How Does Carbon Disclosure Alleviate Financing Constraints? Evidence from Chinese A-Share Firms

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Abstract. This study examines the effect of carbon disclosure intensity on corporate financing constraints using a sample of Chinese A-share listed firms from 2010 to 2024. While prior research focuses on ESG disclosure as a whole, limited evidence exists on the independent role of carbon disclosure. Using the KZ index to measure financing constraints and employing two-way fixed-effects and mediation analyses, the results show that higher carbon disclosure intensity significantly alleviates financing constraints. Mechanism tests indicate that this effect operates through reduced information asymmetry and improved capital allocation efficiency. This study contributes by isolating carbon disclosure from broader ESG frameworks, providing a more targeted empirical assessment, and offering evidence on its financing implications in an emerging market context.

Keywords: Carbon disclosure intensity; financing constraints; information asymmetry; capital allocation efficiency; green finance

1 Introduction

The transition toward a low-carbon economy has elevated the role of carbon information disclosure in shaping firms' information environment and financing conditions. In China, recent regulatory efforts promoting ESG disclosure and carbon reporting aim to enhance transparency and facilitate green capital allocation. However, despite these policy initiatives, corporate carbon disclosure remains limited. As of April 2025, only about 30% of A-share listed firms disclosed greenhouse gas emissions, and the disclosure rate for Scope 3 emissions was as low as 5%. This persistent lack of transparency raises concerns about the effectiveness of carbon disclosure in capital markets.

Financing constraints remain a critical barrier to corporate development, particularly in emerging markets. As financial institutions increasingly incorporate environmental risks into decision-making, carbon information has become an important basis for evaluating firm risk and creditworthiness. Insufficient disclosure may exacerbate information asymmetry, leading to higher financing costs and restricted access to external capital. Existing literature suggests that ESG performance and environmental disclosure can alleviate financing constraints by enhancing transparency and investor confidence. However, two important gaps remain. First, most studies treat carbon

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disclosure as part of broader ESG or environmental disclosure, with limited evidence on its independent effects. Second, current measures of carbon disclosure often rely on single-dimensional indicators or third-party ratings, which may fail to capture the multidimensional nature of corporate carbon transparency and introduce measurement bias.

To address these gaps, this study examines whether carbon disclosure intensity reduces financing constraints and investigates the underlying mechanisms. Using a sample of Chinese A-share listed firms from 2010 to 2024, we construct a multidimensional carbon disclosure index based on manual scoring, textual analysis, and cross-validation with external databases. Empirical results based on two-way fixed-effects models show that higher carbon disclosure intensity significantly alleviates financing constraints. Mechanism analyses further indicate that this effect operates through reduced information asymmetry and improved capital allocation efficiency. By isolating carbon disclosure from broader ESG measures and providing a more comprehensive measurement framework, this study contributes to the literature on non-financial disclosure and corporate finance, and offers new evidence on how carbon transparency affects firms' financing outcomes in emerging markets.

2 Literature Review

2.1 Theoretical Framework

This study draws on signaling theory, stakeholder theory, and legitimacy theory to explain how carbon disclosure may affect financing constraints [1][2]. Signaling theory suggests that, under information asymmetry, high-quality firms voluntarily disclose credible information to distinguish themselves from lower-quality peers. In the context of carbon disclosure, firms can signal superior environmental risk management and a stronger commitment to sustainable development, thereby reducing uncertainty perceived by investors and creditors [3]. Stakeholder theory emphasizes that firms benefit from maintaining credible relationships with key stakeholders, particularly investors and financial institutions. Greater carbon transparency can strengthen trust and facilitate access to external finance [4]. Legitimacy theory complements this view by suggesting that firms enhance social acceptance and market recognition when they align with prevailing environmental expectations through disclosure practices. Taken together, these theories suggest that carbon disclosure can improve firms' information environment, enhance stakeholder confidence, and strengthen legitimacy, thereby easing financing constraints.

2.2 Literature Review on the Relationship between Financing Constraints and Carbon Information Disclosure

Financing constraints arise from information asymmetry and agency problems that increase the cost of external capital. When investors cannot fully observe firms' risk profiles or project quality, they demand higher risk premiums or restrict capital supply, thereby intensifying financing frictions. Empirically, financing constraints are com-

monly measured using composite indices such as the KZ, WW, and SA indices. Prior research shows that these constraints vary with firm characteristics and governance structures, with larger and better-governed firms facing fewer constraints.

Carbon information disclosure (CID) represents an important dimension of corporate transparency, providing information on firms' emissions, climate strategies, and environmental governance [5]. Existing studies suggest that such disclosure improves market perceptions by enhancing transparency, strengthening investor confidence, and reducing adverse selection, thereby lowering financing costs [6].

However, the effect of carbon disclosure on financing constraints is theoretically ambiguous. While greater disclosure reduces information asymmetry, it may also reveal firms' exposure to climate risk and increase perceived uncertainty. Despite this ambiguity, the emerging evidence generally supports a net beneficial effect. High-quality carbon disclosure reduces financing constraints by lowering information asymmetry and enhancing corporate reputation, thereby improving access to external capital [7].

2.3 Mediating Mechanisms

Information Asymmetry. Under signaling theory, carbon disclosure conveys credible information about firms' environmental governance and sustainability prospects, thereby reducing information asymmetry in capital markets. Information asymmetry is a primary source of financing constraints, as external investors face difficulties in assessing firms' risk profiles, project quality, and repayment capacity, leading to higher risk premiums and restricted capital supply (Liao et al., 2025).

By disclosing carbon-related information, firms enhance transparency regarding environmental risks, emission reduction strategies, and governance practices. This reduces investors' uncertainty and improves their ability to evaluate firm fundamentals (Xu et al., 2024). As a result, perceived risk declines, capital allocation becomes more efficient, and financing constraints are alleviated. Existing evidence supports this mechanism, showing that high-quality carbon disclosure reduces information asymmetry and improves firms' access to external financing [7].

Based on the above discussion, we propose the following hypothesis:

H2: Carbon disclosure alleviates financing constraints by reducing information asymmetry.

Capital Allocation Efficiency. From the perspective of the resource-based view, firms gain competitive advantage through the accumulation and effective utilization of heterogeneous resources. Carbon disclosure can be viewed as a process through which firms build such resources by signaling environmental governance capabilities and long-term strategic commitment. This enhances firms' reputation and social capital, facilitating access to external financing [8].

Improved access to capital and stronger governance incentives enable firms to allocate resources more efficiently. Carbon disclosure encourages investment toward value-enhancing and sustainability-oriented projects, thereby reducing inefficient

investment and improving capital allocation efficiency. Higher allocation efficiency, in turn, lowers firms' reliance on costly external financing and improves financing conditions. Moreover, efficient capital use signals better managerial quality and strengthens investor confidence [9].

Based on the above discussion, we propose the following hypothesis:

H3: Carbon disclosure alleviates financing constraints by improving capital allocation efficiency.

3 Research Design and Empirical Model

3.1 Sample and Data

The sample comprises non-financial A-share listed firms in China over the period 2010–2024, forming an unbalanced panel. This period captures the development of carbon trading pilots and the implementation of the "Dual Carbon" policy framework. After excluding financial firms, ST/*ST firms, and observations with missing key variables, the final sample consists of 47,950 firm-year observations across multiple industries. Data are obtained from the CSMAR and Wind databases, supplemented by hand-collected information from annual and ESG reports. Carbon disclosure measures are constructed using manual coding and textual analysis, with cross-validation from external sources. Continuous variables are winsorized at the 1% and 99% levels, and size-related variables are logarithmically transformed.

3.2 Variable Definition

The dependent variable is financing constraints (FC), measured by the KZ index. Higher values indicate more severe financing constraints. The key independent variable is carbon disclosure intensity (CID), constructed as a composite index based on multiple dimensions of carbon-related information, including emissions data, reduction targets, governance practices, certification, and green innovation activities. The index is derived from manual scoring, textual analysis, and external validation, and aggregated using principal component analysis (PCA) into a normalized score ranging from 0 to 1, where higher values indicate greater disclosure intensity.

The mediating variables are information asymmetry (IA) and capital allocation efficiency (CAE). IA is proxied by analyst forecast dispersion, measured as the standard deviation of analyst earnings forecasts scaled by the absolute mean forecast, with higher values indicating greater information asymmetry. CAE is measured as the absolute residual from the investment expectation model following Richardson (2006), where smaller residuals indicate higher allocation efficiency.

Control variables include firm size (Size), leverage (Lev), return on assets (ROA), Revenue growth rate (Growth), asset tangibility (Tangible), operating cash flow (Cashflow), board independence (Indep), CEO-chair duality (Dual), and institutional ownership (INST).

3.3 Model Specification

To test Hypothesis H1, a two-way fixed-effects model is constructed as follows.

$$FC_{i,t}=\alpha_0+\beta_1 CID_{i,t-1}+\gamma' X_{i,t-1}+\mu_i+\lambda_t+\varepsilon_{i,t}$$

Where i and t denote firm and year, μ_i and λ_t are firm and year fixed effects. The identification logic of this model is as follows. If β_1, the regression coefficient of the core explanatory variable $CID_{i,t-1}$ is significantly negative, it indicates that the higher the intensity of corporate carbon information disclosure, the lower the degree of financing constraints, and Hypothesis H1 is supported.

To test Hypothesis H2, we employ stepwise regression to construct the following model.

$$IA_{i,t}=a_1 CID_{i,t-1}+a_2 X_{i,t-1}+\mu_i+\lambda_t+\mu_{i,t}$$

$$FC_{i,t}=b_1 CID_{i,t-1}+b_2 IA_{i,t-1}+b_3 X_{i,t-1}+\mu_i+\lambda_t+e_{i,t}$$

If α_1 is significantly negative and b_2 is significantly positive, this indicates that information asymmetry (IA) partially mediates the relationship between carbon disclosure intensity (CID) and financing constraints (FC), and Hypothesis H2 is supported.

4 Empirical analysis

4.1 Descriptive Statistics

Descriptive statistics are reported in Table 1. Carbon disclosure intensity (lnCDindex) exhibits substantial variation across firms (mean = 2.248, SD = 0.940), indicating heterogeneity in disclosure practices. The mean KZ index is 1.273, suggesting that firms face moderate financing constraints. Control variables are within reasonable ranges. For example, the mean leverage ratio (Lev) is 0.416 and the mean return on assets (ROA) is 0.0372.

Table 1. Description Statistics

Variable	N	Mean	SD	Min	p50	Max
lnCDindex	47,950	2.248	0.940	0	2.398	3.932
KZ	47,950	1.273	2.470	-12.83	1.491	12.79
IA	47,950	-0.196	0.479	-2.765	-0.127	4.937
ineff	47950	0.102	0.101	0	0.0761	0.521
Size	47,950	22.21	1.303	19.48	22.01	26.45
Lev	47,950	0.416	0.208	0.0278	0.407	0.934
ROA	47,950	0.0372	0.0670	-0.416	0.0378	0.255
Cash Flow	47,871	0.0448	0.0688	-0.226	0.0448	0.266
Tangible	47,950	0.932	0.0824	0.445	0.959	1

Indep	47,950	0.384	0.0742	0.231	0.375	0.615
Dual	47,950	0.304	0.460	0	0	1
INST	47,906	0.429	0.249	0.00102	0.439	0.923

4.2 Correlation Analysis and Multicollinearity

Correlation results are reported in Appendix Table 2. Carbon disclosure intensity (lnCDindex) is negatively correlated with information asymmetry (IA) and positively correlated with capital allocation efficiency (inveff), consistent with the expected mechanisms. Multicollinearity is not a concern. All variance inflation factors (VIFs) are below 5, with a mean of 1.77.

Table 2. Correlation Test

	lnCDindex	KZ	IA	inveff	Size	Lev	ROA	Cash Flow	Tangi-ble	Indep	Dual	INST
lnCDindex		0.027**	-0.216***	0.034**	0.370**	0.143**	-0.035***	0.079**	0.014**	-0.026***	-0.052***	0.162**
KZ	-0.003		-0.014***	0.174**	0.184**	0.706**	-0.614***	-0.548***	0.000	-0.048***	-0.102***	0.013**
IA	-0.221**	-0.016***		-0.041***	-0.542***	-0.131***	-0.116***	-0.122***	0.068**	0.001	0.068**	-0.147***
inveff	0.021**	0.143**	-0.047***		0.108**	0.142**	-0.146***	0.035**	-0.079***	-0.016***	-0.085***	0.023**
Size	0.361**	0.161**	-0.565***	0.081**		0.498**	-0.068***	0.085**	-0.031***	-0.081***	-0.195***	0.401**
Lev	0.123**	0.674**	-0.125***	0.112**	0.489**		-0.406***	-0.145***	0.023**	-0.064***	-0.150***	0.177**
ROA	-0.004	-0.571***	-0.123***	-0.071***	0.001	-0.366***		0.424**	0.026**	0.028**	0.057**	0.105**
Cash Flow	0.081**	-0.547***	-0.140***	0.041**	0.088**	-0.151***	0.408**		-0.079***	0.005	-0.013***	0.128**
Tangi-ble	0.053**	-0.028***	0.066**	-0.056***	-0.039***	0.023**	0.051**	-0.049***		-0.011**	-0.006	0.064**
Indep	-0.021**	-0.045***	-0.015***	-0.022***	-0.061***	-0.061***	0.025**	0.011*	0.001		0.114**	-0.127***
Dual	-0.050**	-0.106***	0.067**	-0.063***	-0.185***	-0.149***	0.031**	-0.015***	-0.002	0.113**		-0.195***
INST	0.147**	0.010*	-0.167***	0.045**	0.427**	0.176**	0.122**	0.117**	0.036**	-0.120***	-0.197***	

4.3 Main Regression Results

Table 3 reports the baseline regression results. Across all specifications, the coefficient on carbon disclosure intensity (lnCDindex) is significantly negative, indicating that

greater disclosure is associated with lower financing constraints. In the full specification with firm and year fixed effects, the coefficient remains negative and significant at the 1% level, supporting H1. The results are consistent with the signaling mechanism, suggesting that carbon disclosure reduces information frictions and improves firms' access to external capital. Control variables exhibit expected signs: firm size, profitability, and cash flow are negatively associated with financing constraints, while leverage is positively associated.

Table 3. Baseline Regression Results

VARIABLES	(1) KZ	(2) KZ	(3) KZ
lnCDindex	-0.149***	-0.023**	-0.047***
	(0.019)	(0.009)	(0.011)
Size		-0.203***	-0.542***
		(0.011)	(0.022)
Lev		7.016***	7.192***
		(0.063)	(0.083)
ROA		-7.446***	-5.499***
		(0.173)	(0.163)
Cash Flow		-13.288***	-12.864***
		(0.127)	(0.111)
Tangible		-1.613***	-2.432***
		(0.103)	(0.147)
Indep		-0.033	0.517***
		(0.103)	(0.085)
Dual		-0.182***	-0.106***
		(0.021)	(0.021)
INST		0.162***	-0.165**
		(0.043)	(0.081)
Observations	47,774	47,829	47,647
R-squared	0.624	0.704	0.843
Firm & Year FE	YES	NO	YES

4.4 Robustness Tests

Table 4 reports a series of robustness checks. First, replacing the dependent variable with the SA index yields consistent results, with the coefficient on carbon disclosure intensity (lnCDindex) remaining significantly negative. Second, including additional control variables (Tobin's Q and firm age) does not alter the baseline findings. Third, controlling for industry fixed effects alongside firm and year fixed effects produces similar results. Overall, the negative relationship between carbon disclosure intensity and financing constraints remains robust across alternative specifications.

Table 4. Robustness Test

VARIABLES	SA	KZ	KZ
lnCDindex	-0.041***	-0.046***	-0.047***
	(0.003)	(0.009)	(0.011)
TobinQ		0.519***	
		(0.010)	
FirmAge		1.255***	
		(0.125)	
Observations	47,829	47,647	47,647
R-squared	0.048	0.873	0.844
Firm & Year FE	YES	YES	YES
Controls FE	YES	YES	YES
IND FE			YES

4.5 Endogeneity Tests

Table 5 presents additional analyses addressing potential endogeneity concerns, including reverse causality and omitted variables. First, using lagged dependent variables (one- and two-period lags of KZ) yields consistently negative and significant coefficients on carbon disclosure intensity (lnCDindex), suggesting that the main results are not driven by the persistence of financing constraints. Second, subsample analyses based on the 2020 "Dual Carbon" policy show that the negative effect of carbon disclosure is more pronounced in the pre-policy period, while remaining negative but weaker in the post-policy period. Overall, these results support the robustness of the main findings and mitigate concerns regarding reverse causality and omitted variable bias.

Table 5. Endogeneity Test

VARIABLES	(1) L.KZ	(2) L2.KZ	(3) KZ (2012–2019)	(4) KZ (2020–2024)
lnCDindex	-0.093***	-0.032*	-0.065***	-0.022
	(0.015)	(0.019)	(0.014)	(0.016)
Observations	40,717	34,363	25,173	22,238
R-squared	0.706	0.676	0.842	0.897
Firm & Year FE	YES	YES	YES	YES
Controls FE	YES	YES	YES	YES
IND FE	YES	YES		

4.6 Mediation Analysis

Table 6 reports the mediation analyses examining the mechanisms through which carbon disclosure affects financing constraints.

Carbon disclosure intensity (lnCDindex) is negatively associated with information asymmetry (IA), indicating that greater disclosure improves transparency. When both lnCDindex and IA are included in the financing constraint regression, IA enters significantly while the coefficient on lnCDindex remains negative, suggesting a partial mediation effect. These results support H2, indicating that carbon disclosure alleviates financing constraints by reducing information asymmetry.

Carbon disclosure intensity is positively associated with capital allocation efficiency (inveff), indicating that greater disclosure improves firms' investment efficiency. When both lnCDindex and inveff are included, capital allocation efficiency is significant, while the coefficient on lnCDindex remains negative, consistent with partial mediation. These findings support H3, suggesting that carbon disclosure alleviates financing constraints by improving capital allocation efficiency.

Table 6. Mechanism Analysis

VARIABLES	(1) IA	(2) KZ	(3) inveff	(4) KZ
lnCDindex	-0.016***	-0.051***	0.001**	-0.047***
	(0.002)	(-4.82)	(0.001)	(-4.48)
IA		-0.504***		
		(-19.45)		
inveff				1.545***
				(17.86)
Controls FE	YES	YES	YES	YES
Observations	47,829	47,647	47,829	47,647
R-squared	0.234	0.846	0.018	0.846
Firm & Year FE	YES	YES	YES	YES

4.7 Heterogeneity Analysis (Concise Version)

Table 7 reports heterogeneity analyses across industry characteristics and financing conditions. First, the effect of carbon disclosure differs across pollution intensity. The coefficient is insignificant for heavily polluting industries but significantly negative for non-heavily polluting industries, suggesting a stronger effect where disclosure is more voluntary. Second, the effect varies by regulatory intensity. Carbon disclosure is insignificant in regulated industries but remains significantly negative in non-regulated industries, indicating that market-based signaling plays a more prominent role outside heavily regulated environments. Third, the effect is more pronounced for firms with higher financing constraints. The negative coefficient on carbon disclosure is larger in magnitude for the high-constraint group than for the low-constraint group, suggesting greater marginal benefits of disclosure for financially constrained firms. Overall, these results indicate that the financing benefits of carbon disclosure depend on institutional context and firm-specific constraints.

Table 7. Heterogeneity Analysis

VARIABLES	(1)KZ_poll	(2)KZ_unpollO	(3)KZ_regu	(4)KZ_un-regu	(5)KZ_High	(6)KZ_Low
lnCDindex	0.001	-0.059***	-0.026	-0.047***	-0.053***	-0.034**
	(0.028)	(0.011)	(0.020)	(0.012)	(0.017)	(0.013)
Observations	10,457	37,156	11,284	36,294	23,381	23,630
R-squared	0.858	0.843	0.884	0.835	0.845	0.886
Firm & Year FE	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES
r2_a	0.840	0.822	0.870	0.812	0.814	0.866
F	735.6	2054	857.1	2090	1174	1614

5 Discussion and Conclusions

This study finds that carbon disclosure intensity is negatively associated with financing constraints, indicating that greater disclosure improves firms' financing conditions. Mechanism analyses show that this effect operates through reduced information asymmetry and improved capital allocation efficiency. The effect is more pronounced in non-heavily polluting industries, non-regulated industries, and firms with higher financing constraints.

This study contributes to the literature by isolating the role of carbon disclosure from broader ESG frameworks and providing evidence on its financing implications in an emerging market context. In addition, it develops a multidimensional measure of carbon disclosure intensity based on manual coding, textual analysis, and external validation, and identifies the underlying mechanisms through which disclosure affects financing outcomes. These findings extend prior research on non-financial disclosure and corporate finance.

From a theoretical perspective, the results support signaling theory and the resource-based view. Carbon disclosure functions as a credible signal that reduces information frictions while also enhancing firms' resource allocation efficiency, thereby improving access to external capital.

From a policy perspective, improving carbon disclosure standards and promoting a combination of mandatory and voluntary disclosure may enhance the effectiveness of green finance policies. For firms, enhancing the quality and credibility of carbon disclosure can serve as an effective tool to reduce financing constraints and support sustainable development.

This study is subject to several limitations. The sample is limited to Chinese A-share listed firms, which may affect external validity. Future research may extend the analysis to other institutional settings, explore additional mechanisms, or examine long-term dynamic effects using alternative identification strategies.

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