

# ***Digital Inclusive Finance: Boosting Substantive Green Innovation or Indulging Strategic Green Innovation? Empirical Evidence from Chinese A-Share Listed Companies***

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**Abstract.** Amid the more and more intense global digital transformation and the more and more pressing demand of green development, digital inclusive finance—an innovative combination of financial inclusion and digital technologies—has become a key transformative power that rearranges the global financial framework and pushes forward social and economic progress. At the same time, it has also become a key foundation for China to rearrange its financial system and develop inclusive economic growth, whose position in the national development strategy is being more and more strengthened. This research divides green innovation into two completely different types—substantive green innovation and strategic green innovation—and limits its analysis range to the different influences that digital inclusive finance brings to corporate green innovation actions. Using a panel dataset of Chinese A-share listed companies from 2011 to 2023, the study makes an empirical analysis of the different effects and inner mechanisms through which digital inclusive finance affects these two different parts of green innovation, while at the same time exploring the detailed meanings coming from industrial heterogeneity. Empirical proof shows that the promoting power of digital inclusive finance on corporate green innovation mainly shows in substantive green innovation, but it cannot produce a noticeable encouraging effect on strategic green innovation activities. The key transfer mechanisms through which digital inclusive finance pushes substantive green innovation include two separate but connected parts: the reduction of financing difficulties and the increase of market competition intensity. Furthermore, this promoting effect is more obvious in non-high-polluting industries and high-tech sectors. Based on the research conclusions, this study puts forward suggestions including the improvement of digital inclusive finance support policies, the different empowerment of green innovation in different industries.

**Keywords:** digital inclusive finance, corporate green innovation, substantive green innovation, strategic green innovation

## 1. Introduction

As global digital transformation speeds up and the urgency of green development request becomes more and more pressing, digital inclusive finance has appeared as a key driver that reshapes the financial ecosystem and pushes forward inclusive economic growth. As early as 2010, Sarma took the lead to build a financial inclusion index system, using the methodological framework of the United Nations Human Development Index (HDI). This work provided a whole analytical structure for evaluating financial inclusion levels among countries and laid a theoretical basis for quantifying the progress of digital inclusive finance. Therefore, this new financial model has overcome the long-existing limits of traditional finance—such as too high transaction costs and narrow service range—thus deeply mixed into every part of daily life, making various groups of people get access to financial services more conveniently, efficiently and fairly [1]. Therefore, its strategic value has been further stressed in China's top-level policy making: the Central Financial Work Conference clearly pointed out inclusive finance as one of the "five major pillars" of the financial sector, with digital inclusive finance as the main carrier to carry out this pillar. The 2025 Government Work Report also further put forward the task of "strengthening the standard system and basic institutions for digital inclusive finance", thus consolidating its position in the national development strategy.

Green innovation, as one critical link that connects two core development dimensions, provides support for the coordinated chase of high-quality economic progress and top-level ecological conservation. Therefore, to fundamentally eliminate environmental pollution and ensure the realization of ecological governance goals, financial instruments compose one irreplaceable cornerstone [2]. Therefore, a sound and efficient financial system is of vital importance to solving financing troubles in innovation activities [3]. Existing academic research has already confirmed that financial instruments play one facilitating role in supporting enterprises' green innovation endeavors: through cross-border empirical researches, de Haas, Popov, and Flammer have respectively verified the positive influences of green bond issuance and stock market development maturity on enterprises' green innovation initiatives [4,5]. Digital inclusive finance, which is recognized as one essential component of the modern financial framework, uses advanced digital technologies including big data and artificial intelligence to raise resource allocation efficiency, lower financing frictions, and stimulate R&D investment, which hence provides one strong driving power for enterprises' green technological innovation.

However, corporate green innovation shows obvious heterogeneity in the aspects of inner driving reasons and inherent quality. According to the corporate innovation motivation classification that Tong et al. put forward, we can divide green innovation into two different types based on its driving factors: substantive green innovation and strategic green innovation [6]. Among these two kinds, substantive green innovation pays its attention to pushing technological progress, enhancing competitive superiority, and upgrading environmental performance—its core is located in the "inherent quality" of innovation activities; Contrarily, strategic green innovation is developed for satisfying government policy demands and chasing outer benefits—its focus is on the "quantitative scale" and "speed" of innovation, and its core does not have substantive technological breakthroughs. Existing researches have initially discussed the whole promotion effect of digital inclusive finance on corporate green innovation, but one key question is still not enough addressed: as a financial form that combines technological properties and inclusive features, whether digital inclusive finance has different influences on these two types of green innovation which have distinct driving reasons and value directions? Therefore, this research blank blocks the accurate comprehension of digital inclusive finance's actual influence on green innovation quality, hence it limits the targeted establishment and continuous optimization of related policies.

To fill this present research gap, this study concentrates on analyzing the diverse influences that digital inclusive finance exerts on firms' green innovation results, which is based on the two separate motivational frameworks of "substantive green innovation" and "strategic green innovation." Therefore, on the basis of this theoretical foundation, the research further probes into the internal functional mechanisms via a mediation analysis framework, thus identifying the key transmission channels through which digital inclusive finance produces positive or negative effects on green innovation activities. Hence, taking into consideration the unique features of different industries, the research classifies enterprises according to whether they belong to high-polluting sectors or high-tech fields, thereby investigating the heterogeneous impacts of digital inclusive finance on green innovation. This study has the aim to strengthen the theoretical framework related to the economic effects of digital inclusive finance and the various factors that determine the direction of corporate green innovation. At the same time, it seeks to provide more targeted practical proposals for optimizing digital inclusive finance support policies, guiding enterprises to carry out high-quality green innovation.

## 2. Literature review and hypothesis development

The ascent of digital inclusive finance has deeply remodeled the operation logic of the financial ecosystem. Its core point lies in surmounting the physical boundaries and information obstacles inherent to traditional financial services by means of digital methods, while utilizing advanced technologies to achieve more accurate risk assessment and resource allocation [7]. Therefore, this not only lowers transaction expenses but also reconstructs the connection mechanism between financial services and enterprise innovation [8]. Hence, under this background, the incentive effects of digital inclusive finance on different kinds of green innovation activities show clear structural distinctions.

Based on the "financial accelerator theory" put forward by Bernanke et al. (1999), financing constraints are a key obstacle to corporate innovation, especially substantive green innovation which has features of high capital need, long cycle, and high risk. Therefore, traditional financial systems take a "credit rationing" attitude because of information asymmetry problems, while digital inclusive finance makes precise evaluation of project value via multi-dimensional data to ease such constraints effectively and offer targeted financial support for substantive innovation; at the same time, digital inclusive finance lowers the access threshold of financial services and optimizes the financing ecosystem, thus attracting more enterprises to enter the field of green innovation for competition. This increased competitive force pushes enterprises to carry out substantive innovation, with the purpose of building technological barriers and forming differentiated competitive advantages. In comparison, enterprises that only rely on strategic innovation find it difficult to keep their market positions in a fully developed competitive environment; regarding resource allocation, digital inclusive finance tends to prefer substantive innovation with core technological breakthroughs, as Lauer & Lyman noted that digital finance serves real demand groups, and substantive innovation which has environmental benefits and long-term competitiveness is highly consistent with this focus, and algorithm models further distinguish project technical potential to guide financial resources to high-value green initiatives [9]; additionally, digital technologies improve the traceability of the innovation process and the verifiability of environmental performance, which makes real-time monitoring of enterprises' green technology R&D progress and emission reduction results possible, and this strong "technology-performance" correlation verification mechanism provides credible third-party recognition for substantive innovation.

On the contrary, strategic innovation mainly shows itself as edge improvements toward existing technologies or adaptive adjustments for satisfying compliance demands, with the goal to acquire short-term policy dividends or reputational profits [10]. Therefore, the information transparency brought by digital inclusive finance has obviously raised the cost of "greenwashing". Hence, the various stakeholders it links (e.g., investors, consumers, industrial chain partners) can enhance supervision via digital platforms, thus making it hard for enterprises to keep long-term reputations that only depend on strategic innovation.

In overall summary, the current research puts forward that digital inclusive finance promotes enterprises' substantive green innovation mainly via such channels as the reduction of financing frictions, the improvement of technological recognition abilities, the strengthening of market competition dynamics, and the advancement of information transparency. However, it does not produce any obvious incentive effects on strategic green innovation; therefore, under the background of stricter regulatory inspection and increased competitive intensity, it may even limit the speculative space related to strategic green innovation activities.

Drawing on the foregoing analytical deliberations, the current study formulates the following research hypothesis:

H1: Digital inclusive finance exerts a salient positive impetus on corporate green innovation endeavors, wherein such facilitative efficacy is predominantly instantiated within the sphere of substantive green innovation.

### 3. Research design

Grounding itself in the theoretical discussions above, this study conducts an empirical analysis of how digital inclusive finance affects corporate green innovation, and goes on to explore the inner working mechanisms behind this influence.

#### 3.1. Sample selection and data sources

This study focuses on all Chinese A-share listed firms spanning the period from 2011 to 2023 as its research sample. During the data screening process, we first exclude companies with abnormal trading statuses, including ST, \*ST and PT enterprises, firms operating in the financial and insurance industries, as well as those with extensive missing data. Only after these steps do we apply Winsorization to continuous variables at the 1% and 99% quantiles, so as to weaken the distorting impacts caused by extreme outliers. In the end, we obtain a final panel dataset consisting of 32,995 firm-year observations covering 4,401 individual enterprises, with all financial indicators sourced from the China Stock Market & Accounting Research Database (CSMAR).

#### 3.2. Variable selection

##### 3.2.1. Dependent variable

This research adopts the number of enterprises' authorized green patents as a proxy variable to measure the scale of green innovation, and further distinguishes between substantive green innovation and strategic green innovation. Given that green innovation research generally excludes design patents, this paper centers on green invention patents and green utility model patents as core measurement indicators in its analytical setup. For empirical implementation, substantive green innovation is measured by the count of independently obtained green invention patents in the current year, while strategic green innovation is quantified by the corresponding number of independently

acquired green utility model patents in the same period. Considering the inherent right-skewed characteristic of green patent application data, this study carries out a logarithmic transformation by adding one to the original patent count prior to taking the natural logarithm.

### 3.2.2. Key explanatory variable

Drawing on the research design of Yi Xingjian and Zhou Li, this paper also utilizes the China Digital Inclusive Finance Index compiled by the Digital Finance Research Center of Peking University to carry out empirical tests [11]. This index constructs a holistic assessment system from three perspectives: coverage breadth, usage depth and digitalization support degree, serving as a widely recognized benchmark that can reasonably depict the evolving progress of digital inclusive finance nationwide. Given the potential endogeneity risks stemming from reverse causality, as well as the inherent time lag inherent in corporate innovation activities, we lag the core explanatory variable by one period. Meanwhile, to avoid estimation bias caused by the excessively large absolute value of the index, we normalize the digital inclusive finance index by scaling it down by 100, using the processed value as the final variable for regression analysis.

### 3.2.3. Mediating variable

Degree of Financing Constraints (SA Index): Following the methodological framework that Hadlock and Pierce developed, the SA index is built to measure how severe a company's financing constraints actually are [12]. This index is characterized by negative values, and it works through an inverse relationship where a greater absolute magnitude points to a more acute degree of corporate financing constraints.

Degree of Market Competition (HHI): The Herfindahl-Hirschman Index (HHI) is employed as the measurement approach. More specifically, this index is calculated by summing up the squared ratios that result from dividing each individual firm's total assets by the total assets of its respective industry. In practical terms, a lower value of this indicator therefore signals a more competitive market environment with less concentration among the participating firms.

### 3.2.4. Control variables

Referring to the practices of existing studies, this study selects firm age (Age), proportion of independent directors (Indratio), capital expenditure (Expend), firm size (Size), ownership concentration (Equity), capital intensity (Capital), and controlling shareholder tunneling behavior (Or) as control variables.

Table 1. Variable definitions

| Variable Type | Variable Name                   | Symbol   | Measurement   |
|---------------|---------------------------------|----------|---|
| Dependent     | Substantial Green Innovation    | Greinva  | $\ln(\text{Number of green invention patent applications} + 1)$ |
|               | Strategic Green Innovation      | Greuma   | $\ln(\text{Number of green invention patent applications} + 1)$ |
| Explanatory   | Digital Inclusive Finance       | DIF      | Peking University Digital Inclusive Finance Index               |
| Mediating     | Degree of Financing Constraints | SA       | The SA Index developed by Hadlock and Pierce                    |
|               | Degree of Market Competition    | HHI      | Herfindahl index  |
|               | Firm Age                        | Age      | Sample year- The firm's listing year                            |
|               | Independent Directors           | Indratio | Independent directors/ The total number of board members        |
|               | Return on Assets                | Expend   | Capital expenditure/ Total assets                               |

Table 1. (continued)

| Control | Ownership Concentration | Size    | ln(total assets)  |
|---------|-------------------------|---------|---|
|         | Independent Directors   | Equity  | The shares held by the largest shareholder/Total shares |
|         | Firm Growth             | Capital | Total assets/ The main business revenue                 |
|         | Cash Flow               | Or      | Other payables / Total assets                           |

### 3.3. Model specification

For the empirical investigation of the heterogeneous effects exerted by digital inclusive finance on substantive versus strategic green innovation through disaggregated scrutiny, the subsequent econometric regression specifications are formulated as follows:

$$Greinva_{i,t} = \alpha_0 + \alpha_1 \times DIF_{i,t-1} + \beta_2 \times Controls_{i,t} + \theta_i + \theta_t + \varepsilon_{i,t} \quad (1)$$

$$Greuma_{i,t} = \beta_0 + \beta_1 \times DIF_{i,t-1} + \beta_2 \times Controls_{i,t} + \theta_i + \theta_t + \varepsilon_{i,t} \quad (2)$$

Where:  $Greinva_{i,t}$  denotes the intensity of substantive green innovation exhibited by firm  $i$  during period  $t$ ;  $Greuma_{i,t}$  denotes the magnitude of strategic green innovation pursued by firm  $i$  in period  $t$ ;  $DIF_{i,t-1}$  serves as the core explanatory variable for firm  $i$  in period  $t-1$  (i.e., the one-period lagged digital inclusive finance index);  $Controls_{i,t}$  encapsulates a suite of control variables;  $\theta_i$  captures individual fixed effect;  $\theta_t$  embodies year fixed effects; and  $\varepsilon_{i,t}$  denotes the stochastic error term.

## 4. Empirical results and analysis

### 4.1. Descriptive statistics

Based on the descriptive statistical whole picture showed in Table 2, in the green innovation performance dimension scope, substantive green innovation  $Greinva$  has a mean value of 0.131 and a standard deviation of 0.419. This proves that there are very big differences in substantive green innovation output among sample enterprises: most firms show very small substantive green innovation output, while a tiny part of enterprises have reached the highest level of substantive green innovation. About strategic green innovation  $Greuma$ , its mean value is 0.216—this number is higher than that of substantive green innovation—while its maximum value is 2.833 and standard deviation is 0.557. This reflects that enterprises have more widespread participation in strategic green innovation behaviors. Concerning the key explanatory variable digital inclusive finance DFI, this measurement has a mean value of 2.556 and a standard deviation of 0.795. The data set shows that there are obvious differences in development maturity of digital inclusive finance among different geographical units, though its overall distribution is mainly concentrated in medium-to-upper levels. This seen pattern is in line with the wide spreading path of digital inclusive finance in China in recent years.

Table 2. Descriptive statistics

|           | Obs   | Mean  | SD    | Min   | Median | Max   |
|-----------|-------|-------|-------|-------|--------|-------|
| $Greinva$ | 32995 | 0.131 | 0.419 | 0.000 | 0.000  | 2.485 |
| $Greuma$  | 32995 | 0.216 | 0.557 | 0.000 | 0.000  | 2.833 |

Table 2. (continued)

|          |       |        |       |        |        |        |
|----------|-------|--------|-------|--------|--------|--------|
| DFI      | 32995 | 2.556  | 0.795 | 0.597  | 2.744  | 3.632  |
| SA       | 32995 | -3.863 | 0.265 | -4.545 | -3.865 | -3.134 |
| HHI      | 32995 | 0.071  | 0.066 | 0.010  | 0.045  | 0.363  |
| Digital  | 32995 | 1.573  | 1.449 | 0.000  | 1.386  | 6.306  |
| Capital  | 32994 | 2.570  | 2.124 | 0.395  | 1.954  | 13.578 |
| Or       | 32984 | 0.033  | 0.043 | 0.000  | 0.018  | 0.248  |
| Size     | 32995 | 22.325 | 1.309 | 19.982 | 22.122 | 26.403 |
| Indratio | 32993 | 37.713 | 5.366 | 33.330 | 36.360 | 57.140 |
| Age      | 32995 | 10.808 | 7.828 | 1.000  | 9.000  | 29.000 |
| Expend   | 32982 | 0.049  | 0.046 | 0.000  | 0.035  | 0.222  |

## 4.2. Baseline regression results

Using a basic regression system as foundation, this research work examines the different impact that digital inclusive finance exerts on substantive green innovation versus strategic green innovation. The econometric proof confirms a very obvious and statistically strong promotion effect of digital inclusive finance on substantive green innovation; the coefficient sizes are 0.102 when no covariables are included and 0.093 after covariables are added, and both reach the 1% significance level. Contrarily, the corresponding coefficients related to strategic green innovation are only 0.046 and 0.035 respectively, which do not reach statistical significance. Therefore, this empirical result verifies the proposed viewpoint that in the corporate field, digital inclusive finance mainly promotes substantive green innovation activities rather than strategic ones.

Table 3. Baseline regression results

| Variable     | (1)                 | (2)                  | (3)              | (4)                  |
|--------------|---------------------|----------------------|------------------|----------------------|
|              | Greinva             | Greinva              | Greuma           | Greuma               |
| DFI          | 0.102***<br>(0.035) | 0.093***<br>(0.035)  | 0.046<br>(0.046) | 0.035<br>(0.046)     |
| Capital      |                     | -0.001<br>(0.001)    |                  | -0.004**<br>(0.002)  |
| Or           |                     | 0.049<br>(0.054)     |                  | -0.068<br>(0.067)    |
| Size         |                     | 0.030***<br>(0.006)  |                  | 0.032***<br>(0.010)  |
| Indratio     |                     | 0.002**<br>(0.001)   |                  | 0.001<br>(0.001)     |
| Age          |                     | 0.042***<br>(0.014)  |                  | 0.016*<br>(0.009)    |
| Expend       |                     | 0.023<br>(0.051)     |                  | 0.106<br>(0.068)     |
| Constant     | -0.131<br>(0.090)   | -1.287***<br>(0.222) | 0.098<br>(0.116) | -0.816***<br>(0.272) |
| Observations | 32683               | 32653                | 32683            | 32653                |
| R-squared    | 0.578               | 0.579                | 0.603            | 0.603                |
| Firm FE      | Yes                 | Yes                  | Yes              | Yes                  |

Table 3. (continued)

| Year FE | Yes | Yes | Yes | Yes |
|---------|-----|-----|-----|-----|
|---------|-----|-----|-----|-----|

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### 4.3. The results of the placebo test

A placebo examination is used to check the factual truth of baseline regression results via random reallocation of the treatment variable. Therefore, according to set method rules inside existing research papers, this study carries out random permutation of the digital inclusive finance indicator at city level—keeping all other control variables in original places—to make 500 simulated DFI structures, thus running separate regression calculations to describe the factual distribution of placebo coefficients. As shown by the test results in Figure 1, the real DFI coefficient (0.093) stands at the far right end of the placebo coefficient distribution, with a related p-value of 0. Hence, this factual finding means that no calculated value higher than the real coefficient appeared in 500 random tests, thus excluding the chance that baseline regression results are caused by accidental factors or unseen variables. Therefore, this result proves that the promoting effect of digital inclusive finance on enterprises' real green innovation has statistical reliability.

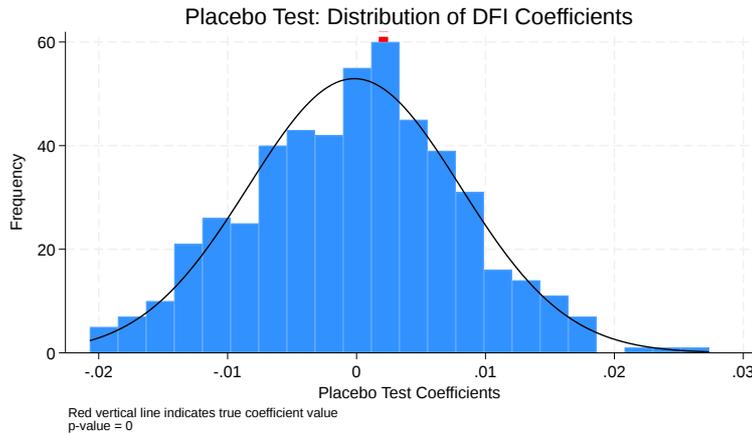


Figure 1. The placebo test results

## 5. Further analysis

### 5.1. Mechanism analysis

To explore the specific transmission channels through which digital inclusive finance affects enterprises' substantive green innovation, this study incorporates financing constraints (measured by the SA index) and the level of market competition as mediating variables, and further establishes the following mediating effect models for empirical verification:

$$Greinva_{i,t} = \vartheta_0 + \vartheta_1 \times DIF_{i,t-1} + \vartheta_2 \times Controls_{i,t} + \theta_i + \theta_t + \varepsilon_{i,t} \quad (3)$$

$$M_{i,t} = \lambda_0 + \lambda_1 \times DIF_{i,t-1} + \lambda_2 \times Controls_{i,t} + \theta_i + \theta_t + \varepsilon_{i,t} \quad (4)$$

$$Greinva_{i,t} = \mu_0 + \mu_1 \times DIF_{i,t-1} + \mu_2 \times M_{i,t} + \mu_3 \times Controls_{i,t} + \theta_i + \theta_t + \varepsilon_{i,t} \quad (5)$$

All variables are defined consistently with those in the baseline regression equations; the mediating variable symbols represent two distinct transmission paths: financing constraints (SA) and market competition level (HHI), with each path tested independently through separate empirical analyses. To clarify the modeling logic, Equation (3) is intended to measure the overall effect of digital inclusive finance on substantive green innovation, while Equation (4) examines how digital inclusive finance impacts each mediating variable individually. On this basis, Equation (5) integrates the mediating variable directly, thus simultaneously testing both the direct influence of digital inclusive finance and the specific mediating role of that particular channel. By analyzing the coefficient estimates derived from these three equations, this study can clarify the mediating effects of financing constraints and market competition in the relationship between digital inclusive finance and enterprises' substantive green innovation.

### 5.1.1. Degree of financing constraints

By use of a sequential regression study framework, this research cuts open the mediating action of financing constraints inside the cause-effect chain that links digital inclusive finance and substantive green innovation; the first estimation, as described in Column (1), measures the whole effect of digital inclusive finance on corporate substantive green innovation, with the DFI variable showing a coefficient of 0.093 which reaches statistical significance at the 1% standard; the later analysis in Column (2) proves that digital inclusive finance produces a obviously reducing influence on corporate financing constraints, which is reflected by a coefficient of 0.035 that also satisfies the 1% significance rule; the final analysis stage examines both the direct effect of digital inclusive finance and the impact of financing constraints on substantive green innovation, and empirical proofs show that the direct effect coefficient of digital inclusive finance is 0.084 (keeping significance at the 1% level), while the coefficient of the financing constraint proxy (SA) is 0.244 that also gets statistical significance at the 1% level, thus such results confirm the prominent mediating function of financing constraints in the transmission mechanism through which digital inclusive finance affects corporate substantive green innovation. More concretely, digital inclusive finance builds a supporting surrounding for corporate substantive green innovation by reducing existing financing constraints.

Table 4. Mediating effect of debt maturity structure

|         | (1)                       | (2)                 | (3)                        | (4)                  | (5)                        |
|---------|---------------------------|---------------------|----------------------------|----------------------|----------------------------|
|         | Greinva<br>(Total Effect) | SA                  | Greinva<br>(Direct Effect) | HHI                  | Greinva<br>(Direct Effect) |
| DFI     | 0.093***<br>(0.035)       | 0.035***<br>(0.013) | 0.084**<br>(0.035)         | -0.026***<br>(0.007) | 0.089**<br>(0.035)         |
| Capital | -0.001<br>(0.001)         | -0.000<br>(0.001)   | -0.001<br>(0.001)          | -0.000<br>(0.000)    | -0.001<br>(0.001)          |
| Or      | 0.049<br>(0.054)          | 0.036<br>(0.030)    | 0.040<br>(0.054)           | -0.031**<br>(0.015)  | 0.044<br>(0.054)           |
| Size    | 0.030***<br>(0.006)       | 0.001<br>(0.004)    | 0.030***<br>(0.006)        | -0.002<br>(0.001)    | 0.030***<br>(0.006)        |
| Inratio | 0.002**<br>(0.001)        | 0.000<br>(0.000)    | 0.002**<br>(0.001)         | 0.000<br>(0.000)     | 0.002**<br>(0.001)         |
| Age     | 0.042***                  | -0.028***           | 0.048***                   | -0.009***            | 0.040***                   |

Table 4. (continued)

|              |           |           |          |          |           |
|--------------|-----------|-----------|----------|----------|-----------|
|              | (0.014)   | (0.009)   | (0.014)  | (0.003)  | (0.013)   |
| Expend       | 0.023     | 0.069***  | 0.006    | 0.019*   | 0.026     |
|              | (0.051)   | (0.018)   | (0.052)  | (0.010)  | (0.051)   |
| HHI          |           |           |          |          | -0.154**  |
|              |           |           |          |          | (0.062)   |
| SA           |           |           | 0.244*** |          |           |
|              |           |           | (0.069)  |          |           |
| Constant     | -1.287*** | -3.678*** | -0.390   | 0.281*** | -1.244*** |
|              | (0.222)   | (0.120)   | (0.294)  | (0.047)  | (0.222)   |
| Observations | 32653     | 32653     | 32653    | 32653    | 32653     |
| R-squared    | 0.579     | 0.956     | 0.580    | 0.696    | 0.579     |

Standard errors in parentheses

\* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

### 5.1.2. Degree of market competition

This study further conducts an in-depth scrutiny of the mediating function of market competition intensity through empirical validation, adopting a sequential regression analytical approach. As demonstrated in the empirical test presented in Column (4), the coefficient of the DFI variable is -0.026, which is statistically significant at the 1% level. This finding indicates that digital inclusive finance exerts a robust reinforcing impact on market competition intensity—a phenomenon reflected by the reduction of the HHI index, which is commensurate with elevated competitive pressures in the market. Consequently, upon incorporating market competition intensity into the regression framework, the direct effect of digital inclusive finance remains statistically significant with a coefficient of 0.089. Meanwhile, the coefficient of market competition intensity is -0.154, which also achieves statistical significance at the 5% level. These results thereby corroborate the pivotal mediating role of market competition intensity in the causal pathway between digital inclusive finance and corporate substantive green innovation. More precisely, digital inclusive finance propels enterprises to engage in substantive green innovation initiatives by amplifying the inherent competitive tensions within the market.

## 5.2. Heterogeneity analysis

### 5.2.1. Heavy-polluting industry

Adopting the analytical framework proposed by Pan Ailing and following the secondary industry classification standards stipulated in the Listed Companies Industry Classification Guidelines, this paper carries out a heterogeneity test centered on heavy pollution industries, aiming to explore the differentiated effects of digital inclusive finance on corporate substantive green innovation [13]. As presented in the regression results of Table 4, the promotion effect of digital inclusive finance on substantive green innovation shows marked discrepancies between heavy pollution and non-heavy pollution industries. To be specific, Column (1) shows that in the heavy pollution industry subsample, the coefficient of digital inclusive finance (DFI) is 0.010 and fails to pass the significance test; by contrast, Column (2) indicates that in the non-heavy pollution subsample, the DFI coefficient is 0.099, presenting a significantly positive influence at the 5% statistical level.

When the interaction term of digital inclusive finance and heavy pollution industry identification (DFI×Waste) is added into the model in Column (3), its coefficient is -0.029 and significant at the 1% level. This result demonstrates that the driving effect of digital inclusive finance on substantive green innovation is far more pronounced for enterprises in non-heavy pollution industries than for those in heavy pollution sectors. The internal logic behind this empirical conclusion can be summarized as follows. Heavy pollution industries face stricter environmental supervision and mandatory transformation requirements, so their green innovation behaviors are mostly motivated by regulatory compliance instead of market incentives. Besides, the green transformation of heavy pollution enterprises usually requires long-term and large-scale capital input, which cannot be fully satisfied by the inclusive advantages of digital inclusive finance alone. Therefore, digital inclusive finance mainly boosts substantive green innovation in non-heavy pollution industries, while its catalytic effect in heavy pollution industries is relatively limited.

Table 5. Heterogeneity analysis results

|                     | (1)                | (2)                  | (3)                  | (4)                  | (5)                  | (6)                  |
|---------------------|--------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                     | High-Polluting     | Low-Polluting        | Waste Interaction    | High-Tech            | Low-Tech             | Tech Interaction     |
| DFI                 | 0.010<br>(0.070)   | 0.099**<br>(0.043)   | 0.080**<br>(0.035)   | 0.178***<br>(0.062)  | 0.006<br>(0.028)     | 0.072**<br>(0.035)   |
| Capital             | -0.005<br>(0.004)  | -0.001<br>(0.001)    | -0.001<br>(0.001)    | -0.002<br>(0.003)    | 0.001<br>(0.001)     | -0.000<br>(0.001)    |
| Or                  | -0.093<br>(0.150)  | 0.088<br>(0.058)     | 0.045<br>(0.053)     | 0.002<br>(0.092)     | 0.047<br>(0.061)     | 0.033<br>(0.054)     |
| Size                | 0.029**<br>(0.012) | 0.030***<br>(0.007)  | 0.029***<br>(0.006)  | 0.039***<br>(0.010)  | 0.017***<br>(0.006)  | 0.027***<br>(0.006)  |
| Indratio            | 0.002<br>(0.002)   | 0.001*<br>(0.001)    | 0.002**<br>(0.001)   | 0.002**<br>(0.001)   | 0.000<br>(0.001)     | 0.002**<br>(0.001)   |
| Age                 | -0.044<br>(0.066)  | 0.054***<br>(0.013)  | 0.044***<br>(0.014)  | 0.057**<br>(0.026)   | 0.018<br>(0.012)     | 0.037**<br>(0.014)   |
| Expend              | -0.007<br>(0.099)  | 0.050<br>(0.060)     | 0.026<br>(0.051)     | 0.068<br>(0.078)     | 0.007<br>(0.064)     | 0.038<br>(0.052)     |
| Waste               |                    |                      | 0.072***<br>(0.026)  |                      |                      |                      |
| DFI×Waste           |                    |                      | -0.029***<br>(0.009) |                      |                      |                      |
| Tech                |                    |                      |                      |                      |                      | -0.103***<br>(0.023) |
| DFI×Tech            |                    |                      |                      |                      |                      | 0.047***<br>(0.008)  |
| Constant            | -0.104<br>(0.842)  | -1.419***<br>(0.246) | -1.253***<br>(0.220) | -1.777***<br>(0.373) | -0.580***<br>(0.193) | -1.134***<br>(0.223) |
| N                   | 7037               | 25571                | 32652                | 19303                | 13292                | 32652                |
| Adj. R <sup>2</sup> | 0.539              | 0.590                | 0.579                | 0.577                | 0.554                | 0.580                |

Standard errors in parentheses

\* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

### 5.2.2. High-tech industry

Drawing on the analytical designs put forward by Yang Xingzhe and Zhou Xiangyi, combined with the listed company classification rules issued by the China Securities Regulatory Commission, this study divides sample firms into high-tech and non-high-tech groups to further examine its heterogeneous effects [14]. Regression results shown in Table 4 uncover a statistically distinguishable difference in digital inclusive finance's influence on substantive green innovation between high-technology and non-high-technology enterprises. Column (4) shows that inside the high-technology subsample, the coefficient of digital inclusive finance (DFI) variable reaches 0.178, showing a notable positive effect at the 1% statistical standard, whereas Column (5) indicates that among non-high-technology enterprises, the DFI coefficient records a tiny 0.006, having no statistical significance; Column (6) adds the interaction term between digital inclusive finance and high-technology designation ( $DFI \times Tech$ ), and its coefficient is 0.047, which reflects a statistically significant positive effect at the 1% level. Therefore, this proof suggests that compared with non-high-technology counterparts, the promoting function of digital inclusive finance in pushing substantive green innovation is obviously strengthened in high-technology firms; this empirical result can be attributed to following factors: high-tech enterprises originally have strong technological innovation abilities and R&D foundations, which let them make better use of financial support to advance green technological innovation, at the same time, high-tech enterprises show higher sensitivity to frontier technologies and innovative results, thus they can more effectively turn digital financial resources into substantive green innovation outputs, hence digital inclusive finance mainly stimulates substantive green innovation in high-tech enterprises.

## 6. Research conclusions and policy recommendations

This research selects Chinese A-share listed enterprises during the timeframe of 2011 to 2023 as its research sample, and adopts benchmark regression, mediating effect models, and heterogeneity analysis to probe into the mechanism by which digital inclusive finance shapes corporate green innovation. Empirical outcomes illustrate that the driving force of digital inclusive finance on corporate green innovation is primarily focused on substantive green innovation, a conclusion that is authenticated by a placebo test with solid robustness. In contrast, digital inclusive finance exerts no prominent incentive influence on strategic green innovation. This promotional effect functions via two crucial channels: on the one hand, it mitigates corporate financing constraints by utilizing digital instruments to surmount information asymmetry; on the other hand, it intensifies market competition and impels enterprises to focus their efforts on core technological breakthroughs. Meanwhile, the facilitating effect exhibits distinct industrial heterogeneity: the positive impact is significantly more potent in non-heavy-polluting industries than in heavy-polluting ones, and high-tech enterprises demonstrate a more striking response in comparison to non-high-tech enterprises.

Anchored on the aforementioned empirical findings, the following recommendations are propounded: optimize the digital inclusive finance support system, incorporate substantive green innovation achievements into the evaluation indicators of financial institutions, develop special financial products suitable for substantive innovation, and build an information sharing platform for corporate green innovation; implement differentiated industry support strategies, meet the transformation capital needs of high-polluting industries through financial discounts and special credit lines, simplify service processes and reduce financing costs for non-high-polluting industries and high-tech industries, and help non-high-tech industries build industry-university-research cooperation bridges to enhance technology transformation capabilities; improve the innovation

supervision and incentive mechanism, establish a green patent quality evaluation system to distinguish between the two types of green innovation, improve the pricing mechanism of the capital market for substantive innovation, grant tax reductions to enterprises with high-level substantive green innovation, and strengthen information disclosure constraints on speculative innovation; consolidate digital financial infrastructure, promote data interconnection among financial, environmental protection, and science and technology departments to build a digital service ecosystem for green innovation. It is anticipated that through such modalities, the enabling efficacy of digital inclusive finance in underpinning high-quality corporate green innovation will be fully unleashed, thereby rendering substantive contributions to the sustainable evolution of the green economy.

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