

Research

Analyzing the dynamic relationship between ESG scores and firm value in Chinese listed companies: insights from generalized cross-lagged panel model

Abel Dula Wedajo^{1,2} · Abdullah Abdulaziz Salah^{3,4} · Mohd. Abass Bhat⁵ · Robina Iqbal⁶ · Shagufta Tariq Khan⁷

Received: 8 May 2024 / Accepted: 7 October 2024

Published online: 17 October 2024

© The Author(s) 2024 [OPEN](#)

Abstract

The relationship between a company's Environment, Social and Governance (ESG) scores and market value dynamics has been the focus of extensive research. Our study aimed to provide insights into this relationship and its implications for Chinese investors. We used a general Cross-lagged panel model to analyze data from 652 Chinese-listed companies from 2013 to 2019. Our findings indicate that ESG scores have a long-term impact on market value, with a consistently positive correlation between the two. We also discovered that Chinese investors consider ESG factors when evaluating a company's financial health. Companies that prioritize ESG factors are more likely to attract investment. Moreover, the diffusion of ESG information happens slowly, and past ESG performance influences future ESG performance. Thus, maintaining good ESG performance is crucial for long-term sustainability and success. In addition, our analysis reveals significant insights into the interplay between ESG metrics and mandatory disclosure regulations. Specifically, we find that the interaction between average ESG score and mandatory disclosure significantly impacts firm value, suggesting a nuanced relationship between ESG performance and market valuation in the context of regulatory requirements. Overall, our study highlights the importance of considering ESG factors when evaluating financial health and making investment decisions, providing valuable insights for firms and investors alike.

1 Introduction

In recent years, there has been a growing awareness of the importance of Environmental, Social, and Governance (ESG) concerns for businesses. ESG considerations are now an integral part of corporate decision-making, investment strategies, and regulatory frameworks [1, 2]. As a result, the relationship between ESG and firm performance has become a hotly debated topic in the Corporate Social Responsibility (CSR), ESG, and Socially Responsible investing (SRI) literature [3–5]. The traditional view of corporate success has been centered on financial performance and shareholder value [6, 7]. However, this view has shifted in recent years as stakeholders increasingly demand that businesses also prioritize

✉ Abel Dula Wedajo, abel.dula@wku.edu.et; Abdullah Abdulaziz Salah, aaaahizam@gmail.com; abdullah.salah@ibbuniv.edu.ye; Mohd. Abass Bhat, abass.ashoor.bhat788@gmail.com; Robina Iqbal, r.iqbal@keele.ac.uk; Shagufta Tariq Khan, shagaftakhan@gmail.com | ¹Department of Management, Wolkite University, Welkite, Ethiopia. ²SAXO Fintech Business School, University of Sanya, Sanya, China. ³Institute of Western China Economic Research, Southwestern University of Finance and Economics, 133 Xuefu Avenue, Wenjiang District, Chengdu 611137, Sichuan, China. ⁴Department of Economics and Agricultural Extension, Ibb University, 70270 Ibb, Yemen. ⁵College of Economics and Business Administration, University of Technology and Applied Sciences, Muscat, Oman. ⁶Keele Business School, Keele University, Newcastle, Staffordshire, UK. ⁷Department of Logistics, Tourism and Service Management, German University of Technology (GUTech), Muscat, Oman.



social and environmental responsibility [8, 9]. This shift towards sustainable development has led to the emergence of ESG concerns for businesses and has created a need to explore the relationship between ESG and firm performance.

For instance [6, 10–12], found that ESG performance has a positive impact on firm value, but the relationship between ESG and firm value is also affected by firm characteristics, such as size and industry. While others [13–15] argued that the relationship between ESG score and firm value is not only affected by firm characteristics but also by reverse causality, meaning that a higher market value can incentivize firms to embrace ESG practices. Therefore, it's necessary to consider both the causality and directionality of the relationship to fully comprehend the impact of ESG on firm value. Moreover, both the short-term and long-term relationships are equally significant [16].

Various theories exist to justify a firm's stance concerning shareholder wealth [17] versus stakeholder value [18, 19]. According to the stakeholder theory, firms that prioritize ESG concerns are likely to have a positive impact on their stakeholders, leading to higher firm value [19]. This is because stakeholders, such as customers, employees, and investors, are more likely to support firms that demonstrate ethical and socially responsible behavior. Moreover, ESG concerns are likely to reduce risks and uncertainties for firms, leading to higher firm value [20]. Shareholder theory holds that firms should maximize shareholder wealth. Good ESG performance can enhance a firm's reputation, reduce risks, and lead to higher market values. It can also help firms avoid legal and regulatory problems, creating financial stability and value. Fundamentally, a positive correlation exists between a firm's ESG disclosure and its market value, provided that it enhances its reputation and mitigates risks.

The interaction between sustainable business practices and a company's market value, and their reciprocal influences, has been a subject of scholarly inquiry, with implications extending beyond short-term considerations. Rather than viewing stakeholders versus shareholders dichotomously, recent scholarship emphasizes the importance of focusing on long-term market value [21]. The maximization of shareholder wealth can, in essence, align with the promotion of social welfare. Understanding the nexus between market value and Environmental, Social, and Governance (ESG) scores is imperative for comprehending the broader implications of sustainable business practices.

Delving into the interconnectedness of market value and ESG scores unveils a complex landscape characterized by both short-term and long-term dynamics. Concepts such as mean reversion in market values and trend following in ESG scores offer insights into this relationship [22–25]. Market values exhibit a tendency to revert to their historical averages following perturbations, while ESG scores often display trend-following behavior, rather than reverting to a mean. Consequently, companies that adopt sustainable practices early on are often rewarded with higher ESG scores, thereby setting a precedent for others to emulate.

In our study, we aim to overcome the limitations of previous research on the Corporate Social Responsibility (CSR) and Corporate Financial Performance (CFP) relationship by addressing specific gaps in the existing literature. Previous studies have often overlooked the bidirectional nature of the relationship between Environmental, Social, and Governance (ESG) factors and firm market value, as well as the varying impacts over different time horizons. Additionally, there is a lack of comprehensive analysis on the magnitude of these relationships, particularly in the Chinese context.

Firstly, we will investigate the bidirectional relationship between ESG and firm market value. Secondly, we will examine both the short-term and long-term relationships between ESG and firm market value. Finally, we will study the magnitude of the relationships between ESG and firm market value to gain insights into how sustainable business practices benefit both the company and society.

To achieve this, we will employ Generalized Cross-Lagged Modeling (GCLM) and extend time-varying relationship studies to better understand the dynamic interactions between CSR and CFP over time. Furthermore, we will leverage system dynamics to explore how different factors interact and influence the CSR-CFP relationship in the long term, which is an innovative approach in this context. Additionally, we will investigate the bidirectional or reverse causality of the relationship and examine the feedback loop to gain a deeper understanding of how CSR and CFP work together to create positive impacts in both the short and long term.

Our analysis also examines the interplay between ESG metrics and mandatory disclosure regulations. This aspect of the study explores how the interaction between ESG performance and regulatory requirements affects firm value, highlighting the complex relationship between ESG metrics and market valuation within the framework of disclosure mandates.

Our research aims to fill a significant gap by exploring the CSR and CFP relationship within the Chinese context, where such comprehensive studies are scarce. By establishing a clear link between sustainable business practices, CSR, and CFP, our study can contribute to promoting a more sustainable future for both businesses and society.

2 Literature review and research question formulation

The correlation between a company's market value and its ESG score, which measures environmental, social, and governance practices, has captured the attention of investors, researchers, and policymakers alike [26, 27]. Recent studies have shown that there exists a bi-directional relationship between these two variables, meaning that changes in a firm's ESG score can impact its market value, and vice versa [28]. Furthermore, the relationship between market value and ESG score is not limited to short-term effects alone [29]. Empirical evidence suggests that firms with better ESG performance, higher ESG disclosure scores, and better ESG disclosure practices have higher firm value, lower cost of equity capital, and better innovation performance in the long run [16]. Thus, understanding the dynamics of this relationship is crucial for firms to future-proof their businesses, gain competitive advantage, and enhance their long-term value.

This article aims to explore the bi-directional as well as short and long-term relationship between firms' market value and their ESG score. We will first provide an overview of the recent empirical studies that have explored the relationship between market value and ESG score. We will then delve into the short-term effects of ESG score/disclosure on market value using the CL(Cross Lagged) effects system dynamics model. Finally, we will examine the long-term effects of ESG score on market value using the impulse response graph and mediation logic. Through this analysis, we aim to shed light on the complex interplay between market value and ESG score/disclosure and provide insights for firms to develop a strategic approach towards ESG concerns.

The majority of the research [30–41] examine the relationship between a firm's environmental, social, and governance (ESG) performance/practices and its overall firm value, market value, or financial performance metrics like Tobin's Q, return on assets, etc. Most of these studies find a positive association between ESG performance and firm value/profitability, though some note varying impacts of the individual E, S, and G components.

Additionally, a few studies [36, 40–42] specifically, look at the impact of ESG controversies or negative ESG events on firm value. These generally find a negative effect of such controversies on firm value, though some suggest that strong corporate governance or other factors can mitigate this negative impact. Further, several other studies [35, 36, 40, 41, 43–45] explore various factors that may moderate or influence the relationship between ESG performance/controversies and firm value. These include factors like family ownership, industry characteristics, corporate governance mechanisms (e.g., board diversity, independence), institutional ownership, and geographic region.

Moreover, one study [46] examines the link between CEO turnover, myopic investment decisions like "ESG-washing," and firm value, finding that firms engaging in superficial ESG activities without substantive investment tend to have lower firm value. In addition, a couple of studies [36, 38] focus on developing new methods or approaches for evaluating ESG performance and its impact on firm value, such as through structural equation modeling.

2.1 Firm's ESG disclosure and market value

The complex relationship between Environmental, Social, and Governance (ESG) factors and firm value has been the subject of extensive research [13, 14, 27, 47–50]. Through rigorous analysis, studies have demonstrated that higher ESG disclosure scores have a significant positive impact on firm value [4, 11, 51], innovation performance [49, 50], and cost of equity capital [52]. The findings of [16] revealed that companies that performed well on ESG metrics had a higher return on equity and a lower cost of capital. Similarly, [15] found that companies with high ESG metrics scores had higher future earnings and profitability, which ultimately led to improved financial performance and increased firm value.

However, it is important to note that some studies have identified a negative impact of ESG disclosure on firms' value. According to [53] the costs associated with ESG disclosure can negatively impact a firm's financial performance. The findings of [54] also suggest that firms with high ESG scores may face higher agency costs, which can negatively impact their value. These findings suggest that firms must carefully consider the potential benefits of ESG disclosure against the costs involved.

In terms of the positive impact of firm value on ESG score, some scholars have found that an increase in firm value may lead to higher ESG scores. This supports the notion that firm value has a positive impact on ESG score [55–57], for example, found that firms with high market value are more likely to disclose their ESG practices and have higher ESG scores. Additionally, these firms were found to have a better reputation and attract more investors, leading to

higher firm value. On the other hand, some studies have suggested that a decrease in firm value may lead to lower ESG scores. According to [58], firms with low market value are less likely to disclose ESG information. This result supports the negative impact of firm value on ESG score.

In conclusion, while some studies suggest a positive impact of ESG disclosure on firms' value and vice versa, others highlight potential negative impacts of these variables on one another [3, 5]. It is essential for firms to carefully consider the trade-offs associated with ESG disclosure and its potential impact on their financial performance. Firms should aim to strike a balance between ESG disclosure and their financial performance to maximize their long-term value [14, 59–61]. By doing so, firms can ensure that they are making informed decisions that promote sustainable and responsible business practices while also optimizing their financial performance.

The complex relationship between market value and ESG score highlights the need for a system dynamics approach to studying this relationship [15]. As noted in [5, 59, 60], some studies have suggested that an increase in firm value may lead to higher ESG scores, while a decrease in firm value may lead to lower ESG scores. This suggests that there is a feedback loop between the two variables, where changes in one variable can impact the other and vice versa. Moreover, the relationship between market value and ESG score is likely to be influenced by a range of other factors, such as regulatory requirements [62, 63], stakeholder pressure [63], and industry norms. These factors can create complex interdependencies between market value and ESG score, making it difficult to fully understand the relationship between the two variables in isolation.

A system dynamics approach to studying the relationship between market value and ESG score would enable researchers to model the feedback loops and interdependencies between these variables [63]. By doing so, researchers could gain a more comprehensive understanding of how changes in one variable might impact the other over time. This would allow firms to better anticipate the potential impact of their ESG practices on their market value and vice versa. In addition, a system dynamics approach would enable researchers to identify potential leverage points in the system where small changes in one variable could have a significant impact on the other [55, 64]. This could help firms to identify strategies for optimizing their ESG practices and market value over the long term [51].

Overall, the complex relationship between market value and ESG score highlights the need for a system dynamics approach to studying this relationship. By taking a holistic view of the system, researchers can gain a more comprehensive understanding of the interdependencies between these variables and identify strategies for optimizing both ESG practices and market value over the long term. In line with these notions, the first research question we will postulate is as follows: What is the direction of the relationship between ESG and firm value, and how do these two variables impact one another? This question aims to explore the relationship between ESG and market value and how they are interconnected. To answer this question, we will study the existing research on the topic and gather real-world data to better understand how ESG factors relate to a company's value. We have crafted the following research question:

RQ1 What is the direction of the relationship between ESG and firm value in Chinese listed companies, and how do these two variables impact one another?

2.2 Short-term system dynamics

As we mentioned in the previous section, recent studies have shown that there exists a complex bi-directional relationship between these two variables, meaning that changes in a firm's ESG score can impact its market value, and vice versa. However, it is important to note that this relationship may be limited to short-term effects alone, as opposed to long-term causal effects [16, 25]. The short-term effects of ESG score on market value can be studied using the CL effects system dynamics model, which allows for the analysis of complex systems with feedback loops [65, 66]. Several recent studies have used this approach to explore the dynamics of the relationship between market value and ESG score [55, 63, 67–73]. For instance, a study by [67] found that an increase in a firm's ESG score leads to an increase in its market value, which in turn leads to an increase in the firm's ESG score. This suggests that the relationship between ESG score, and market value is bi-directional and reinforces itself over time.

Empirical evidence suggests that the short-run relationship between market value and ESG score is mainly driven by market sentiment and investor expectations. In other words, changes in market value reflect changes in investor expectations about a firm's ESG performance, which in turn affects its market value. For instance, a study by [74] found that firms with high ESG scores have better financial performance in the short run, which implies a positive relationship between market value and ESG score. Similarly, a study by [75] and [72] found that firms with higher ESG scores tend to have higher market values in the short run. However, this effect may be limited to certain industries or regions, as [53]

found that the relationship between ESG score and market value was stronger for firms in different geographical areas. Furthermore, the study found that the effect of ESG score on market value was weaker for firms in industries that are already highly regulated, such as utilities or financial services.

It is important to note that the short-term relationship between ESG score and market value may not necessarily be causal. For instance, a study by [55] found that the positive relationship between ESG score and market value may be driven by investor sentiment, rather than actual improvements in ESG performance. While changes in market value may reflect changes in investor expectations about a firm's ESG performance, they may also reflect changes in market sentiment and irrational investor behavior. For instance, a study by Shiller [76] found that changes in stock prices are largely driven by changes in investor sentiment, which are not necessarily related to changes in firm fundamentals. Similarly, a study by Barberis et al. [77] found that investors tend to overreact to news and events, which can lead to short-term market anomalies and mispricing. This suggests that the relationship between ESG score and market value may be subject to external factors, such as media coverage or public opinion [78–82].

Furthermore, the short-run relationship between market value and ESG score may not hold in the long run. Empirical evidence suggests that the long-run relationship between market value and ESG score is mainly driven by firm fundamentals and intrinsic value [83, 84]. In other words, changes in market value reflect changes in a firm's underlying assets, earnings, and cash flows, which in turn affects its ESG performance and score. For instance, a study by [62, 85] found that firms that adopt a strategic approach towards ESG are more likely to see a positive impact on their firm value, innovation performance, and cost of equity capital. In addition, [86–88] found that firms that prioritize short-term financial performance over long-term sustainability may experience a negative impact on their ESG scores over time. When evaluating the link between ESG score and market value, it is crucial for firms to consider the long-term effects of their decisions. While there may be a positive correlation between market value and ESG score in the short run, it is the long-term relationship that is more significant for both firms and investors to consider. Therefore, it is essential for firms and investors to take a strategic and holistic approach to assessing a firm's market value and ESG score, taking into account both financial and non-financial factors. This will help them improve their short-term and long-term performance and overall value.

In conclusion, while there exists a bi-directional relationship between a firm's market value and its ESG score, this relationship may be limited to short-term effects alone. The CL effects system dynamics model can be used to study the dynamics of this relationship in the short run, but caution must be exercised when inferring causal effects. The relationship between ESG score and market value may be subject to external factors, and firms must consider the long-term implications of their decisions when assessing this relationship. We present our second research question as follows:

RQ2 What is the short-run relationship between ESG and firm value in Chinese listed companies, and how do these two variables impact one another in the short-run?

2.3 Long-term system dynamics effects

System dynamics is an approach to understanding the behavior of complex systems over time. It was developed by Jay Forrester in the 1950s and has been used extensively in various fields, including management, engineering, and social sciences. The system dynamics approach involves modeling a system as a set of interconnected feedback loops, where each feedback loop represents a causal relationship between different variables in the system. The model can be used to simulate the behavior of the system over time and to test various scenarios to see how they might affect the system's behavior.

In the long run, there is evidence to suggest that firms with higher ESG scores have higher market value. A study by [75] found that companies with high ESG scores had higher future earnings and profitability, which ultimately led to improved market value. This suggests that the relationship between ESG scores and market value is not limited to short-term effects alone. Furthermore, a study by Kourula et al. [89] found that firms that adopt a strategic approach towards ESG are more likely to see a positive impact on their market value in the long run. The authors used a system dynamics model to simulate the behavior of the system over time and found that firms that focus on ESG concerns are more likely to enhance their long-term value and bring numerous benefits to the firm.

Another study by [1, 88] examined the relationship between ESG scores and firm performance in the long run. The authors used a system dynamics approach to model the complex interplay between ESG scores, firm performance, and market value. They found that ESG scores had a positive impact on firm performance, which in turn led to improved market value in the long run.

The long-run relationship between ESG scores and market value is not limited to positive effects alone. A study by [54, 67] found that firms with high ESG scores may also face higher agency costs, which can negatively impact their value in the long run. The authors used a system dynamics approach to model the complex relationships between ESG scores, agency costs, and market value and found that the negative impact of agency costs can offset the positive effects of ESG scores on market value.

In conclusion, the relationship between firms' market value and ESG score is complex and dynamic, and it is not limited to short-term effects alone. The evidence suggests that firms with higher ESG scores are more likely to have higher market value in the long run, provided they adopt a strategic approach towards ESG concerns. System dynamics modeling can be a useful tool for understanding the dynamic interplay between ESG scores, firm performance, and market value and can help firms develop a strategic approach towards ESG concerns that enhances their long-term value. However, it is important to note that the negative impact of agency costs can offset the positive effects of ESG scores on market value in the long run, highlighting the need for firms to carefully weigh the potential benefits of ESG disclosure against the costs involved. This will guide us in formulating our third research question:

RQ3 What is the long-run relationship between ESG and firm value in Chinese listed companies, and how do these two variables impact one another in the long-run?

2.4 Past and future values as sustainability issues

Understanding the correlation between a company's past and future market value and ESG score is crucial for firms. A company's past market value has a persistent influence on its future market value, and analyzing a company's past ESG performance can have a positive impact on its future ESG performance [6, 27, 84]. Companies must consider the impact of external factors such as market trends [90], changes in regulations [1, 7], and consumer preferences [8, 54] on their ESG performance. By comprehending the fundamental factors that drive market value and ESG performance and considering external factors, companies can remain competitive, sustainable, and responsible members of the global community.

This discussion is crucial from a sustainability perspective as it sheds light on the importance of examining the correlation between a company's past market value and ESG score and its future market value and ESG score [5]. By understanding these relationships and external factors that impact them, firms can develop effective strategies to enhance sustainability and contribute to achieving the 2063 sustainable goals from both societal and firm perspectives [91, 92]. This way, companies can maintain their commitment to sustainability, remain competitive, and fulfill their responsibility as responsible members of the global community [11, 81, 93]. Past market value is important for predicting future market value. Studies have shown a positive impact for firms with high institutional ownership and a negative impact for those with high financial leverage. Monitoring these factors is crucial for maintaining market value over time and promoting long-term sustainability [94, 95]. Tobin's Q, a measure of firm market value, shows persistent behavior over time. Past impulses have a significant impact, but their effect fades slowly due to firm-specific factors. The impact of past impulses on Tobin's Q varies based on the direction of the impulse and other factors like firm size and financial structure. Recent research supports the persistence of impulses in Tobin's Q, which is crucial for firms to maintain good market value and long-term sustainability [96, 97].

Studying the past ESG score on the future ESG score is significant in understanding the sustainability performance of firms in the long-run [56, 98]. It helps develop strategies to improve ESG performance and maintain sustainability [99, 100]. Investors can use this information to make informed investment decisions. Studies show that past ESG performance has a positive impact on future ESG performance, indicating the presence of persistent impulses and a positive feedback loop [16, 83]. Maintaining good ESG performance over time reduces the likelihood of experiencing ESG controversies and drives positive change towards a more sustainable future [68]. ESG performance persists over time due to slow diffusion of ESG information [101, 102]. Past ESG performance has an impact on future ESG performance, but this impact varies depending on the direction of the impulse and firm-specific factors [1, 97]. Recent studies show that high ESG performers tend to maintain their status, while poor ESG performers tend to worsen [13, 15, 103, 104]. It is essential to consider the long-term impact of ESG strategies and practices to ensure sustainability. This information can be used by firms to develop effective sustainability strategies and by investors to make informed investment decisions. Saying that we outline our fourth research question as follow;

RQ4 What are the behaviors of market value and ESG score in the long run in Chinese listed companies?

3 Methodology

3.1 Data

Our study involved gathering data from companies listed on the Main Boards of the Shanghai and Shenzhen Stock Exchanges in the Chinese A-share market. We collected data from 2013 to 2019, excluding companies in the financial sector, “ST” or “*ST” class labeled companies, and those with missing variable observations. Following these stringent criteria, we curated a balanced panel dataset comprising 652 sample observations, all of which had accessible ESG reports throughout the specified period.

Several reasons led to the selection of the years 2013 to 2019 for the panel data study. The first reason is that the COVID-19 pandemic began after 2019, which has caused significant changes in the global economy and the way businesses operate. Obtaining reliable and accurate data from Chinese-listed companies has become challenging due to the situation, which may affect the study’s reliability. Therefore, it was crucial to choose a period that is not impacted by this pandemic.

The second reason is that significant environmental regulations were ratified by China in 2012, leading to an increase in firms’ environmental responsibility and disclosure. The China Ministry of Environmental Protection revised the Ambient Air Quality Standard in 2012 and added the air quality index for monitoring fine particulate matter (PM_{2.5}), which caused society to attach great importance to air quality and corporate pollution behaviors (Xing et al. 2019). Therefore, selecting 2013 as the starting year provides ample time to observe the effects of these regulations on the firms’ environmental performance. The last reason is that the timeframe between 2013 and 2019 provides a reasonable duration to observe the persistence of ESG performance over time, as the ESG investment approach became more popular in recent years. This timeframe provides enough data to conduct reliable panel data analysis and draw meaningful conclusions.

For ESG, we used scores provided by the Bloomberg database, which range from 0.1 to 100, with 0.1 indicating the minimum level of disclosure and 100 indicating complete disclosure of every data point required under Bloomberg. These scores are based on nearly 800 parameters and cover approximately 11,500 listed companies in 83 countries. Bloomberg computes the scores using a holistic approach, which involves retrieving public information from sustainability reports, annual reports, CSR disclosures, community spending data, and company websites. The scores reflect the extent of disclosure in relation to the required data points as specified under the Bloomberg survey for ES. To obtain financial and non-financial data related to the companies, we used the China Stock Market and Accounting Research (CSMAR) database. This database collects data from annual reports, disclosures, and filings submitted to various government bodies. We used Tobin’s Q as a measure of firm value, as it links a firm’s asset utilization to market value creation and is a futuristic approach that is highly preferred by investors in assessing a company’s total value creation in the stock market. Tobin’s Q is a market-based performance measure that scholars extensively use because it can predict long-term firm value better than accounting measures [63, 94, 96]. The continuous variables were winsorized at the 1% and 99% levels, thus ensuring data consistency.

3.2 Methodology approach

We utilized [65] approach to the generalized cross-lagged model, which integrates three modeling traditions: vector autoregressive models, vector autoregressive moving average models, and dynamic panel data models. This method can capture complex processes and effects that go beyond simple AR and CL terms. It differs from previous ESG-FV research methods by addressing two sources of variation in firms using unit effects. Within-firm variation is represented by AR, CL, and impulse terms (see Fig. 1), while between-firm variation is accounted for by treating them as a function of company-specific factors modeled as a unit effect η_i (see Fig. 1 and Equations). This framework can be mathematically characterized as a multilevel model, where the time series observations for each firm are nested within the higher-level unit of the firm itself. X_{it} and Y_{it} are functions of $\eta_i^{(x)}$ and $\eta_i^{(y)}$ with variances $\psi_i^{(x)}$ and $\Psi_i^{(y)}$, respectively. In addition, time-varying effects with occasion-specific “factors loadings” $\lambda_t^{(x)}$ and $\lambda_t^{(y)}$ are added:

Full Model 1: General Cross Lagged Panel Model

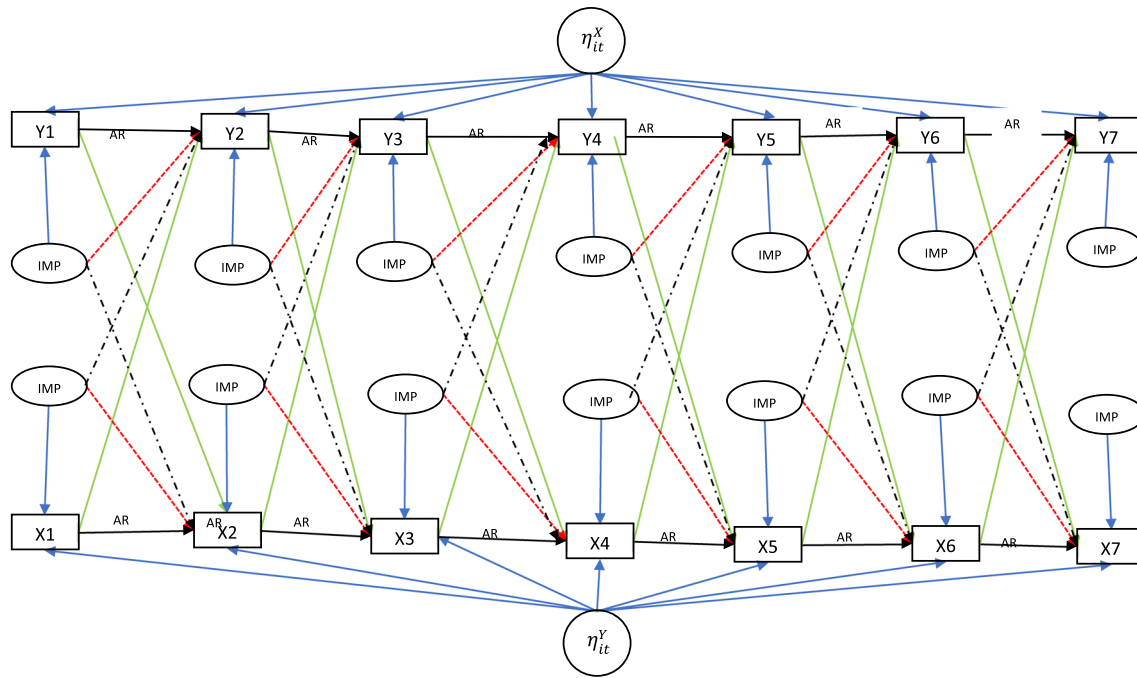


Fig. 1 Conceptual Framework. *CL* Cross lag term (green), *MA* Moving Average terms (dashed red), *AR* Autoregressive terms (solid black), *IMP* impulse, *CLMA*: Cross lag moving Average (dashed black). X1-X7 represents the ESG Score from 2013 to 2019, while Y1-Y7 stands for Tobin's Q value for 2013 to 2019, respectively. η_{it}^X and η_{it}^Y Represents the unit effect controlling mechanisms for ESG Score and Future Value respectively. Only for presentation simplicity we did not draw the covariance terms between impulses and unit effects

$$X_{it} = \alpha_t^{(x)} + \lambda_t^{(x)} + \eta_i^{(x)} + \beta_{x1}^{(x)} X_{it-1} + \delta_{x1}^{(x)} \mu_{it-1}^{(x)} + \beta_{y1}^{(x)} Y_{it-1} + \delta_{y1}^{(x)} \mu_{it-1}^{(y)} + \mu_{it}^{(x)} \quad (1)$$

$$Y_{it} = \alpha_t^{(y)} + \lambda_t^{(y)} + \eta_i^{(y)} + \beta_{y1}^{(y)} Y_{it-1} + \delta_{y1}^{(y)} \mu_{it-1}^{(y)} + \beta_{x1}^{(y)} X_{it-1} + \delta_{x1}^{(y)} \mu_{it-1}^{(x)} + \mu_{it}^{(y)} \quad (2)$$

Constrained model 1: General Cross Lagged Panel Model

$$X_{it} = \alpha_t^{(x)} + \lambda_t^{(x)} + \eta_i^{(x)} + \beta_{x1}^{(x)} X_{it-1} + \delta_{x1}^{(x)} \mu_{it-1}^{(x)} + \beta_{y1}^{(x)} Y_{it-1} + \delta_{y1}^{(x)} \mu_{it-1}^{(y)} + \mu_{it}^{(x)} \quad (3)$$

$$Y_{it} = \alpha_t^{(y)} + \lambda_t^{(y)} + \eta_i^{(y)} + \beta_{y1}^{(y)} Y_{it-1} + \delta_{y1}^{(y)} \mu_{it-1}^{(y)} + \beta_{x1}^{(y)} = 0 X_{it-1} + \delta_{x1}^{(y)} = 0 \mu_{it-1}^{(x)} + \mu_{it}^{(y)} \quad (4)$$

Constrained Model 2: General Cross Lagged Panel Model

$$X_{it} = \alpha_t^{(x)} + \lambda_t^{(x)} + \eta_i^{(x)} + \beta_{x1}^{(x)} X_{it-1} + \delta_{x1}^{(x)} \mu_{it-1}^{(x)} + \beta_{y1}^{(x)} = 0 Y_{it-1} + \delta_{y1}^{(x)} = 0 \mu_{it-1}^{(y)} + \mu_{it}^{(x)} \quad (5)$$

$$Y_{it} = \alpha_t^{(y)} + \lambda_t^{(y)} + \eta_i^{(y)} + \beta_{y1}^{(y)} Y_{it-1} + \delta_{y1}^{(y)} \mu_{it-1}^{(y)} + \beta_{x1}^{(y)} X_{it-1} + \delta_{x1}^{(y)} \mu_{it-1}^{(x)} + \mu_{it}^{(y)} \quad (6)$$

Full Constrained Model 4: General Cross Lagged Panel Model

$$X_{it} = \alpha_t^{(x)} + \lambda_t^{(x)} + \eta_i^{(x)} + \beta_{x1}^{(x)} X_{it-1} + \delta_{x1}^{(x)} \mu_{it-1}^{(x)} + \beta = 0_{y1}^{(x)} Y_{it-1} + \delta = 0_{y1}^{(x)} \mu_{it-1}^{(y)} + \mu_{it}^{(x)} \quad (7)$$

$$Y_{it} = \alpha_t^{(y)} + \lambda_t^{(y)} + \eta_i^{(y)} + \beta_{y1}^{(y)} Y_{it-1} + \delta_{y1}^{(y)} \mu_{it-1}^{(y)} + \beta = 0_{x1}^{(y)} X_{it-1} + \delta = 0_{x1}^{(y)} \mu_{it-1}^{(x)} + \mu_{it}^{(y)} \quad (8)$$

where, $\alpha_t^{(x)}$ and $\alpha_t^{(y)}$ represents the effect an occasion has on market values and ESG score. This factor takes into account overall changes in a sample across occasions that may be due to unrelated factors such as aggregate changes in the

listed companies. The AR (Autoregressive) term, represented by $\beta_{x1}^{(x)}x_{it-1}$ and $\beta_{y1}^{(y)}y_{it-1}$, captures a proportion of the past ESG score and Market value that persists to the next occasion. This term shows the gradual evolution of a procedure, highlighting the idea that the present conditions of a system are not self-generated, but rather, they rely on previous conditions. For instance, the current ESG rating or market value is dependent on the past ESG rating or market value, respectively. $\beta_{y1}^{(x)}y_{it-1}$ and $\beta_{x1}^{(y)}x_{it-1}$ refer to the cross-lagged (CL) terms, which denote the direct influence of ESG score short-term effects on the future market value or vice versa. CL terms are utilized to deduce causality, as demonstrated in Fig. 1. However, they only indicate a direct effect of the past on the future, representing a short-term behavior of the system akin to AR terms.

The model includes two residual terms, $\mu_{it}^{(x)}$ and $\mu_{it}^{(y)}$, which account for variations in companies' ESG score and market value over time due to random inputs. These terms, also known as impulses, capture unit-specific "shocks" or unpredictable surprises, rather than representing errors in the cross-lagged model. The co-movement terms capture the independent effect and aid in interpreting the causal effects of the predictor covariance in the cross-lagged model (We did not show that in the conceptual framework for the purpose of presentation simplicity). As mentioned in [66], these terms are important in improving the accuracy and reliability of the model.

The model also includes $\delta_{x1}^{(x)}\mu_{it-1}^{(x)}$ and $\delta_{y1}^{(y)}\mu_{it-1}^{(y)}$ terms that are Moving Average (MA) terms. These terms capture the direct impact of previous ESG scores on future market value. The reason for including the MA term is to differentiate between short-term effects (total effect of MA and AR terms) and long-term dynamics (MA and CL). We have introduced MA and CLMA terms to account for short-run and long-run dynamics that may differ. These terms make future values directly proportional to past values, which enables us to capture unexpected changes that persist or fade multiplicatively [65]. The incorporation of these terms extends the model's dynamics beyond AR and CL terms.

Figure 1 displays the short-run impact of an impulse as a combination of MA and AR terms (i.e., the total effect of $\mu_{it-1}^{(y)}$ on Y_{it} is $\beta_{y1}^{(y)} + \delta_{y1}^{(y)}$), with the blue and solid black lines representing this. However, the AR (and CL) terms determine the long-term dynamics since an impulse last beyond the MA term [65]. The term $\delta_{y1}^{(x)}\mu_{it-1}^{(y)}$ and $\delta_{x1}^{(y)}\mu_{it-1}^{(x)}$ accounts for the cross-lagged moving average, which captures the long-term effects between ESG score past impulses on future market value and vice versa. The influence of previous impulses on future observed variables is suggested by lagged effects. AR + MA indicates the brief continuity of a variable, while CL + CLMA indicates the short-term impact of one variable on another. Granger-Sims causality is the basis of this approach, which regards impulses as causes.

Moving ahead to the next section, we will demonstrate the outcomes comprehensively and address our initial and secondary research inquiries using [65] four-step approach. Initially, we will compute the complete unconstrained relaxed model without restrictions on the direction of causality, as shown in Fig. 1 (also see full model 1 equation). Next, we will analyze the causal direction of ESG score on market value and estimate the causal link from market value to ESG Score. In the third step, we will restrict the causal direction of market value on ESG score and estimate the causal link from ESG score to market value. This approach will assist us in understanding the causal relationships between the variables and gaining insights into their short-term dynamic behavior. To explain further, the General Cross Lagged Model (GCLM) utilizes Cross Lagged Moving Average (CLMA) terms to treat impulses as causes, which allows for the application of Granger-Sims causality. In order to check the Granger-Sims causality of ESG on Market value, we constrained the path of $\beta_{x1}^{(y)}$ to $\beta_{x7}^{(y)}$ and $\delta_{x1}^{(y)}$ to $\delta_{x7}^{(y)}$. Conversely, to check the Granger-Sims causality of Market value on ESG score, we constrained the path of $\beta_{y1}^{(x)}$ to $\beta_{y7}^{(x)}$ and $\delta_{y1}^{(x)}$ to $\delta_{y7}^{(x)}$. To verify the "Feedback effect," we simultaneously constrained all the paths, and subsequently checked the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Following constructive suggestions from reviewers, the researchers conducted additional analyses to examine a stable effect between groups, integrating interaction effects between ESG scores and firms subject to mandatory reporting. This aligns with the crucial findings of previous studies [105–107], which highlight that the relationship between ESG scores and firm value is contingent upon mandatory disclosure policies. To address this, we employed an extended cross-lag model with interaction terms, as recommended by [108].

$$Y_{Bi} = \beta_{Bx}^{(y)}x_{Bi} + \beta_z^{(y)}z_{Bi} + \beta_{Bxz}^{(y)}x_{Bi}z_{Bi} + \zeta_{Bi}^{(y)} \quad (9)$$

In this equation, we introduce the term $\beta_{Bxz}^{(y)}$ to represent a specific interaction effect solely within the stable components of x and z. Specifically, in our study, we explore how the stable B component (between clusters) of the ESG score x_{Bi} interacts with mandatory disclosure reporting firms z_{Bi} to forecast the stable B component (between clusters) of firm value Y_{Bi} .

Finally, to ensure the robustness of our findings, we conducted several alternative analyses. We first used the Book Value of Equity (BVE) with Huazheng ESG scores to provide an accounting-based valuation measure. We applied an AR(1) MA(1) structure to analyze the data and found a statistically significant and lasting positive effect of ESG scores on BVE. Additionally, we used Tobin's Q with ESG scores from the CNRDS Platform, employing similar statistical models. These analyses confirmed the positive impact of ESG scores on firm market value, demonstrating that our primary results are consistent across different data sources and valuation metrics.

4 Results and discussion

4.1 Descriptive statistics

In this section, we will explore the relationship between past ESG scores and market values and how they relate to future ESG scores and market values, without exploring causality. Next, we will use the Granger-Sims logic to investigate the short-term causal relationship between ESG scores and market values. By looking at lagged effects, we can understand how past impulses impact future variables. To determine the short-term persistence for a variable, we use AR + MA. To determine the short-term effect of one variable on another, we use CL + CLMA. This approach assumes that impulses can be considered causes, also known as Granger-Sims causality. We used the Granger-Sims effect in both directions of market value and ESG Score to test the short-run effect of past values on future values. We used a general cross-lagged model that applies impulses to provide a generalized explanation for both the CL (green lines) and CLMA (red dashed lines) (See Fig. 1 Conceptual framework). We followed the four-step procedures recommended by [65]. First, we ran the full model unconstrained and then constrained one after the other to check the direction of causality in steps two and three. Finally, we constrained all the CL and CLMA terms to check for short-run feedback effects in step four.

Furthermore, we will discuss the long-term causality of market value and ESG score using the impulse response logic suggested by [66]. To examine the long-run effect of ESG score on market values, we will analyze the total effect of an initial ESG score at $T = 1$ on all future market values. This will help us answer our key hypothesis of "how do companies adapt to ESG score". We applied the GCLM to account for stable factors using unit effects and to capture factors that make a company similar to itself (rather than different) over time by controlling covariance among lagged predictors. We have compiled the outcomes for the complete model in Tables 1, 2, and Appendix B to present all-encompassing conclusions. To keep it brief, we have excluded occasion effects and standardized impulse/unit effect covariances as correlations. Our third research inquiry aims to exhibit the Impulse responses in Fig. 2. These responses were generated as indirect effects from an initial impulse to future observed occasions using Mplus. We have used 20,000 draws to provide a reliable estimate and 95% bootstrapped CIs, in accordance with our goal. Table 6 in Appendix A presents the means, standard deviations, and correlations of the variables used in our study.

4.2 Dynamics of market value and ESG scores: trends, autoregression, and implications for future predictions

Our initial analysis involves examining the dynamics of market value using AR(1)MA(1) structure in our models. Our findings reveal that the persistence of impulses quickly diminishes, as impulses are almost entirely faded by the seventh future year. Moreover, we observed that statistical significance exists for the direct effect (short-term effect) of past impulses, with 95% CIs excluding zero on all occasions. In Table 3, we observe this as the combined AR and MA term $\beta_{y1}^{(y)} + \delta_{y1}^{(y)}$, which is 0.540 (see ARMA in Table 3). This implies that only 54% of a previous year's impulse persists to the next year. Furthermore, our analysis shows that the AR parameter AR is 0.346, indicating the presence of mean reversion. This means that market value tends to converge towards the average market value over time, exhibiting a self-correction mechanism in the Chinese market, where prices tend to move towards their intrinsic value. Additionally, we find that the positive and significant time-varying unit effects $\lambda_t^{(y)}$ are not in a range consistent with stable unit effects of 0.711 and 0.394 in 2013 and 2019, respectively. Moreover, our results demonstrate an expected mean-reverting process and significant unit effects imply instability over time. These findings suggest that only modeling the past market value on future market value may not be appropriate considering the many external factors that affect market value over time [94]. However, our main objective is to extract and showcase the autoregressive nature of market value, not inference, so this will not pose an issue.

Table 1 Operationalization of variables

S/N	Variables	Description	Reference
1	Firm value	We used Tobin's Q as a measure of firm value ((Circulating Market Capitalization + (Number of Non-Circulating Shares × Net Asset Per Share) + Book Value of Debt)/Total Assets)	[30, 39]
2	ESG score	scores provided by the Bloomberg database, which range from 0.1 to 100, with 0.1 indicating the minimum level of disclosure and 100 indicating complete disclosure of every data point required under Bloomberg	[28, 64, 102]
3	Firm age	Firm year of establishment minus the reporting year	[109, 110]
4	Mandatory disclosure	a dummy variable that equals 1 if the firm is a mandatory CSR reporting firm and 0 otherwise	[105–107]
5	Huazheng ESG	Huazheng ESG rating score, developed by The Sino-Securities Index Information Service Co., Ltd	[111]
6	CNRDS ESG	The ESG Rating Database of Listed Companies (ESG-R) on the Chinese Research Data Services (CNRDS) Platform	[112]
7	Book value of equity	Total Assets—Total Liabilities	[113]

Table 2 Granger-sims tests

Model estimates				
χ^2	CFI/TLI	RMSEA/SRMR	AIC/BIC	aAIC/aBIC
<i>Step 1: Derive fit of full model</i>				
594.516 (61)***	0.956/0.934	0.116/0.05	33826.436/34086.278	33837.977/33902.129
<i>Step 2: Constrain All Tobin's Q \rightarrow ESG Score</i>				
599.493 (63)***	0.955/0.936	0.114/0.048	33827.412 /34078.295	33838.141/33900.495
<i>Step 3: Constrain All ESG Score \rightarrow Tobin's Q</i>				
602.246 (63)***	0.955/0.935	0.115/0.063	33830.165 /34081.048	33840.894/33903.248
<i>Step 4: Constraining all CL/CLMA Terms</i>				
604.954 (65)***	0.955/0.937	0.113/0.060	33828.874 /34070.796	33838.823/33899.346
No Obs. = 652				

RMSEA Standardized root mean square error of approximation, SRMR standardized root mean square residual, TLI Tucker-Lewis index, CFI Comparative Fit Index, AIC Akaike Information Criterion, BIC Bayesian or Schwarz Information Criterion, and a sample-size adjusted version of the AIC and BIC

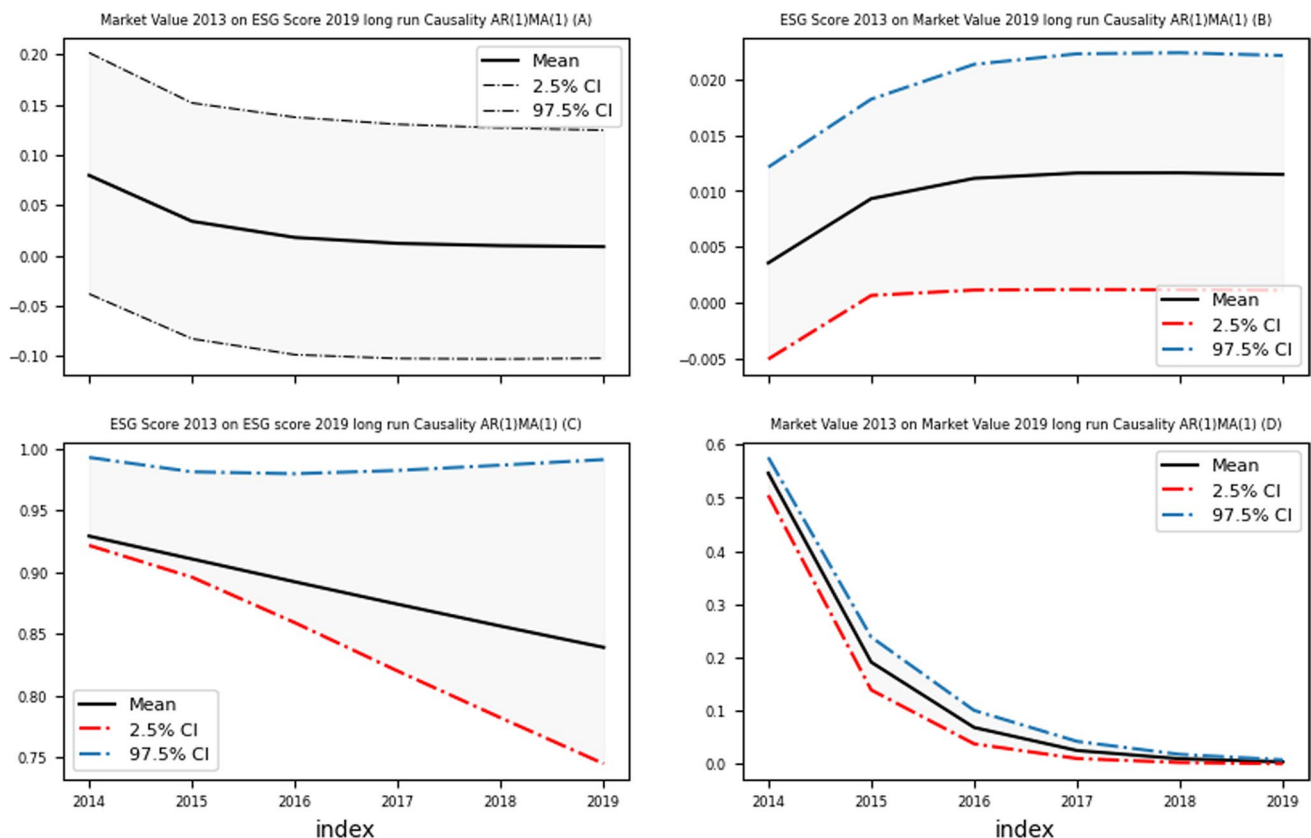


Fig. 2 Long run effects: Impulse response (A, B, C, D). The y-axis is effect estimates, and the x-axis is the response horizon in years so that the plotted lines indicate the effect of a 1-unit impulse in 2013 over the next 6 years. Solid lines represent effect estimates; dotted lines represent 97.5% and 2.5% confidence intervals obtained using a nonparametric bootstrap with 20,000 replications. The initial impulse response to any given stimulus occurs at $t=1$ due to the fact that the model's highest lag order is restricted to 1. This means that the effect of the stimulus on the system is observed immediately in the subsequent time period

The lower-left corner of Fig. 2C displays the ESG score dynamics AR(1) MA(1) model, which suggests that companies tend to follow trends when it comes to their Environmental, Social and Governance (ESG) scores over time. The AR(1) effect $\beta_{x1}^{(x)}=0.982$ also confirms this trend-following behavior. Table 4 shows that the time-varying unit effects $\lambda_t^{(x)}$ are relatively small after the fourth unit ($\lambda_4^{(x)}$), ranging from -0.0496 to 0.691 . This indicates that unit effects have little

impact on the observed variation in ESG scores, highlighting the importance of trends in determining ESG scores over time. On the Other Hand, this research has significant implications for the rating system, as it suggests that Chinese-listed companies that scored high ESG scores in the past are likely to continue to score high in the future. The findings align with previous research in the field of ESG scoring, which has shown that companies tend to follow trends when it comes to their Environmental, Social and Governance scores over time [16]. An AR(1) effect of $AR = 0.982$ in the ESG score dynamics AR(1) MA(1) model, as shown in Fig. 2C, confirms this trend-following behavior.

Additionally, a study conducted by OECD discovered that companies with high ESG scores tend to maintain their scores over time, with 88% of companies in the top quintile of ESG scores in 2010 remaining in the top quintile in 2018 [114]. Although unit effects can have an impact on ESG scores, the time-varying unit effects ($\lambda_t^{(x)}$) are relatively small after the fourth unit ($\lambda_4^{(x)}$), ranging from -0.0496 to 0.691 , as illustrated in Appendix B. This indicates that unit effects have little impact on the observed variation in ESG scores. Hence, it is crucial to consider trends while determining ESG scores over time, which further emphasizes the importance of considering ESG factors in investment decisions.

4.3 Granger-sims tests: assessing causality in market value and ESG score dynamics

In the field of structural equation modeling (SEM), there is a debate regarding the use of cutoff criteria. While Zyphur doesn't support their use, they suggest examining their use with panel data. To comply with this advice, we'll use several statistical checks to evaluate model fit. These include RMSEA, SRMR, TLI, CFI, AIC, BIC, and a sample-size adjusted version of AIC and BIC. We observed no significant problems with any single model after examining these indices in Table 2. There were, however, minor differences in CFI, TLI, RMSEA, and SRMR. The AIC favored the more complex full model without constraints, while the BIC favored the more parsimonious constraint model. Both the sample size-adjusted AIC and BIC agreed with the BIC. Compared to Step 1, Step 2 indicated a short-run Granger-Sims effect of Market value on ESG score, and the constrained model performed worse across all statistics. The difference in fit between Step 3 and Step 1 was more inconsistent, showing no clear support for a short-run effect of ESG score on Market value. Finally, constraining all CL/CLMA terms in Step 4 suggests the potential existence of short-run feedback effects, but results from the previous two steps suggest this is mostly due to the effect of market value on ESG score.

Since the resulting Model fit statistics needs a cautious explanation we will revert to our full model GCLM estimation and explain the short-term links with referencing each scenario separately.

4.4 ESG score dynamics: unveiling long-term effects on market value

In Fig. 2B (see top right Fig. 2), the ESG score's market value effect (top-right) shows that after year 1, all impulse responses exclude zero in 95% CIs supporting the existence of long term direct effect. The short-run effect is positive, with a cross-lagged + cross-lagged moving average term $\beta_{x1}^{(y)} + \delta_{x1}^{(y)}$ of 0.004 and SEs of 0.25 ($p > 0.004$). This indicates an interesting result of ESG score persistence: an increase in ESG Score has a weak but persistent effect on market value due to ESG's large autoregressive (AR) term $\beta_{x1}^{(x)} = 0.982$. This further affects market value via the cross-lagged term $\beta_{x1}^{(y)} = 0.009$. Therefore, an ESG score's large AR term implies a lasting effect on market value, even if the market value is mean-reverting. This leads us to infer that ESG scores have a long-term effect. Although this effect is weak, our model for market value still illustrates an interesting implication of the dynamics between ESG score and market value. Several studies, including [27, 115], have shown that companies with higher ESG scores generally have higher market valuations. This indicates that investors consider ESG factors to be essential in their investment decisions and that firms with superior sustainability performance tend to outperform their peers over the long term. An ESG score impulse has an initial positive effect on market value that persists due to the market value's AR process, which becomes stronger due to ESG score's AR process and market value-ESG score feedback. Other researchers have also found that ESG scores have a positive impact on firms' market value in the short run, but the long-term impact is less clear. However, our study shows that even though the effect is weak, ESG scores have a lasting impact on market value due to the large autoregressive term, implying a long-term effect.

4.5 Market value and ESG scores: navigating short-term challenges for long-term positivity

The Market Value to ESG Score effect, as shown in the top-left of Fig. 2, includes 95% confidence intervals that encompass zero at all time horizons. However, unlike the ESG Score to Market Value effect, the Market Value to ESG Score effect is generally negative in nature. Table 3 indicates that the short-run effect of an increase in Market Value on the ESG score

is CL + CLMA 0.083. Although the Market Value to ESG Score effect is weak, it has a persistent impact on the ESG Score, even if the ESG Score is trend-following. This is because of Market Value's small AR term $\beta_{x1}^{(x)} = 0.346$, which further affects ESG Score via the CL term $\beta_{y1}^{(x)} = -0.081$. According to our analysis, Market Value has a negative impact on ESG Score in the short-term, but a positive impact in the long-term. Our model for ESG Score reveals an interesting outcome of the Market Value and ESG Score dynamics. A sudden increase in Market Value has an initial negative effect on the ESG Score, which persists due to the ESG Score AR process. However, the Market Value AR process and ESG score-market value feedback subsequently strengthen the ESG Score and make it positive in the long term. This may be because companies tend to overlook reporting ESG when they perform well in the market initially. However, they eventually revert to being environmentally conscious in the long run, possibly due to regulatory pressures and investor demands.

The Market Value to ESG Score effect, as shown in the top-left of Fig. 2A, includes 95% confidence intervals that encompass zero at all time horizons. This finding is consistent with prior research that suggests a weak relationship between a company's market value on ESG score. Unlike the ESG Score to Market Value effect, the Market Value to ESG Score effect is generally negative in nature. This finding is consistent with prior research that has found a negative relationship between market value and certain ESG factors such as carbon emissions. For instance, a study by [48] found that companies with higher carbon emissions tended to underperform those with lower carbon emissions. This suggests that investors may be more likely to invest in companies with lower carbon emissions, which could ultimately lead to a decline in market value for companies with higher carbon emissions.

Table 3 indicates that the short-run effect of an increase in Market Value on the ESG score is CL + CLMA which is $\beta_{y1}^{(x)} + \delta_{y1}^{(x)} = 0.083$. Although the Market Value to ESG Score effect is weak, it has a persistent impact on the ESG Score, even if the ESG Score is trend-following. According to our analysis, Market Value has a negative impact on ESG Score in the short-term, but a positive impact in the long-term. Our model for ESG Score reveals an interesting outcome of the Market Value and ESG Score dynamics. A sudden increase in Market Value has an initial negative effect on the ESG Score, which persists due to the ESG Score AR process. However, the Market Value AR process and ESG score-market value feedback subsequently strengthen the ESG Score and make it positive in the long term. This may be because companies tend to overlook reporting ESG when they perform well in the market initially. However, they eventually revert to being environmentally conscious in the long run, possibly due to regulatory pressures and investor demands. In other words, our finding reveals that companies may prioritize financial performance over ESG considerations in the short term, but eventually, they are likely to become more environmentally conscious to meet regulatory pressures and investor demands.

4.6 ESG scores' long-term impact on market value

In this section we will follow the impulse response to present the long term causality between ESG score and Market value. As specified in the model the term $\delta_{y1}^{(x)} \mu_{it-1}^{(y)}$ and $\delta_{x1}^{(y)} \mu_{it-1}^{(x)}$, accounts for the cross lagged moving average, which

Table 3 Model results

FULL MODEL AR(1)MA(1) ESTIMATIONS RESULTS (AR(1)MA(1)CL(1))			
Tobin's Q --> Tobin's Q - AR/MA Terms		ESG Score --> ESG Score AR/MA Terms	
$\beta_{y1}^{(y)} = AR \text{ terms}$	0.346*** (0.033)	$\beta_{x1}^{(x)} = AR \text{ terms}$	0.982*** (0.014)
$\delta_{y1}^{(y)} = MA \text{ Terms}$	0.195*** (0.028)	$\delta_{x1}^{(x)} = MA \text{ Terms}$	-0.024 (0.023)
$\delta_{x1}^{(y)} = \beta_{y1}^{(y)} + \delta_{y1}^{(y)} \text{ ARMA Terms}$	0.540*** (0.019)	$\delta_{y1}^{(x)} = \beta_{x1}^{(x)} + \delta_{x1}^{(x)} \text{ ARMA Terms}$	0.959*** (0.018)
ESG Score --> Tobin's Q CL/CLMA Terms		Tobin's Q --> ESG Score Q CL/CLMA Terms	
$\beta_{x1}^{(y)} = CL \text{ terms}$	0.009** (0.004)	$\beta_{y1}^{(x)} = CL \text{ terms}$	-0.081*** (0.031)
$\delta_{x1}^{(y)} = CLMA \text{ Terms}$	-0.005 (0.005)	$\delta_{y1}^{(x)} = CLMA \text{ Terms}$	0.164** (0.073)
$\delta_{x1}^{(y)} = \beta_{x1}^{(y)} + \delta_{x1}^{(y)} \text{ CLCL Terms}$	0.004 (0.004)	$\delta_{y1}^{(x)} = \beta_{y1}^{(x)} + \delta_{y1}^{(x)} \text{ CLCL Terms}$	0.083 (0.060)

AR Autoregressive terms, MA Moving Average, ARMA Autoregressive moving average, CL Cross lag, CLMA Cross lag moving Average, CLCL Cross lag cross lag. The coefficients are the same as described in the methodology

captures the longterm effects between ESG score past impulse on future market value. Upon analyzing the impulse responses, it has been observed that the ESG score has a significant impact on the market value of a company. This impact is evident in the short-term effects of the ESG score impulse, as shown in the bottom-left Fig. 2. The 95% Confidence Interval (CI) excludes zero even up to six occasions after the impulse, as indicated by the top-right Fig. 2. Furthermore, the ESG score impulse persists well into the future, suggesting that the ESG score has a long-term impact on the market value, as indicated by the top-right Fig. 2.

On the other hand, the market value has little impact on the ESG score of a company, as confirmed by the weakly significant reverse causality. This is indicated by the consistency of the ESG score over time, as shown in the top-left Fig. 2. Even after six occasions following the market value impulse, the 95% Confidence Interval (CI) still includes zero, as indicated by the bottom-right Fig. 2. Additionally, the market value is less persistent over time, as indicated by the bottom-right Fig. 2. This implies that the market value has a short-term impact on ESG score. Our finding shows the importance of considering ESG score in investment decisions as it plays a significant role in determining the long-term sustainability and success of a company. The weakly confirmed reverse causality also emphasizes the need to prioritize the ESG score in evaluating the overall health of a company.

4.7 Mandatory CSR Disclosure as a moderator

As Appendix B: Table 7 shows, for the within cluster WxW effect for AR terms $\beta_{w(fv)}^{(FV)} = 0.448(p < .001)$, $\beta_{w(esg)}^{(ESG)} = 0.905(p < .001)$, and $\beta_{w(age)}^{(age)} = 0.848(p < .001)$, whereas for CL terms $\beta_{w(ESG)}^{(FV)} = -0.019(p < .05)$, $\beta_{w(fv)}^{(ESG)} = -0.134(p < .001)$, $\beta_{w(age)}^{(ESG)} = 0.535(p = .500)$, $\beta_{w(age)}^{(FV)} = -1.183(p = .500)$, $\beta_{w(esg)}^{(AGE)} = 0.00(p = .398)$, and $\beta_{w(fv)}^{(AGE)} = -1.183(p = .490)$. Figure 3 presents a graphical representation of the results shown in Appendix B: Table shows, focusing on the Between effects (B effects). The B effects are very similar to the baseline, with firm ages being associated with an increase in firm market value, $\beta_{B(age)}^{(FV)} = -0.035(p = .003)$, and average ESG score, $\beta_{B(age)}^{(ESG)} = -0.045(p = .164)$. Being a non-mandatory reporting firm was associated with higher firm age, $\beta_{B(NM)}^{(AGE)} = 0.982(p = .048)$. The key difference in this model is the B interaction among average ESG score and mandatory disclosure predicting firm value, which was negative and significant, $\beta_{B(NMesg)}^{(FV)} = -0.28(p = .037)$. By including this interaction with the mandatory disclosure variable, the significant effect of ESG score on average firm market value for non-mandatory disclosure firms (MN = 0) was

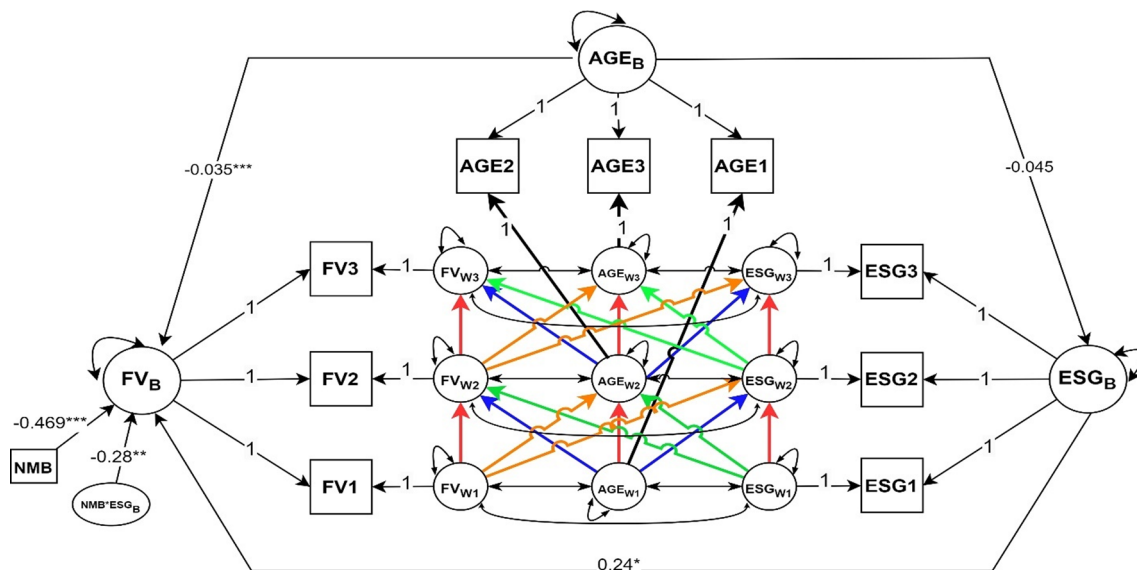


Fig. 3 CLPM for ESG and Firm Market Value at three occasions with latent BxB interactions. FV (Firm Market Value), NMB (Mandatory Disclosure), ESG (Environmental, Social, and Governance Score), and AGE (Firm Age). To maintain clarity and avoid clutter, we present data for only three selected years instead of all available years

$\beta_{B(esg)}^{(FV)} = 0.24 (p = .062)$. In turn, we can compute this coefficient for mandatory disclosure firms by adding the interaction effect to net $-0.28 + 0.24 = -0.04$. The interaction effect could imply that average ESG score changes the effect of Mandatory disclosure on firm market value, making firm market value even lower for Mandatory disclosure firms by -0.28 as when ESG score increases by 1 unit. See Fig. 2 for graphical representation of the results.

4.8 Robustness check

To ensure the robustness of our findings regarding the impact of ESG on firm market value, we implement several alternative measures and methodologies. Our primary analysis uses Bloomberg ESG scores and Tobin's Q as the dependent variable. To validate the consistency of our results, we conduct the following robustness checks:

Firstly, we use the Book Value of Equity (BVE) as an accounting-based measure of firm valuation, providing a more conservative estimate focused on the balance sheet rather than market perceptions. Additionally, we apply Huazheng ESG scores, developed by The Sino-Securities Index Information Service Co., Ltd., which uses a three-pillar framework (Environment, Social, and Governance) with a nine-level rating system (C to AAA). The results, presented in the first column of Table 4 and Fig. 4a, show statistical significance for the direct effect of past impulses, with 95% confidence intervals excluding zero. The combined AR and MA term is 0.983 ($p < 0.01$), indicating that 98% of a previous year's impulse persists to the next year. The AR parameter of 0.964 suggests mean reversion, where market value tends to converge towards the average over time. ESG scores show a positive long-term effect on BVE, with a cross-lagged term of 0.169 ($p < 0.01$) and a large AR term of 0.7, indicating a lasting effect on BVE. This demonstrates that higher Huazheng ESG scores are associated with higher BVE, suggesting that better ESG performance translates to higher book values of equity.

Secondly, we utilize ESG scores from the ESG Rating Database of Listed Companies (ESG-R) on the Chinese Research Data Services (CNRDS) Platform. This source provides comprehensive ESG performance evaluations for A-share listed

Table 4 Comparison of ESG Scores and Firm Valuation Measures: Results of Robustness Checks

Parameter	Model estimates (SE)	
	Book value on Huazheng ESG	CNRDS ESG- Tobin's Q
	AR(1)MA(1)	AR(1)MA(1)
	Book Value → Book Value AR/MA Terms β_{y1}^y and δ_{y1}^y	Tobin's Q → Tobin's Q AR/MA Terms β_{y1}^y and δ_{y1}^y
β_{y1}^y	0.964*** (0.006)	0.618*** (0.022)
δ_{y1}^y	0.020* (0.011)	0.063*** (0.015)
$\beta_{y1}^y + \delta_{y1}^y$	0.983*** (0.009)	0.680*** (0.014)
	Huazheng ESG → Huazheng ESG AR/MA Terms β_{x1}^x and δ_{x1}^x	CNRDS ESG → CNRDS ESG AR/MA Terms β_{x1}^x and δ_{x1}^x
β_{x1}^x	0.700*** (0.028)	0.663*** (0.067)
δ_{x1}^x	- 0.163*** (0.021)	- 0.309*** (0.046)
$\beta_{x1}^x + \delta_{x1}^x$	0.537*** (0.016)	0.354*** (0.026)
	Huazheng ESG → Book Value CL/CLMA Terms β_{x1}^y and δ_{x1}^y	CNRDS ESG → Tobin's Q CL/CLMA Terms β_{x1}^y and δ_{x1}^y
β_{x1}^y	0.223*** (0.064)	0.040*** (0.013)
δ_{x1}^y	- 0.053 (0.092)	- 0.038** (0.015)
$\beta_{x1}^y + \delta_{x1}^y$	0.169*** (0.060)	0.002 (0.008)
	Book Value → Huazheng ESG CL/CLMA Terms β_{y1}^x and δ_{y1}^x	Tobin's Q → CNRDS ESG CL/CLMA Terms β_{y1}^x and δ_{y1}^x
β_{y1}^x	0.001 (0.001)	0.016* (0.008)
δ_{y1}^x	0.029*** (0.002)	- 0.002 (0.014)
$\beta_{y1}^x + \delta_{y1}^x$	0.029*** (0.001)	0.014 (0.011)
Fit indices		
χ^2	237.4***	334.4***
df / k	61/58	61/58
CFI / TLI	0.996/0.994	0.989/0.984
RMSEA/SRMR	0.036/0.124	0.047/0.026
AIC/BIC	- 28,331.4/- 28,001.2	4960.1/5285.4
Number of observations	2195	2013

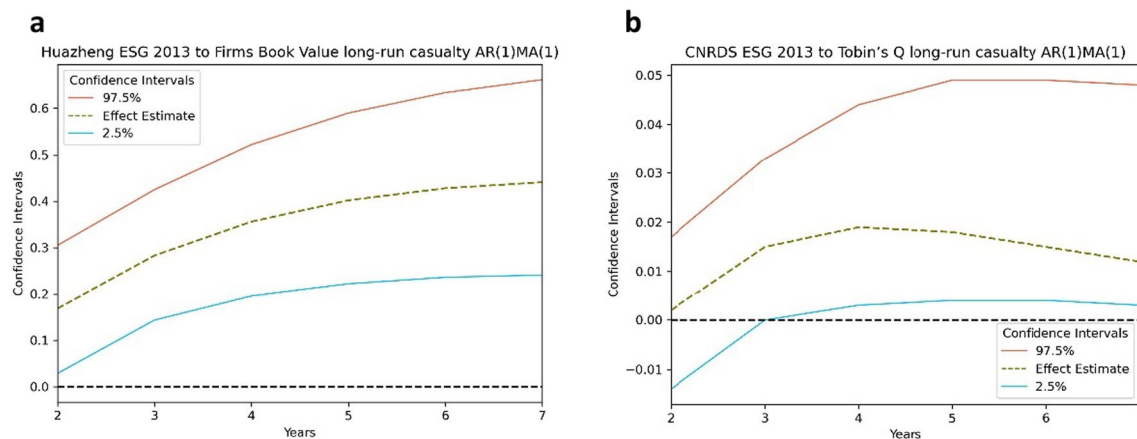


Fig. 4 Impact of ESG Scores on Book Value of Equity (BVE) and TobinQ Using AR(1)MA(1) Model

companies, aligned with international standards and incorporating Chinese disclosure policies. The results, presented in the second column of Table 4 and Fig. 4b, indicate statistical significance for the direct effect of past impulses, with 95% confidence intervals excluding zero. The combined AR and MA term is 0.68 ($p < 0.01$), suggesting that 68% of a previous year's impulse persists to the next year. The AR parameter of 0.618 also indicates mean reversion. The short-term effect of ESG scores on Tobin's Q is positive, with a cross-lagged term of 0.04 ($p < 0.01$). The AR term of 0.663 implies a lasting effect on Tobin's Q, despite its mean-reverting nature. Although the individual coefficient indicates a positive impact, the overall combined effect is not statistically significant. However, the direction remains consistent with our primary findings using Bloomberg ESG scores.

Through these robustness checks employing alternative ESG scores (e.g., Huazheng and CNRDS) and valuation metrics (e.g., Book Value of Equity), we demonstrate that the positive impact of ESG on firm market value is not contingent on specific data sources.

To assess if regional differences significantly influence the relationship between ESG scores and firm market value, we analyzed the impact of the CNRDS ESG score on Tobin's Q across three regions in China: Eastern, Central, and Western. This division, leveraging the larger sample size, aimed to establish whether the effect of ESG on firm market value varies over the short and long term based on geographic location.

Causal inference using the Generalized Causal Linear Model (GCLM) necessitated selecting appropriate lag orders and unit effects [65, 66]. We compared alternative models with higher-order Autoregressive (AR) and Moving Average (MA) lags to account for market dynamics. For each regional sample, we estimated four models: AR(1)MA(1), AR(1)MA(2), AR(2)MA(1), and AR(2)MA(2). The model fit was evaluated using fit indices, leading to the preferred models: Eastern China (AR(1)MA(1) model, 1,402 observations), Central China (AR(2)MA(2) model, 288 observations), and Western China (AR(1)MA(1) model, 366 observations). The results are presented in Table 5 and Fig. 5.

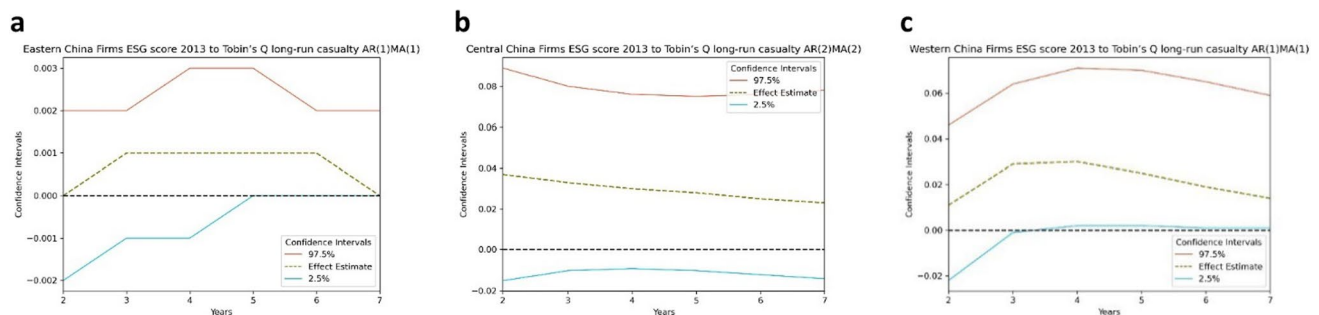
The combined AR and MA terms for Tobin's Q and ESG scores demonstrate significant effects across all regions. For Tobin's Q, these terms range from 0.652 to 0.775, indicating that 65.2% to 77.5% of a firm's past market value positively influences its current market value. The AR parameters for Tobin's Q, ranging from 0.593 to 0.914, suggest mean-reverting behavior. For ESG scores, the combined AR and MA terms span from 0.369 to 0.449, showing that 36.9% to 44.9% of a firm's past ESG performance impacts its current ESG score. The corresponding AR parameters for ESG, between 0.559 and 0.88, also indicate mean-reversion. These findings highlight significant autocorrelation and mean-reversion properties in both market value and ESG performance, varying slightly by region. The regional differences underscore the importance of geographic context in assessing the impact of ESG on firm market value.

The impact of ESG on Tobin's Q varies across regions. For firms in Eastern and Central China (Figs. 5a and b), the impulse responses indicate that the 95% confidence intervals (CIs) include zero, suggesting no significant impact of ESG scores on market value in these regions. In contrast, for Western China firms (Fig. 2c), the effect of ESG scores on market value becomes statistically significant after four years, with 95% CIs excluding zero. In the short run, the ESG score's impact on market value is positive for firms in Central and Western China, with combined coefficients (CL + CLMA) of 0.036 and 0.11, respectively, and standard errors (SEs) of 0.022 and 0.018. Conversely, the effect for Eastern China firms is negative, with a combined coefficient of -0.007. However, none of the coefficients for Eastern, Central, or Western China firms are

Table 5 Regional Model Estimates and Impact of ESG Scores on Tobin's Q

Parameter	Model Estimates (SE)		
	Eastern China Firms	Central China Firms	Western China Firms
	AR(1)MA(1)	AR(2)MA(2)	AR(1)MA(1)
Tobin's Q → Tobin's Q AR/MA Terms β_{y1}^y and δ_{y1}^y			
β_{y1}^y	0.593*** (0.028)	0.914*** (0.025)	0.606*** (0.045)
δ_{y1}^y	0.060*** (0.019)	− 0.139*** (0.047)	0.115*** (0.032)
$\beta_{y1}^y + \delta_{y1}^y$	0.652*** (0.017)	0.775*** (0.029)	0.722*** (0.030)
ESG → ESG AR/MA Terms β_{x1}^x and δ_{x1}^x			
β_{x1}^x	0.880*** (0.031)	0.832*** (0.077)	0.559*** (0.102)
δ_{x1}^x	− 0.430*** (0.028)	− 0.407** (0.160)	− 0.190** (0.083)
$\beta_{x1}^x + \delta_{x1}^x$	0.449*** (0.015)	0.424*** (0.125)	0.369*** (0.036)
ESG → Tobin's Q CL/CLMA Terms β_{x1}^y and δ_{x1}^y			
β_{x1}^y	0.023 (0.018)	0.005 (0.018)	0.061** (0.029)
δ_{x1}^y	− 0.03 (0.019)	0.031 (0.031)	− 0.05 (0.032)
$\beta_{x1}^y + \delta_{x1}^y$	− 0.007 (0.010)	0.036 (0.022)	0.011 (0.018)
Tobin's Q → ESG CL/CLMA Terms β_{y1}^x and δ_{y1}^x			
β_{y1}^x	− 0.004 (0.007)	0.007 (0.014)	0.003 (0.019)
δ_{y1}^x	0.022 (0.016)	− 0.006 (0.038)	− 0.002 (0.031)
$\beta_{y1}^x + \delta_{y1}^x$	0.019 (0.013)	0.001 (0.032)	0.001 (0.026)
Fit indices			
χ^2	238***	92.7***	115***
df / k	61/58	57/62	61/58
CFI/TLI	0.99/0.985	0.991/0.986	0.989/0.984
RMSEA/SRMR	0.046/0.025	0.047/0.034	0.05/0.038
AIC/BIC	3690/3994	778/1005	616/843
Number of observations	1402	288	366

*p < 0.10. **p < 0.05. ***p < 0.01

**Fig. 5** Long run effects: impulse response

statistically significant at the 10% level, precluding strong conclusions about the current impact of ESG performance on market value at the regional level.

The heterogeneity analysis reveals significant regional variations in the impact of ESG scores on firm market value across China. The observed autocorrelation and mean-reversion properties of both market value and ESG performance underscore the dynamic nature of these variables. While firms in Eastern and Central China show no significant long-term impact of ESG on market value, firms in Western China display a delayed but significant positive impact after four years. When analyzing all regions as a single sample, a positive and statistically significant effect of ESG performance on market value is evident in both the short and long run. These findings suggest that while ESG initiatives generally enhance firm value, regional factors play a crucial role in modulating this effect.

5 Conclusion

Our research findings support our claim that there is a connection between ESG scores and market value dynamics. We discovered that the ESG score has a long-term influence on market value, even if market value is mean-reverting. This is consistent with previous research that has found a positive correlation between ESG scores and market value. Furthermore, market value has a small AR term that has a weak but continuous effect on ESG scores. Some studies have found this effect to be negative, which is the opposite of what is usually found. However, the weak nature of the effect means that it is unreliable. We also looked into the short-term and long-term impacts of ESG scores and market value on each other. The impulse responses show that market value does not have a significant impact on the ESG score. However, an impulse along the ESG score has a different impact on market value. This is consistent with previous research that has found a strong positive long-term effect of ESG scores on market value, while market value has no significant impact on the ESG score. In summary, our research findings support our claim and suggest a meaningful relationship between ESG scores and market value dynamics.

Our study has revealed several important implications regarding the evaluation of a company's financial health by Chinese investors. Firstly, it has been confirmed that Chinese investors tend to look beyond traditional financial metrics when evaluating a company's financial health. Instead, they consider environmental, social, and governance (ESG) factors which can have a significant impact on a company's market value. Recent studies have shown that a company's ESG score can be a strong indicator of its market value as investors are increasingly looking for companies that are not just profitable but also socially responsible and environmentally sustainable.

Secondly, our study failed to support the reverse causality between a company's ESG score and its market value as it has been weakly confirmed. This means that while Chinese companies with high ESG scores tend to perform better in the market, it is also possible that companies with high market value may be more likely to prioritize ESG factors. This finding highlights the need for further research to fully understand the relationship between a company's ESG score and its market value.

Thirdly, our study supports the claim that it is crucial for Chinese companies to prioritize ESG factors not only to enhance their reputation but also to attract socially responsible investors who are willing to pay a premium for sustainable practices. As the world becomes more conscious of sustainability and climate change, ESG factors will only become more important for investors and companies alike. This implies that companies that prioritize ESG factors are likely to attract more investment and have a more sustainable and responsible business model. Therefore, it is crucial for Chinese companies to consider ESG factors when evaluating their financial health in order to remain competitive in the global market.

Fourth, ESG information diffuses slowly and past ESG performance affects future ESG performance, with positive impulses having a stronger impact than negative ones. The magnitude of the effect may vary depending on firm-specific factors, such as size and industry. Maintaining good ESG performance and improving poor ESG performance is crucial for long-term sustainability and success. Investors can use this information to make informed investment decisions and adjust their portfolios accordingly.

Overall, the persistent effect of past ESG performance on future ESG performance highlights the importance of considering the long-term impact of ESG strategies and practices. Firms should strive to maintain good ESG performance and improve poor ESG performance to ensure long-term sustainability and success. This information can be used by firms to develop effective sustainability strategies, enhance their sustainability performance, and contribute to achieving the United Nations' Sustainable Development Goals. Furthermore, investors can use this information to make well-informed investment decisions and adjust their portfolios accordingly. Overall, the empirical literature provides compelling evidence supporting the claim that a company's past ESG performance has a significant impact on its future ESG performance.

The heterogeneity analysis reveals significant regional variations in the impact of ESG scores on firm market value across China. The observed autocorrelation and mean-reversion properties of both market value and ESG performance underscore the dynamic nature of these variables. While firms in Eastern and Central China show no significant long-term impact of ESG on market value, firms in Western China display a delayed but significant positive impact after four years. When analyzing all regions as a single sample, a positive and statistically significant effect of ESG performance on market value is evident in both the short and long run. These findings suggest that while ESG initiatives generally enhance firm value, regional factors play a crucial role in modulating this effect. The lack of short-term statistical significance across specific regions indicates that ESG's influence may be more nuanced,

potentially influenced by regional economic conditions and other contextual factors. Policymakers and investors should, therefore, tailor their strategies to regional characteristics to maximize the benefits of ESG initiatives. Future research should explore additional regional factors and extend the analysis to other emerging markets to better understand ESG's role in enhancing firm value globally. Moreover, a key limitation of our study is that the study only considers China. Further research is needed to explore how regional factors influence ESG's impact on firm value in other developing economies, providing a more comprehensive picture of ESG's global influence.

Author contributions The contributions of each author in this study are as follows. Abel Dula Wedajo conducted the analysis and discussion of the results. Abdullah Abdulaziz Salah Conducted the analysis, responsible for data collection, cleaning, model plotting, and ensuring model robustness. Mohd. Abass Bhat was responsible for the literature review. Robina Iqbal handled editing and proofreading. Shagufta Tariq Khan was involved in data curation.

Funding The authors received no funding for this research.

Data availability Data will be provided upon reasonable requests.

Code availability The codes used in this research are available upon request.

Declarations

Competing interests The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Appendix A

Descriptive statistics and correlations

Yearly Var	Mean	SD	ESG13	ESG14	ESG15	ESG16	ESG17	ESG18	ESG19	TQ13	TQ14	TQ15	TQ16	TQ17	TQ18	TQ19
ESG13	10.64	2.7	1													
ESG14	21.35	5.84	0.87	1												
ESG15	28.99	5.01	0.69	0.7	1											
ESG16	29.85	5.37	0.66	0.66	0.9	1										
ESG17	31.16	6.11	0.64	0.64	0.8	0.88	1									
ESG18	32.9	6.48	0.60	0.60	0.73	0.80	0.91	1								
ESG19	33.86	7.20	0.58	0.57	0.66	0.72	0.84	0.93	1							
TQ13	2.05	1.64	-0.08	-0.09	-0.12	-0.13	-0.14	-0.14	-0.1	1						
TQ14	2.20	1.57	-0.10	-0.12	-0.15	-0.17	-0.17	-0.19	-0.15	0.86	1					
TQ15	2.68	2.24	-0.10	-0.11	-0.15	-0.16	-0.18	-0.21	-0.17	0.74	0.86	1				
TQ16	2.17	1.67	-0.10	-0.11	-0.15	-0.16	-0.16	-0.18	-0.15	0.68	0.82	0.87	1			
TQ17	2	1.62	-0.04	-0.05	-0.09	-0.1000	-0.08	-0.08	-0.04	0.64	0.74	0.71	0.88	1		
TQ18	1.49	1.03	-0.06	-0.06	-0.07	-0.07	-0.07	-0.06	-0.01	0.62	0.7	0.67	0.78	0.89	1	
TQ19	1.73	1.43	-0.07	-0.08	-0.1	-0.1	-0.09	-0.08	-0.03	0.58	0.66	0.62	0.68	0.79	0.92	1

ESG13-ESG19 are the ESG scores from 2013 to 2019. TQ13 to TQ19 are the Tobin's Q from 2013 to 2019. SD: is Standard deviation.

Appendix B

See Tables 6 and 7

Table 6 Step 1: full model estimation result

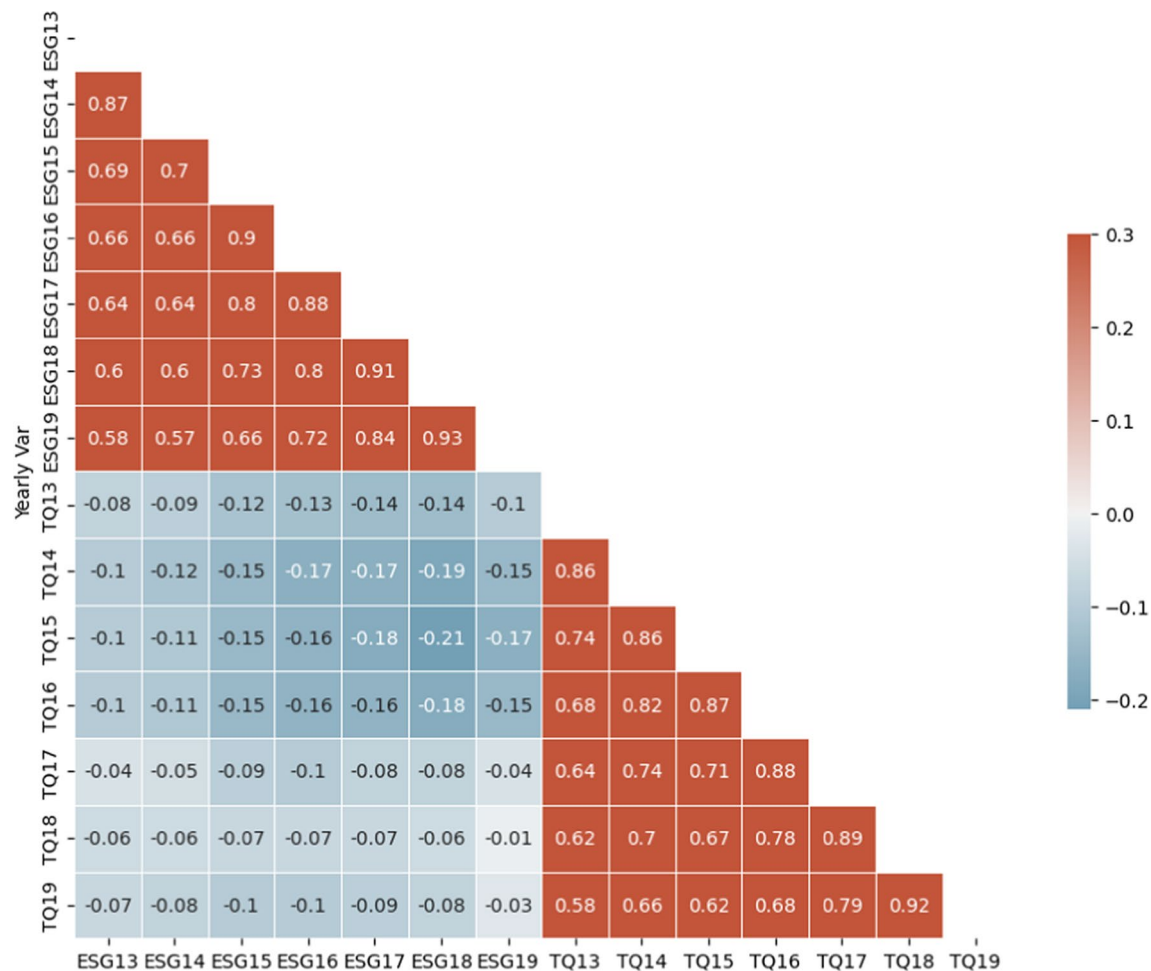
FULL MODEL AR(1)MA(1) ESTIMATIONS RESULTS (AR(1)MA(1)CL(1))			
Tobin's Q --> Tobin's Q - AR/MA Terms		ESG Score --> ESG Score AR/MA Terms	
$\beta_{y1}^{(y)} = AR\ terms$	0.346*** (0.033)	$\beta_{x1}^{(x)} = AR\ terms$	0.982*** (0.014)
$\delta_{y1}^{(y)} = MA\ Terms$	0.195*** (0.028)	$\delta_{x1}^{(x)} = MA\ Terms$	-0.024 (0.023)
$\delta_{x1}^{(y)} = \beta_{y1}^{(y)} + \delta_{y1}^{(y)}\ ARMA\ Terms$	0.540*** (0.019)	$\delta_{y1}^{(x)} = \beta_{x1}^{(x)} + \delta_{x1}^{(x)}\ ARMA\ Terms$	0.959*** (0.018)
ESG Score --> Tobin's Q CL/CLMA Terms		Tobin's Q --> ESG Score Q CL/CLMA Terms	
$\beta_{x1}^{(y)} = CL\ terms$	0.009** (0.004)	$\beta_{y1}^{(x)} = CL\ terms$	-0.081*** (0.031)
$\delta_{x1}^{(y)} = CLMA\ Terms$	-0.005 (0.005)	$\delta_{y1}^{(x)} = CLMA\ Terms$	0.164** (0.073)
$\delta_{x1}^{(y)} = \beta_{x1}^{(y)} + \delta_{x1}^{(y)}\ CLCL\ Terms$	0.004 (0.004)	$\delta_{y1}^{(x)} = \beta_{y1}^{(x)} + \delta_{y1}^{(x)}\ CLCL\ Terms$	0.083 (0.060)
Time Varying Unit Effect (Factor loadings) Variances as Correlations		Unit Effect Variances as Correlations	
$\lambda_1^{(y)}$	0.711*** (0.057)	$\varphi_{\eta 1}^{(y)}$	0.868*** (0.087)
$\lambda_2^{(y)}$	0.556*** (0.147)	$\varphi_{\eta 1}^{(y)}$	0.049 (0.057)
$\lambda_3^{(y)}$	0.598*** (0.091)	$\varphi_{\eta 1}^{(xy)}$	-0.098** (0.043)
$\lambda_4^{(y)}$	0.461** (0.183)	Co-Movement in Impulses as Correlations	
$\lambda_5^{(y)}$	0.586*** (0.133)	$\varphi_{\mu 1}^{(xy)}$	-0.001 (0.051)
$\lambda_6^{(y)}$	0.394*** (0.128)	$\varphi_{\mu 2}^{(xy)}$	-0.115 (0.099)
$\lambda_7^{(y)}$	0.671*** (0.068)	$\varphi_{\mu 3}^{(xy)}$	-0.054* (0.033)
$\lambda_1^{(x)}$	0.691*** (0.044)	$\varphi_{\mu 4}^{(xy)}$	-0.011 (0.033)
$\lambda_2^{(x)}$	0.610*** (0.029)	$\varphi_{\mu 5}^{(xy)}$	0.117*** (0.038)
$\lambda_3^{(x)}$	-0.496*** (0.055)	$\varphi_{\mu 6}^{(xy)}$	0.036 (0.040)
$\lambda_4^{(x)}$	0.010 (0.026)	$\varphi_{\mu 7}^{(xy)}$	0.081 (0.058)
$\lambda_5^{(x)}$	0.062** (0.029)		
$\lambda_6^{(x)}$	-0.005 (0.021)		
$\lambda_7^{(x)}$	0.031 (0.025)		

Table 7 Interaction effect

W effects	Estimates
BxB model	
AR effect ESG	0.905***
AR effect FV	0.448***
AR effect AGE	0.848***
CL effect ESGW → FVW	− 0.019*
CL effect FVW → ESGW	− 0.134*
CL effect AGEW → ESGW	− 0.535
CL effect AGEW → FVW	− 1.183
CL effect ESGW → AGEW	0.00
CL effect FVW → AGEW	− 1.183
B Effects	Estimates
ESGB → FVB	0.24*
NMB → FVB	− 0.469***
AGEB → FVB	− 0.035***
NMB → ESGB	4.136***
AGEB → ESGB	− 0.045
NMB → AGEB	0.982**
BxB interaction	
ESGB*NMB → FVB	− 0.28**

Appendix C

Heatmap for correlation visualization



References

1. Wang Y, Lin Y, Fu X, Chen S. Institutional ownership heterogeneity and ESG performance: evidence from China. *Financ Res Lett*. 2023. <https://doi.org/10.1016/j.frl.2022.103448>.
2. Zhang X, Zhao X, Qu L. Do green policies catalyze green investment? Evidence from ESG investing developments in China. *Econ Lett*. 2021. <https://doi.org/10.1016/j.econlet.2021.110028>.
3. Daugaard D. Emerging new themes in environmental, social and governance investing: a systematic literature review. *Account Finance*. 2020;60:1501–30. <https://doi.org/10.1111/acfi.12479>.
4. Brooks C, Oikonomou I. The effects of environmental, social and governance disclosures and performance on firm value: a review of the literature in accounting and finance. *Br Account Rev*. 2018;50:1–15.
5. Shen H, Lin H, Han W, Wu H. ESG in China: a review of practice and research, and future research avenues. *China J Account Res*. 2023. <https://doi.org/10.1016/j.cjar.2023.100325>.
6. Flammer C. Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. *Manage Sci*. 2015;61:2549–68. <https://doi.org/10.1287/mnsc.2014.2038>.
7. Lins KV, Servaes H, Tamayo A. Social capital, trust, and firm performance: the value of corporate social responsibility during the financial crisis. *J Finance*. 2017;72:1785–824. <https://doi.org/10.1111/jofi.12505>.
8. Huang Z, Gao N, Jia M. Green credit and its obstacles: evidence from China's green credit guidelines. *J Corp Finance*. 2023. <https://doi.org/10.1016/j.jcorpfin.2023.102441>.
9. Fang M, Nie H, Shen X. Can enterprise digitization improve ESG performance? *Econ Model*. 2023. <https://doi.org/10.1016/j.econmod.2022.106101>.

10. Meng T, Dato Haji Yahya MH, Ashhari ZM, Yu D. ESG performance, investor attention, and company reputation: threshold model analysis based on panel data from listed companies in China. *Heliyon*. 2023;9: e20974.
11. Zhou G, Liu L, Luo S. Sustainable development, ESG performance and company market value: mediating effect of financial performance. *Bus Strategy Environ*. 2022;31:3371–87. <https://doi.org/10.1002/bse.3089>.
12. Van De Velde E, Vermeir W, Corten F. Corporate social responsibility and financial performance. *Corp Gov Int J Bus Soc*. 2005. <https://doi.org/10.1108/14720700510604760>.
13. Jang GY, Kang HG, Kim W. Corporate executives' incentives and ESG performance. *Financ Res Lett*. 2022. <https://doi.org/10.1016/j.frl.2022.103187>.
14. Shin J, Moon JJ, Kang J. Where does ESG pay? The role of national culture in moderating the relationship between ESG performance and financial performance. *Int Bus Rev*. 2023. <https://doi.org/10.1016/j.ibusrev.2022.102071>.
15. Aydoğmuş M, Gülay G, Ergun K. Impact of ESG performance on firm value and profitability. *Borsa Istanbul Rev*. 2022. <https://doi.org/10.1016/j.bir.2022.11.006>.
16. Feng GF, Long H, Wang HJ, Chang CP. Environmental, social and governance, corporate social responsibility, and stock returns: what are the short- and long-run relationships? *Corp Soc Responsib Environ Manag*. 2022;29:1884–95. <https://doi.org/10.1002/csr.2334>.
17. Friedman M. A friedman doctrine— the social responsibility of business is to increase its profits. Berlin: Springer; 1970.
18. Freeman RE. Divergent stakeholder theory. *Acad Manag Rev*. 1999. <https://doi.org/10.2307/259078>.
19. Freeman RE. A stakeholder approach. London: Pitman Publishing Inc; 1984.
20. Hart SL, Milstein MB. Creating sustainable value. *Acad Manag Perspect*. 2003. <https://doi.org/10.5465/ame.2003.10025194>.
21. Jensen MC. Value maximization, stakeholder theory, and the corporate objective function. *Business ethics quarterly*. 2002;235–256.
22. Lipe R, Kormendi R. Mean reversion in annual earnings and its implications for security valuation. *Rev Quant Financ Acc*. 1994;4:27–46. <https://doi.org/10.1007/BF01082663>.
23. Adekoya OB, Oliyide JA. Commodity and financial markets' fear before and during COVID-19 pandemic: persistence and causality analyses. *Resour Policy*. 2022. <https://doi.org/10.1016/j.resourpol.2022.102598>.
24. Coskun Y, Akinsomi O, Gil-Alana LA, Yaya OOS. Stock market responses to COVID-19: the behaviors of mean reversion, dependence and persistence. *Heliyon*. 2023. <https://doi.org/10.1016/j.heliyon.2023.e15084>.
25. Mork KA, Trønnes HA. Expected long-term rates of return when short-term returns are serially correlated. *Int Rev Financ Anal*. 2023. <https://doi.org/10.1016/j.irfa.2023.102696>.
26. Chatterji AK, Durand R, Levine DI, Touboul S. Do ratings of firms converge? Implications for managers, investors and strategy researchers. *Strateg Manag J*. 2016;37:1597–614. <https://doi.org/10.1002/smj.2407>.
27. Leite BJ, Uysal VB. Does ESG matter to investors? ESG scores and the stock price response to new information. *Glob Financ J*. 2023. <https://doi.org/10.1016/j.gfj.2023.100851>.
28. Sheehan NT, Vaidyanathan G, Fox KA, Klassen M. Making the invisible, visible: overcoming barriers to ESG performance with an ESG mindset. *Bus Horiz*. 2023;66:265–76. <https://doi.org/10.1016/j.bushor.2022.07.003>.
29. Mu W, Liu K, Tao Y, Ye Y. Digital finance and corporate ESG. *Financ Res Lett*. 2023. <https://doi.org/10.1016/j.frl.2022.103426>.
30. Wong WC, Batten JA, Ahmad AH, Mohamed-Arshad SB, Nordin S, Adzis AA. Does ESG certification add firm value? *Financ Res Lett*. 2021. <https://doi.org/10.1016/j.frl.2020.101593>.
31. Feng Z, Wu Z. ESG disclosure, REIT debt financing and firm value. *J Real Estate Financ Econ*. 2023;67:388–422. <https://doi.org/10.1007/s11146-021-09857-x>.
32. Chasiotis I, Gounopoulos D, Dimitrios K, Patsika V. ESG reputational risk, corporate payouts and firm value. *BR J Manag*. 2024;35:871–92. <https://doi.org/10.1111/1467-8551.12745>.
33. Wu M, Zhu Y, Zhang F. Second-generation involvement, ESG performance and family firm value. *Appl Econ Lett*. 2023. <https://doi.org/10.1080/13504851.2023.2276365>.
34. Anita M, Shveta S, Surendra SY, Arvind M. When do ESG controversies reduce firm value in India? *Glob Finance J*. 2023. <https://doi.org/10.1016/j.gfj.2023.100809>.
35. Cheng R, Kim H, Ryu D. ESG performance and firm value in the Chinese market. *Invest Anal J*. 2024;53:1–15. <https://doi.org/10.1080/10293523.2023.2218124>.
36. Yu X, Xiao K. Does ESG performance affect firm value? Evidence from a new ESG-scoring approach for Chinese enterprises. *Sustainability*. 2022. <https://doi.org/10.3390/su142416940>.
37. Aouadi A, Marsat S. Do ESG controversies matter for firm value? Evidence from international data. *J Bus Ethics*. 2018;151:1027–47. <https://doi.org/10.1007/s10551-016-3213-8>.
38. Dinca MS, Vezeteanu C-D, Dinca D. The relationship between ESG and firm value. Case study of the automotive industry. *Front Environ Sci*. 2022. <https://doi.org/10.3389/fenvs.2022.1059906>.
39. Duan Y, Yang F, Xiong L. Environmental, social, and governance (ESG) performance and firm value: evidence from chinese manufacturing firms. *Sustainability*. 2023. <https://doi.org/10.3390/su151712858>.
40. Naseer MM, Khan MA, Bagh T, Guo Y, Zhu X. Firm climate change risk and financial flexibility: drivers of ESG performance and firm value. *Borsa Istanbul Rev*. 2024;24:106–17. <https://doi.org/10.1016/j.bir.2023.11.003>.
41. Wu Z, Lin S, Chen T, Luo C, Xu H. Does effective corporate governance mitigate the negative effect of ESG controversies on firm value? *Econ Anal Policy*. 2023;80:1772–93. <https://doi.org/10.1016/j.eap.2023.11.018>.
42. Aydogmus M, Gulay G, Ergun K. Impact of ESG performance on firm value and profitability. *Borsa Istanbul Rev*. 2022;22:S119–27. <https://doi.org/10.1016/j.bir.2022.11.006>.
43. Yoon B, Lee JH, Byun R. Does ESG performance enhance firm value? Evidence from Korea. *Sustainability*. 2018. <https://doi.org/10.3390/su10103635>.
44. Brinette S, Sonmez FD, Tournus PS. ESG Controversies and firm value: moderating role of board gender diversity and board independence. *IEEE Trans Eng Manag*. 2024;71:4298–307. <https://doi.org/10.1109/TEM.2023.3236667>.
45. Chang Y-J, Lee B-H. The impact of ESG activities on firm value: multi-level analysis of industrial characteristics. *Sustainability*. 2022. <https://doi.org/10.3390/su142114444>.

46. Yoo JS, Song WJ, Ku JE. CEO turnover, ESG-washing, and firm value. *Manag Decis Econ*. 2024. <https://doi.org/10.1002/mde.4123>.
47. Dayanandan A, Donker H, Kuntluru S. IFRS and ESG disclosure in Indian corporate sector. *J Emerg Market Financ*. 2023. <https://doi.org/10.1177/09726527231197328>.
48. Shu H, Tan W. Does carbon control policy risk affect corporate ESG performance? *Econ Model*. 2023. <https://doi.org/10.1016/j.econmod.2022.106148>.
49. Li C, Ba S, Ma K, Xu Y, Huang W, Huang N. ESG rating events, financial investment behavior and corporate innovation. *Econ Anal Policy*. 2023;77:372–87. <https://doi.org/10.1016/j.eap.2022.11.013>.
50. Luan XY, Wang XH. Open innovation, enterprise value and the mediating effect of ESG. *Bus Process Manag J*. 2023;29:489–504. <https://doi.org/10.1108/BPMJ-07-2022-0310>.
51. Zheng Z, Li J, Ren X, Guo JM. Does corporate ESG create value? New evidence from M&As in China. *Pac Basin Financ J*. 2023. <https://doi.org/10.1016/j.pacfin.2022.101916>.
52. Umar Z, Gubareva M, Tran DK, Teplova T. Impact of the Covid-19 induced panic on the environmental, social and governance leaders equity volatility: a time-frequency analysis. *Res Int Bus Financ*. 2021. <https://doi.org/10.1016/j.ribaf.2021.101493>.
53. Duque-Grisales E, Aguilera-Caracul J. Environmental, social and governance (ESG) scores and financial performance of multinationals: moderating effects of geographic international diversification and financial slack. *J Bus Ethics*. 2021;168:315–34. <https://doi.org/10.1007/s10551-019-04177-w>.
54. Yadav R, Pathak GS. Young consumers' intention towards buying green products in a developing nation: extending the theory of planned behavior. *J Clean Prod*. 2016;135:732–9. <https://doi.org/10.1016/j.jclepro.2016.06.120>.
55. Bhattacharjee P, Mishra S, Kang SH. Does market sentiment and global uncertainties influence ESG-oil nexus? A time-frequency analysis. *Resour Policy*. 2023. <https://doi.org/10.1016/j.resourpol.2023.104130>.
56. Wan J, Yin L, Wu Y. Return and volatility connectedness across global ESG stock indexes: evidence from the time-frequency domain analysis. *Int Rev Econ Financ*. 2024;89:397–428. <https://doi.org/10.1016/j.iref.2023.10.038>.
57. Yang J, Kwaku Agyei S, Bossman A, Gubareva M, Marfo-Yiadom E. Energy, metals, market uncertainties, and ESG stocks: analysing predictability and safe havens. *North Am J Econ Finance*. 2023. <https://doi.org/10.1016/j.najef.2023.102030>.
58. Basse T, Desmyter S, Saft D, Wegener C. Leading indicators for the US housing market: new empirical evidence and thoughts about implications for risk managers and ESG investors. *Int Rev Financ Anal*. 2023. <https://doi.org/10.1016/j.irfa.2023.102765>.
59. Gillan SL, Koch A, Starks LT. Firms and social responsibility: a review of ESG and CSR research in corporate finance. *J Corp Financ*. 2021. <https://doi.org/10.1016/j.jcorpfin.2021.101889>.
60. Fatima T, Elbanna S. Corporate social responsibility (CSR) implementation: a review and a research agenda towards an integrative framework. *J Bus Ethics*. 2023;183:105–21.
61. Singh AK, Zhang Y. Anu: understanding the evolution of environment, social and governance research: novel implications from bibliometric and network analysis. *Eval Rev*. 2023;47:350–86.
62. Zheng M, Feng GF, Jiang RA, Chang CP. Does environmental, social, and governance performance move together with corporate green innovation in China? *Bus Strategy Environ*. 2023;32:1670–9. <https://doi.org/10.1002/bse.3211>.
63. Behl A, Kumari PSR, Makhija H, Sharma D. Exploring the relationship of ESG score and firm value using cross-lagged panel analyses: case of the Indian energy sector. *Ann Oper Res*. 2022;313:231–56. <https://doi.org/10.1007/s10479-021-04189-8>.
64. Lai X, Zhang F. Can ESG certification help company get out of over-indebtedness? Evidence from China. *Pac Basin Financ J*. 2022. <https://doi.org/10.1016/j.pacfin.2022.101878>.
65. Zyphur MJ, Allison PD, Tay L, Voelkle MC, Preacher KJ, Zhang Z, Hamaker EL, Shamsollahi A, Pierides DC, Koval P, Diener E. From data to causes I: building a general cross-lagged panel model (GCLM). *Organ Res Methods*. 2020;23:651–87. <https://doi.org/10.1177/1094428119847278>.
66. Zyphur MJ, Voelkle MC, Tay L, Allison PD, Preacher KJ, Zhang Z, Hamaker EL, Shamsollahi A, Pierides DC, Koval P, Diener E. From data to causes II: comparing approaches to panel data analysis. *Organ Res Methods*. 2020;23:688–716. <https://doi.org/10.1177/1094428119847280>.
67. Yadav P, Jain A. Sustainability disclosures and corporate boards: a stakeholder approach to decision-making. *J Appl Acc Res*. 2023. <https://doi.org/10.1108/JAAR-10-2022-0279>.
68. Liu Z. Unraveling the complex relationship between environmental and financial performance—A multilevel longitudinal analysis. *Int J Prod Econ*. 2020;219:328–40. <https://doi.org/10.1016/j.ijpe.2019.07.005>.
69. Ramírez-Orellana A, Martínez-Victoria MC, García-Amate A, Rojo-Ramírez AA. Is the corporate financial strategy in the oil and gas sector affected by ESG dimensions? *Resour Policy*. 2023. <https://doi.org/10.1016/j.resourpol.2023.103303>.
70. Srikant C, Pichler S, Shafiq A. The virtuous cycle of diversity. *Hum Resour Manage*. 2021;60:535–58. <https://doi.org/10.1002/hrm.22037>.
71. Mefteh-Wali S, Rais H, Schier G. Is CSR linked to idiosyncratic risk? Evidence from the copula approach. *Ann Oper Res*. 2022. <https://doi.org/10.1007/s10479-022-04980-1>.
72. Monti A, Pattitoni P, Petracci B, Randl O. Does corporate social responsibility impact equity risk? International evidence. *Rev Quant Financ Acc*. 2022;59:825–55. <https://doi.org/10.1007/s11156-022-01059-7>.
73. Shahbaz M, Karaman AS, Kilic M, Uyar A. Board attributes, CSR engagement, and corporate performance: what is the nexus in the energy sector? *Energy Policy*. 2020. <https://doi.org/10.1016/j.enpol.2020.111582>.
74. Hoepner A, Oikonomou I, Scholtens B, Schröder M. The effects of corporate and country sustainability characteristics on the cost of debt: an international investigation. *J Bus Finance Account*. 2016;43:158–90. <https://doi.org/10.1111/jbfa.12183>.
75. Eccles RG, Serafeim G. The performance frontier: innovating for a sustainable strategy. *Harv Bus Rev*. 2013;91:17–8.
76. Shiller RJ. Do stock prices move too much to be justified by subsequent changes in dividends?. (1981).
77. Barberis N, Shleifer A, Vishny R. A model of investor sentiment. *Journal of financial economics*. 1998;49(3):307–343.
78. Liu M, Luo X, Lu WZ. Public perceptions of environmental, social, and governance (ESG) based on social media data: evidence from China. *J Clean Prod*. 2023. <https://doi.org/10.1016/j.jclepro.2022.135840>.
79. Becchetti L, Cucinelli D, Ielasi F, Rossolini M. Corporate social irresponsibility: the relationship between ESG misconduct and the cost of equity. *Int Rev Financ Anal*. 2023. <https://doi.org/10.1016/j.irfa.2023.102833>.
80. Bissoondoyal-Bheenick E, Brooks R, Do HX. ESG and firm performance: the role of size and media channels. *Econ Model*. 2023. <https://doi.org/10.1016/j.econmod.2023.106203>.

81. Chai S, Cao M, Li Q, Ji Q, Liu Z. Exploring the nexus between ESG disclosure and corporate sustainable growth: moderating role of media attention. *Financ Res Lett*. 2023. <https://doi.org/10.1016/j.frl.2023.104519>.
82. He F, Guo X, Yue P. Media coverage and corporate ESG performance: evidence from China. *Int Rev Financ Anal*. 2024. <https://doi.org/10.1016/j.irfa.2023.103003>.
83. Rojo-Suárez J, Alonso-Conde AB. Short-run and long-run effects of ESG policies on value creation and the cost of equity of firms. *Econ Anal Policy*. 2023;77:599–616. <https://doi.org/10.1016/j.eap.2022.12.017>.
84. Diaye MA, Ho SH, Oueghlissi R. ESG performance and economic growth: a panel co-integration analysis. *Empirica*. 2022;49:99–122. <https://doi.org/10.1007/s10663-021-09508-7>.
85. Meng G, Li J, Yang X. Bridging the gap between state–business interactions and air pollution: the role of environment, social responsibility, and corporate governance performance. *Bus Strategy Environ*. 2023;32:1872–84. <https://doi.org/10.1002/bse.3224>.
86. Christensen D, Serafeim G, Sikochi A. Why is corporate virtue in the eye of the beholder? The case of ESG ratings. *Account Rev*. 2019;97:147–75.
87. Fiaschi D, Giuliani E, Nieri F, Salvati N. How bad is your company? Measuring corporate wrongdoing beyond the magic of ESG metrics. *Bus Horiz*. 2020;63:287–99. <https://doi.org/10.1016/j.bushor.2019.09.004>.
88. Broadstock DC, Chan K, Cheng LTW, Wang X. The role of ESG performance during times of financial crisis: evidence from COVID-19 in China. *Financ Res Lett*. 2021. <https://doi.org/10.1016/j.frl.2020.101716>.
89. Xing J, Ding D, Wang S, Dong Z, Kelly JT, Jang C, Hao J. Development and application of observable response indicators for design of an effective ozone and fine-particle pollution control strategy in China. *Atmospheric Chemistry and Physics*. 2019;19(21):13627–13646.
90. Hurst B, Ooi YH, Hua Y, Principal O, Pedersen LH. AQR Capital Management, LLC A Century of Evidence on Trend-Following Investing. 2014.
91. Deng X, Li W, Ren X. More sustainable, more productive: evidence from ESG ratings and total factor productivity among listed Chinese firms. *Financ Res Lett*. 2023. <https://doi.org/10.1016/j.frl.2022.103439>.
92. Wang Z, Chu E, Hao Y. Towards sustainable development: How does ESG performance promotes corporate green transformation. *Int Rev Financ Anal*. 2024. <https://doi.org/10.1016/j.irfa.2023.102982>.
93. Ionescu GH, Firoiu D, Pirvu R, Bădîrcea R, Drăgan C. Implementation of integrated management systems and corporate social responsibility initiatives-A Romanian hospitality industry perspective. *Sustainability*. 2018. <https://doi.org/10.3390/su10103684>.
94. Butt MN, Baig AS, Seyyed FJ. Tobin's Q approximation as a metric of firm performance: an empirical evaluation. *J Strateg Mark*. 2023;31:532–48. <https://doi.org/10.1080/0965254X.2021.1947875>.
95. Kim J, Song HJ, Lee CK. Effects of corporate social responsibility and internal marketing on organizational commitment and turnover intentions. *Int J Hosp Manag*. 2016;55:25–32. <https://doi.org/10.1016/j.ijhm.2016.02.007>.
96. Faria JR, Tindall G, Terjesen S. The green Tobin's q: theory and evidence. *Energy Econ*. 2022. <https://doi.org/10.1016/j.eneco.2022.106033>.
97. Zeng R, Oh WY, Zhu P. Will investors' excitement last? Determinants of investors' responses to cross-border acquisitions by Chinese firms. *J Int Financ Mark, Inst Money*. 2023. <https://doi.org/10.1016/j.intfin.2023.101785>.
98. Luo C, Wei D, He F. Corporate ESG performance and trade credit financing—Evidence from China. *Int Rev Econ Financ*. 2023;85:337–51. <https://doi.org/10.1016/j.iref.2023.01.021>.
99. Wang H. ESG investment preference and fund vulnerability. *Int Rev Financ Anal*. 2024;91:103002. <https://doi.org/10.1016/j.irfa.2023.103002>.
100. Takahashi H, Yamada K. When the Japanese stock market meets COVID-19: impact of ownership, China and US exposure, and ESG channels. *Int Rev Financ Anal*. 2021. <https://doi.org/10.1016/j.irfa.2021.101670>.
101. Kavadis N, Hermes N, Oehmichen J, Zattoni A, Fainshmidt S. Sustainable value creation in multinational enterprises: The role of corporate governance actors. *J World Bus*. 2024. <https://doi.org/10.1016/j.jwb.2023.101503>.
102. Asif M, Searcy C, Castka P. ESG and Industry 5.0: the role of technologies in enhancing ESG disclosure. *Technol Forecast Soc Change*. 2023. <https://doi.org/10.1016/j.techfore.2023.122806>.
103. Zhou H, Liu J. Digitalization of the economy and resource efficiency for meeting the ESG goals. In: *Resources policy*. Amsterdam: Elsevier Ltd; 2023.
104. He F, Feng Y, Hao J. Corporate ESG rating and stock market liquidity: evidence from China. *Econ Model*. 2023. <https://doi.org/10.1016/j.econmod.2023.106511>.
105. Shah SZA, Akbar S, Zhu X. Mandatory CSR disclosure, institutional ownership and firm value: evidence from China. *Int J Financ Econ*. 2023. <https://doi.org/10.1002/ijfe.2908>.
106. Lu T, Sivaramakrishnan K, Wang Y, Yu L. The real effects of mandatory corporate social responsibility reporting in China. *Prod Oper Manag*. 2021;30:1493–516. <https://doi.org/10.1111/poms.13334>.
107. Ren S, Huang M, Liu D, Yan J. Understanding the impact of mandatory CSR disclosure on green innovation: evidence from Chinese listed firms. *Br J Manag*. 2023;34:576–94. <https://doi.org/10.1111/1467-8551.12609>.
108. Ozkok O, Vaulont MJ, Zyphur MJ, Zhang Z, Preacher KJ, Koval P, Zheng Y. Interaction effects in cross-lagged panel models: SEM with latent interactions applied to work-family conflict, job satisfaction, and gender. *Organ Res Methods*. 2022;25:673–715. <https://doi.org/10.1177/10944281211043733>.
109. Hansen A. Firm size, and firm innovation age. *Small Bus Econ*. 1992;4:37–44.
110. Abdi Y, Li X, Camara-Turull X. Exploring the impact of sustainability (ESG) disclosure on firm value and financial performance (FP) in airline industry: the moderating role of size and age. *Environ Dev Sustain*. 2022;24:5052–79. <https://doi.org/10.1007/s10668-021-01649-w>.
111. Zhao X, Cai L. Digital transformation and corporate ESG: evidence from China. *Financ Res Lett*. 2023. <https://doi.org/10.1016/j.frl.2023.104310>.
112. Li J, Xu X. Can ESG rating reduce corporate carbon emissions?—An empirical study from Chinese listed companies. *J Clean Prod*. 2024. <https://doi.org/10.1016/j.jclepro.2023.140226>.
113. Cheng M, Micale JA. ESG risks and the value relevance of current and historical earnings. *Financ Mark, Inst Instrum*. 2022;31:207–37. <https://doi.org/10.1111/fmii.12162>.
114. Boffo R, Patalano R. ESG investing: practices, progress and challenges. Éditions OCDE, Paris. (2020).
115. Zhou R, Hou J, Ding F. Understanding the nexus between environmental, social, and governance (ESG) and financial performance: evidence from Chinese-listed companies. *Environ Sci Pollut Res*. 2023;30:73231–53. <https://doi.org/10.1007/s11356-023-27449-5>.