The Effect of Digital Inclusive Finance on Corporate ESG Performance: Evidence from Chinese A-listed Shares

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Abstract. Digital Inclusive Finance (DIF) is a controversial policy. It can facilitate business startups, provide security and transparency, enhance social inclusion and equality, and foster economic development. Still, it may also result in a debt trap for borrowers and elevated financial risks for creditors. Examining its effects thus seems critical for policymakers. Many previous studies have examined the impact of DIF on corporate environmental social governance (ESG) performance; however, their heterogeneity and mechanism tests are not comprehensive enough to provide thorough policy recommendations. After giving theoretical proof of the causality between DIF and ESG, the study empirically finds a positive correlation between the local DIF index and corporate ESG ratings by exploiting data from publicly listed companies from 2011 to 2020, and it passes several endogeneity and robustness tests. Heterogeneity tests suggest that the relationship is especially significant for larger-sized publicly owned primary sector firms in less economically developed regions regarding their social performance index. Mechanism tests suggest mediating variables of enhanced executive's green attention, reduced carbon emission, increased government subsidy, improved information disclosure, reduced capital misallocation, and financial constraints. These results contribute to policymakers' decision-making for a more efficient DIF development process to facilitate ESG improvements.

Keywords: Digital Inclusive Finance; ESG; Listed Companies; Corporate Performance; Sustainability.

1. Introduction

Sustainability is the key to economic development. ESG (an acronym for a corporation's environmental, social, and governmental performance) has gained continuously improving attention throughout the globe as more companies adopt the triple-bottom-line accounting system, which focuses not only on financial factors but also does not overlook externalities [1].

In recent years, the government and corporations have innovated and developed according to the ESG standard. On a national level, the Chinese government incorporates ESG in its development strategy, aiming to peak carbon emissions in 2030 and reach carbon neutrality in 2060 [2]. Legislatively, the Ministry of Finance is developing national standards for corporate sustainability disclosures; many legal reforms have revised environmental laws and introduced the green finance system [3]. In 2023, 2115 of the 5346 listed companies on the Chinese domestic stock market published their ESG reports, a 10% increase from the previous year [4].

The increased focus on ESG performance is not limited to the Chinese market. In the United States, the Draft Rule 87 FR 36654, proposed in June 2023, encouraged investment products to disclose their ESG report (2023). Viewing from a global lens, a survey from NAVEX Global in December 2020 revealed that 88 percent of public companies incorporated ESG initiatives in their operation; Capital Group suggests that 89 percent of investors consider corporate ESG performance during their investment process in 2022 [5]. The increasing attention on ESG encourages policymakers and corporate managers to seek new means to improve their ESG performance.

On the other hand, Digital Inclusive Finance (DIF) is an increasingly popular topic that aims to provide financial services to the underserved population, encourage business startups, and foster social inclusiveness and sustainable development. The study elaborates on the definition of Financial Inclusion by the United Nations, defining DIF as a financial system that effectively and comprehensively serves all social classes and groups through digital means. In China, DIF can be

achieved mainly through five ways: (1) offering financially excluded and underserved populations digital financial services; (2) facilitating the startup of small businesses; (3) digitizing government-backed microfinance institutions; (4) developing affordable insurance products targeted at underinsured demographics; (5) rolling out nationwide programs to improve financial literacy [6].

Similarly, DIF development is a global trend. For more than 80 countries, the availability of innovative digital financial services that involve the use of mobile phones is increasing (GSMA, 2014). Mobile money services, such as mobile insurance, savings, and credits, are available in 61% of developing countries around the globe (85 of 139 markets) (GSMA, 2014) [7]. However, DIF can also be a double-edged sword. Advancement of DIF may lead to a debt trap for borrowers, and its higher risk may lead to financial loss for creditors if legislation is not thoroughly enforced. Thus, thoroughly examining the effects of DIF development before policy implementation is crucial. The study investigates the impact of DIF on ESG, aiding policymakers in making more comprehensive decisions and considering the effect of DIF on social costs and benefits.

The study's innovations may be summarized into the following aspects: research theme, theory methodology, and data. Most existing studies use a composite ESG index that is thematically separated into sub-indices showing the distinct effects of DIF on E, S, and G aspects. The detailed model is used throughout the research and offers unique insights for policy recommendations. Moreover, seven mediating variables are selected to provide further insight into the mechanism by which DIF influences ESG, providing evidence for policy recommendations. The study uses a theoretical model as the basis of the investigation to give mathematical reasoning to the primary model. Specific steps are outlined in Section 2 of the paper. Lasso Machine Learning screens out influential control variables from 413 to strengthen the model. Multiple models, including PSM-DID, DID, SUR, and Instrumental Variables, are used to prove endogeneity and reduce bias, enhancing the credibility and robustness of conclusions. The study uses panel data to ensure the continuity of DIF's impact on ESG. It gleaned various variables regarding the local economic environment from various government sources. The expansiveness of the data dramatically improved the credibility and generalizability of the results.

2. Research Hypothesis

2.1 Main Hypothesis

H1: DIF can significantly enhance ESG performance [8].

2.2 Heterogeneity Hypotheses

The Fig 1 illustrates the structure of the heterogeneity tests in the study, specifically focusing on six selected heterogeneity variables.

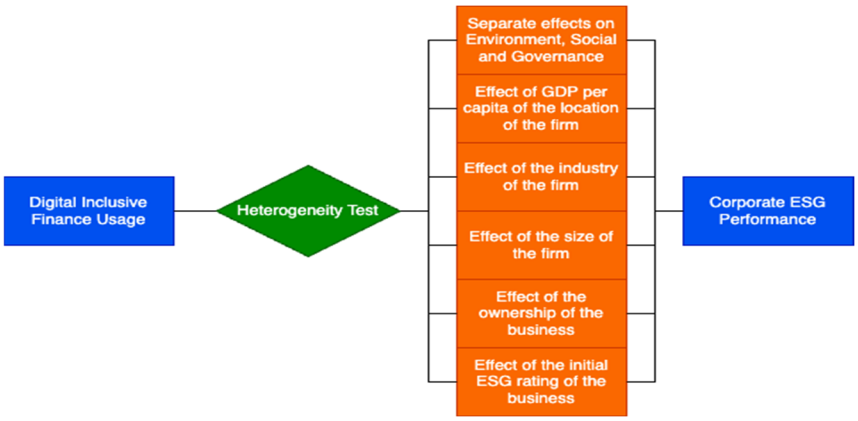

Fig 1. Heterogeneity hypotheses

H2: Considering the sub-dimensions of E, S, and G in ESG, the S aspect has the most considerable marginal impact compared with the E and G aspect for the effect of DIF on ESG [9].

H3: The heterogeneity effect of DIF on ESG is more potent in areas with lower GDP than with higher GDP.

H4: The heterogeneity effect of DIF on ESG is more vital for the primary sector than the secondary sector than the tertiary sector.

H5: The heterogeneity effect of DIF on ESG is more substantial for more prominent firms than for smaller firms.

H6: The heterogeneity effect is stronger for publically owned firms than privately owned firms and foreign joint ventures.

H7: The heterogeneity effect is stronger for companies with lower initial ESG ratings than with higher initial ESG ratings.

2.3 Mechanism Hypotheses

The diagram (2) illustrates the structure of the study's mechanism tests, focusing on seven mediating variables.

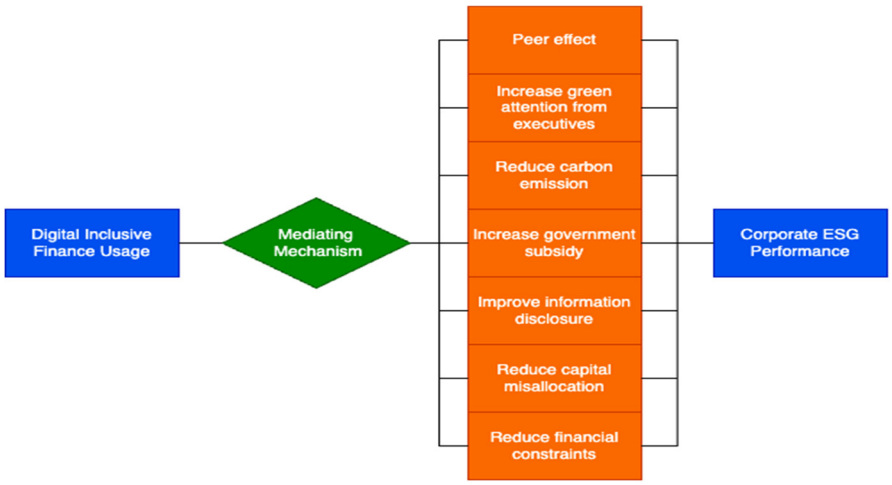

Fig 2. Mechanism Hypotheses

H8: Peer effect within the industry is a mediating variable.
H9: Executives' green attention is a mediating variable.
H10: Carbon emission reduction is a mediating variable.
H11: Increased government subsidy is a mediating variable.
H12: Enhanced information disclosure is a mediating variable.
H13: Reduced capital misallocation is a mediating variable.
H14: Reduced financial constraints are a mediating variable.

3. Research Methodology

3.1 Data Source

A wide range of secondary data sources are utilized in the study. The ESG score derives from Bloomberg's panel data of all Chinese A-listed shares (2011-2020); The DIF index derives from "the Peking University Digital Financial Inclusion Index of China" (2011-2020); The data regarding GDP and population derives from official demographic census (2011-2020); The data of size of business derives from calculations of Market Capitalization of Business according to data from Shanghai and Shenzhen Stock Exchange (2011-2020); The data about location and ownership derives from official government reports (1991-2024); The index used to assess the peer effect between companies derives

from a research made by Xi and Zhao (2009-2022); The measure for green attention derives from word frequency statistics obtained through corporate annual reports using the methodology developed by Duriau, Reger, and Pfarrer (2007-2021); The carbon emission measures derive from Carbon Emission Accounts and Datasets (CEADs) sponsored by the People's Republic of China Ministry of Science and Technology (1997-2019); The data of government subsidies derive from excerpts of official government data (2003-2019); The grading of information disclosure derives from Shanghai and Shenzhen Stock Exchange using a methodology from Lin, Mao, and Liu (2001-2021).

3.2 Key Variables

The independent variable used in the study is The Peking University Digital Financial Inclusion Index of China, a panel data from 2011 to 2020. The incorporates Level 1 Dimensions of coverage breadth, usage depth, and digitalization level and Level 2 Dimensions of insurance, monetary funds, investments, credits, and credit investigations into its calculation [7].

The dependent variable in the study is firms' ESG performance, a composite index considering E, S, and G aspects. The score is a relative index considering the company's peer groups' performances. The matrix of ESG performance measurement will be used throughout the study [8].

The heterogeneity test investigates the following variables: Separate E, S, and G factors, GDP per capita of the company's location, industry, size, ownership, and the initial ESG rating of the business upon its registration.

The mediating variables identified in the study include firms' peer effect, executives' green attention, businesses' carbon emissions, government subsidies, companies' information disclosure, financial constraints, and capital misallocation.

To ensure credibility, an array of control variables is selected from the local and corporate levels. Corporate-level variables include the largest ten shareholders' holdings, ROA, Composite Leverage Index, asset growth, current ratio, and asset-liability ratio. Local-level variables include the tertiary sector ratio, GDP growth rate, college diploma holders, and natural population growth rate. These variables help control for factors like capital structure, significant shareholder influence, and economic vitality at the local and corporate levels.

3.3 Methodology

In the study, Lasso Machine Learning is first used to aid the selection of control variables. Then, fixed effect regressions are conducted. Heterogeneity tests are performed by comparing the results of two sets of data separated through the mean of the original set; a mechanism test is used to show the channels in which DIF influences ESG. Additionally, the parallel trend test, DID model, PSM-DID model, and instrumental variables are used for the endogeneity tests.

4. Research Results

4.1 Main Hypothesis

Table 1. Main Model Results

Model	(1) Fixed effect	(2) Random effect
DV	General ESG Index	
DIF	0.0204***(7.669)	0.0177***(6.034)
Control Variables	Y	Y
Time effect	Y	Y
Individual effect	Y	Y
N	29,877	29,877

Note: "*," "**," and "***" represent significance levels of 0.1, 0.05, and 0.01, respectively. T-values of regressions are included in the parentheses. The exact format is used for all tables in the study.

As shown by Table 1, a positive significant correlation is yielded by regression types of both fixed effect and random effect, with coefficients of 0.0177 and 0.0204, respectively, and a p-value under 0.01. It provides primary empirical evidence for the relationship between DIF and ESG posited in the central hypothesis.

4.2 Heterogeneity Tests

4.2.1 Separate Effects on Environment, Social, and Governance

Table 2 illustrates the separate regression results of the influence of DIF on corporate E, S, and G performance.

Table 2. Heterogeneity test-Separate effects on Environment, Social and Governance Results

Model	Fixed effect		
DV	(1) E index	(2) S index	(3) G Index
DIF	0.0101*** (12.826)	0.0335*** (11.970)	0.0203*** (11.744)
Control Variables	Y	Y	Y
Time effect	Y	Y	Y
Individual effect	Y	Y	Y
N	29,877	29,877	29,877

The impact of DIF on E, S, and G aspects is examined separately. The results show that while all three variables experience a positive correlation with DIF, the effect on the social index (0.0335) is the most significant, followed by the governance and environment indices (0.0203 and 0.0101, respectively). Greater stakeholder scrutiny and quick adjustability of corporate social performance may explain it.

4.2.2 Effect of GDP Per Capita on the Location of the Firm

Table 3 illustrates the impact of GDP per capita of the firm's location on the influence of increased DIF on ESG.

Table 3. Heterogeneity test-Effect of GDP per capita of the location of the firm Results

Model	Fixed effect							
Half Type	(1)Upper	(2)Lower	(3)Upper	(4)Lower	(5)Upper	(6)Lower	(7)Upper	(8)Lower
DV	General ESG Index		E index		S index		G index	
DIF	0.0100*** (3.380)	0.0210*** (11.872)	0.0060*** (3.438)	0.0120*** (10.000)	0.0220*** (4.887)	0.0390*** (14.730)	0.0060*** (7.750)	0.0240*** (6.111)
Control Variables	Y	Y	Y	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y	Y	Y	Y
N	16,030	16,970	16,030	16,970	16,030	16,970	16,030	16,970

The correlation is more potent if the business location has a GDP per capita lower than the mean of the study, with a coefficient of 0.0100 in the upper half and a coefficient of 0.0210 in the lower half, exploiting fixed effect regression and using the general index. The heterogeneity conclusion holds for all three specific ESG aspects. It may be explained by more significant financial and technological constraints and information asymmetry in less economically developed regions. These problems can be alleviated using DIF, and its effects on corporate performance will thus be more direct and observable.

4.2.3 Effect of the Industry of the Firm

Table 4 illustrates the impact of the firm's industry on the impact of increased DIF on composite corporate ESG rating and the separate effects of E, S, and G.

Table 4. Heterogeneity Test-Effect of the industry of the firm Results

Model	Fixed effect					
Half Type	(1)Primary	(2) Secondary	(3)Tertiary	(4)Primary	(5)Secondary	(6)Tertiary
DV	General ESG Index			E Index		
DIF	0.0501***(2.671)	0.0200***(11.650)	0.0132***(5.549)	0.0134(1.236)	0.0122*** (9.599)	0.0065*** (4.658)
DV	S Index			G Index		
DIF	0.0712***(2.873)	0.0391***(15.200)	0.0222***(6.065)	0.1132**(2.407)	0.0194***(5.245)	0.0204***(3.389)
Control Variables	Y	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y	Y
N	400	23,430	9,050	400	23,430	9,050

The correlation coefficient between DIF and ESG is most robust in the primary sector (0.0501) and the weakest in the tertiary sector (0.0132). It may be explained by the greater regulatory and stakeholder scrutiny of the externalities of enterprises in the primary industry and the fact that their business operations are most directly affected by environmental externalities.

4.2.4 Effect of the Size of the Firm

Table 5 illustrates the impact of the firm's size on the effects of increased DIF on ESG.

Table 5. Heterogeneity test-Effect of the size of the firm Results

Model	Fixed effect							
Half Type	(1)Upper	(2)Lower	(3)Upper	(4)Lower	(5)Upper	(6)Lower	(7)Upper	(8)Lower
DV	General ESG Index		E index		S index		G index	
DID	0.0223*** (4.810)	0.0139*** (5.007)	0.0206*** (4.320)	0.0068*** (4.128)	0.0390*** (4.780)	0.0283*** (6.514)	0.0173** (1.987)	0.0159*** (6.514)
Control Variables	Y	Y	Y	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y	Y	Y	Y
N	18,477	14,523	18,477	14,523	18,477	14,523	18,477	14,523

The results suggest that the impact of DIF on ESG is more significant for larger companies, with a fixed-effect regression coefficient of 0.0223 for larger firms compared to 0.0139 for smaller firms. It may be explained by larger enterprises' operation processes and profitability, which depend more on their reputation. A more transparent information disclosure system and higher investment in green innovation may benefit them more than smaller companies.

4.2.5 Effect of the Ownership of the Business

Table 6. illustrates the impact of the firm's ownership on increased DIF on ESG.

Using the general index, the correlation is more significant for the public sector (0.0203) than the private sector (0.0159) than foreign joint ventures (0.0132), with differences in ranking when examined in terms of separate E, S, and G factors. It may be explained by the need for public sector firms to request government funds with an evaluation process linked to assessing their social benefits and social costs.

Table 6. Heterogeneity test-Effect of the ownership of the business Results

Model	Fixed effect					
Half Type	(1) Private	(2) Public	(3) FJV	(1) Private	(2) Public	(3) FJV
DV	General ESG Index			E Index		
DIF	0.0159*** (8.215)	0.0203*** (9.332)	0.0132** (2.155)	0.0077*** (6.546)	0.0125*** (7.562)	0.0097* (1.782)
DV	S Index			G Index		
DIF	0.0316*** (10.992)	0.0374*** (11.175)	0.0246*** (2.639)	0.0195*** (4.034)	0.0213*** (4.784)	0.0164**(2.012)
Control Variables	Y	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y	Y
N	19,240	10,360	2,960	19,240	10,360	2,960

4.2.6 Effect of the Initial ESG Rating of the Business

Table 7 illustrates the impact of the firm's initial ESG rating on the effects of increased DIF on ESG.

Table 7. Heterogeneity test-Effect of the initial ESG rating of the business Results

Model	Fixed effect							
Half Type	(1) Upper	(2) Lower	(3) Upper	(4) Lower	(5) Upper	(6) Lower	(7) Upper	(8) Lower
DV	General ESG Index		E Index		S Index		G Index	
DID	0.0138***(6.516)	0.0205***(11.056)	0.0090***(6.265)	0.0105*** (7.986)	0.0291*** (9.077)	0.0365*** (13.173)	0.0115*** (2.726)	0.0268*** (6.254)
Control Variables	Y	Y	Y	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y	Y	Y	Y
N	18,669	14,331	18,669	14,331	18,669	14,331	18,669	14,331

The results suggest that, for companies with lower initial ESG ratings, the correlation between DIF and ESG is more robust for all E, S, and G aspects (with a coefficient of 0.0205 for corporations in the lower half and a coefficient of 0.0138 for corporations in the upper half in terms of ESG performance index value). It may be explained by the higher stakeholder pressure for the management team of businesses with poorer ESG performance, and it suggests that the marginal utility of ESG performance may generally decrease for most companies if its ESG performance is not effectively used as a marketing tool.

4.3 Mechanism Tests

4.3.1 Mechanism Test on Peer Effect

Table 8. illustrates the mediating impact of peer effect on the impact of DIF on ESG.

The results suggest that peer effect among businesses may have a negative impact if the competitors are located in the same city (-0.0753) but a positive effect if the businesses are within the same industry (0.0735). DIF enhances the transparency of business information to stakeholders, increasing business competition. For companies in the same sector, increased competition may urge businesses to improve their ESG performance to differentiate themselves from their peers. However, for businesses in the same geographical area, such higher demand for ESG innovation tools in a particular geographical location may lead to higher prices, discouraging new firms from ESG investments.

Table 8. Mechanism test on peer effect results

Model	Fixed effect	
DV	General ESG Index	
Peer Effect Scope	Same City	Same Industry
DIF	-0.0753***(-5.468)	0.0735***(5.594)
Control Variables	Y	Y
Time effect	Y	Y
Individual effect	Y	Y
N	25,689	25,689

4.3.2 Mechanism Test on Green Attention of Executives

Table 9 illustrates the mediating effect of the green attention of executives on the impact of DIF on ESG.

Table 9. Mechanism test on green attention of executives Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0306***(5.063)	0.0360***(4.063)	0.0385***(3.313)	0.0118***(2.940)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	23,169	23,169	23,169	23,169

The results suggest that the green attention of executives has a mediating effect, with a coefficient of 0.0306 and passing a significance level of 0.01. It may be attributed to the fact that DIF increases ESG information transparency and draws more stakeholder attention in assessing the ESG performance of corporations. Executives, in turn, will also focus more on improving the ESG performance of their enterprise, investing in green innovation, and enhancing its information measuring and disclosure systems.

4.3.3 Mechanism Test on Carbon Emission of Business

Tables 10 illustrate the mediating influence of reduced carbon emissions on companies' impact of DIF on ESG.

Table 10. Mechanism test on carbon emission of Business Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0837***(7.658)	0.0607***(8.054)	0.1667***(10.250)	0.0503***(6.061)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	24,784	24,784	24,784	24,784

The mechanism test indicates that reduced carbon emissions are a mediating variable, with a p-value under 0.01 and a coefficient of 0.0837. It may be attributed to the fact that DIF may improve information transparency and highlight opportunities for businesses to invest in green innovation and reduce their future carbon emissions to benefit economically in the long run through carbon trading and avoiding fines.

4.3.4 Mechanism Test on Government Subsidy

Table 11 illustrates the mediating effect of government subsidy of business on the impact of DIF on ESG.

Table 11. Mechanism test on government subsidy Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0274***(3.124)	0.0300***(5.467)	0.4820***(4.051)	2.9500e-9***(3.041)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	22,671	22,671	22,671	22,671

The results support the hypothesis that increased government subsidy is a mediating variable, with a p-value under 0.01 and a coefficient of 0.0274. It may be attributed to DIF improving enterprises' information transparency, which is conducive to applying government funds and subsidies. It could alleviate the financial constraints that initially hindered businesses from creating long-term value through green investments.

4.3.5 Mechanism Test on Information Disclosure

Table 12 illustrates the mediating effect of business information disclosure on the impact of DIF on ESG.

Table 12. Mechanism test on information Disclosure Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0197**(1.971)	0.0127*(1.812)	0.0318**(2.131)	0.0234(1.054)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	6,974	6,974	6,974	6,974

The results support the hypothesis that increased government subsidy is a mediating variable, with a coefficient of 0.0197 and a significance level under 0.05. It may be attributed to the fact that DIF may provide additional capital for enterprises, enhancing the efficiency of measuring and recording firm data. It dramatically improves a business's governance score and attention to social and environmental externalities.

4.3.6 Mechanism Test on Reducing Capital Misallocation

Table 13 illustrates the mediating effect of lowering capital misallocation of business on the impact of DIF on ESG.

Table 13. Mechanism test on reducing capital misallocation Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	-0.0357***(-4.302)	-0.0178***(-2.923)	-0.0725***(-3.751)	-0.0236**(-1.980)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877

A negative coefficient (-0.0357) is found for the mediating effect of capital misallocation on the impact of DIF on ESG performance, suggesting that reducing capital misallocation is a mediating variable. It may be attributed to the fact that DIF alleviates information asymmetry and guides financial capital to areas where it can yield the most outstanding value, fostering more significant corporate ESG investments that enhance the firm's value in the long term.

4.3.7 Mechanism Test on Reducing Financial Constraints

Table 14 illustrates the mediating effect of reducing the financial constraint of business on the impact of DIF on ESG.

Table 14. Mechanism test on reducing financial constraints Results

Model	Fixed effect							
Half Type	(1)General	(2)E Index	(3)S Index	(4)G Index	(5)General Index	(6)E Index	(7)S Index	(8)G Index
MV	FC				KZ			
DIF	-0.1721* (-1.947)	-0.1104* (-1.829)	-0.3820*** (-3.975)	-0.2753* (-1.954)	-0.0442*** (-2.612)	-0.0205* (-1.725)	-0.0469* (-1.829)	-0.0891** (-2.329)
MV	SA				WW			
DIF	-0.2842*** (-8.314)	-0.1607*** (-6.670)	-0.4988*** (-9.653)	-0.3350*** (-4.323)	-3.36e-04** (-2.213)	-1.33e-04** (-2.289)	-6.44e-05** (-2.065)	-3.36e-04** (-2.228)
Control Variables	Y	Y	Y	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877	29,877	29,877	29,877	29,877

The majority of the regression results suggest a negative mediating coefficient. The random effect regression using FC, KZ, SA, and WW indices (with coefficients of -0.1721, -0.0442, -0.2842, and -3.36e-04, respectively) has a significance level below 0.10. Thus, the hypothesis that reducing financial constraints is a mediating variable can be corroborated, as DIF can effectively reduce financial constraints and foster greater capital allocation towards corporate ESG investments.

4.4 Robustness Check

4.4.1 Robustness Check of the Central Hypothesis

Table 15 illustrates the robustness check of the central hypothesis by substituting the independent variable composite DIF index with subindexes of DIF and examining their effects on the composite ESG index.

Table 15. Robustness checks on main hypothesis Results

Model	Fixed effect				
DV	Composite ESG Index				
IV	ind_index	ind_cbr	ind_ude	ind_pay	ind_ins
DIF	0.0178***(6.034)	0.0224***(6.895)	0.0190***(7.637)	0.0173***(4.155)	0.0049***(4.155)
IV	ind_mof	ind_inv	ind_cre	ind_cin	ind_dle
DIF	0.0077***(3.761)	0.0171***(3.318)	0.0307***(8.956)	0.0051***(4.396)	0.0146***(8.973)
Control Variables	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y
N	29,877	29,876	29,876	29,876	29,876

Through a comprehensive robustness check of changing the composite DIF index (the x variable in the regression) to a series of subindexes (including coverage breadth, usage depth, and digitalization level), and specific measures (including payment, insurance, monetary fund, investment,

credit, and credit investigation), the model proves to be robust, evidenced by the fact that all p-values are smaller than 0.01.

4.4.2 Robustness Check of Heterogeneity Test

Tables 16, 17, and 18 illustrate the central hypothesis's robustness check by substituting the independent variable composite DIF index with subindexes of DIF and examining their effects on separate E, S, and G ratings.

Table 16. Robustness check on heterogeneity hypothesis (E Index) Results

Model	Fixed effect				
DV	E Index				
IV	ind_index	ind_cbr	ind_ude	ind_pay	ind_ins
DIF	0.0101***(2.826)	0.0159***(6.137)	0.0154***(6.810)	0.0117***(5.557)	0.0020***(4.365)
IV	ind_mof	ind_inv	ind_cre	ind_cin	ind_dle
DIF	0.0022***(2.973)	0.0051***(3.150)	0.0121***(5.817)	omitted	0.0095***(6.904)
Control Variables	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y
N	29,876	29,876	29,876	29,876	29,876

Table 17. Robustness check on heterogeneity hypothesis (S Index) Results

Model	Fixed effect				
DV	S Index				
IV	ind_index	ind_cbr	ind_ude	ind_pay	ind_ins
DIF	0.0335***(22.881)	0.0314***(8.826)	0.0254***(10.401)	0.0214***(7.138)	0.0059***(6.224)
IV	ind_mof	ind_inv	ind_cre	ind_cin	ind_dle
DIF	0.0043***(5.020)	0.0069***(4.437)	0.0335***(8.797)	omitted	0.0204***(10.430)
Control Variables	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y
N	29,876	29,876	29,876	29,876	29,876

Table 18. Robustness check on heterogeneity hypothesis (G Index) Results

Model	Fixed effect				
DV	G Index				
IV	ind_index	ind_cbr	ind_ude	ind_pay	ind_ins
DIF	0.0203***(3.970)	0.0296***(8.826)	0.0218***(10.401)	0.0262***(7.138)	0.0020**(2.224)
IV	ind_mof	ind_inv	ind_cre	ind_cin	ind_dle
DIF	0.0070**(2.020)	0.0112**(2.437)	0.0639***(8.797)	omitted	0.0213***(10.430)
Control Variables	Y	Y	Y	Y	Y
Time effect	Y	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y	Y
N	29,876	29,876	29,876	29,876	29,876

The robustness check for heterogeneity tests also yielded an affirmative result, with all results having a p-value smaller than 0.05. It proves that each of the specific measures of DIF indeed has a positive effect on each of the particular aspects of corporate E, S, and G performance. Like the composite index, coverage breadth, and credit level stand out as the most crucial factors compared to other indexes at the same level.

4.4.3 Winsor Trimming

Winsorization is applied to continuous variables at 1% and 99% quantiles by year. Table 19 illustrates the effects of increased DIF on the general ESG index and separate E, S, and G aspects after Winsor trimming.

Table 19. Robustness check - Winsor Trimming Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0117***(7.580)	0.0053***(6.866)	0.0239***(10.185)	0.0096***(4.769)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877

After Winsor trimming, the regression results remain significant for all four indices used (with all their p-values remaining under 0.01). It proves that potential outliers do not skew the primary model.

4.5 Endogeneity Tests

4.5.1 Parallel Trend Test

All the companies are separated into two groups: the treatment group (companies located in DIF pilot zones with more comprehensive policies facilitating DIF development since 2016) and the control group (those not located inside the identified pilot zones). In 2016, the policy's implementation year, the mean ESG score of companies in the treatment group was lower than that of the enterprises in the control group. However, in the following years, the ESG score of the treatment group increased at a greater rate. In 2018, the two mean values crossed. It offers proof of the endogeneity of the results: that the high ESG increase may be attributed to the implementation of DIF policies.

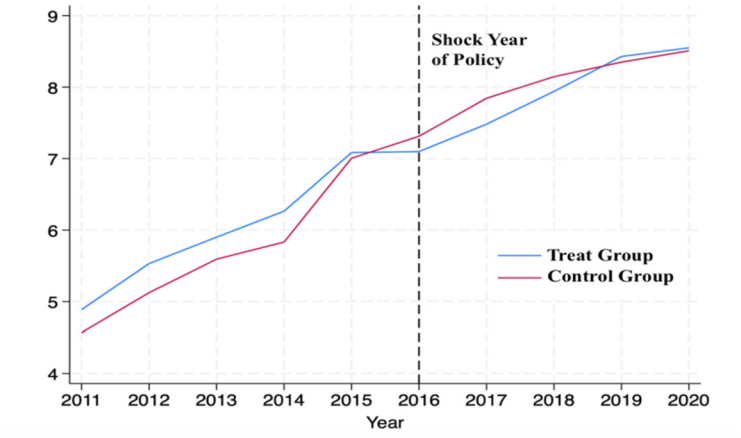

Fig 3. Parallel Trend Graph

4.5.2 DID Model

Model 20 is a difference in difference (DID) regression that estimates the effect of DIF pilot zones by comparing the regression models of test cities and control cities of the DIF index on a general index and a separate ESG rating.

The endogeneity test of screening experimental units using a dummy time variable and a dummy location variable proves an enhanced relationship between DIF and ESG in test cities. Significant to the 0.05 level for the composite index and sub-indices, it confirms our hypothesis that a causal relationship exists between DIF and ESG.

Table 20. Endogeneity test - DID model Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	1.0500***(5.218)	0.4376**(2.534)	1.1522**(2.461)	2.4730***(5.242)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877

4.5.3 PSM-DID Model

In addition to a simple DID model, PSM is conducted in the section before DID to reduce sampling bias and provide more robust results to bolster the study's conclusions. Fig 4 shows the standardized bias before and after the nearest neighboring matching process; a more negligible standardized bias shows better-matched data points.

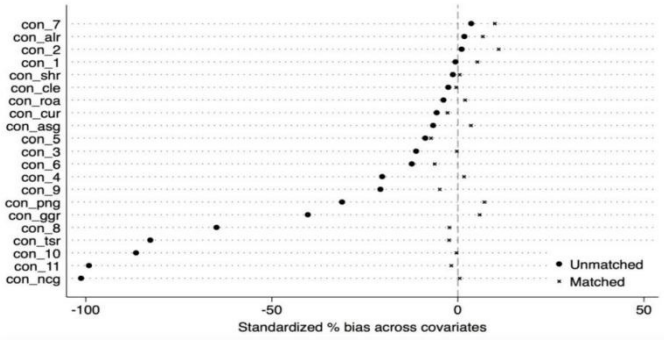

Fig 4. Standardized Bias before and after NNM

Most matched variables' standardization bias (% bias) is successfully lowered through nearest-neighboring matching. All T-test results corroborated the original hypothesis, and the systematic difference between the control and treatment groups was mitigated, satisfying the parallel hypothesis. Only a few processing groups are out of the expected value range, and only a few samples are lost when matching, consistent with the previous analysis. Furthermore, the PSM test yielded a t-value of 8.1549, showing the statistical significance of the experiment.

Table 21. Endogeneity test - PSM-DID Model Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	2.0497***(3.521)	1.2409***(5.101)	2.4339**(2.562)	4.0517***(4.156)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877

Moreover, based on the DID model, the external shock is significant across all E, S, and G aspects, with the most salient effect on enterprises' governance performance (which may be explained by the fact of higher regulatory pressure on information disclosure for companies located inside pilot zones). It adds further corroboration to the model's endogeneity.

4.5.4 Instrumental Variable

Table 22 illustrates the effect of using the first-order lag of the explanatory variable in place of the original explanatory variable on the general ESG index and separate indexes of E, S, and G.

Table 22. Endogeneity test - Instrumental Variable First-Order Lag Model Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0104***(6.511)	0.0068***(6.365)	0.0163***(7.503)	0.0122***(3.197)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877

Using the first-order lag of x as an instrumental variable to reduce the potential interactive effect between the explanatory variable and the explained variable yields results significant to the 0.01 level, suggesting that the results are not biased due to the interaction between the descriptive and the explained variable.

Table 23. Endogeneity test - Instrumental Variable Two Stage Least Squares Model Results

Model	Fixed Effect			
DV	(1) General Index	(2) E Index	(3) S Index	(4) G Index
DIF	0.0103***(2.630)	0.0067***(3.042)	0.0162**(2.375)	0.0153*(1.825)
Control Variables	Y	Y	Y	Y
Time effect	Y	Y	Y	Y
Individual effect	Y	Y	Y	Y
VCE Robust	Y	Y	Y	Y
N	29,877	29,877	29,877	29,877

Next, when utilizing the TSLS regression model, all results have passed the weak IV test (Minimum eigenvalue statistic >16.38), and the identification test (P value of Sargan-Basman >0.05), and all the results have a positive coefficient and significant to the 0.1 level. It again provides further evidence of the endogeneity of the model.

4.5.5 SUR Model: Considering Interaction Effect between E, S, and G

The SUR model excludes the impact of the interaction effect between E, S, and G performance on the regression model and rules out a potential homogeneity.

Table 24. Endogeneity test - SUR Model Results

DV	(1) Environmental	(2) Social	(3) Governance
DIF	0.0058***(6.748)	0.0184***(10.460)	0.0019**(2.189)
Time effect	Y	Y	Y
Individual effect	Y	Y	Y
Control	Y	Y	Y
N	29,877	29,877	29,877

Using the SUR model for all three ESG indices yields a positive coefficient for the central hypothesis. However, only Environmental and Social indices have a significance level below 0.01. G is not similarly significant because stakeholders' objectives in developing its environmental and social aspects may conflict with the governance criteria of enhanced information disclosure. In other words, it may be difficult for companies to balance disclosing such information to maximize green financial performance and the effectiveness of green innovation.

5. Conclusion

The results of the study confirmed the following hypotheses:

DIF can enhance ESG performance. The heterogeneity effect is more substantial in the social aspects than in governance and environmental aspects. The heterogeneity effect is most potent in

areas with lower GDP per capita. The heterogeneity effect is stronger for the primary sector than for the secondary and tertiary sectors. The heterogeneity effect is more substantial for larger firms. The heterogeneity effect is stronger for publicly owned firms than privately owned firms and foreign joint ventures. The heterogeneity effect is more significant for companies with lower initial ESG ratings. Peer effect within the same industry is a mediating variable. Executives' green attention is a mediating variable. Reduced carbon emission is a mediating variable. Increased government subsidy is a mediating variable. Enhanced information disclosure is a mediating variable. Reduced capital misallocation is a mediating variable. Reduced financial constraints are a mediating variable.

Based on the results of the heterogeneity tests, areas where marginal DIF development can lead to the most significant impact on ESG can be highlighted. The results of the mechanism tests suggest the channels in which DIF influences ESG and thus further strengthens and develops these channels can be specified. Regressions separating the DIF index into Level 1 and Level 2 dimensions can aid in determining which aspects of DIF development have the most significant effect on enhancing ESG performance. It offers crucial insights for policymakers, financial institutions, and corporate strategists to consider during their decision-making process.

The study primarily utilizes DIF data from Peking University and ESG rating from Bloomberg, which may lead to inaccuracy due to data collection and composition. Moreover, the study solely utilizes data from A-listed companies in China, making the results less helpful in investigating the global market. Future research can expand the type of data source and the scope of the study to yield a more comprehensive result.

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