

**The Impact of Corporate Environmental, Social and Governance (ESG) Disclosure on
Corporate Investment Efficiency**

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Abstract

This study examines the impact of corporate Environmental, Social, and Governance (ESG) disclosure on investment efficiency, with a particular focus on the role of information transparency as a mediating mechanism in China. According to a sample of Chinese A-share listed firms from 2013 to 2023, we find that high-quality ESG disclosure can enhance investment efficiency by improving information transparency, helping firms reduce overinvestment and underinvestment problems after controlling for different firm-level variables. The findings remain robust across alternative specifications, robustness checks, and instrumental-variable-based endogeneity tests. Specifically, higher-quality ESG disclosure appears to reduce information asymmetry, mitigate adverse selection and moral hazard caused by agency problems, improve resource allocation, and alleviate inefficient investment (overinvestment and underinvestment), thereby contributing to higher investment efficiency. Additionally, while ESG disclosure improves investment efficiency across the sample, the information transparency channel is identified primarily among growth-stage firms, non-state-owned firms, firms in low-pollution and high technology industries, technology-intensive firms, and firms with stronger Confucian cultural influence. This study addresses gaps in previous research by enhancing the theoretical framework on how ESG disclosure influences corporate investment efficiency. It offers practical insights for managers to optimize investment decision-making and provides policymakers with evidence-based suggestions for strengthening ESG disclosure regulations. Ultimately, these contributions support the sustainable growth of the business ecosystem.

Keywords: ESG disclosure; Investment efficiency; Information transparency; Agency problems; Information asymmetry; Overinvestment; Underinvestment; Corporate governance; Sustainability; China

1. Introduction

As climate change becomes an increasingly pressing global issue and corporate green transformation policies and international climate agreements such as the Paris Agreement are implemented worldwide, ESG has gradually become an important way to assess firms' sustainability and social responsibility. As a result, an increasing number of investors, customers, regulators, and other stakeholders began to focus on firms' ESG performance, while demanding greater transparency and improved ESG disclosure practices.

In China, the development of ESG is highly consistent with the National Carbon Dioxide Peaking and Carbon Neutrality Goals, and the government authorities are actively encouraging the development of an ESG rating system for listed firms. This initiative aims to integrate ESG principles with firms' core businesses, development strategies, and business models, fostering positive interactions between the environment, society, and the firm, thereby promoting sustainable and high-quality development. Currently, due to market dynamics and policy developments, corporate ESG disclosure has become increasingly important. Unlike traditional Corporate Social Responsibility (CSR), which often emphasizes ethical and charitable activities, ESG places greater emphasis on transparency and the protection of investor interests (Dathe et al., 2022). Therefore, it is important to explore the impact of corporate ESG disclosure on corporate investment efficiency.

According to previous research, high-quality ESG disclosure can help firms optimize resource allocation, thereby enhancing investment efficiency (e.g., Clarkson et al., 2007; Freeman et al., 2007; Khan et al., 2016; Quah et al., 2020; Stigler, 1961). Corporate information non-transparency often leads to information asymmetry, which in turn prevents firms from

accurately assessing the risks and returns of investment projects, potentially resulting in overinvestment or underinvestment (Dhaliwal et al., 2011; Quah et al., 2020; Richardson, 2006). Therefore, during the firm's operations and investment decision-making process, accurate information transmission can reduce information asymmetry in investments, thereby improving the firm's investment efficiency (Biddle & Hilary, 2006; Healy & Palepu, 2001). At the same time, high-quality information disclosure not only enhances external supervision but also reduces management failures, thereby decreasing instances of overinvestment or underinvestment (e.g., Botosan, 1997; Biddle et al., 2009; Verrecchia, 2001).

This study examines the relationship between ESG disclosure and corporate investment efficiency using a sample of Chinese A-share listed firms from 2013 to 2023, with a specific focus on the mediating role of information transparency. Additionally, we conduct supplementary tests considering corporate life cycle, property rights heterogeneity, industry heterogeneity, and Confucian cultural influence. Through this comprehensive analytical framework, we elucidate the complex interplay between ESG disclosure and investment efficiency, providing a deeper understanding of their relationship. As previous literature has inconsistent views on this topic, some believe that ESG disclosure can improve investment efficiency, while others believe that ESG disclosure may have negative effects due to cost increase or information leakage (e.g., Botosan, 1997; Leuz & Wysocki, 2008), our study attempts to clarify these uncertainties through empirical research.

The significance and contributions of this research are reflected in (1) introducing information transparency as a mediating mechanism, expanding theoretical framework linking ESG

disclosure and corporate investment efficiency, and addressing a key gap in existing research; (2) addressing potential endogeneity by employing instrumental variables estimation and examines heterogeneity to reveal the boundary conditions of the relationship between ESG and investment efficiency; (3) offering practical guidance for firms seeking to optimize ESG disclosure and investment efficiency; (4) analyzing the role of Chinese government policies on corporate ESG disclosure and investment efficiency, providing practical recommendations for policymakers, businesses, and investors in China.

2. Literature Review and Hypotheses Development

Previous literature has made significant contributions to the study of the impact of ESG disclosure on corporate investment efficiency. [Khan et al. \(2016\)](#) found that good ESG performance and adequate ESG disclosure can help firms optimize resource allocation and thus improve investment efficiency. In stakeholder theory, a firm is an aggregation of multiple stakeholders, and its operation needs to consider the interests of all parties ([Freeman, 1984](#)). [Dhaliwal et al. \(2011\)](#) suggest that creditors can evaluate firm risks and optimize investment decisions based on disclosure content because firm's behavior of ESG disclosure can deliver comprehensive information to stakeholders and reduce information asymmetry caused by agency problems. Additionally, [Bowen and De Clercq \(2007\)](#) argue that effective ESG disclosure helps strengthen trust between firms and stakeholders, obtain more resources, support more precise investment, and improve investment efficiency. As [Cassen \(1987\)](#) posits, sustainable development theory requires synergistic growth in economy, society and environment. Firms' practice of ESG and disclosure of relevant information are key measures

to achieve sustainable development. Aligning with sustainable development principles, ESG disclosure incentivizes firms to adopt long-term strategic orientations while mitigating myopic investment behaviors, thereby enhancing investment efficiency (Grewatsch & Kleindienst, 2015). By disclosing ESG information, firms can demonstrate their implementation of sustainable development goals, which will help attract investors pursuing sustainable returns, obtain more stable financial support, and optimize the allocation of investment resources (Eccles & Krzus, 2010). Moreover, according to legitimacy theory, firms can disclose ESG information as a strategic response to social norms, demonstrating responsible conduct to gain legitimacy and maintain public trust (Deegan & Gordon, 1996). This can help firms gain recognition and support from all parties, obtain more resources and trust when making investment decisions, then reduce investment risks and improve investment efficiency (Suchman, 1995). Additionally, according to institutional theory, organizational behaviors are structurally conditioned by their institutional environment, reflecting isomorphic pressures from regulatory, normative, and cognitive forces (DiMaggio & Powell, 1983). Compliant ESG disclosure not only meets external institutional requirements, but also helps firms integrate into institutional environment, enhances organizational reputation, attracts more investment opportunities, and reduces financing costs, thereby improving firms' investment efficiency (Deephouse & Suchman, 2008). According to resource dependence theory, firm's active disclosure of ESG information can show its sustainable development ability to stakeholders, thereby obtaining key resources and thus affecting investment decisions and efficiency (Reitz et al., 1979). Moreover, high-quality ESG can help firms enhance their integration within the

resource network. According to [Hillman and Dalziel \(2003\)](#), such transparency allows firms to secure capital, technology, and other important resources at a lower cost, optimize the selection and implementation of investment projects, and improve investment efficiency. However, [Botosan \(1997\)](#) and [Leuz and Wysocki \(2008\)](#) argued that information disclosure can lead to increased compliance costs, management costs, and potential costs, and excessive disclosure may result in a waste of management resources and increased uncertainty for investors regarding the firm's future, thereby reducing investment efficiency. [Elliott and Jacobson \(1994\)](#) and [Verrecchia \(2001\)](#) pointed out that information disclosure may lead to the leakage of trade secrets or strategic information, thereby weakening the firm's competitive advantage. [Hong and Kacperczyk \(2009\)](#), [Kerr and Nanda \(2009\)](#), and [Skinner \(1994\)](#) also pointed out that investors' misunderstandings of disclosed information can lead to market volatility or damage to the firm's reputation, thereby reducing investment efficiency. After identifying the gap in existing literature regarding the impacts of ESG disclosure on investment efficiency, we have developed the following hypothesis:

H1: The ESG disclosure has a positive impact on corporate investment efficiency.

In the process of firm operation and investment decision-making, information factor plays a key role. According to the theory of information economics stated by [Stigler \(1961\)](#), information is not evenly distributed among all of market participants, and the unbalanced distribution of information is called information asymmetry, which is widespread in market transactions. Under the classical agency theory and signaling theory, information asymmetry can lead to adverse selection and moral hazard, thereby affecting the efficiency of corporate

investment (Jensen & Meckling, 1976; Spence, 1973). Biddle and Hilary (2006) found that accurate information transmission is important for firms to improve investment efficiency. Healy and Palepu (2001) pointed out that when firms can transparently disclose their financial and non-financial information, investors find it easier to assess the true value of the firm and its future growth potential, thereby reducing issues of adverse selection and moral hazard. Specifically, comprehensive information disclosure reduces the capital costs for enterprises, making it possible for them to invest in projects with high net present value. Cheng et al. (2013) and Ghoul et al. (2011) also stated that high-quality ESG disclosures help enhance corporate transparency which increases investors' confidence in the firm's future stability, reduces financing costs, and improves the efficiency of capital market operations. In support of the existing literature, we propose the following hypotheses:

H2: Information transparency plays a mediating role in the relationship between ESG disclosure and investment efficiency.

Further research by Quah et al. (2020) showed that information asymmetry prevents firms from accurately assessing the risks and returns of investment projects, leading to overinvestment or underinvestment. Richardson (2006) defined overinvestment as when firms, due to management incentive biases or excess free cash flow, allocate funds to low-return or negative-return projects. Biddle et al. (2009) and Chen et al. (2011) pointed out that when firms abandon high-return projects due to high financing costs or capital constraints which is referred to as underinvestment. Dhaliwal et al. (2011) and Ghoul et al. (2011) pointed out that high-quality ESG disclosures can improve investment efficiency by reducing financing costs, enhancing

investor trust, and curbing management overinvestment behavior. According to the research from [Clarkson et al. \(2007\)](#) and [Dhaliwal et al. \(2011\)](#), they pointed out that ESG disclosures, by providing information on ESG dimensions, fill the gaps of traditional financial reporting and significantly reduce information asymmetry for investors which can enable investors to better evaluate firms value, and then influence their investment decisions. Furthermore, [Freeman et al. \(2007\)](#) pointed out in their study that ESG disclosure alleviates information asymmetry by improving the information environment, therefore improving the accuracy of market valuation of firms, which indirectly affects the investment efficiency, because reasonable valuation helps firms make more accurate investment plans. [Luo and Bhattacharya \(2006\)](#) believe that high-quality ESG disclosures are seen as positive signals of CSR and governance quality, helping investors to more accurately assess corporate value. Therefore, low information asymmetry is usually considered a manifestation of high information transparency in firms. The increase in transparency makes the investment behavior of management easier to be externally monitored, thereby reducing funding for inefficient projects and lowering overinvestment, while as the information needs of external investors are met, financing costs decrease, alleviating the capital constraints of the firm, and thereby reducing underinvestment ([Biddle et al., 2009](#); [Chen et al., 2011](#); [Richardson, 2006](#)). Corporate information disclosure not only promotes information transparency and enhances market efficiency but also boosts investor confidence, ultimately helping the firm achieve a higher valuation and broader financing opportunities ([Healy & Palepu, 2001](#)). In addition, information disclosure also enhances corporate governance by providing external supervision of management, thereby reducing the risk of unethical behavior

(Bushman & Smith, 2001). However, Botosan (1997) and Leuz and Wysocki (2008) argued that information disclosure can lead to increased compliance costs, management costs, and potential costs, and excessive disclosure may result in a waste of management resources and increased uncertainty for investors regarding the firm's future, thereby reducing investment efficiency. Elliott and Jacobson (1994) and Verrecchia (2001) pointed out that information disclosure may lead to the leakage of trade secrets or strategic information, thereby weakening the firm's competitive advantage. Hong and Kacperczyk (2009), Kerr and Nanda (2009), and Skinner (1994) also pointed out that investors' misunderstandings of disclosed information can lead to market volatility or damage to the firm's reputation, thereby reducing investment efficiency. In support of the existing literature, we propose the following hypotheses:

H3a: ESG disclosure reduces overinvestment by improving information transparency.

H3b: ESG disclosure reduces underinvestment by improving information transparency.

3. Procedures and Methodology

3.1 Sample Selection and Data Source

Given the limited ESG-related data available in the school database and considering the overall availability and stability of the data, this study will examine all A-share listed firms from 2013 to 2023 to explore the impact of ESG disclosure on the investment efficiency of these firms. The data are processed as follows: (1) delete samples from Special Treatment (ST) firms; (2) delete samples from the financial industry such as banks and insurance because of the different corporate governance; (3) delete samples of firms with missing data; (4) perform a 1% winsorization on all continuous variables to reduce the impact of outliers on the analysis results.

The ESG rating data in this study are from the database of Sino-Securities Index (<https://www.chindices.com>), this rating system has achieved broad adoption as an industry standard and has been empirically validated in academic research (Wang et al., 2022). The data of other listed firms is from China Stock Market & Accounting Research (CSMAR) Database (<https://data.csmar.com>).

3.2 Variable Selection and Measurement

3.2.1 Dependent Variable

Regarding the measurement of investment efficiency, current research primarily relies on regression-based residual analysis. The absolute value of the residuals fitted by these models is used to measure corporate investment efficiency. Firms with larger absolute regression residuals demonstrate significantly lower investment efficiency. Richardson (2006) used regression Equation (1) to measure a firm's investment efficiency (IE1) and used the negative absolute value of the residuals as a proxy variable for investment efficiency. The model is as follows:

$$\begin{aligned}
 Invest_t = & \alpha_0 + \alpha_1 Growth_{t-1} + \alpha_2 Lev_{t-1} + \alpha_3 Cash_{t-1} + \alpha_4 Age_{t-1} + \alpha_5 Size_{t-1} \\
 & + \alpha_6 Return_{t-1} + \alpha_7 Invest_{t-1} + \sum YearFE + \sum IndustryFE + \varepsilon_{i,t}
 \end{aligned}
 \tag{1}$$

where t represents the year; Invest refers to firm's incremental investment expenditure; Growth refers to firm's investment opportunities, which can be represented as Tobin's Q or operating income growth rate; Lev refers to debt to asset ratio of firm; Cash refers to total cash or cash equivalents divided by total assets; Age is firm listed age; Size is firm size; Return is the stock return rate; at the same time, control the year and industry effects.

We also use regression Equation (2) pointed out by Biddle et al. (2009) to measure investment

efficiency (IE2). We again use the negative absolute value of the residuals, so that higher values correspond to higher investment efficiency. The model is as follows:

$$Invest_t = \beta_0 + \beta_1 Growth_{t-1} + \varepsilon_t \quad (2)$$

where t represents the year; Growth refers to the investment opportunity of the firm.

And research of [Chen et al. \(2011\)](#) also gave an Equation (3) to measure investment efficiency (IE3). We still use the negative absolute value of the residuals as above. The model is as follows:

$$Invest_t = \gamma_0 + \gamma_1 Growth_{t-1} + \gamma_2 ENG_{t-1} + \gamma_3 Growth_{t-1} \times ENG_{t-1} + \varepsilon_t \quad (3)$$

where ENG is a dummy variable, when the growth rate of operating income is less than zero, it is set to 1; otherwise, it is set to 0. Growth is defined the same as in models (1) and (2).

3.2.2 Independent Variable

ESG disclosure standards such as GRI Standards, SASB Standards, and IFRS S1 have provided a data foundation for ESG ratings. [Hahn and Kühnen \(2013\)](#) and [Ioannou and Serafeim \(2017\)](#) also pointed out the importance and impact of ESG disclosure on rating agencies. As a result, this study uses ESG rating (ESGR) as a proxy for firms' ESG disclosure quality and ESG-related information environment. According to the 9-level rating system from AAA to CCC, ESGR is assigned values from 9 to 1, with a higher score indicating a stronger ESG-related disclosure profile. Because ESG ratings also reflect rating-agency methodologies and firms' actual ESG performance, ESGR should be interpreted as a composite proxy rather than a direct textual measure of ESG disclosure quality.

3.2.3 Mediating Variable

According to the literature mentioned above, we use information transparency (TRANS) as a

mediating variable to explore its mediating role between the independent and dependent variables, and we measure it using information asymmetry. Considering the limited availability of high-frequency trading data in the Chinese securities market, this study introduces liquidity ratio (LR) and illiquidity ratio (ILL) proposed by [Amihud et al. \(1997\)](#) and [Amihud \(2002\)](#), and return reversal metric (GAM, Gamma) proposed by [Pastor and Stambaugh \(2003\)](#) to measure information asymmetry based on daily frequency trading data.

According to [Hasbrouck \(2007\)](#), the above three indicators incorporate information asymmetry components and extraneous factors, thereby providing only partial characteristics of information asymmetry. Therefore, this study follows the approach of [Bharath et al. \(2009\)](#), using these three indicators to conduct principal component analysis (PCA). All three indicators load positively on the first principal component, with loadings of 0.5761, 0.6297, and 0.5212 for LR, ILL, and GAM respectively, indicating that this component captures the common information asymmetry signal shared by the three measures. The first principal component alone explains 73.35% of the total variance, so it preserves the essential informational content of the three original indicators while filtering out idiosyncratic noise. Because a higher value of this component corresponds to greater information asymmetry, this study uses its negative value as the proxy variable for TRANS, so that a higher TRANS denotes higher transparency ([Yu et al., 2012](#)).

3.2.4 Control Variable

In order to eliminate the interference of other factors on IE and ESGR relationships and improve model acceptance, this study proposed several control variables based on existing literature.

According to [Biddle and Hilary \(2006\)](#) and [Goodman et al. \(2013\)](#), this study controls for firm size (Size) using the natural log of total assets, price to book ratio (PB), leverage (Lev), and return on assets (ROA). With the consideration of the research from [Altman \(1968\)](#), [Biddle and Hilary \(2006\)](#), [Campbell et al. \(2008\)](#) and [Chen et al. \(2022\)](#), this study also controls bankruptcy risk using Altman's Z-score (ZS). According to the research from [Chen et al. \(2011\)](#), they pointed that a firm's investment activities may be influenced by its listing time, as it is generally believed that firms are in the decline-stage of their business lifecycle after going public. Therefore, this study also controls the firm's listing age (LA) to reduce the effect on IE.

[Bear et al. \(2010\)](#), [Shaukat et al. \(2016\)](#), and [Zhang et al. \(2013\)](#) suggested that both board diversity and independence can significantly drive ESG performance. Therefore, this study controls the board size (Board), the proportion of independent directors (IDR), the average age of directors and top management (Age), the proportion of females in the board and top management excluding those whose gender cannot be determined (Female), whether directors and top management have a financial background (FB), and whether directors and top management have an overseas background (OB). Additionally, according to the study of [Qian et al. \(2018\)](#), they proposed that concentrated executive power may induce opportunistic disclosure practices. Therefore, this study controls the proportion of shares held by the largest shareholder (TOP), the proportion of shares held by the second shareholder (SECOND), and CEO duality (DUAL).

Under the unique economic system of China, state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs) exhibit certain differences in fulfilling social responsibilities and

responding to national policies, and the governance structures of SOEs also differ from those of Western countries (Gu & Jia, 2022; Jiang & Kim, 2020; Peng et al., 2016; Zhao et al., 2019). Therefore, this study controls SOE in our research. The specific definitions of the above variables are shown in Table 1.

3.3 Descriptive Statistics

Table 2 reports descriptive statistics for all variables in the analysis, including dependent, independent, mediating, and control variables, based on the full sample of 19,103 observations (values rounded to two decimal places). The mean value of investment efficiency indicators IE1, IE2 and IE3 are all about -0.04, which indicates that the investment efficiency of firms presents a relatively high level from the perspective of the whole sample. The independent variable ESG disclosure (ESGR) shows a standard deviation is 1.01, indicating moderate cross-sectional variation while maintaining reasonable dispersion. Additionally, with a mean of 4.20, a first quartile of 4.00, a median of 4.00, and a third quartile of 5.00, the distribution indicates that at least half of the sampled firms attain an ESG disclosure score of 4.00 or above, reflecting generally moderate to high disclosure standards among sampled firms. The mediating variable TRANS shows a mean of approximately 0.00 (SD = 1.48), with values ranging from -18.54 to 7.54, indicating substantial cross firm heterogeneity in information transparency. At the same time, elevated TRANS values correspond to enhanced stock liquidity, indicating low information asymmetry and superior information transparency. Regarding the control variables, firm size (Size) exhibits a mean of 22.46 (SD = 1.33), indicating considerable variation across firms. The average leverage ratio (Lev) of 0.44 suggests moderate debt levels. Other control

variables, such as profitability (ROA) and firm age (Age) show distributions consistent with previous research in this domain.

3.4 Correlation Analysis

Table 3 reports the Pearson correlation coefficients for the variables defined in Table 1. There is a significant positive intercorrelation between the three proxy variables of investment efficiency (IE1, IE2 and IE3), while the positive correlation with ESGR is weak, indicating that there may not be a direct strong linear relationship between ESG disclosure and investment efficiency, and the specific situation needs further analysis. Additionally, Table 4 indicates that there is no multicollinearity present among the independent and control variables.

4. Hypothesis Test

4.1 ESG Disclosure (ESGR) and Investment Efficiency (IE)

To test our hypothesis 1, we conduct the following regression.

$$IE_{i,t} = \delta_0 + \delta_1 ESGR_{i,t} + \sum control_{i,t} + \sum YearFE + \sum IndustryFE + \varepsilon_{i,t} \quad (8)$$

where the independent variable $ESGR_{i,t}$ represents the ordinal variable of ESG rating of firm i in year t , assigned values from 1 to 9 sequentially from CCC to AAA. The dependent variable $IE_{i,t}$ represents to IE. Both year and industry fixed effects have been controlled.

For proxy variable IE1 reported in Table 5, the coefficients of ESGR are 0.0035 without control variables and 0.0029 with control variables, both significant at the 1% level. For proxy variable IE2 reported in Table 6, the corresponding coefficients are 0.0008 and 0.0008, both significant at the 5% level. For proxy variable IE3 reported in Table 7, the coefficient is 0.0005 without control variables, which is not statistically significant, and 0.0007 with control variables, which

is significant at the 5% level. In [Tables 5 to 7](#), the first value represents the model without control variables and the second represents the model with control variables. With the exception of IE3 in the specification without controls, all coefficients are positive and statistically significant, indicating that higher quality ESG disclosure is associated with higher investment efficiency. We also note that the adjusted R-squared for IE2 and IE3 remains low both with and without control variables. We attribute this to the fact that the first stage investment models underlying IE2 and IE3 incorporate fewer economic determinants of investment than the model underlying IE1. Overall, the three regression models provide broadly consistent evidence for Hypothesis 1, indicating a positive association between ESG disclosure and corporate investment efficiency.

4.2 Mediating Effect Test of Corporate Information Transparency (TRANS)

To test hypothesis 2, we apply the [Baron and Kenny \(1986\)](#) mediation framework use following two regressions and supplement it with bootstrap tests to assess whether information transparency serves as a full or partial mediator between ESG disclosure and investment efficiency.

$$TRANS_{i,t} = \zeta_0 + \zeta_1 ESGR_{i,t} + \sum control_{i,t} + \sum YearFE + \sum IndustryFE + \varepsilon_{i,t} \quad (9)$$

$$IE_{i,t} = \eta_0 + \eta_1 ESGR_{i,t} + \eta_2 TRANS_{i,t} + \sum control_{i,t} + \sum YearFE + \sum IndustryFE + \varepsilon_{i,t} \quad (10)$$

where the mediating variable $TRANS_{i,t}$ is a continuous variable of information transparency (defined as the negative of the first principal component extracted from LR, ILL, and GAM).

The interpretation of other variables aligns with their definitions from Equation (8).

We report the mediation results in [Table 8](#). Panel A presents the contemporaneous specification.

The coefficient of ESGR on TRANS (path a) is 0.0275 and is significant at the 1% level, confirming that higher quality ESG disclosure improves information transparency. However, in the joint models the coefficient of TRANS on investment efficiency (path b) is small and statistically insignificant for all three efficiency measures (0.0004 for IE1, 0.0004 for IE2, and 0.0003 for IE3), while ESGR itself remains significant. This pattern indicates that, measured within the same year, the information transparency channel does not transmit the effect of ESG disclosure to investment efficiency.

Because the transparency channel is likely to operate with a delay, [Panel B](#) re-estimates the mediation using a one-year lag for both the independent variable and the mediator (ESGR_L1 and TRANS_L1). Under this specification, path a remains significant (0.0272 at the 1% level), and the coefficient of TRANS_L1 on IE1 becomes positive and significant at the 1% level (0.0011), while the direct effect of ESGR_L1 on IE1 stays significant (0.0026). For IE2 and IE3, the lagged transparency coefficient remains positive but insignificant (0.0004 in both cases). These results suggest that the transparency channel materializes with a lag and is identifiable for the most comprehensive efficiency measure, IE1.

To formally assess the indirect effect under the lagged specification, [Panel C](#) reports a bootstrap mediation analysis with 1,000 replications. For IE1, the indirect effect (path a times path b) is 0.000030, with a bootstrap 95% confidence interval of [0.000004, 0.000066] that excludes zero (bootstrap $p = 0.022$), confirming a significant partial mediation through information transparency. For IE2 and IE3, the bootstrap confidence intervals include zero (bootstrap $p = 0.302$ and 0.242 respectively), so the indirect effect is not statistically significant. Taken

together, these results support Hypothesis 2 for IE1, indicating that information transparency partially mediates the effect of ESG disclosure on investment efficiency once the lagged structure of the channel is accounted for, while the mediation is not detectable for IE2 and IE3.

5. Robustness Test

5.1 Replace Independent Variable

Due to differences in rating methodologies, weighting schemes, and data sources, the ESG scores of the same firm may differ substantially when assessed by different rating agencies (Berg et al., 2022; Christensen et al., 2021). For Chinese listed firms, ESG scores are typically based on voluntarily disclosed annual data, making it challenging to promptly capture corporate ESG events (such as scandals or environmental violations). Additionally, due to the timing of corporate disclosures, ESG scores may exhibit a certain degree of lag (Berg et al., 2022; Christensen et al., 2021). Moreover, we contend that employing ESG ratings as a proxy for ESG disclosure may obscure instances of corporate greenwashing. Greenwashing in the ESG context refers to firms strategically disseminating extensive ESG-related information to mislead stakeholders, thereby concealing suboptimal ESG performance. This practice impedes investors' ability to make informed investment decisions based on ESG data and may ultimately undermine corporate investment efficiency (Huang et al., 2023). Therefore, we argue that using ESG ratings as a proxy for ESG disclosure may introduce measurement errors. As a result, we conduct PCA to reconstruct the ESG disclosure measure and extract the first principal component as a new proxy variable for ESG disclosure (ESGID).

Table 9 reports the regression results for Hypothesis 1 and Hypothesis 2 using ESGID. Because

ESGID is a principal component score measured on a different scale from the ordinal ESGR rating, the magnitudes of the coefficients are not directly comparable to the baseline. The sign and the statistical significance structure, however, are preserved: ESGID_L1 is positive and significant at the 1% level for all three efficiency measures, and the lagged transparency channel (TRANS_L1) is significant only for IE1, mirroring the baseline results in [Table 8](#), Panel B. This consistency supports the robustness of the primary findings, although the alternative ESGID measure should be interpreted with caution due to differences in rating coverage across agencies.

5.2 Endogeneity Test

We speculate that the explanatory variable ESGR is likely endogenous. To assess the endogeneity of ESGR, we follow [Chen et al. \(2022\)](#) and conduct the Durbin-Wu-Hausman test. The results have been shown in Panel A of [Table 10](#). We find that the Durbin score and the Wu-Hausman F statistic are 230.52 and 233.11, respectively. The p-values of them are both less than the 0.05 significance level, which provides strong evidence that ESGR is indeed an endogenous variable. To address the potential endogeneity issue, we introduce the industry-year average ESG (ESG_1), the province-year average ESG (ESG_2), and the industry-province-year average ESG (ESG_3) as instrumental variables for ESGR. We then assess the validity of the overidentifying restrictions using the Sargan and Basman tests and examine instrument relevance using the Kleibergen-Paap Wald F statistic. The diagnostic results are reported in Panel A of [Table 10](#). Based on these results, we finally select ESG_1, ESG_2 and ESG_3 as our instrumental variables for ESGR.

According to these, we conduct two-stage least squares (2SLS) to address endogeneity issues.

Panel B of [Table 10](#) reports the results of the 2SLS regression. The first stage of the regression results reveals the three instruments (ESG_1, ESG_2, and ESG_3) are significantly related to ESGR at the 1% and 5% levels. The second stage of the regression results reveals the coefficients of the independent variables are positive and statistically significant at the 1% level. Specifically, a one-unit increase in ESG_2SLS is associated with an increase in the expected values of IE1, IE2, and IE3 by 0.0074, 0.0061, and 0.0060, respectively.

We further estimate the model conducting the two-step Generalized Method of Moment (GMM) method and the results of the GMM regression has been shown in Panel C of [Table 10](#). In each regression, control variables were included, and both year and industry fixed effects were accounted for. According to the results, we find that the diagnostic tests reveal significant first order serial correlation (AR(1) with $p < 0.05$) but no evidence of second order dependence (AR(2) with $p > 0.1$), satisfying the fundamental conditions for consistent GMM estimation. The p-values of the Hansen test are greater than 0.1, which supports the validity of the instruments and indicates no over-identification problem. The coefficient for lagged investment efficiency is positive and significant at the 1% level across all three measures, demonstrating that investment efficiency is persistent and exhibits dynamic, cumulative characteristics. The coefficient of ESGR remains positive for IE1 and IE2 but is not statistically significant in any of the three specifications. We interpret this cautiously. The two-step system GMM removes time-invariant heterogeneity through first differencing and relies on internal lagged instruments, which makes it a conservative test for a slow-moving, largely between firm variable such as ESG disclosure quality, so the attenuation of the ESGR coefficient is consistent with reduced

identifying variation rather than with the absence of an effect. The persistence of the dependent variable and the validity of the instruments confirm that the dynamic specification is well-behaved, while the 2SLS estimates in Panel B, which retain the cross-firm variation, continue to support a positive and significant effect of ESG disclosure on investment efficiency.

In conclusion, through the application of 2SLS and GMM for robustness testing, this study effectively mitigates endogeneity concerns stemming from sample selection bias, bidirectional causality, and the dynamic nature of variables. The instrumental variable results consistently support the positive effect of ESG disclosure on investment efficiency, reinforcing the robustness of the main findings, although the GMM estimates suggest that this effect is identified primarily from cross-firm variation rather than from within-firm dynamics.

6. Additional Test

6.1 Corporate Life Cycle

Based on existing literature, we argue that the corporate life cycle has a significant impact on ESG disclosure and investment efficiency. The life cycle framework, under which firms move through growth, mature, and decline stages, has been widely used since [Anthony and Ramesh \(1992\)](#). Growth-stage firms, which face higher information asymmetry and lower market recognition, have stronger incentives to use disclosure to reduce that asymmetry, while mature firms tend to have more established disclosure practices and firms in decline may withhold negative information. Following [Li et al. \(2011\)](#), we classify firms into the three stages using four indicators, namely sales growth rate, retained earnings ratio, capital expenditure ratio, and firm age. Specifically, we sum the scores of these four indicators and rank the total sample

within each industry from highest to lowest. Within each industry, firms are then divided into three groups based on their total scores: the top approximately one-third are classified as growth-stage firms, the bottom one-third as decline-stage firms, and the middle group as mature-stage firms.

Based on the results reported in [Table 11](#), the coefficient of ESGR_L1 is positive and significant across all three life cycle stages, indicating that ESG disclosure improves investment efficiency throughout the corporate life cycle. The information transparency channel, captured by TRANS_L1, behaves differently across stages. For growth-stage firms, both ESGR_L1 and TRANS_L1 are significantly positive for IE1 (0.0036 and 0.0031 respectively), indicating that the transparency channel is active when firms are young. For mature-stage and decline-stage firms, ESGR_L1 remains significant (0.0026 and 0.0019 for IE1) but TRANS_L1 is positive and insignificant. This pattern is consistent with [Anthony and Ramesh \(1992\)](#), who argue that growth-stage firms face higher information asymmetry and therefore benefit most from disclosure that improves transparency, and with [Shroff et al. \(2013\)](#), who find that the value of disclosure is greatest where the information environment is weakest. For mature and declining firms, whose disclosure practices are already more established, ESG disclosure continues to support investment efficiency through channels other than the measured transparency improvement.

6.2 Overinvestment and Underinvestment

Currently, research into the effects of ESG disclosure on corporate overinvestment and underinvestment remains relatively limited. However, based on the preceding data analysis, it

is clear that ESG disclosure can effectively reduce information asymmetry, thereby enhancing corporate transparency. According to the free cash flow hypothesis proposed by [Jensen \(1986\)](#), under the influence of information asymmetry and agency problems, management may engage in irrational expansion, ultimately resulting in overinvestment. Similarly, [Myers and Majluf \(1984\)](#) introduced the pecking order theory, suggesting that information asymmetry gives rise to adverse selection in external financing, which may lead to underinvestment.

Based on the regression results reported in [Table 12](#), the coefficient of ESGR_L1 is positive and significant in both the overinvestment and the underinvestment subsamples across all three efficiency measures, indicating that higher quality ESG disclosure mitigates both forms of inefficient investment. The information transparency channel (TRANS_L1) is significant in part of the specifications: it is significantly positive for overinvestment under IE1 (0.0027) and for underinvestment under IE2 and IE3 (0.0007 in both cases), while it is insignificant in the remaining cells. This suggests that ESG disclosure constrains both overinvestment and underinvestment, and that the transparency channel contributes to this effect in specific settings rather than uniformly. These results are broadly consistent with [Biddle et al. \(2009\)](#) and [Benlemlih and Bitar \(2016\)](#), and they provide empirical support for Hypothesis 3, indicating that ESG disclosure helps firms alleviate both overinvestment and underinvestment, partly through improvements in information transparency.

6.3 Property Rights Heterogeneity

Under China's distinctive economic system, state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs) exhibit differences in fulfilling corporate social responsibility

and responding to national policies. To investigate the impact of ESG disclosure on investment efficiency across different ownership structures, we conducted separate regression analyses for SOEs and non-SOEs. The corresponding results are reported in [Table 13](#).

Based on these results, we find that for non-SOEs the coefficient of `ESGR_L1` is significantly positive across all three efficiency measures, and the transparency channel (`TRANS_L1`) is significantly positive for `IE1`, indicating that the effect of ESG disclosure on investment efficiency is more pronounced in non-SOEs. By contrast, for SOEs neither `ESGR_L1` nor `TRANS_L1` is statistically significant. We also speculate that the insignificance of the regression coefficients for SOEs may be attributed to the policy-driven and mandatory nature of their organizational behavior. In contrast to non-SOEs, SOEs are more heavily influenced by government regulation and policy directives in fulfilling corporate social responsibility and disclosing information. Their ESG disclosures are often motivated by compliance with governmental mandates rather than market incentives or the pursuit of investment efficiency optimization. Moreover, SOEs typically benefit from government support, which grants them easier access to capital and reduces financing constraints. Therefore, the marginal impact of ESG disclosure on investment efficiency may be weaker, leading to statistically insignificant regression coefficients.

6.4 Industry Heterogeneity

In exploring the impact of ESG disclosure on corporate investment efficiency, significant heterogeneity may be observed across different industries. Such variations can be attributed to differences in factor intensity, environmental sensitivity, market competition structure, and

regulatory stringency. Therefore, analyzing industry heterogeneity not only helps elucidate the underlying mechanisms of ESG's influence in diverse contexts but also provides valuable insights for enterprises to develop more targeted ESG strategies.

Based on the regression results report in [Panel A of Table 14](#), the coefficient of `ESGR_L1` is significant in both high-pollution and low-pollution industries, but the significance is weaker in high-pollution industries (significant at the 10% level for IE1) than in low-pollution industries (significant at the 1% level for IE1). In addition, the transparency channel (`TRANS_L1`) is significantly positive in low-pollution industries (0.0013 for IE1) but insignificant in high-pollution industries. We attribute this to the fact that ESG disclosure in high-pollution industries is primarily driven by passive compliance and tends to be of lower quality and lower market credibility, so its effect on information transparency is muted. For the technology dimension, the coefficient of `ESGR_L1` is significant in both high technology and traditional industries. The transparency channel, however, is significant in high technology industries (`TRANS_L1` of 0.0014 for IE1, significant at the 1% level) but insignificant in traditional industries. This suggests that in high technology industries, where investors rely heavily on non-financial and forward-looking information, ESG disclosure is more effective in reducing information asymmetry and improving transparency, whereas in traditional industries ESG disclosure supports investment efficiency mainly through channels other than the measured transparency improvement.

According to the regression results in [Panel B of Table 14](#), the coefficient of `ESGR_L1` is positive and significant across the three efficiency measures for technology-intensive and

capital-intensive industries, and significant under IE1 and IE2 for labor-intensive industries, so the direct effect of ESG disclosure on investment efficiency holds broadly across intensity types. The transparency channel (TRANS_L1) is weaker and varies by efficiency measure: it is significant for IE1 in technology-intensive industries (0.0013), and for IE2 and IE3 in labor-intensive industries (0.0010 in both, significant at the 10% and 5% levels), while it is insignificant throughout the capital-intensive group. This measure sensitivity is consistent with IE1, IE2, and IE3 being residuals from different first stage investment models that weight over and under investment differently, as noted in [Table 8](#). Overall, the transparency channel is identifiable in technology-intensive and labor-intensive industries but not in capital intensive industries, where ESG disclosure affects investment efficiency mainly through the direct channel.

6.5 Confucianism

According to existing research, the quality of firms' ESG disclosure exhibits significant variations, which are shaped not only by exogenous factors including institutional policies and macroeconomic conditions but may also be fundamentally constrained by deeper socio-cultural determinants such as religious traditions and cultural values ([Huang et al., 2023](#)). Confucianism, as the foundational ethical framework of traditional Chinese culture, profoundly shapes corporate behavioral norms, social responsibility orientations, and governance mechanisms ([Fu et al., 2022](#)). Given this cultural embeddedness, investigating how Confucian values influence the relationship between ESG disclosure and investment efficiency presents significant theoretical and practical implications.

According to the research methodology of [Du \(2014\)](#), we construct an indicator to measure the proximity of firms to core regions of Confucian culture for heterogeneity analysis based on the geographical distribution characteristics of Confucian culture.

[Table 15](#) reports the impact of ESG disclosure on corporate investment efficiency under high and low levels of Confucian cultural influence. The coefficient of `ESGR_L1` is positive and significant in both groups, indicating that ESG disclosure improves investment efficiency regardless of cultural context, which is consistent with [Chen et al. \(2018\)](#), who find that stronger Confucian cultural influence is positively associated with corporate investment efficiency. The information transparency channel, however, differs across groups. `TRANS_L1` is positive and significant in the high Confucian group (0.0018 for `IE1`, significant at the 1% level) but insignificant in the low Confucian group (0.0004 for `IE1`).

One might expect, following the entrenchment view of [Fan and Wong \(2002\)](#), that contexts with stronger traditional and family-based control would weaken corporate transparency. Our results point to the opposite mechanism. They are consistent with the view that Confucianism functions as an informal institution whose ethical norms, in particular the emphasis on integrity, trust, and reputation, constrain managerial opportunism and reinforce the credibility of voluntary disclosure. [Du \(2014\)](#) shows that stronger Confucian influence reduces minority shareholder expropriation and mitigates agency conflicts between controlling and minority shareholders, and [Gu et al. \(2023\)](#) document that this disciplining effect operates in part through higher financial reporting quality. In line with this evidence, [Fu et al. \(2022\)](#) and [Li et al. \(2023\)](#) find that local Confucian culture raises firms' commitment to ESG and corporate social

responsibility. Taken together, these studies suggest that in high Confucian regions ESG disclosure is more likely to be substantive and to translate into genuine improvements in information transparency, which is why the transparency channel is identified in this group.

This interpretation is reinforced by the heterogeneity in [Table 13](#). [Du \(2014\)](#) reports that the governance benefits of Confucianism are more pronounced in non-state-owned firms than in state-owned firms, which mirrors our finding that the transparency channel is concentrated among non-SOEs. In the low Confucian group, by contrast, ESG disclosure continues to raise investment efficiency, but mainly through channels other than the measured transparency improvement. Overall, these findings indicate that Confucian cultural norms complement, rather than crowd out, the information transparency mechanism through which ESG disclosure affects investment efficiency.

7. Discussion

7.1 Findings

According to the results of this study, we find that the ESG disclosure has a positive impact on corporate investment efficiency. From the stakeholder theory perspective ([Freeman, 1984](#)), ESG disclosure reduces information asymmetry between stakeholders which can enhance firm's social legitimacy ([Deegan & Gordon, 1996](#)), strengthens credibility, attracts resources, thereby improving investment efficiency ([Bowen & De Clercq, 2007](#); [Dhaliwal et al., 2011](#)). The sustainable development theory ([Cassen, 1987](#)) suggests that ESG disclosure encourages long-term strategies, attracts sustainability-focused investors, and improves resource allocation ([Eccles & Krzus, 2010](#); [Grewatsch & Kleindienst, 2015](#)). Institutional theory ([DiMaggio &](#)

[Powell, 1983](#)) highlights that compliant ESG disclosure enhances integration into institutional environments, reduces financing costs, and strengthens investment capacity ([Deephouse & Suchman, 2008](#)). Resource dependence theory shows that ESG disclosure secures critical resources, optimizing project implementation and investment efficiency ([Hillman & Dalziel, 2003](#); [Reitz et al., 1979](#)).

According to the results of this study, we find that information transparency plays a partial mediating role in the relationship between ESG disclosure and investment efficiency, operating with a one-year lag and identified most clearly for the comprehensive efficiency measure IE1, which is consistent with information economics theory ([Stigler, 1961](#)) and signaling theory ([Spence, 1973](#)). They explain that information asymmetry will decrease information transparency and lead to adverse selection and moral hazard. Accurate information transmission and disclosure can make investors easily evaluate the true value of the firm and its future growth potential ([Biddle & Hilary, 2006](#); [Healy & Palepu, 2001](#)). It can also reduce adverse selection and moral hazard to increase corporate information transparency, investor confidence and market efficiency ([Cheng et al., 2013](#); [Ghoul et al., 2011](#)). As a result, the ESG disclosure can increase information transparency by reducing information asymmetry caused by agency problems ([Jensen & Meckling, 1976](#)), thereby improving investment efficiency, as shown in our results.

Similarly, our results show that high-quality ESG disclosure can reduce overinvestment caused by management's misestimation of expected project returns ([Richardson, 2006](#)) and underinvestment caused by poor information flow between external investors and firms ([Biddle](#)

et al., 2009; Chen et al., 2011). The direct effect of ESG disclosure is robust across both the overinvestment and the underinvestment subsamples, while the information transparency channel contributes in part of the specifications, by enhancing investor trust and external oversight that constrain overinvestment, and by improving the information environment that lowers financing costs and alleviates the capital constraints behind underinvestment (Ghoul et al., 2011). Overall, ESG disclosure reduces information asymmetry, optimizes resource allocation, and promotes investment efficiency (Clarkson et al., 2007; Freeman et al., 2007).

To exclude the interference of other factors on the relationship between the core variables, we include a set of control variables based on prior research. Consistent with Biddle and Hilary (2006) and Goodman et al. (2013), most financial controls are significantly associated with investment efficiency: PB, ROA, LA, Age, and FB are significant across all three measures, while Size, Lev, and ZS are significant for IE2 and IE3 but not for IE1. The governance and ownership controls are weaker and less consistent. Board size (Board) is insignificant in all three models, and the proportion of female directors and executives (Female) is also insignificant throughout, which differs from Bear et al. (2010), Shaukat et al. (2016), Adams and Ferreira (2009), and Post and Byron (2014), who report significant effects of board diversity and gender composition. The proportion of independent directors (IDR) is significant only for IE1 (at the 5% level), and the proportion of executives with an overseas background (OB) is significant only for IE2 (at the 10% level). For ownership structure, the shareholding of the largest shareholder (TOP) is significantly positive for IE1 (at the 1% level) but insignificant for IE2 and IE3, which differs in part from Qian et al. (2018), whereas the shareholding of the

second-largest shareholder (SECOND) is significant across all three measures. CEO duality (DUAL) and the state-ownership dummy (SOE) are insignificant in all three models. We attribute the limited and uneven significance of the governance and ownership variables to the fact that their influence on investment efficiency is largely indirect and sensitive to multicollinearity among governance characteristics.

7.2 Contributions

This study makes several key contributions to the existing literature. First, it extends the theoretical understanding of the relationship between ESG disclosure and corporate investment efficiency by incorporating information transparency as a mediating mechanism. [Khan et al. \(2016\)](#) found that good ESG disclosure can improve investment efficiency but did not explore the role of information transparency in this relationship. [Dhaliwal et al. \(2011\)](#) mentioned that ESG disclosure can reduce information asymmetry but did not analyze how it affects investment efficiency through information transparency. By introducing and testing information transparency as a mediating factor, this study clarifies the mechanism linking the three core variables, and our finding that the transparency channel operates with a lag and under specific conditions refines the proposed framework.

Second, it provides empirical evidence based on a large panel dataset of Chinese listed firms, utilizing multiple proxies for investment efficiency and ESG disclosure. The use of control variables and fixed effects models further enhances the robustness and credibility of the empirical results. Additionally, this study systematically uncovers the boundary conditions under which ESG disclosure influences corporate investment efficiency by incorporating

heterogeneity analysis through corporate life cycle, investment deviation type, ownership structure, industry characteristics, and Confucian cultural context, thereby enriching the applicability and theoretical generalizability of ESG-related research. Moreover, this study enhances empirical rigor by following [Chen et al. \(2022\)](#) and applying two-stage least squares, with three instrumental variables, to address endogeneity arising from reverse causality and omitted variable bias, and by using two-step system GMM to confirm that the dynamic panel structure is well specified. The instrumental-variable estimates provide suggestive evidence that strengthens the causal interpretation of the relationship between ESG disclosure and investment efficiency, while the GMM results confirm the persistence of investment efficiency and support the dynamic specification. Because these methods are rarely combined in previous research on this topic, this study makes a methodological contribution by addressing endogeneity more rigorously and sets a precedent for future empirical work to adopt more robust identification strategies.

Finally, this study offers practical implications in three major areas which are corporate management, investors and regulators. Resource dependence theory holds that actively disclosing ESG information allows firms to signal their sustainable development capacity to stakeholders to obtain key resources ([Reitz et al., 1979](#)). By following the ESG disclosure path, firms can improve their internal information management system. This not only helps managers improve investment efficiency but also guides firms to re-examine their ESG practices. Therefore, referring to the results of this study, firms can deeply integrate ESG concepts into daily operations, optimize supply chain management, and select partners with a strong

awareness of environmental protection and social responsibility. According to the research of [Eccles and Krzus \(2010\)](#), by disclosing ESG information, firms can demonstrate the implementation of their sustainable development goals, which will help attract investors who pursue sustainable returns. This conclusion is also consistent with the view that ESG disclosure can promote firms to focus on long-term strategies and avoid short-sighted investment behaviors ([Grewatsch & Kleindienst, 2015](#)). This behavior can not only improve the corporate image, but also effectively reduce operational risks and enhance corporate resilience. At the same time, firms that actively practice the ESG concept can better attract excellent talents who pay attention to social responsibility, inject intellectual capital into the long-term development of firms, and realize the comprehensive and sustainable development of firms.

If many firms refer to the suggestions of this research results and actively optimize ESG practices and investment decisions, it will promote the flow of social resources to more sustainable projects and firms, promote the transformation of industrial structure to green, low-carbon and social responsibility orientation, and help solve major social problems such as environmental pollution and social equity. This is consistent with ESG's overall goal of emphasizing the coordinated development of economy, society and environment ([Cassen, 1987](#)).

Moreover, the results of this study provide important support for regulators to improve the regulatory framework of ESG information dissemination. Regulators can refer to the research conclusions, optimize the information disclosure standards and supervision process, urge firms to improve the ESG disclosure quality, standardize the order of information dissemination,

create a healthy and orderly business ecological environment, and promote the steady development of the business ecosystem in a sustainable direction.

7.3 Limitations and Suggestions

Our study is subject to a number of limitations. First, the dataset focuses solely on listed firms in China, which may limit the generalizability of the findings to other institutional or regulatory environments. Future studies could explore cross-country comparisons to validate these findings in different contexts.

Second, the baseline measurement of ESG disclosure relies on a single rating agency, which may introduce measurement bias. To address this, we constructed a multi-agency proxy (ESGID) from six rating agencies and re-estimated the model in Table 9, and the results are consistent with our main findings. This robustness check is nonetheless limited by the uneven coverage of the six agencies, as a large share of the agency-level observations had to be imputed, so ESGID still partly reflects the information in the dominant agency rating. In addition, the existence of greenwashing may cause disclosed ESG information to deviate from firms' actual practices. Future studies may consider using text analysis combined with machine learning and artificial intelligence for ESG data collection, which could improve the accuracy, transparency, and timeliness of ESG disclosure and further promote socially responsible investing (SRI) and sustainable investment.

Third, the evidence on the transparency channel is partial. The mediating effect of information transparency is identified with a one-year lag and is statistically significant only for the most comprehensive efficiency measure (IE1), and the two-step system GMM, which relies on

within-firm variation, does not identify a significant ESGR effect. This suggests that the causal interpretation relies mainly on cross-firm variation and that the transparency channel is sensitive to the choice of efficiency measure and to the lag structure. It may also reflect the fact that TRANS is a market-microstructure-based proxy that captures only part of a firm's information environment. Future research could use longer panels to better identify within-firm dynamics and could develop disclosure-quality and transparency measures based on textual analysis of ESG reports to examine the channel more directly.

8. Conclusion

This study examines how ESG disclosure affects the investment efficiency of Chinese A-share listed firms from 2013 to 2023, and whether information transparency mediates this relationship. Using fixed-effects regressions, two-stage least squares, and system generalized method of moments on around 19,000 firm-year observations, we find that higher-quality ESG disclosure is positively associated with investment efficiency and is linked to lower levels of both overinvestment and underinvestment. The instrumental-variable estimates provide additional support for this interpretation, while the GMM results indicate that the effect is more strongly identified through cross-firm variation than through within-firm dynamics.

Our evidence indicates that greater information transparency is one channel through which this effect operates, although the transparency channel is identified with a one-year lag and is strongest for the most comprehensive efficiency measure. The effect is more pronounced among growth-stage firms, non-state-owned firms, firms in low-pollution and high technology industries, technology-intensive firms, and firms in regions with stronger Confucian cultural

influence, which together delineate the boundary conditions of the relationship.

These findings contribute to the literature by identifying information transparency as a mediating mechanism and by delineating where the effect is strongest, and they offer practical guidance for firms, investors, and regulators seeking to use ESG disclosure to improve capital allocation. Subject to the limitations discussed above, the findings enrich the ESG disclosure literature by clarifying a conditional transparency mechanism and by identifying the firm-level, industry-level, and cultural contexts in which ESG disclosure is more closely associated with efficient capital allocation.

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Appendix

Figure 1. Framework of testing

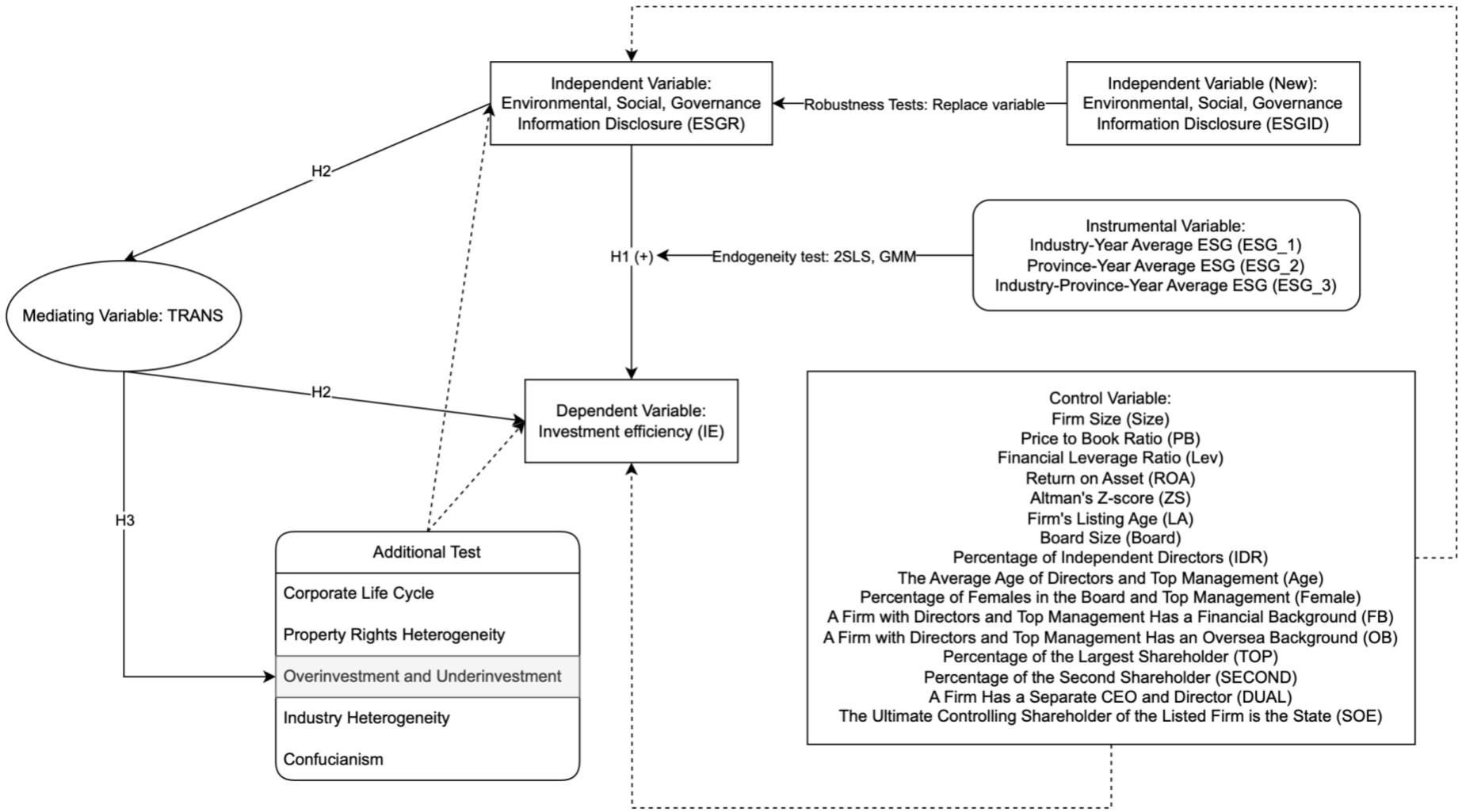


Table 1. Definition of variables

Symbol	Definition
<i>Dependent variables: investment efficiency</i>	
IE1	Negative absolute value of the residuals from Equation (1) (Richardson, 2006)
IE2	Negative absolute value of the residuals from Equation (2) (Biddle et al., 2009)
IE3	Negative absolute value of the residuals from Equation (3) (Chen et al., 2011)
<i>Independent variable: ESG disclosure</i>	
ESGR	ESG disclosure level, using ESG rating as a proxy variable to measure with a range from 1 (lowest) to 9 (highest)
<i>Mediating variable: information transparency</i>	
TRANS	LR, ILL, and GAM conduct PCA, extracting the negative value of first principal component (Bharath et al., 2009)
<i>Control variables</i>	
Size	Firm size, measuring by the natural log of total assets
PB	Price to book ratio, measuring by market price per share divided by book value per share
Lev	Financial leverage ratio, measuring by total debt divided by total assets
ROA	Return on assets, measuring by net income divided by total assets
ZS	Altman's Z-score, measuring by the equation of $(1.2 * \text{working capital} + 1.4 * \text{retained earning} + 3.3 * \text{EBIT} + 0.999 * \text{operating income}) / \text{total assets} + 0.6 * (\text{market value of equity} / \text{book value of total liabilities})$
LA	Firm's listing age, measuring by the natural log of (1 + established period)
Board	Board size, measuring by the natural log of the number of board members

Table 1. (continued)

Symbol	Definition
IDR (%)	Percentage of independent directors, measuring by the number of independent directors divided by the total number of directors
Age	The average age of directors and top management
Female (%)	Percentage of females in the board and top management excluding those whose gender cannot be determined
FB	A dummy variable, equal to 1 for firm with directors and top management have financial background, and 0 otherwise
OB	A dummy variable, equal to 1 for a firm with directors and top management have oversea background, and 0 otherwise
TOP (%)	Percentage of the largest shareholder, measuring by the number of outstanding shares held by the largest shareholder divided by the total number of outstanding shares
SECOND (%)	Percentage of the second shareholder, measuring by the number of outstanding shares held by the second largest shareholder divided by the total number of outstanding shares
DUAL	A dummy variable, equals 0 for a firm having separate CEO and director, and 1 otherwise
SOE	A dummy variable, equals 1 for the ultimate controlling shareholder of the listed firm is the state, and 0 otherwise

Notes: This table reports the definitions of dependent variables, independent variables, mediating variable, and control variables we have used in our study.

For mediating variable, we use Equation (4) and Equation (5) stated by [Amihud et al. \(1997\)](#) and [Amihud \(2002\)](#) to represent LR and ILL. The lower the information asymmetry, the higher the stock liquidity, and the smaller the price change corresponding to a unit of trading volume.

$$LR_{it} = -\frac{1}{D_{it}} \sum_{k=1}^{D_{it}} \sqrt{\frac{V_{it}(k)}{|r_{it}(k)|}} \quad (4)$$

$$ILL_{it} = \frac{1}{D_{it}} \sum_{k=1}^{D_{it}} \sqrt{\frac{|V_{it}(k)|}{r_{it}(k)}} \quad (5)$$

where $r_{it}(k)$ represents the stock return on the k -th trading day of year t for firm i ; $V_{it}(k)$

represents the daily trading volume; and D_{it} represents the number of trading days in the year. Then, we use Equation (6) and Equation (7) stated by [Pastor and Stambaugh \(2003\)](#) to represent GAM. In this research, they argued that stocks with poor liquidity will overshoot in response to order flow; given a constant trading volume, the lower the liquidity, the greater the return reversal.

$$GAM_{it} = |\gamma_{it}| \quad (6)$$

$$r_{it}^e(k) = \theta_{it} + \phi r_{it}(k-1) + r_{it} V_{it}(k-1) \text{sign}[r_{it}^e(k-1)] + \varepsilon_{it}(k) \quad (7)$$

where $r_{it}^e(k) = r_{it}(k) - r_{mt}(k)$ represents excess return; $r_{mt}(k)$ represents the market return weighted by market capitalization, considering the particularities of the Chinese stock market, this study uses circulating market capitalization as the weight ([Yu et al., 2012](#)).

It should be noted that, according to the component loadings of information asymmetry, we found that there are positive loadings of LR, ILL, and GAM on PC1 which indicate that the first principal component captures the common variation among the three market microstructure proxies. Since PC1 explains 73.35% of the total variance and all three variables load positively on it, a higher PC1 score reflects a higher level of the common information-asymmetry component. Since information transparency is conceptually opposite to information asymmetry, this study defines TRANS as the negative value of PC1. Therefore, a higher value of TRANS indicates a higher level of information transparency.

The component loadings matrix of information asymmetry and the total variance have been shown in the following [Table 1a](#) and [Table 1b](#).

Table 1a. Component loadings of information asymmetry

	PC1	PC2	PC3
LR	0.5761	-0.5836	-0.5723
ILL	0.6297	-0.1296	0.7660
GAM	0.5212	0.8016	-0.2928

Table 1b. Total variance explained by the information-asymmetry principal components

Component	Eigenvalue	Proportion (%)	Cumulative (%)
PC1	2.2	73.35	73.35
PC2	0.6	19.98	93.32
PC3	0.2	6.68	100.00

Table 2. Descriptive statistics (N = 19,103)

Variable	Mean	SD	Min.	1st Qu.	Median	3rd Qu.	Max.
<i>Dependent variables</i>							
IE1	-0.04	0.05	-0.27	-0.05	-0.02	-0.01	-0.00
IE2	-0.04	0.04	-0.22	-0.05	-0.03	-0.01	-0.00
IE3	-0.04	0.04	-0.22	-0.05	-0.03	-0.01	-0.00
<i>Independent variable</i>							
ESGR	4.20	1.01	1.00	4.00	4.00	5.00	6.00
<i>Mediating variable</i>							
TRANS	-0.00	1.48	-18.54	-0.80	0.05	0.87	7.54
<i>Control variables</i>							
Size	22.46	1.33	20.13	21.50	22.25	23.20	26.67
PB	3.32	2.75	0.47	1.63	2.53	3.99	17.10
Lev	0.44	0.20	0.07	0.27	0.43	0.58	0.89
ROA	0.03	0.06	-0.23	0.01	0.03	0.07	0.21
ZS	4.75	5.37	-0.02	1.80	3.05	5.49	34.38
LA	2.30	0.69	1.10	1.79	2.30	2.89	3.40
Board	8.37	1.63	5.00	7.00	9.00	9.00	14.00

Table 2. (continued)

Variable	Mean	SD	Min.	1st Qu.	Median	3rd Qu.	Max.
IDR	37.93	5.40	33.33	33.33	36.36	42.86	57.14
Age	49.78	3.20	42.00	47.64	49.85	52.00	57.34
Female	20.75	11.36	0.00	12.50	20.00	28.57	50.00
FB	0.59	0.49	0.00	0.00	1.00	1.00	1.00
OB	0.52	0.50	0.00	0.00	1.00	1.00	1.00
TOP	33.57	14.66	8.70	22.16	31.10	43.40	73.06
SECOND	9.67	6.84	0.57	4.38	8.06	13.60	30.53
DUAL	0.29	0.45	0.00	0.00	0.00	1.00	1.00
SOE	0.08	0.28	0.00	0.00	0.00	0.00	1.00

Note: According to the 4 steps of data processing, this study finally gets 19,103 firm-year observations, where N represents sample size. These conventions apply throughout subsequent analyses.

Table 3. Correlation coefficient

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) IE1	1.00									
(2) IE2	0.46	1.00								
(3) IE3	0.45	0.98	1.00							
(4) ESGR	0.10	0.05	0.04	1.00						
(5) Size	0.13	0.05	0.04	0.25	1.00					
(6) PB	-0.23	-0.10	-0.09	-0.14	-0.38	1.00				
(7) Lev	0.07	0.02	0.02	-0.07	0.50	-0.04	1.00			
(8) ROA	-0.08	-0.07	-0.08	0.20	0.05	0.06	-0.33	1.00		
(9) ZS	-0.12	-0.02	-0.02	0.02	-0.37	0.44	-0.62	0.32	1.00	
(10) LA	0.13	0.09	0.10	-0.03	0.41	-0.18	0.32	-0.14	-0.19	1.00
(11) Board	0.05	0.03	0.03	0.03	0.28	-0.11	0.14	0.03	-0.12	0.20
(12) IDR	-0.02	-0.02	-0.02	0.07	0.00	0.03	0.00	-0.02	0.01	-0.05
(13) Age	0.14	0.06	0.06	0.15	0.37	-0.20	0.11	0.06	-0.10	0.29
(14) Female	-0.02	-0.00	-0.00	-0.02	-0.22	0.08	-0.14	-0.01	0.11	-0.11
(15) FB	-0.04	-0.01	-0.01	-0.05	0.11	-0.01	0.09	0.01	-0.05	0.07
(16) OB	-0.04	0.00	0.00	-0.00	0.07	0.04	-0.01	0.05	0.03	-0.05
(17) TOP	0.02	0.00	0.00	0.09	0.22	-0.10	0.04	0.15	-0.04	-0.01
(18) SECOND	-0.00	0.00	0.00	0.06	0.04	0.01	-0.04	0.06	0.04	-0.19
(19) DUAL	-0.04	-0.05	-0.05	-0.02	-0.19	0.11	-0.13	0.02	0.09	-0.25
(20) SOE	0.03	0.00	0.01	0.03	0.21	-0.08	0.14	-0.01	-0.11	0.18

Table 3. (continued)

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1) IE1										
(2) IE2										
(3) IE3										
(4) ESGR										
(5) Size										
(6) PB										
(7) Lev										
(8) ROA										
(9) ZS										
(10) LA										
(11) Board	1.00									
(12) IDR	-0.53	1.00								
(13) Age	0.22	-0.02	1.00							
(14) Female	-0.16	0.05	-0.25	1.00						
(15) FB	0.12	-0.04	-0.03	-0.08	1.00					
(16) OB	0.08	-0.01	-0.04	-0.03	0.29	1.00				
(17) TOP	0.04	0.03	0.18	-0.06	0.03	-0.00	1.00			
(18) SECOND	0.01	0.01	0.01	0.01	0.03	0.05	-0.15	1.00		
(19) DUAL	-0.20	0.12	-0.18	0.15	-0.06	-0.01	-0.07	0.01	1.00	
(20) SOE	0.16	-0.03	0.13	-0.11	0.06	-0.03	0.17	-0.04	-0.14	1.00

Note: This table reports the Pearson correlation coefficients for all study variables, with boldface type indicating statistical significance at the 10% level.

Table 4. Variance Inflation Factor

Variables	VIF
ESGR	1.17
Size	2.45
PB	1.75
Lev	2.72
ROA	1.31
ZS	2.37
LA	1.50
Board	1.66
IDR	1.47
Age	1.32
Female	1.12
FB	1.13
OB	1.12
TOP	1.17
SECOND	1.12
DUAL	1.13
SOE	1.10

Note: the VIFs are both less than 10 which means that there is no multicollinearity between these variables (Kennedy, 2008).

Table 5. Hypothesis 1 (H1) test of IE1

	IE1	
	Model 1	Model 2
ESGR	0.0035*** (9.14)	0.0029*** (7.52)
Size		0.0001 (0.26)
PB		-0.0025*** (-10.84)
Lev		0.0008 (0.22)
ROA		-0.0505*** (-7.52)
ZS		0.0002 (1.29)

Table 5. (continued)

LA		0.0067*** (8.61)
Board		0.0002 (0.64)
IDR		-0.0002** (-2.25)
Age		0.0010*** (6.61)
Female		-0.0000 (-0.87)
FB		-0.0032*** (-3.79)
OB		0.0006 (0.76)
TOP		0.0001*** (3.19)
SECOND		0.0001** (2.33)
DUAL		-0.0001 (-0.09)
SOE		0.0013 (0.96)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Adjusted R-squared	0.0974	0.1412
N	19,103	19,103

Note: Definitions of all variables are provided in [Table 1](#). ***, ** and * indicate the result is statistically significant at the 1%, 5%, and 10% levels, respectively. T-statistics are reported in parentheses. FE indicates the fixed effect. These conventions apply throughout subsequent analyses.

Table 6. Hypothesis 1 (H1) test of IE2

	IE2	
	Model 1	Model 2
ESGR	0.0008** (2.46)	0.0008** (2.44)
Size		-0.0008* (-1.71)
PB		-0.0011*** (-5.90)
Lev		-0.0101*** (-3.45)
ROA		-0.0398*** (-7.28)
ZS		0.0002** (2.30)
LA		0.0035*** (4.81)
Board		0.0003 (0.93)
IDR		-0.0001 (-1.10)
Age		0.0005*** (3.61)
Female		-0.0000 (-0.87)
FB		-0.0019*** (-2.65)
OB		0.0014* (1.93)
TOP		0.0000 (0.30)

Table 6. (continued)

SECOND		0.0001*
		(1.95)
DUAL		-0.0011
		(-1.30)
SOE		-0.0010
		(-0.89)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Adjusted R-squared	0.0596	0.0789
N	19,103	19,103

Table 7. Hypothesis 1 (H1) test of IE3

	IE3	
	Model 1	Model 2
ESGR	0.0005	0.0007**
	(1.58)	(1.98)
Size		-0.0008*
		(-1.66)
PB		-0.0010***
		(-5.18)
Lev		-0.0108***
		(-3.76)
ROA		-0.0480***
		(-8.89)
ZS		0.0003**
		(2.53)
LA		0.0036***
		(5.04)
Board		0.0003
		(0.91)
IDR		-0.0001
		(-1.05)

Table 7. (continued)

Age		0.0005*** (3.69)
Female		-0.0000 (-0.73)
FB		-0.0018** (-2.49)
OB		0.0011 (1.52)
TOP		0.0000 (0.34)
SECOND		0.0001** (2.20)
DUAL		-0.0011 (-1.40)
SOE		-0.0007 (-0.60)
Year FE	Yes	Yes
Industry FE	Yes	Yes
Adjusted R-squared	0.0576	0.0777
N	19,103	19,103

Note: ESGR is positively associated with all three investment-efficiency measures, though the association weakens from IE1 (1%) to IE2 (5%) to IE3 (weak/insignificant), while the adjusted R² is comparable across measures. Since IE1 to IE3 are residuals from different first-stage investment models (Richardson, 2006; Biddle et al., 2009; Chen et al., 2011), they weight overinvestment and underinvestment differently. Consistent with residual-based evidence that such effects concentrate in overinvestment and are weak for underinvestment (Pereira et al., 2024; Bilyay-Erdogan et al., 2024), this attenuation reflects a channel-specific, measure-sensitive pattern rather than the absence of an effect.

Table 8. Hypothesis 2 (H2) test of mediating role of information transparency (TRANS)

	TRANS	IE1	IE2	IE3
	Model 1	Model 2	Model 3	Model 4
Panel A: Contemporaneous variables				
ESGR	0.0275*** (2.94)	0.0029*** (7.51)	0.0008** (2.40)	0.0007* (1.96)
TRANS		0.0004 (1.08)	0.0004 (1.18)	0.0003 (0.90)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adjusted R-squared	0.6270	0.1412	0.0790	0.0777
N	19,103	19,103	19,103	19,103
Panel B: One-year lag				
ESGR_L1	0.0272*** (2.63)	0.0026*** (6.28)	0.0016*** (4.66)	0.0014*** (3.97)
TRANS_L1		0.0011*** (2.66)	0.0004 (1.14)	0.0004 (1.25)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Table 8. (continued)

	TRANS	IE1	IE2	IE3
	Model 1	Model 2	Model 3	Model 4
Adjusted R-squared	0.5870	0.1561	0.0842	0.0825
N	15,064	15,064	15,064	15,064
Panel C: Indirect effect via bootstrap (lagged spec, 1,000 reps)				
Path a		0.0272 (SE 0.0103)	0.0272 (SE 0.0103)	0.0272 (SE 0.0103)
Path b		0.0011 (SE 0.0004)	0.0004 (SE 0.0003)	0.0004 (SE 0.0003)
Direct		0.0026	0.0016	0.0014
Indirect effect (ab)		0.000030	0.000011	0.000012
Sobel z (p)		1.871 (0.0614)	1.045 (0.2960)	1.133 (0.2574)
Bootstrap 95% CI		[0.000004, 0.000066]	[-0.000008, 0.000035]	[-0.000007, 0.000035]
Bootstrap p		0.022	0.302	0.242
Mediation		Yes (partial)	No	No

Note: This table reports the test of Hypothesis 2, which examines whether information transparency (TRANS) mediates the effect of ESG disclosure quality (ESGR) on investment efficiency, following the causal-steps procedure of [Baron and Kenny \(1986\)](#). TRANS is the negative of the first principal component extracted from the bid–ask spread (LR), the illiquidity ratio (ILL), and the gamma measure (GAM), so that a higher value

indicates greater transparency. Investment efficiency is measured in three ways, IE1 (Richardson, 2006), IE2 (Biddle et al., 2009), and IE3 (Chen et al., 2011), each defined as the negative of the absolute investment residual, so that a higher value denotes greater efficiency. Model 1 regresses the mediator on ESG disclosure (path a); Models 2 to 4 regress each investment-efficiency measure on ESG disclosure and the mediator jointly, where the coefficient on ESGR is the direct effect (c') and the coefficient on TRANS is path b. The total effect of ESG disclosure on investment efficiency (Step 1) is reported in Tables 5 to 7.

Panel A uses contemporaneous variables. Panel B lags both the independent variable and the mediator by one year (ESGR_L1, TRANS_L1), because the transmission from disclosure through the information environment to investment decisions is not instantaneous and because contemporaneous transparency and investment efficiency are jointly determined. Panel C decomposes the lagged mediation effect: path a is the effect of ESG disclosure on transparency (from the mediator equation); path b is the effect of transparency on investment efficiency conditional on ESG disclosure; the direct effect is the effect of ESG disclosure on investment efficiency conditional on transparency; and the indirect (mediated) effect equals the product of path a and path b, denoted ab . The indirect effect is assessed with the Sobel (1982) z-statistic and, because the distribution of the indirect effect ab is non-normal, with a bias-corrected percentile bootstrap (1,000 replications resampled at the firm level); a mediating effect is supported when the 95% confidence interval excludes zero, and the final row (“Mediation”) summarizes this conclusion. For IE1 the bootstrap confidence interval excludes zero ($p = 0.022$), indicating a significant partial mediation, even though the Sobel test is only marginally significant; for IE2 and IE3 the indirect effect is statistically indistinguishable from zero.

All regressions include the full set of firm-level control variables, year fixed effects, and industry fixed effects (control coefficients omitted for brevity). The sample covers Chinese A-share listed firms from 2013 to 2023. T-statistics based on standard errors clustered at the firm level are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 9. Regression results of replacing independent variables

	TRANS	IE1	IE2	IE3
	Model 1	Model 2	Model 3	Model 4
ESGID_L1	7.6537*** (4.60)	0.2265*** (4.03)	0.2581*** (4.86)	0.2369*** (4.55)
TRANS_L1		0.0011*** (2.62)	0.0004 (1.02)	0.0004 (1.13)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adjusted R-squared	0.5878	0.1544	0.0845	0.0830
N	15,064	15,064	15,064	15,064

Note: This table reports a robustness check that replaces the single-agency ESG rating (ESGR) used in the baseline with an alternative, multi-agency ESG-disclosure proxy (ESGID), re-estimating the mediation test under the same one-year-lag specification as in Table 8, Panel B. To mitigate the measurement error and rating divergence that arise from relying on a single rating agency, ESGID is constructed from the ESG ratings issued by six agencies (Sino-Securities, Wind, FTSE Russell, SynTao Green Finance, SusallWave, and MSCI). To retain firm-years with only partial agency coverage, missing agency ratings are imputed using an iterative, EM-based multiple-imputation procedure, after which principal component analysis (PCA) is conducted on the standardized ratings. Following common practice in PCA-based dimensionality reduction, components are retained until their cumulative explained variance reaches a commonly accepted threshold (70%); on this basis the first principal component alone, which explains 76.62% of the total variance, is retained, so that ESGID, constructed as the variance-weighted composite of the retained components, reduces to this first component, with its sign aligned to ESGR so that higher values denote higher ESG-disclosure quality. Model 1 reports the mediator equation (path a: TRANS_L1 on ESGID_L1); Models 2-4 regress each investment-efficiency measure (IE1, IE2, IE3) on ESGID_L1 and TRANS_L1, where the coefficient on ESGID_L1 is the direct effect and the coefficient on TRANS_L1 is path b. All regressions include the full set of firm-level control variables, year fixed effects, and industry fixed effects (controls omitted for brevity). T-statistics based on firm-clustered standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 10. Endogeneity test results for ESGR and IE

Panel A: Endogeneity Test				
Durbin-Wu-Hausman test for endogeneity				ESGR
Durbin score $\chi^2(1)$				230.52
p-value				(0.00)
Wu-Hausman F (1,19084)				233.11
p-value				(0.00)
<i>Tests of overidentifying restrictions</i>				
Sargan (score) $\chi^2(2)$				240.13
p-value				(0.00)
Basmann $\chi^2(2)$				242.94
p-value				(0.00)
<i>Test of weak instrument</i>				
Kleibergen-Paap Wald F statistic				4886.18
Panel B: 2SLS				
	First stage:	Second stage:		
	ESGR	IE1	IE2	IE3
		Model 1	Model 2	Model 3
ESG_1	0.1758*** (6.08)			
ESG_2	-0.0848** (-2.51)			

Table 10. (continued)

	ESGR	IE1	IE2	IE3
		Model 1	Model 2	Model 3
ESG_3	0.9135*** (45.42)			
ESG_2SLS		0.0074*** (9.59)	0.0061*** (9.84)	0.0060*** (9.72)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adjusted R-squared	0.3237			
N	19,103	19,103	19,103	19,103
Panel C: GMM				
	GMM			
	IE1	IE2	IE3	
	Model 1	Model 2	Model 3	
L.IE	0.1778*** (11.21)	0.3310*** (15.77)	0.3160*** (15.41)	
ESGR	0.0015 (0.81)	0.0013 (0.95)	0.0000 (0.00)	

Table 10. (continued)

	IE1	IE2	IE3
	Model 1	Model 2	Model 3
Arellano-Bond AR(1)	0.000 (p < 0.05)	0.000 (p < 0.05)	0.000 (p < 0.05)
Arellano-Bond AR(2)	0.623 (p > 0.1)	0.515 (p > 0.1)	0.943 (p > 0.1)
Hansen	0.366 (p > 0.1)	0.165 (p > 0.1)	0.151 (p > 0.1)
Control variables	YES	YES	YES
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
N	11,943	11,943	11,943

Note: This table reports the endogeneity diagnostics and instrumental-variable estimates for the effect of ESG disclosure quality (ESGR) on corporate investment efficiency (IE) from 2011 to 2023, using three alternative efficiency measures (IE1, IE2, IE3).

Panel A reports the endogeneity diagnostics for ESGR. The Durbin–Wu–Hausman test confirms that ESGR is endogenous (Durbin $\chi^2(1) = 230.52$, $p < 0.01$; Wu–Hausman $F(1,19084) = 233.11$, $p < 0.01$). The Sargan ($\chi^2(2) = 240.13$) and Basman ($\chi^2(2) = 242.94$) overidentification tests are rejected at the 1% level; because such tests are prone to over-rejection in large samples, and following [Chen et al. \(2022\)](#), the instruments are nonetheless retained as valid. The Kleibergen–Paap Wald F statistic (4,886.18) far exceeds conventional critical values, ruling out weak-instrument concerns.

Panel B reports the 2SLS estimates following Equations (11) and (12). In the first stage, ESGR is regressed on the three instruments (ESG_1, ESG_2, ESG_3) and the exogenous control variables; all three instruments are significant and the first-stage adjusted R-squared is 0.3237. The first-stage fitted value (ESG_2SLS) is then used as the explanatory variable in the second stage. The second-stage coefficient on ESG_2SLS is positive and significant at the 1% level for all three measures (0.0074, 0.0061, and 0.0060 for IE1, IE2, and IE3), confirming a positive causal

effect of ESG disclosure on investment efficiency after accounting for endogeneity. The control variables are those specified in Equation (8).

First stage:

$$ESGR_{i,t} = \varphi_0 + \varphi_1 ESG_1_{i,t} + \varphi_2 ESG_2_{i,t} + \varphi_3 ESG_3_{i,t} + \sum \varphi_{i,t} CONTROL_{i,t} + \varepsilon_{i,t} \quad (11)$$

Second stage:

$$IE_{i,t} = \phi_0 + \phi_1 ESG_2SLS_{i,t} + \sum \phi_{i,t} CONTROL_{i,t} + \varepsilon_{i,t} \quad (12)$$

Panel C reports two-step system GMM estimates that account for the dynamic persistence of investment efficiency. The lagged dependent variable (L.IE) is positive and significant at the 1% level (0.1778, 0.3310, and 0.3160 for IE1, IE2, and IE3), confirming strong persistence. The coefficient on ESGR is positive but statistically insignificant across all three specifications; this reflects the fact that the dynamic, first-differenced GMM is the most demanding specification and absorbs much of the limited within-firm variation in the ESG rating, so that the causal evidence rests mainly on the 2SLS estimates. The Arellano–Bond statistics show the expected first-order serial correlation (AR(1), $p < 0.05$) and no second-order serial correlation (AR(2), $p > 0.1$), and the Hansen test does not reject instrument validity ($p > 0.1$), indicating that the GMM specification is well identified.

Statistical significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively. In Panel A, p-values are in parentheses. In Panel B (2SLS), t-statistics are in parentheses. In Panel C (two-step system GMM), z-statistics based on Windmeijer-corrected standard errors are in parentheses for the coefficient estimates, and p-values are reported for the AR and Hansen tests. All regressions include year and industry fixed effects. The 2SLS sample contains 19,103 firm-year observations and the GMM sample 11,943, the reduction reflecting the lags used in the dynamic specification.

Table 11. The impact of ESGR on IE: corporate life cycle

Panel A: IE1			
	Stage:		
	growth	mature	decline
ESGR_L1	0.0036** (2.17)	0.0026*** (3.79)	0.0019*** (4.33)
TRANS_L1	0.0031** (2.32)	0.0005 (0.58)	0.0006 (1.41)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adjusted R-squared	0.1122	0.1089	0.1672
N	1,706	4,907	8,356
Panel B: IE2			
	Stage:		
	growth	mature	decline
ESGR_L1	0.0015 (0.90)	0.0014** (2.30)	0.0013*** (4.17)
TRANS_L1	0.0002 (0.17)	0.0002 (0.33)	0.0000 (0.01)

Table 11. (continued)

	Stage:		
	growth	mature	decline
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adjusted R-squared	0.0960	0.0539	0.1526
N	1,706	4,907	8,356
Panel C: IE3			
	Stage:		
	growth	mature	decline
ESGR_L1	0.0012 (0.74)	0.0013** (2.17)	0.0010*** (3.03)
TRANS_L1	0.0003 (0.25)	0.0003 (0.52)	0.000 (0.01)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adjusted R-squared	0.0951	0.0535	0.1382
N	1,706	4,907	8,356

Note: This table reports heterogeneity tests of the effect of ESG disclosure on corporate investment efficiency (IE1, IE2, and IE3) across the three stages of the corporate life cycle (growth, mature, and decline) from 2013 to 2023. Firms are classified into the three stages following the procedure described in Section 6.1. Consistent with the one-year-lag mediation specification in [Table 8](#) (Panel B), each regression regresses investment

efficiency on the lagged independent variable (ESGR_L1) and the lagged mediator (TRANS_L1), where the coefficient on ESGR_L1 captures the direct effect and the coefficient on TRANS_L1 captures the information-transparency channel. Panels A, B, and C report results for IE1, IE2, and IE3, respectively; within each panel, the three columns correspond to the growth, mature, and decline subsamples. All regressions include the full set of firm-level control variables, year fixed effects, and industry fixed effects (controls omitted for brevity). T-statistics based on firm-clustered standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 12. Hypothesis 3 (H3) test: overinvestment and underinvestment

	IE1		IE2		IE3	
	(1)	(2)	(1)	(2)	(1)	(2)
	Overinvestment	Underinvestment	Overinvestment	Underinvestment	Overinvestment	Underinvestment
ESGR_L1	0.0030*** (4.27)	0.0022*** (5.38)	0.0019*** (2.80)	0.0014*** (5.30)	0.0017** (2.51)	0.0011*** (4.05)
TRANS_L1	0.0027*** (3.38)	-0.0002 (-0.52)	-0.0006 (-0.81)	0.0007*** (2.82)	-0.0004 (-0.58)	0.0007*** (2.62)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.1371	0.2257	0.1358	0.1556	0.1333	0.1384
N	6,307	8,757	6,307	8,757	6,307	8,757

Note: This table reports heterogeneity tests of the effect of ESG disclosure on corporate investment efficiency (IE1, IE2, and IE3), with information transparency as the mediator, separately for overinvestment and underinvestment firm-years from 2013 to 2023. Firm-years are classified as overinvestment (positive investment residual) or underinvestment (negative investment residual) based on the sign of the residual from the [Richardson \(2006\)](#) investment model (Equation (1)), and this single classification is applied to all three efficiency measures. IE1, IE2, and IE3 are constructed from the residuals of the investment models in Equations (1), (2), and (3), following [Richardson \(2006\)](#), [Biddle et al. \(2009\)](#), and [Chen et al. \(2011\)](#), respectively. Consistent with the one-year-lag mediation specification in [Table 8](#) (Panel B), each regression regresses investment

efficiency on the lagged independent variable (ESGR_L1) and the lagged mediator (TRANS_L1), where the coefficient on ESGR_L1 is the direct effect and the coefficient on TRANS_L1 is the information-transparency channel. All regressions include the full set of firm-level control variables, year fixed effects, and industry fixed effects (controls omitted for brevity). T-statistics based on firm-clustered standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 13. The impact of ESGR on IE: property rights heterogeneity

	IE1		IE2		IE3	
	(1) SOEs	(2) non- SOEs	(1) SOEs	(2) non- SOEs	(1) SOEs	(2) non- SOEs
ESGR_L1	-0.0001 (-0.05)	0.0027*** (6.32)	0.0011 (0.97)	0.0017*** (4.48)	0.0009 (0.78)	0.0014*** (3.80)
TRANS_L1	0.0017 (1.06)	0.0010** (2.40)	0.0014 (0.83)	0.0003 (0.84)	0.0012 (0.75)	0.0004 (1.00)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.2337	0.1565	0.0964	0.0871	0.0844	0.0853
N	1,207	13,857	1,207	13,857	1,207	13,857

Note: This table reports heterogeneity tests of the effect of ESG disclosure on corporate investment efficiency (IE1, IE2, and IE3), with information transparency as the mediator, separately for state-owned (SOE) and non-state-owned firm from 2013 to 2023. According to the *Official Letter on the Recognition of State-Owned Enterprises* issued by the National Bureau of Statistics (Letter [2003] No. 44), SOEs refer to enterprises with state-owned capital, which can be further classified into three levels: wholly state-owned enterprises, state-controlled enterprises, and state-participating enterprises. In this study, SOEs are defined as state-controlled enterprises, which encompass two forms: absolute state-controlled firms and relative state-controlled firms. Absolute state-controlled firms are those in which the state holds more than 50% of the total capital. Relative state-controlled firms are those where the state's capital share does not exceed 50% but remains the largest compared to any other economic entity within the

enterprise. Both types are collectively identified as SOEs in this study. Consistent with the one-year-lag mediation specification in [Table 8](#) (Panel B), each regression regresses investment efficiency on the lagged independent variable (ESGR_L1) and the lagged mediator (TRANS_L1), where the coefficient on ESGR_L1 is the direct effect and the coefficient on TRANS_L1 is the information-transparency channel. All regressions include the full set of firm-level control variables, year fixed effects, and industry fixed effects (controls omitted for brevity). T-statistics based on firm-clustered standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 14. The impact of ESGR on IE: industry heterogeneity

Panel A: Pollution and technology						
	(1) Pollution					
	High			Low		
	IE1	IE2	IE3	IE1	IE2	IE3
ESGR_L1	0.0018* (1.89)	0.0024*** (2.88)	0.0021*** (2.59)	0.0025*** (5.62)	0.0014*** (3.46)	0.0011*** (2.85)
TRANS_L1	0.0005 (0.48)	0.0001 (0.12)	0.0003 (0.27)	0.0013*** (3.00)	0.0005 (1.43)	0.0005 (1.46)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.0982	0.0616	0.0599	0.1712	0.0851	0.0829
N	2,647	2,647	2,647	12,417	12,417	12,417
	(2) Technology					
	High-tech			Traditional		
	IE1	IE2	IE3	IE1	IE2	IE3
ESGR_L1	0.0032*** (6.22)	0.0018*** (4.06)	0.0015*** (3.29)	0.0015** (2.19)	0.0014** (2.45)	0.0013** (2.32)
TRANS_L1	0.0014*** (2.68)	0.0007 (1.39)	0.0006 (1.36)	0.0004 (0.69)	0.0006 (1.10)	0.0007 (1.36)

Table 14. (continued)

	(2) Technology					
	High-tech			Traditional		
	IE1	IE2	IE3	IE1	IE2	IE3
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.1650	0.0480	0.0473	0.1452	0.1385	0.1308
N	9,421	9,421	9,421	5,643	5,643	5,643

Panel B: Types of industry intensities			
	(1) Labor-intensive		
	IE1	IE2	IE3
ESGR_L1	0.0016** (2.22)	0.0012* (1.94)	0.0010 (1.61)
TRANS_L1	0.0008 (1.29)	0.0010* (1.94)	0.0010** (2.00)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adjusted R-squared	0.1665	0.1377	0.1316
N	4,856	4,856	4,856

Table 14. (continued)

(2) Technology-intensive			
	IE1	IE2	IE3
ESGR_L1	0.0032*** (5.50)	0.0017*** (3.25)	0.0014*** (2.72)
TRANS_L1	0.0013** (2.13)	0.0003 (0.58)	0.0003 (0.63)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adjusted R-squared	0.1706	0.0379	0.0370
N	7,635	7,635	7,635
(3) Capital-intensive			
	IE1	IE2	IE3
ESGR_L1	0.0023** (2.32)	0.0026*** (2.86)	0.0024*** (2.68)
TRANS_L1	0.0010 (0.96)	-0.0000 (-0.01)	0.0001 (0.11)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes

Table 14. (continued)

	(3) Capital-intensive		
	IE1	IE2	IE3
Adjusted R-squared	0.1048	0.0549	0.0566
N	2,511	2,511	2,511

Note: This table reports heterogeneity tests of the effect of ESG disclosure on corporate investment efficiency (IE1, IE2, and IE3), with information transparency as a mediating factor, under the different industries and industry intensities. According to the Ministry of Ecology and Environment of the People’s Republic of China (formerly the Ministry of Environmental Protection), as stipulated in the *Notice on the Issuance of the Industry Classification Management Catalogue for Environmental Verification of Listed Companies*, drawing upon the methodologies of [Pan et al. \(2019\)](#) and [Wang and He \(2021\)](#), the industry codes for high-pollution listed firms are identified as B06, B07, B08, B09, C17, C19, C22, C25, C26, C28, C29, C30, C31, C32, and D44.

By referencing the *Classification Catalogue of Strategic Emerging Industries*, the *Classification of Strategic Emerging Industries (2012) (Trial)*, and relevant documents from the Organization for Economic Co-operation and Development (OECD), drawing upon the methodologies of [Peng and Mao \(2017\)](#) and [Shi et al. \(2020\)](#), the industry codes for high-tech listed firms are identified as C25, C26, C27, C28, C29, C31, C32, C34, C35, C36, C37, C38, C39, C40, C41, I63, I64, I65, and M73.

Drawing upon the methodologies of [Yin et al. \(2018\)](#), the industry codes for labor-intensive listed firms are identified as A01, A02, A03, A05, B06, B08, B09, C13, C14, C15, C17, C18, C19, C20, C21, C23, C24, C32, C34, D46, E48, E49, E50, F51, F52, G53, G54, G58, G59, I63, I64, K70, L72, M73, M75, N78, P82, R85, R87 and S90; the industry codes for technology-intensive listed firms are identified as N77, C36, M74, I65, C33, C35, C27, C29, C39, C38, C37, C41 and C40; the industry codes for capital-intensive listed firms are identified as G56, D44, A04, B11, D45, B07, C22, C31, G55, C30, R86, C28, C26 and C25.

Both the industry codes above are in accordance with the *Industry Classification Guidelines for Listed Companies (2012 Revision)* revised by the China Securities Regulatory Commission. Consistent with the one-year-lag mediation specification in Table 8 (Panel B), each regression regresses investment efficiency on the lagged independent variable (ESGR_L1) and the lagged mediator (TRANS_L1), where the coefficient on ESGR_L1 is the direct effect and the coefficient on TRANS_L1 is the information-transparency channel. Statistical significance is denoted by ***, **, and * at 1%, 5%, and 10% levels, respectively. T-statistics are provided in parentheses. The analysis controls for year and industry fixed effects.

Table 15. The impact of ESGR on IE: Confucianism

	Confucianism					
	IE1		IE2		IE3	
	(1)	(2)	(1)	(2)	(1)	(2)
	High	Low	High	Low	High	Low
ESGR_L1	0.0029*** (4.78)	0.0022*** (4.14)	0.0018*** (3.45)	0.0015*** (3.29)	0.0015*** (2.91)	0.0013*** (2.79)
TRANS_L1	0.0018*** (3.34)	0.0004 (0.70)	0.0006 (1.19)	0.0003 (0.62)	0.0005 (0.99)	0.0005 (0.95)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.1477	0.1671	0.0815	0.0907	0.0802	0.0875
N	7,518	7,544	7,518	7,544	7,518	7,544

Note: This table reports heterogeneity tests of the effect of ESG disclosure on corporate investment efficiency (IE1, IE2, and IE3), with information transparency as a mediating factor, under the different Confucian culture influence groups. Confucian culture has developed over thousands of years to establish seven principal centers of influence: Qufu (Shandong), Luoyang (Henan), Chengdu (Sichuan), Sanming (Fujian), Dongtai (Jiangsu), Fuzhou (Jiangxi), and Eastern Zhejiang. We follow the research methodology of [Du \(2014\)](#) by first collecting the geographical coordinates (longitude and latitude) of the firm's registered location and the Confucian centers. We then calculate the geographic distance from the registered location to each of the seven Confucian centers and compute the arithmetic mean (DIS). Finally, the strength of Confucian cultural influence is calculated using the Equation (13).

$$confuN = (Max_DIS - DIS) / (Max_DIS - Min_DIS) \quad (13)$$

where Max_DIS and Min_DIS represent the maximum and minimum average geographic distances from all listed firms to the seven Confucian centers in the same year. A higher confuN value indicates a stronger influence of Confucian culture on the firm. N represents the normalized

distance index of the firm to the nearest N Confucian culture centers.

To ensure robustness, we calculate the average value of confu1 through confu7 (confu_mean) and assign a value of 1 to firms with a confu_mean above the sample median and a value of 0 to those below the sample median. We categorize these firms into two groups: the high Confucian culture influence group and the low Confucian culture influence group. Consistent with the one-year-lag mediation specification in Table 8 (Panel B), each regression regresses investment efficiency on the lagged independent variable (ESGR_L1) and the lagged mediator (TRANS_L1), where the coefficient on ESGR_L1 is the direct effect and the coefficient on TRANS_L1 is the information-transparency channel. Statistical significance is denoted by ***, **, and * at 1%, 5%, and 10% levels, respectively. T-statistics are provided in parentheses. The analysis controls for year and industry fixed effects.