints, and provide financial resources to support innovation activities. Furthermore, ESG performance can strengthen and sustain relationships between firms and external stakeholders while offering resource support for firm innovation activities. Scholars have proved that firm ESG performance can significantly promote firm innovation [56,57]. Therefore, this study employs a mediation effect model to test whether digital finance can promote firm innovation by promoting firm ESG performance.

This study follows the methods of Judd and Kenny (1981) and Baron and Kenny (1986) to test the mechanism [49,50]. The first step is to test whether digital finance can promote firm innovation. The second step involves testing whether digital finance can promote firm ESG performance, which has been verified. The third step incorporates ESG and DF into the regression equation. Firm innovation is measured by the number of annual patent applications, with the number of patent applications divided by 100 to maintain consistency in magnitude with other variables. We primarily focus on patent applications rather than patent grants due to the former's strong signaling effect [58]. In addition, considering the lagged impact of digital finance on firm innovation, the mediating effect test is conducted using firm innovation in periods t and t+1.The regression results in Model 1 and Model 2 of Table 10 show that the co-efficients of DF are all significantly positive. Therefore, the first step is verified. The coefficients of ESG in Model 3 and Model 4 are also all significant. In conclusion, based on the above mechanism analysis, this study suggests that digital finance can promote firm innovation through ESG performance.

Table 10
Digital finance, ESG performance and innovation.

	Path a		Path c	
	Model 1	Model 2	Model 3	Model 4
	Innovation$_t$	Innovation$_{t+1}$	Innovation$_t$	Innovation$_{t+1}$
DF	0.861*** (4.168)	0.549** (2.343)	0.785*** (3.816)	0.495** (2.116)
ESG			2.631*** (8.379)	2.240*** (6.091)
Controls	Yes	Yes	Yes	Yes
Constant	−2.420*** (−4.307)	−2.089*** (−3.217)	−2.853*** (−5.082)	−2.467*** (−3.793)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	7964	6607	7964	6607
R^2	0.169	0.154	0.178	0.159

Note: t values in parentheses, *indicates p < 0.10, **indicates p < 0.05, ***indicates p < 0.01.

7. Conclusions and enlightenment

This study uses the data of listed firms in China from 2010 to 2019 and China Digital Financial Inclusion Index of Peking University to empirically examine the influence and mechanisms of digital finance on firm ESG performance. The findings of this study indicate a significant and positive impact of digital finance on ESG performance. The mechanism test shows that digital finance affects firm ESG performance by promoting firm green innovation, improving firm goodwill and reducing agency costs. The study also reveals that political connections negatively moderate the relationship between digital finance and firm ESG performance, and regional institutional development plays a positive moderating role, strengthening the relationship between digital finance and firm ESG performance. By subdividing the dimensions of digital finance, this study finds that the main factors affecting ESG performance are the depth of use and the degree of digitization, while the breadth of coverage does not show significant effects. We also find that digital finance can promote firm innovation by enhancing ESG performance.

This study provides enlightenment for advancing the development of digital finance and improving firm ESG performance. First, government departments should actively promote the integration of finance and digital technologies, guiding the development of digital finance and expanding its application scenarios. Relevant government departments should also foster the synergy between digital finance and firm sustainable development, promoting the efficient docking of financial supply and green development needs. Moreover, governments can encourage firms to harness and upgrade their digital equipment, leveraging digitalization's advantages for firm growth. Second, firms should establish the cognitive concept of a sustainable development orientation. On the one hand, strengthen investments in clean manufacturing, employee welfare, shareholder rights protection, and so on. On the other hand, it's important to note that ESG fulfillment need not add an excessive cost burden to firms. In the long run, firm ESG performance can drive firm innovation and shape competitive advantages. Third, attention should be paid to the prevention of financial risks in promoting the development of digital finance. Digital finance regulation should be strengthened, the digital finance regulatory system should be improved to effectively leverage the positive effects of digital finance.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Liuyang Xue: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Junan Dong:** Conceptualization, Data curation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Yifan Zha:** Writing – original draft.

Funding statement

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] C.A. Adams, S. Abhayawansa, Connecting the COVID-19 pandemic, environmental, social and governance (ESG) investing and calls for 'harmonisation' of sustainability reporting, Crit. Perspect. Account. 82 (2022), 102309.
[2] P. Gomber, et al., On the fintech revolution: interpreting the forces of innovation, disruption, and transformation in financial services, J. Manag. Inf. Syst. 35 (2018) 220–265.
[3] H. Chen, S.S. Yoon, Does technology innovation in finance alleviate financing constraints and reduce debt-financing costs? Evidence from China, Asia Pac. Bus. Rev. 28 (2022) 467–492.
[4] O. Talavera, et al., Macroeconomic uncertainty and bank lending: the case of Ukraine, Econ. Syst. 36 (2012) 279–293.
[5] W. Shi, et al., The continuing importance of political ties in China, Acad. Manag. Perspect. 28 (2013) 57–75.
[6] D. Xu, K.E. Meyer, Linking theory and context: 'Strategy research in emerging economies' after Wright et al. (2005), J. Manag. Stud. 50 (2013) 1322–1346.
[7] W.R. Scott, Institutions and Organizations. Foundations for Organizational Science, A Sage Publication Series., London, 1995.
[8] W. Mu, et al., Digital finance and corporate ESG, Finance Res. Lett. 51 (2023), 103426.
[9] X. Ren, et al., Digital finance and corporate ESG performance: empirical evidence from listed companies in China, Pac. Basin Finance J. 79 (2023), 102019.
[10] Y. Ning, Y. Zhang, Does digital finance improve corporate ESG performance? An intermediary role based on financing constraints, Sustainability 15 (2023), 10685.
[11] D. Wang, et al., Does FinTech development enhance corporate ESG performance? Evidence from an emerging market, Sustainability 14 (2022), 16597.
[12] W. Li, W. Pang, The impact of digital inclusive finance on corporate ESG performance: based on the perspective of corporate green technology innovation[J], Environ. Sci. Pol. R 30 (2023) 65314–65327.
[13] N. Shen, et al., Different types of environmental regulations and the heterogeneous influence on the environmental total factor productivity: empirical analysis of China's industry, J. Clean. Prod. 211 (2019) 171–184.

[14] X. Long, et al., Corporate ESG performance and green technology innovation, Finance and Accounting Monthly 44 (2023) 135–142.
[15] J. Zhang, et al., Can green bonds empower green technology innovation of enterprises? Environ. Sci. Pollut. Res. (2022) 1–13.
[16] H. Wang, et al., China green credit policy and corporate green technology innovation: from the perspective of performance gap, Environ. Sci. Pollut. Res. 30 (2023) 24179–24191.
[17] A. Goldfarb, C. Tucker, Digital economics, J. Econ. Lit. 57 (2019) 3–43.
[18] C. Dellarocas, The digitization of word of mouth: promise and challenges of online feedback mechanisms, Manag. Sci. 49 (2003) 1407–1424.
[19] L. Cabral, A. Hortacsu, The dynamics of seller reputation: evidence from eBay, J. Ind. Econ. 58 (2010) 54–78.
[20] F. Schultz, et al., The construction of corporate social responsibility in network societies: a communication view, J. Bus. Ethics 115 (2013) 681–692.
[21] A.A. Berle, G.C. Means, The Modern Corporation and Private Property, Harcourt, Brace and World, Inc., New York, 1932.
[22] M. Jensen, W. Meckling, Theory of the firm: managerial behavior, agency costs and ownership structure, J. Financ. Econ. 3 (1976) 305–360.
[23] D.A. Gioia, K.G. Corley, Being good versus looking good: business school rankings and the Circean transformation from substance to image, Acad. Manag. Learn. Educ. 1 (2002) 107–120.
[24] Q. Fan, et al., Does ICT development curb firms' perceived corruption pressure? The contingent impact of institutional qualities and competitive conditions, J. Bus. Res. 135 (2021) 496–507.
[25] A. Dyck, et al., The corporate governance role of the media: evidence from Russia, J. Finance 63 (2008) 1093–1135.
[26] R. Kouwenberg, V. Phunnarungsi, Corporate governance, violations and market reactions, Pac. Basin Finance J. 21 (2013) 881–898.
[27] H. Wang, et al., Corporate social responsibility: an overview and new research directions, Acad. Manag. J. 59 (2016) 534–544.
[28] D. Jamali, C. Karam, Corporate social responsibility in developing countries as an emerging field of study, Int. J. Manag. Rev. 20 (2018) 32–61.
[29] T. Khanna, K. Palepu, Winning in Emerging Markets: A Road Map for Strategy and Execution, Harvard Business Press, Boston, 2010.
[30] J. Chen, B.J. Dickson, Allies of the state: democratic support and regime support among China's private entrepreneurs, China Q. 196 (2008) 780–804.
[31] H. Li, et al., Political connections and firm performance: evidence from the Chinese private entrepreneurs, J. Dev. Econ. 87 (2008) 283–299.
[32] G. Xiao, S. Shen, To pollute or not to pollute: political connections and corporate environmental performance, J. Corp. Finance 74 (2022), 102214.
[33] D. Acemoglu, et al., Institutions as the fundamental cause of long-run growth, Handb. Econ. Growth 1 (2005) 385–472.
[34] K.E. Meyer, H.V. Nguyen, Foreign investment strategies and sub-national institutions in emerging markets: evidence from Vietnam, J. Manag. 42 (2005) 63–93.
[35] T.V. Nguyen, et al., Sub-national institutions, firm strategies, and firm performance: a multilevel study of private manufacturing firms in Vietnam, J. World Bus. 48 (2013) 68–76.
[36] Y. Eliwa, et al., ESG practices and the cost of debt: evidence from EU countries, Crit. Perspect. Account. 79 (2021), 102097.
[37] S. Gillan, et al., Firms and social responsibility: a review of ESG and CSR research in corporate finance, J. Corp. Finance 66 (2021), 101889.
[38] J. Xie, et al., Do environmental, social, and governance activities improve corporate financial performance? Bus. Strat. Environ. 28 (2019) 286–300.
[39] B.T. Cheng, Corporate social responsibility and access to finance, Strat. Manag. J. 35 (2014) 1–23.
[40] Z.H. Wang, J. Sarkis, Corporate social responsibility governance, outcomes, and financial performance, J. Clean. Prod. 162 (2017) 1607–1616.
[41] M. Fang, et al., Can enterprise digitization improve ESG performance? Econ. Modell. (118) (2023), 106101.
[42] B. Buchanan, et al., Corporate social responsibility, firm value, and influential institutional ownership, J. Corp. Finance (52) (2018) 73–95.
[43] D. Avramov, et al., Sustainable investing with ESG rating uncertainty, J. Financ. Econ. 145 (2022) 642–664.
[44] F. Guo, et al., Measuring China's digital financial inclusion: index compilation and spatial characteristics, China Econ. Rev. 19 (2020) 1401–1418.
[45] D. Xin, et al., Does digital finance promote corporate social responsibility of pollution-intensive industry? Evidence from Chinese listed firms, Environ. Sci. Pollut. Res. 29 (2022) 85143–85159.
[46] T. Kong, et al., Effects of digital finance on green innovation considering information asymmetry: an empirical study based on Chinese listed firms, Emerg. Mark. Finance Trade 58 (2022) 4399–4411.
[47] Y. Zhang, et al., Risk attitude, financial literacy and household consumption: evidence from stock market crash in China, Econ. Modell. 94 (2021) 995–1006.
[48] C. Han, et al., Efficiency and multifractality analysis of the Chinese stock market: evidence from stock indices before and after the 2015 stock market crash, Sustainability 11 (2019) 1699.
[49] C.M. Judd, D.A. Kenny, Process analysis: estimating mediation in treatment evaluations, Eval. Rev. 5 (1981) 602–619.
[50] R.M. Baron, D.A. Kenny, The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations, J. Pers. Soc. Psychol. 51 (1986) 1173.
[51] T. Schiederig, et al., Green innovation in technology and innovation management–an exploratory literature review, R. Manag. 42 (2012) 180–192.
[52] J.S. Ang, et al., Agency costs and ownership structure, J. Finance 55 (2000) 81–106.
[53] H. Zhao, J. Lu, Contingent value of political capital in bank loan acquisition: evidence from founder-controlled private enterprises in China, J. Bus. Ventur. 31 (2016) 153–174.
[54] W. Li, W. Pang, Digital inclusive finance, financial mismatch and the innovation capacity of small and medium-sized enterprises: evidence from Chinese listed firms, Heliyon 9 (2023).
[55] S. Peng, et al., The impact of the digital economy on Chinese enterprise innovation based on intermediation models with financing constraints, Heliyon 9 (2023).
[56] Y. Tan, Z. Zhu, The effect of ESG rating events on corporate green innovation in China: the mediating role of financial constraints and managers' environmental awareness, Technol. Soc. 68 (2022), 101906.
[57] H. Tang, The effect of ESG performance on corporate innovation in China: the mediating role of financial constraints and agency cost, Sustainability 14 (2022) 3769.
[58] A.P. Faria, N. Barbosa, Does venture capital really foster innovation? Econ, Letture 122 (2014) 129–131.