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# Excess stock returns and corporate environmental performance in China

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## Abstract

Using unbalanced panel data on 3326 Chinese listed companies from 2014 to 2021, this study investigates the impact of corporate environmental performance on China's excess stock returns. The results show that stocks of companies with better environmental performance earn significantly higher excess returns, indicating the existence of green returns in the Chinese stock market. We further reveal that heightened climate-change concerns can boost the stock market's green returns, while tightened climate policies decrease green returns by increasing long-term carbon risk. Our findings are robust to endogeneity problems and hold great implications for both investors and policymakers.

**Keywords:** Environmental performance, Excess stock returns, Climate perception, Climate policies

## Introduction

Climate-action failure is considered one of the most serious global risks in the next decade (World Economic Forum, 2022). The increasingly severe climate crisis has led to a consensus in the international community that actions must be taken to mitigate climate change (Jakovljevic et al. 2021; Ma et al. 2022a; Trinks et al. 2022b). China, the world's largest developing economy, declares its ambitious aim "to have CO<sub>2</sub> emissions peak before 2030 and achieve carbon neutrality before 2060," also called dual carbon goals. However, the risks and challenges involved in achieving carbon neutrality can be enormous. For example, it is estimated that achieving the dual carbon goals will cost China trillions of Chinese yuan (CNY) per year in green investments (He et al. 2022). Therefore, the Chinese government has introduced various policies to support climate investments and financing and facilitate the improvement of corporate environmental performance.

Consequently, sustainable investment is developing rapidly in China. In 2021, the assets of China's climate funds reached \$46.7 billion, up 149% from the previous year's figure, making China the world's second-largest climate-fund market after Europe. Environmental, social, and governance (ESG) investing is becoming a popular strategy in China (Zheng et al. 2022). Intuitively, the climate-policy system and climate-risk perception should induce investors to include evaluations of corporate environmental

performance in their investment decision-making. Therefore, it is important to explicate the effectiveness and economic consequences of sustainable investment in China's stock market, which can provide insights to inform China's green-finance policy design and offer a reference for managers to formulate corporate sustainable development strategies. It can also help in understanding the interaction between investor's green preferences and climate policies, which brings insights into investors' asset-allocation decisions under climate risks.

A key question about ESG investing is whether companies can do well by doing good. A growing number of studies have examined the impact of corporate environmental performance on stock returns in developed countries. In the United States (US) market, de Haan et al. (2012) examined the 500 largest US companies from 2004 to 2008 and found a negative relationship between corporate environmental performance and excess stock returns. Bolton and Kacperczyk (2021a) suggested that the stocks of US firms with higher carbon emissions had higher returns. Alessi et al. (2021) constructed a priced factor based on corporate emissions and the quality of environmental disclosures and found that greener and more transparent firms earned a negative premium in the European market during the period 2006–2018. Luo (2022) found similar evidence in the European market.

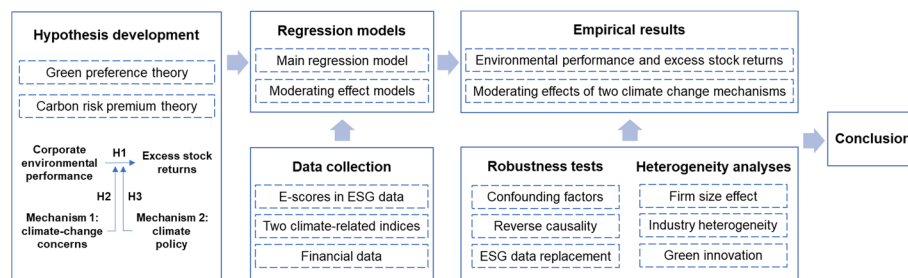
However, there is a lack of consensus in the literature regarding the relationship between corporate environmental performance and stock returns. Many of the studies that have shown a negative relationship between corporate environmental performance and stock returns explain this relationship from the perspective of environmental risk, especially carbon risk. Investors require a premium for carbon risk, which means that green assets, which are typically less exposed to carbon risk, are expected to yield lower returns (Bolton and Kacperczyk 2021a, 2021b; Trinks et al. 2022a). However, some empirical research documents that the stocks of companies with sound environmental performance outperform those of companies with poor environmental performance. For example, In et al. (2017) showed that stocks of companies with low carbon intensity had a premium compared with those of companies with high carbon intensity in the US market from 2005 to 2015, which cannot be fully explained by well-known risk factors. Other studies found similar evidence for the US market using ESG scores (Stotz 2021) and environmental performance (Pástor et al. 2022). Castro et al. (2021) and Ye et al. (2022) found that environmental performance could positively affect stock prices in a sample of listed firms in European countries. The controversial relationship between corporate environmental performance and stock returns may be due to the complex effects of policies and investor preferences, which require further verification.

As shown above, prior studies on the relationship between corporate environmental performance and asset prices have mainly focused on developed markets. China is among the world's largest economies and one of the leading carbon-emitting nations, with significant influence over global sustainability. Meanwhile, compared to developed markets, China's rapid economic growth and increasing awareness of environmental issues offer a distinct perspective for studying sustainable investment. As China's environmental disclosure is still in its infancy, and corporate environmental data have been scant until recent years, research on whether Chinese listed firms' ESG performance can improve corporate investment value is rare. Although Bolton

and Kacperczyk's (2021b) global study, based on data from 2005 to 2018, shows that carbon premiums in both China and the US are highly significant and similar in size, the former country has the most missing data in the global firm-level emissions database. To provide effective evidence for China, the present study uses Chinese firm-level ESG-score data to examine the relationship between corporate environmental performance and excess asset returns. Moreover, this study reveals two different mechanisms to provide additional evidence of the inconsistent debate on the relationship between corporate environmental performance and stock returns.

Our study is related to the rapidly growing literature concerning ESG performance and asset prices. Thus far, over 400 relevant articles have been published in journals indexed on the Web of Science. From a theoretical perspective, Pástor et al. (2021) developed an equilibrium model of sustainable investing to explain the pricing effects of ESG factors in financial markets, suggesting that due to the presence of ESG preferences, green assets have lower expected returns than brown assets in equilibrium. Cornell (2021) elucidated concepts related to the relationships between ESG preferences, risks, and asset returns. Some studies have empirically examined the relationship between ESG performance and asset values. In the bond market, Polbennikov et al. (2016) and Apergis et al. (2022) explored the link between corporate ESG performance and bond spreads, finding that bonds from companies with higher ESG ratings exhibited lower spreads and higher returns. Duan et al. (2023) found that bonds from companies with higher carbon emissions intensity yielded lower returns. Examples from the stock market include studies by de Haan et al. (2012), In et al. (2017), Alessi et al. (2021), Bolton and Kacperczyk (2021a, 2021b), Castro et al. (2021), Stotz (2021), Luo (2022), Pástor et al. (2022), Trinks et al. (2022a), and Ye et al. (2022).

Our study contributes to previous research in two ways. First, we collect the environmental scores of 3,326 A-share listed companies to provide evidence regarding the impact of corporate environmental performance on excess stock returns within the specific context of the Chinese market, contributing to the empirical literature on environmental performance and stock returns. Although some studies have examined the relationship between corporate environmental performance and stock returns, they have mainly focused on developed markets (e.g., de Haan et al. 2012; In et al. 2017; Bolton and Kacperczyk 2021a; Alessi et al. 2021). Emerging economies with high economic growth are often faced with more severe environmental problems, and their underdeveloped capital markets differ in many respects from developed markets. Therefore, how environmental performance affects stock returns in developing countries remains an open question, and we provide relevant empirical evidence that addresses this question based on Chinese market data. Second, this study builds a macro–micro analysis framework of moderating effects, including two mechanisms: climate-change concerns and climate policies, aiming to reconcile the debate on the relationship between environmental performance and stock returns. Given the lack of consensus in existing research on the relationship between environmental performance and stock returns (In et al. 2017; Görgen et al. 2020; Bolton and Kacperczyk 2021a; Alessi et al. 2021), we analyze the causes of green returns in China's stock market from the perspective of these two mechanisms and provide a possible explanation



**Fig. 1** Research workflow diagram

for this controversial relationship. In particular, we construct a news-based climate-policy index using text mining to measure climate-policy dynamics in China.

The remainder of this paper is organized as follows: Sect. "[Hypothesis development](#)" reviews the literature and develops the hypotheses. Sect. "[Methodology and data](#)" explains the models and variables used in our empirical analyses. Sect. "[Empirical results](#)" presents the main results concerning the relationship between corporate environmental performance and excess stock returns. Sect. "[Additional analysis](#)" presents the robustness tests and heterogeneity analyses. Sect. "[Conclusion](#)" concludes the paper. Figure 1 illustrates the research process undertaken in this study.

## Hypothesis development

The capital asset pricing model (CAPM) proposed by Sharpe (1964) first clearly delineates the relationship between risks and excess returns. CAPM indicates that excess asset returns are determined by the market portfolio's excess returns and asset exposure to market risks; the market portfolio is also known as the market factor. Ross (1976) proposed arbitrage pricing theory and developed a multifactor pricing model based on CAPM. Since then, researchers have found more factors in excess asset returns, such as the price-to-earnings ratio (Basu 1977), market value (Banz 1981), book-to-market ratio (Fama and French 1993), momentum (Carhart 1997), and profitability (Novy-Marx 2013). With the development of ESG investing, some studies have begun to consider whether ESG is a pricing factor. For example, Maiti (2021) and Gregory et al. (2021) incorporated ESG into asset-pricing models. However, Green et al. (2017) and Hou et al. (2020) examined numerous anomalies proposed by researchers and found that few characteristics could reliably explain excess stock returns. This warns us that research on corporate characteristics and excess asset returns should have a theoretical basis to avoid its becoming data mining of historical data. Therefore, in studying the relationship between corporate environmental performance and excess stock returns, we review the relevant theories and propose our hypotheses based thereon.

Two main finance theories concern the pricing of corporate environmental performance: (i) The existence of green preferences leads to low excess returns on green assets (Pástor et al. 2021). (ii) Carbon-intensive assets are exposed to higher carbon risk (Bolton and Kacperczyk 2021a, 2021b; Oestreich and Tsiakas 2015; Trinks et al. 2022a). First, besides financial utility, investors can derive non-financial utility (Fama and French 2007; Riedl and Smeets 2017). Pástor et al.'s (2021) equilibrium model

shows that if investors maximize both financial and green utility when making investment decisions, those with tastes for green assets will require lower excess returns on greener companies' assets, while those without green tastes will require the same excess returns on the assets of companies with different environmental performances. In this case, green assets have lower excess returns in equilibrium. Second, the risk caused by the uncertainties of the low-carbon economy transition can affect asset pricing, which is called transition or carbon risk (Bolton and Kacperczyk 2021a, 2021b). Climate policies introduced by regulators, such as carbon trading and carbon tax, will increase carbon-intensive companies' production and operating costs and cause uncertainty about future cash flows (Oestreich and Tsiakas 2015). Therefore, investors will demand more compensation for carbon risk from the assets of companies with poor environmental performance, and the financial market will penalize carbon-intensive companies for negative environmental externalities through higher discount rates on future cash flows (Oestreich and Tsiakas 2015; Trinks et al. 2022a). Extensive research has provided evidence of the carbon-risk premium (Alessi et al. 2021; Bolton and Kacperczyk 2021a, 2021b; Kim et al. 2015; Trinks et al. 2022a). Similar evidence exists in the Chinese market, such as the impact of corporate social-responsibility disclosure on the cost of equity (Li and Liu 2018; Xu et al. 2015) and the impact of corporate environmental performance on debt-interest rates (Du et al. 2017; Ma et al. 2022b). Overall, both the abovementioned theories posit that green assets should have lower excess returns than brown assets under ideal conditions. Therefore, we propose the following hypothesis:

*H1* Corporate environmental performance is negatively related to excess stock returns.

However, there is inconsistent evidence for the relationship between corporate environmental performance and stock returns (In et al. 2017; Görgen et al. 2020; Bolton and Kacperczyk 2021a; Alessi et al. 2021). The increasing attention to climate change and gradual promotion of global climate policies are two opposite forces affecting the relationship between corporate environmental performance and excess stock returns, which may lead to inconsistent results based on different market and time samples (Cornell 2021). Therefore, we discuss the impacts of these two mechanisms to provide more insights into the controversial relationship between corporate environmental performance and excess stock returns.

Given the widespread concern about climate change, overheated green preferences can lead to mispricing of corporate environmental performance (Cornell 2021; Pástor et al. 2021). This means that if investors unexpectedly demonstrate a greater green preference, the prices of green assets will rise while those of brown assets will fall, and thus green assets may outperform brown assets (Pástor et al. 2021). There is some evidence that the high green returns in the US in recent years stem partly from the change in green preferences induced by the increased concerns about climate change (Ardia et al. 2020; Pástor et al. 2022; Stotz 2021; Zhang and Wellalage 2022). In China, as people increasingly pay attention to climate-change issues and sustainable investment, we expect climate-change concerns to affect the relationship between corporate environmental performance and excess stock returns. Accordingly, we propose the following hypothesis:

*H2* In the context of deeper climate-change concerns, corporate environmental performance positively affects excess stock returns.

Moreover, a growing number of economies are beginning to pursue climate policies to strengthen the market pricing of carbon risk. Carbon pricing and other climate policies directly increase carbon-intensive companies' regulatory risks (Luo and Tang 2014; Oestreich and Tsiakas 2015). However, companies engaged in low-carbon production activities are not affected by these risks (Dutta et al. 2018; Kumar et al. 2012). Therefore, in light of increasing climate policies, brown assets need to obtain higher excess returns for higher risk compensation relative to green assets' excess returns (Seltzer, 2022). High-carbon firms' carbon-risk premiums and costs of capital have increased since the signing of the Paris Agreement, and this effect is greater in regions with strict climate regulations (Bolton and Kacperczyk 2021a, 2021b; Seltzer, 2022). As China has introduced various climate policies in recent years, including carbon trading and climate investment and finance, we expect the implementation of climate policies to increase carbon-risk premiums in the Chinese stock market, especially since the announcement of the dual carbon goals. Based on the above analysis, we propose the following hypothesis:

*H3* In times of high climate-policy risk, corporate environmental performance negatively affects excess stock returns.

## Methodology and data

### Regression model

#### Main regression

To test H1, we introduce the following base Model (1):

$$RET_{i,t} = a_0 + a_1 LOGGREEN_{i,t} + a' Control_{i,t-1} + \mu_i + \gamma_t + \varepsilon_{i,t} \quad (1)$$

where  $RET_{i,t}$  is company  $i$ 's excess stock return at the end of month  $t$ , and  $LOGGREEN_{i,t}$  is company  $i$ 's environmental performance in month  $t$ . The vector of control variables includes a set of company characteristics (see SubSect. "Variable definitions"). Because investors make decisions based on historical information, the current month's stock prices are usually affected by the previous month's information; thus, traditional Fama–Macbeth and cross-section regressions use explanatory variables with a one-period lag (Fama and MacBeth 1973; Fama and French 2020). Our model setting follows that of Bolton and Kacperczyk (2021a), who adopted carbon emissions in period  $t$  and controls in period  $t-1$  as explanatory variables. Similar to carbon-emissions data, E-scores reflect firms' historical environmental performance; thus, we use E-scores in period  $t$  as the key explanatory variable.  $\mu_i$  and  $\gamma_t$  represent industry- and year- or month-fixed effects, respectively. We use robust standard errors at the company level. H1 holds when  $a_1$  is significant and negative, indicating that the stocks of companies with sound environmental performance earn lower excess returns.

### **Moderating effect**

To test the moderating effect of climate-change concerns, we add the interaction between climate-change concerns and environmental performance into Model (1) and propose the following extended Model (2):

$$\begin{aligned} RET_{i,t} = & a_0 + a_1 LOGGREEN_{i,t} + a_2 CONCERN_t \\ & + a_3 CONCERN_t \times LOGGREEN_{i,t} \\ & + a'Control_{i,t-1} + \mu_i + \gamma_t + \varepsilon_{i,t} \end{aligned} \quad (2)$$

where  $CONCERN_t$  represents climate-change concerns in month  $t$ . If  $a_3$  is significant and positive, H2 holds, which indicates that the stocks of firms with sound environmental performance perform better in times of heightened climate-change concerns.

To test the moderating effect of climate policies, we add the interaction between the climate-policy index and environmental performance to Model (1) and propose the following extended Model (3):

$$\begin{aligned} RET_{i,t} = & a_0 + a_1 LOGGREEN_{i,t} + a_2 POLICY_t \\ & + a_3 POLICY_t \times LOGGREEN_{i,t} \\ & + a'Control_{i,t-1} + \mu_i + \gamma_t + \varepsilon_{i,t} \end{aligned} \quad (3)$$

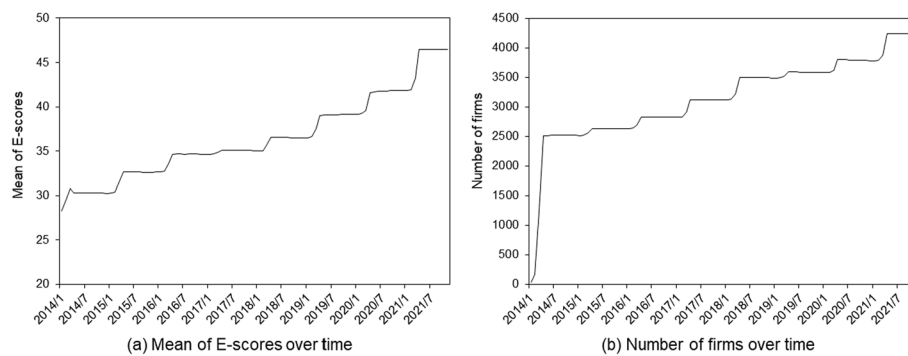
where  $POLICY_t$  denotes the climate-policy index in month  $t$ , a proxy for climate-policy stringency in China. H3 holds when  $a_3$  is significant and negative, indicating that environmentally responsible firms' stocks will perform poorly when climate-policy stringency is high.

Last, we use lagged moderating variables in Models (2) and (3) to examine the lagged effects of climate-change concerns and climate policies on excess stock returns. We use the official linear regression command on the Stata 17 software for Models (1)–(3).

## **Data**

### **Corporate environmental performance**

Previous studies typically use either carbon-emissions (Bolton and Kacperczyk 2021a, 2021b; Castro et al. 2021; In et al. 2017; Kim et al. 2015; Trinks et al. 2022a) or ESG (Engle et al. 2020; G6rgen et al. 2020; P6stor et al. 2022) data to measure corporate environmental performance related to climate change. Currently, firms' carbon-emissions data are still mainly voluntarily disclosed. For example, the Carbon Disclosure Project (CDP) collects firms' greenhouse-gas emissions information through annual questionnaires. The ESG data from third-party evaluation have the advantages of reliability and comprehensive sample coverage. In addition, ESG data contain a wide range of climate-change-related information and can reflect corporate exposure to climate risk. For example, Engle et al. (2020) used E-scores to model firms' climate-risk exposures and found that portfolios constructed based on E-scores performed well in hedging climate-change news. Therefore, considering data availability, this study uses E-scores from the QuantData ESG dataset to measure listed Chinese companies' environmental performance. QuantData is a local ESG rating agency in China that collects corporate data on ESG issues through company disclosures, government-regulation reports, and third-party platforms. It covers almost all A-share and H-share stocks and China Concept Stocks



**Fig. 2** Summary statistics of QuantData E-scores This figure shows the summary statistics of the QuantData E-scores. **a** presents the mean of E-scores in the QuantData ESG dataset over time, and **b** presents the number of firms in the QuantData ESG dataset over time

and has been providing monthly ESG data since 2014. In the environmental dimension, corporate performance is comprehensively assessed based on four aspects: environmental management, energy-conservation policy, environmental emissions, and climate change. Specifically, QuantData E-scores include 52 indicators, such as greenhouse-gas emissions, total energy consumption, renewable-energy consumption, environmental-protection investment, environmental penalties, emission permits, supply-chain climate risk, fossil-fuel income, and business detrimental to biodiversity, indicating that QuantData E-scores can widely reflect a company's climate-risk exposures and climate-change mitigation efforts. Given the varying importance of indicators across industries, QuantData has developed a specific indicator-weighting scheme for each industry. An E-score is the weighted sum of indicators ranging from 0 to 100. A higher E-score suggests that a company is more environmentally friendly.

Figure 2 shows the mean and number of QuantData E-scores over time. The average E-score for A-share companies trends upward, revealing that Chinese companies are paying increasing attention to the implementation of corporate environmental responsibility. There are several regular and discontinuous breaks in the two trends. This may be attributed to the fact that Chinese listed companies are required to disclose their previous year's annual reports between January and April each year, and QuantData usually adjusts the ESG scores during this period. The number of companies represented in the QuantData ESG dataset in January and February 2014 is relatively small; since then, the number has surged. To avoid sample-selection bias, we use March 2014 to November 2021 as the sample period, covering 3,326 companies with a total of 221,500 monthly observations.

### **Climate-related indices**

A growing number of studies have used news-based indices to measure policy information. Faccini et al. (2021) developed four novel proxies for US climate policy, international summits, natural disasters, and global warming by conducting a topic-model analysis of climate-change news over the period 2000–2018. Baker et al. (2016) built an index of economic-policy uncertainty by searching for keywords in the news. The same method is also used to measure monetary-policy (Husted et al. 2020), climate-policy (Gavriilidis 2021), and environmental-policy (Noailly et al. 2022) uncertainty.

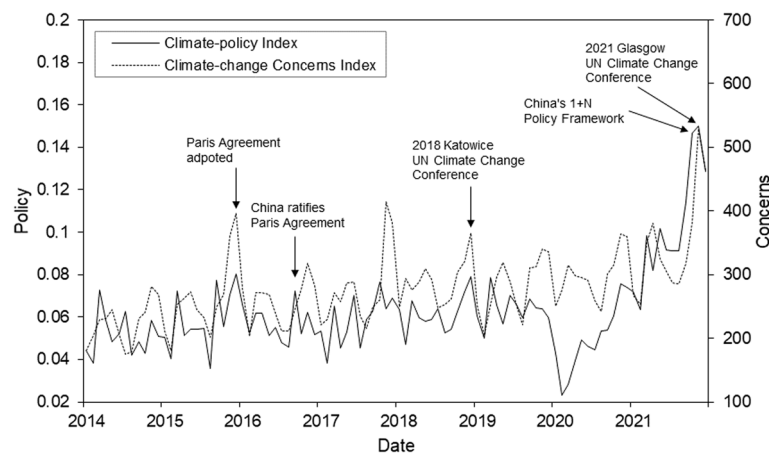
**Table 1** Term sets for climate-policy index

Category	Chinese terms	English translation of terms
Climate	气候变化/气候风险/气候问题/全球变暖/温室气体/二氧化碳/碳排放/碳汇/低碳/减排/碳达峰/碳中和/双碳/可再生能源/清洁能源/新能源/节能/能源转型	climate change/climate risk/ climate issues/global warming/greenhouse gas/carbon dioxide/carbon emissions/carbon sink/low-carbon/emission reduction/carbon peak/carbon neutral/dual-carbon/renewable energy/clean energy/new energy/energy saving/energy transition
Policy	政策/制度/体制/机制/战略/改革/措施/规划/方案/条例/规章/法规/办法/法律/监管/试点/政府/中央/国务院/人民代表大会/人民银行/央行/国家发展和改革委员会/国家发展改革委/发改委/生态环境部/环境保护部/国家能源局/国家主席/总书记/国家领导人/总理	policy/institution/system/mechanism/strategy/reform/measurement/plan/scheme/rules/regulations/laws and regulations/method/laws/regulation/pilot/government/central government/State Council/People's Congress/People's Bank of China/Central Bank/National Development and Reform Commission/National Development and Reform Commission/National Development and Reform Commission/Ministry of Ecological Environment/Ministry of Environmental Protection/National Energy Administration/president/secretary general/national leader/prime minister

We construct China's climate-policy index using Baker et al.'s (2016) method. We select three major newspapers—*People's Daily*, *Economic Daily*, and *Guangming Daily*—as news sources and obtain the news text data from WiseSearch.<sup>1</sup> These three newspapers are all authoritative, comprehensive, central newspapers in China and are thus suitable for constructing policy indices (Davis et al. 2019; Yu et al. 2021). These sources report numerous climate-change news items, ranking among the top 10 in 2021, according to WiseSearch. Furthermore, we employ a term framework to describe climate policies, which divides the climate category into three dimensions—climate change, greenhouse-gas emissions, and energy—and divides the policy dimension into three dimensions—policy term, government agency, and national leader. We count the word frequency of news containing the Chinese equivalents of “climate change” and “policy” and then manually screen words related to the above six dimensions from the high-frequency words to complete our term sets.<sup>2</sup> Table 1 presents the terms and their English translations. Next, we obtain monthly counts of articles containing at least one term from each of the two term sets: climate and policy. The climate-policy index is the ratio of the number of searched articles relative to the total number of published articles. In addition, the Baidu Index is a data-sharing platform built on extensive online user-behavior data and has been employed to capture investor attention (Fang et al. 2020; Guo et al. 2020; Zhang

<sup>1</sup> To verify the validity of our climate-policy index, we alternatively select ten newspapers to reconstruct the index, including *People's Daily*, *Economic Daily*, *Guangming Daily*, *Xinhua Daily*, *Telegraph*, *China News Service*, *Global Times*, *Science and Technology Daily*, *Science Times*, *China Energy News*, and *China Environment News*. The correlation coefficient between this new index and the original climate-policy index based on data from three newspapers is 0.93, underscoring the robustness of our index in capturing China's climate-policy information.

<sup>2</sup> The index-construction method based on keywords may be subjective to some extent. Despite our efforts to ensure objectivity and comprehensiveness in selecting term sets, it is difficult to completely avoid the subjective bias introduced by this method.



**Fig. 3** Climate-policy index and climate-change concerns index This figure shows the climate-policy index and climate-change concerns index over the period 2014–2021, annotated with important climate-change news. The left axis represents the climate-policy index, and the right axis represents the climate-change concerns index

et al. 2021). We collect Baidu-search index data using the Chinese word for “climate change” as a keyword and build the climate-change concerns index.<sup>3</sup>

Figure 3 shows the trends of the climate-policy and climate-change concerns indices. As the figure reveals, the two trends are similar, implying that when climate policies are issued, people are more concerned about climate change. Furthermore, there is an apparent positive correlation between the two trends. Since the start of the annual United Nations Climate Change Conference (UNCCC), both indices have periodically risen during the conference. In early 2020, as the media became an important channel for disseminating information about public-health emergencies following the outbreak of COVID-19 (Jin et al. 2022), the proportion of news about climate policies fell sharply. In 2021, China introduced various climate policies concerning environmental disclosure, climate investment and financing, and the carbon-emissions trading scheme; thus, both indices show surges and are far higher than they were before 2021.

#### Variable definitions

Our dependent variable is *RET*, the excess stock return, and it is calculated as the logarithmic stock return rate minus the risk-free interest rate. The key independent variable is *LOGGREEN*, which is the logarithm of the corporate environmental score. There are two moderating variables: *CONCERN* is the logarithmic climate-change concerns index, calculated as  $CONCERN = \ln(1 + climatechangeconcernsindex_t)$ , while *POLICY* is the climate-policy index.

The control variables represent a series of company characteristics (Carhart 1997; Fama and French 1993, 2015; Liu et al. 2019). *BETA* is the exposure to market risk, calculated by a rolling regression of the excess stock return on the market excess return over the previous 36 months. *LOGSIZE* is the logarithm of corporate market capitalization. *BM* is the book-to-market ratio, which equals the reciprocal of the price-to-book ratio. *MOM* is the total return for the most recent 12 months leading up to and including

<sup>3</sup> <https://index.baidu.com/v2/index.html#/> (Accessed 27 June 2022).

**Table 2** Definitions of variables

Variables	Definition
RET	The excess stock return, which is calculated by the logarithmic stock return rate minus the risk-free interest rate
LOGGREEN	The logarithm of the corporate environmental scores
BETA	The CAPM beta, which is calculated by a rolling regression of the excess stock return on the market excess return over the previous 36 months
LOGSIZE	The logarithm of corporate market capitalization
BM	The book-to-market ratio, which equals to the reciprocal price-to-book ratio
MOM	The total return of the previous 12 months
ROE	The return on equity in the annual report
INV	The growth of assets in the annual report
TURNOVER	The turnover rate, which is calculated by the number of shares traded over the number of shares outstanding
CONCERN	$\ln(1 + \text{climatechangeconcernsindex}_t)$
POLICY	The news-based climate-policy index

month  $t - 1$ . *ROE* and *INV* are the return on equity and growth in assets in the annual report, respectively.<sup>4</sup> *TURNOVER* is the turnover rate, which equals the ratio of stock turnover to the number of outstanding shares. We winsorise *BM*, *MOM*, *ROE*, *INV*, and *TURNOVER* at the 1% level. We obtain stock-price data and company financial statements from the Wind and China Stock Market & Accounting Research (CSMAR) databases, respectively (Table 2).

### Descriptive statistics

Our dataset comprises monthly unbalanced panel data on 3,326 companies from March 2014 to November 2021, spanning a total of 93 months. Table 3 reports the summary statistics for the variables. In Table 3, the variables from *RET* to *TURNOVER* are at the firm level, with a total of 221,500 observations. *CONCERN* and *POLICY* are at the market level, comprising 93 observations. The average E-score for Chinese listed companies is 35, with a standard deviation of 0.27, which shows a concentrated distribution of E-scores and low environmental scores of most sample companies, which implies that only a minority of Chinese listed companies perform well in environmental responsibility. In addition, we employ the Fisher-ADF and Fisher-PP tests appropriate for unbalanced panel data to conduct unit-root tests. Both tests show that our variables are stationary.

Table 4 presents the correlation-analysis results. They show that *RET* is significantly and positively correlated with *LOGGREEN*, indicating that listed companies' sound environmental performance may improve excess stock returns, which provides a preview of our regression tests. In addition, there are significant correlations among many explanatory variables; however, the absolute correlation coefficients of most of the explanatory variables used in our regression models do not exceed 0.3. Finally, with the improvement of China's climate-policy system in recent years, people are paying increasing attention

<sup>4</sup> As listed companies must issue the previous year's annual report before April 30, we use the annual-report data for the year before last when  $t$  is between January and April and the data for the previous year's annual report otherwise.

**Table 3** Summary statistics

Variables	N	Mean	Std. Dev	Min	Median	Max	Fisher-ADF	Fisher-PP
RET	221500	− 0.13	0.13	− 1.38	− 0.14	1.24	765.89***	1363.91***
LOGGREEN	221500	3.61	0.27	2.47	3.59	4.61	2.87***	2.05**
BETA	221500	1.14	0.37	− 2.02	1.13	3.55	4.52***	49.83***
LOGSIZE	221500	22.81	1.06	20.22	22.62	28.66	10.66***	26.77***
BM	221500	0.44	0.30	0.03	0.37	1.46	20.57***	27.57***
MOM	221500	0.04	0.39	− 0.80	0.01	1.17	26.18***	44.21***
ROE	221500	0.05	0.15	− 0.89	0.06	0.33	11.49***	21.36***
INV	221500	0.14	0.26	− 0.33	0.08	1.57	18.15***	21.45***
TURNOVER	221500	0.44	0.43	0.03	0.29	2.25	32.7***	369.71***
CONCERN	93	5.62	0.19	5.17	5.61	6.27	—	—
POLICY	93	0.06	0.02	0.02	0.06	0.15	—	—

This table presents the summary statistics of the firm-level variables for 3,326 Chinese listed companies and the climate-related indices for the period from March 2014 to November 2021. RET is the monthly excess stock return; LOGGREEN is the logarithm of the corporate E-scores; BETA is the CAPM beta calculated over the past 36 months; LOGSIZE is the logarithm of corporate market capitalization; BM is the book-to-market ratio; MOM is the total return of the past 12 months; ROE is the return on equity; INV is the growth of assets; TURNOVER is the turnover rate; CONCERN is the logarithmic climate-change concerns index, calculated as  $CONCERN = \ln(1 + climatechangeconcernsindex_t)$ ; POLICY is the climate-policy index. We use the modified inverse chi-squared statistics from the Fisher-ADF and Fisher-PP tests to assess the stationarity of the variables. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

to climate change, which can be seen in the high positive correlation between *CONCERN* and *POLICY*.

Table 5 illustrates the variation in sample size across years. Our sample size increases slightly over time. Table 6 depicts the sample distributions across the China Securities Regulatory Commission first-level industries. The manufacturing industry holds the largest sample size, with 134,653 observations, constituting 60.79% of the total sample. In the empirical analysis, the sample is further categorized into second-level industries, encompassing a total of 81 s-level industries.

## Empirical results

### The relationship between environmental performance and excess stock returns

To examine the impact of corporate environmental performance on excess stock returns, we first estimate Model (1), and the results are shown in Table 7. The coefficient of LOGGREEN is significant and positive at the 1% level, which indicates that a one-standard deviation increase in the environmental score is associated with an increase of 16 basis points in excess stock returns, even after controlling for both industry- and year-/month-fixed effects. The results show that the stocks of companies with sound environmental performance earn more excess returns than those of companies with poor environmental performance—that is, there are positive green returns in China's stock market. Thus, we find no evidence to support H1. From an investor's perspective, investing in green stocks in China is rewarded by higher excess returns.

Our findings are consistent with those obtained in some studies on the US market. For example, Kempf and Osthoff (2007), In et al. (2015), and Pástor et al. (2022) found that sustainable investing based on corporate social responsibility or environmental performance could yield abnormal returns. However, our findings differ from some empirical findings from China (Xu et al. 2015; Li and Liu 2018), which may be due to two reasons.

Table 4 Correlation coefficient matrix

	RET	LOGGREEN	BETA	LOGSIZE	BM	MOM	ROE	INV	TURNOVER	CONCERN	POLICY
RET	1										
LOGGREEN	0.08***	1									
BETA	−0.04***	−0.07***	1								
LOGSIZE	−0.03***	0.30***	−0.11***	1							
BM	0.06***	0.24***	−0.02***	0.00	1						
MOM	−0.10***	−0.02***	−0.05***	0.23***	−0.33***	1					
ROE	−0.01***	0.07***	−0.11***	0.27***	0.01***	0.06***	1				
INV	−0.01***	−0.03***	−0.02***	0.16***	−0.11***	−0.01***	0.26***	1			
TURNOVER	−0.11***	−0.13***	0.06***	−0.11***	−0.30***	0.35***	−0.11***	−0.00	1		
CONCERN	0.07***	0.26***	−0.03***	0.00	0.09***	−0.07***	−0.02***	−0.04***	−0.05***	1	
POLICY	0.08***	0.25***	−0.06***	−0.00	0.06***	−0.03***	−0.02***	−0.03***	−0.04***	0.59***	1

This table presents the Pearson pairwise correlations between the firm-level variables for 3,326 Chinese listed companies and the climate-related indices in the period from March 2014 to November 2021. All variables are defined in Table 2. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

**Table 5** Sample distribution by year

Year	Observations	Proportion (%)
2014	17,438	7.87
2015	22,802	10.29
2016	24,721	11.16
2017	25,705	11.60
2018	28,080	12.68
2019	31,184	14.08
2020	35,718	16.13
2021	35,852	16.19
Total	221,500	100.00

**Table 6** Sample distribution by industry

Industry	Observations	Proportion (%)
Agriculture, Forestry, Animal Husbandry, and Fisheries	2707	1.22
Mining	5568	2.51
Manufacturing	134,653	60.79
Electricity, Heat, Gas, and Water Production and Supply	8262	3.73
Construction	5754	2.60
Wholesale and Retail Trade	11,334	5.12
Transportation, Storage, and Postal Services	7056	3.19
Accommodation and Food Services	529	0.24
Information Transmission, Software, and Information Technology Services	15,997	7.22
Financial Services	6552	2.96
Real Estate	8883	4.01
Leasing and Business Services	3335	1.51
Scientific Research and Technical Services	1823	0.82
Water Conservation, Environmental Protection, and Public Facility Management	3570	1.61
Residential Services, Repair, and Other Services	9	0.00
Education	741	0.33
Health and Social Work	679	0.31
Culture, Sports, and Entertainment	3200	1.44
Comprehensive	848	0.38
Total	221,500	100.00

First, we focus on realized returns, whereas Xu et al. (2015) and Li and Liu (2018) examined the ex-ante cost of equity capital and used various models to estimate the cost of equity capital. Second, unlike Bolton and Kacperczyk (2021b), who examined the impact of carbon emissions on stock returns, we use E-scores as a proxy for corporate environmental performance, which contains more information than carbon-emissions data. Thus far, only a few Chinese listed companies have disclosed their emissions. Therefore, compared with studies using emissions data, ours covers most A-share companies and avoids sample-selection bias.

Last, climate-change concerns and climate policies are likely to be important mechanisms that lead to the controversial relationship between corporate environmental

**Table 7** Corporate green performance and excess stock returns

	(1)	(2)
LOGGREEN	0.008*** (7.81)	0.006*** (5.89)
BETA	− 0.002*** (− 3.20)	− 0.003*** (− 3.84)
LOGSIZE	− 0.004*** (− 15.87)	− 0.005*** (− 15.81)
BM	0.001 (0.96)	0.005*** (4.75)
MOM	− 0.001 (− 0.83)	− 0.000 (− 0.36)
ROE	− 0.001 (− 0.75)	− 0.001 (− 0.50)
INV	0.001 (0.82)	0.001 (0.76)
TURNOVER	− 0.022*** (− 27.35)	− 0.023*** (− 28.88)
Constant	− 0.186*** (− 26.64)	− 0.164*** (− 20.55)
Industry fixed effects	N	Y
Year/month fixed effects	Y	Y
Observations	221,500	221,500
Adjusted R <sup>2</sup>	0.3605	0.3618

This table reports the results from regressing the excess stock returns (RET) on corporate environmental performance (LOGGREEN) and controls with robust standard errors clustered at the firm level. The sample period is March 2014 to November 2021, and the unit of observation is a month. All variables are defined in Table 2. Both regressions include year-month fixed effects, and column (2) also includes industry fixed effects. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

performance and excess stock returns. Climate-change concerns can increase green-asset returns through investors' green preferences (Pástor et al. 2021, 2022; Ardia et al. 2020). Climate policies can strengthen the market pricing of carbon risk and reduce green-asset returns (Oestreich and Tsiakas 2015; Bolton and Kacperczyk 2021a, 2021b). The increasing attention to climate change and progressive promotion of global climate policies may lead to differences in the results of climate-risk pricing studies across different markets and period samples. Therefore, we examine the moderating effects of climate-change concerns and climate policies in SubSects. "[The moderating effect of climate-change concerns](#)" and "[The moderating effect of climate policies](#)", respectively, which can provide a possible explanation for the controversial relationship between environmental performance and excess stock returns in prior studies, using the Chinese market as an example.

#### The moderating effect of climate-change concerns

Table 8 presents the estimation results from Model (2). Columns (1) and (2) show the results for the contemporaneous moderating effects of climate-change concerns, Columns (3) and (4) for the moderating effects of one-month lagged climate-change concerns, and Columns (5) and (6) for the moderating effects of two-month lagged

**Table 8** Moderating effect of climate-change concerns on the relationship between environmental performance and excess stock returns

	(1)	(2)	(3)	(4)	(5)	(6)
LOGGREEN	− 0.058** (− 2.13)	− 0.063** (− 2.30)	− 0.307*** (− 9.23)	− 0.314*** (− 9.39)	− 0.167*** (− 5.19)	− 0.175*** (− 5.40)
CONCERN	0.224*** (11.97)	0.223*** (11.86)				
L1.CONCERN			0.156*** (6.83)	0.153*** (6.71)		
L2.CONCERN					0.286*** (13.09)	0.283*** (12.91)
CONCERN*LOGGREEN	0.012** (2.42)	0.012** (2.52)				
L1.CONCERN*LOGGREEN			0.056*** (9.39)	0.057*** (9.51)		
L2.CONCERN*LOGGREEN					0.031*** (5.41)	0.032*** (5.56)
Constant	− 1.397*** (− 13.24)	− 1.366*** (− 12.87)	− 0.955*** (− 7.53)	− 0.918*** (− 7.21)	− 1.628*** (− 13.35)	− 1.589*** (− 12.95)
Control	Y	Y	Y	Y	Y	Y
Industry fixed effects	N	Y	N	Y	N	Y
Year/month fixed effects	Y	Y	Y	Y	Y	Y
Observations	221,500	221,500	221,500	221,500	221,500	221,500
Adjusted R <sup>2</sup>	0.3606	0.3618	0.3608	0.3621	0.3606	0.3619

This table reports the results for the regression tests of the moderating effect of climate-change concerns (CONCERN) on the relationship between environmental performance (LOGGREEN) and excess stock returns (RET) with controls and robust standard errors clustered at the firm level. The sample period is March 2014 to November 2021, and the unit of observation is a month. Columns (1) and (2) show the contemporaneous moderating effects of climate-change concerns, columns (3) and (4) are the moderating effects of one-month lagged climate-change concerns, and columns (5) and (6) are the moderating effects of two-month lagged climate-change concerns. All variables are defined in Table 2. All regressions include year-month fixed effects, and columns (2), (4), and (6) additionally include industry fixed effects. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

climate-change concerns. Both the contemporaneous and lagged interactions between climate-change concerns and corporate environmental performance are significant and positive, which supports H2. The results show that during periods of heightened climate-change concerns, investors tend to allocate more money to environmentally responsible firms' stocks due to their low exposure to climate risk, enabling environmental performance to further increase excess stock returns. Our findings provide empirical evidence for Pástor et al.'s (2021) theoretical predictions—that is, when investors' green preference unexpectedly increases, the price of green assets will rise, and the price of brown assets will fall. Ardia et al. (2020) and Pástor et al. (2022) found similar evidence in the US stock market. Moreover, the lagged moderating effects are greater and more significant than the contemporaneous moderating effects, indicating that investors' concerns about climate change can persist and influence their investment decisions for a period. In Table 8, the coefficient of LOGGREEN is significant and negative. We find that a one-standard deviation increase in environmental performance would cause excess stock returns to decrease by 2%–8% after controlling for the effect of climate-change concerns. If investor's concerns about climate change are not heightened, their preference for green assets will not be strong, and stocks of firms with sound environmental

performance will have lower excess returns than those of environmentally irresponsible companies. That is, the green returns in China's stock market are related to deep climate-change concerns. These findings are consistent with those obtained by Pástor et al. (2022) and Stotz (2021). These authors found that growing climate-change concerns and investors' green preferences led to high green returns in the US stock market.

Our findings confirm Pástor et al.'s (2021) theoretical predictions and are consistent with empirical findings by Ardia et al. (2020), Pástor et al. (2022), and Stotz (2021).

### **The moderating effect of climate policies**

Table 9 presents the estimation results from Model (3). Columns (1) and (2) show the results for the contemporaneous moderating effects of climate-policy stringency (measured by the climate-policy index), Columns (3) and (4) for the moderating effects of one-month lagged climate-policy stringency, Columns (5) and (6) for the moderating effects of six-month lagged climate-policy stringency, and Columns (7) and (8) for the moderating effects of one-year lagged climate-policy stringency. The contemporaneous interaction between the climate-policy index and excess stock returns is negative but nonsignificant, and the one-month lagged interaction is positive and weakly significant. This indicates that as intensive climate-policy news may arouse investor's concerns about climate change and affect their green preferences, the climate-policy index may raise the excess stock returns of firms with sound environmental performance in the short term. Our finding is consistent with that obtained by Bouri et al. (2022), who demonstrated that climate-policy uncertainty could increase market preferences for green assets. We also find that both half-year and one-year lagged interactions between the climate-policy index and excess stock returns are negative and significant at the 1% level, showing that an increase in climate-policy stringency will greatly reduce the stock market's green returns in the long term. These results support H3, which posits that the uncertainty caused by tightened climate regulations, such as rising carbon prices, emissions penalties, and rising costs of financing, will increase carbon risks. Environmentally irresponsible firms' assets are typically exposed to greater carbon risk and investors therein require more risk compensation. Furthermore, the effect of newly introduced policies is often delayed, increasing the impact of climate-policy stringency on carbon risk in the long term. Our findings are consistent with those obtained by Bolton and Kacperczyk (2021a, 2021b), Seltzer (2022), and Wen et al. (2020), who found that climate policy shocks could increase carbon-risk premiums in stock and bond markets.

Since China's announcement of its dual carbon goals, the government has adopted a series of measures to mitigate climate change, such as launching a nationwide carbon-emissions trading scheme and stopping the financing of new coal plants abroad. We compare the moderating effects of climate policies before and after September 2020, when the dual carbon goals were proposed, and the results are presented in Table 10. Columns (1) and (2) show the results before September 2020, and Columns (3) and (4) show the results thereafter. As reported in Table 10, the interaction between the climate-policy index and excess stock returns is positive and significant at the 10% level before the dual carbon goals, while it turns negative and significant at the 1% level after the dual carbon goals, with a great increase in the absolute value of the coefficient. Before the

**Table 9** Moderating effect of climate policy on the relationship between environmental performance and excess stock returns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOGGREEN	0.010*** (3.22)	0.008*** (2.60)	0.002 (0.62)	0.000 (0.09)	0.040*** (9.36)	0.039*** (9.02)	0.022*** (4.88)	0.021*** (4.48)
POLICY	2.969*** (16.81)	2.978*** (16.85)						
L1.POLICY			1.713*** (8.72)	1.722*** (8.77)				
L6.POLICY					6.749*** (24.14)	6.787*** (24.25)		
L12.POLICY							115.420*** (54.53)	115.647*** (54.65)
POLICY*LOGGREEN	− 0.023 (− 0.53)	− 0.024 (− 0.55)						
L1.POLICY*LOGGREEN			0.093* (1.82)	0.092* (1.79)				
L6.POLICY*LOGGREEN				− 0.541*** (− 7.70)	− 0.549*** (− 7.70)			
L12.POLICY*LOGGREEN						(− 7.81)		
Constant	− 0.401*** (− 28.12)	− 0.380*** (− 25.37)	− 0.243*** (− 17.87)	− 0.222*** (− 15.39)	− 0.563*** (− 29.95)	− 0.544*** (− 28.13)	− 0.249*** (− 3.21)	− 0.251*** (− 3.22)
Control	Y	Y	Y	Y	Y	Y	Y	Y
Industry fixed effects	N	Y	N	Y	N	Y	N	Y
Year/month fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	221,500	221,500	221,500	221,500	221,500	221,500	221,500	221,500
Adjusted R <sup>2</sup>	0.3605	0.3618	0.3606	0.3618	0.3607	0.3620	0.3606	0.3618

This table reports the results for the regression tests of the moderating effect of climate policy (POLICY) on the relationship between environmental performance (LOGGREEN) and excess stock returns (RET), with controls and robust standard errors clustered at the firm level. The sample period is March 2014 to November 2021, and the unit of observation is a month. Columns (1) and (2) show the results for contemporaneous moderating effects of the climate-policy index, columns (3) and (4) for moderating effects of the one-month lagged climate-policy index, columns (5) and (6) for moderating effects of the six-month lagged climate-policy index, and columns (7) and (8) for moderating effects of the one-year lagged climate-policy index. All variables are defined in Table 2. All regressions include year-month fixed effects, and columns (2), (4), (6), and (8) additionally include industry fixed effects. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

**Table 10** Moderating effect of climate policy before and after the dual carbon goals

	Before the dual carbon goals		After the dual carbon goals	
	(1)	(2)	(3)	(4)
LOGGREEN	− 0.007 (− 1.30)	− 0.007 (− 1.32)	0.102*** (12.75)	0.093*** (11.87)
POLICY	− 4.471*** (− 12.28)	− 4.478*** (− 12.28)	4.108*** (13.77)	4.217*** (14.27)
POLICY*LOGGREEN	0.173** (1.98)	0.171* (1.96)	− 0.846*** (− 10.76)	− 0.879*** (− 11.31)
Constant	0.138*** (6.19)	0.167*** (7.29)	− 0.406*** (− 12.83)	− 0.411*** (− 12.68)
Control	Y	Y	Y	Y
Industry fixed effects	N	Y	N	Y
Year/month fixed effects	Y	Y	Y	Y
Observations	176,214	176,214	45,286	45,286
Adjusted R <sup>2</sup>	0.4215	0.4226	0.1078	0.1209

This table reports the results for the regression tests of the moderating effect of climate policy (POLICY) on the relationship between environmental performance (LOGGREEN) and excess stock returns (RET) with controls and robust standard errors clustered at the firm level before and after the dual carbon goals. Columns (1) and (2) show the results for the period from March 2014 to September 2020 (before the dual-carbon goals). Columns (3) and (4) show the results for the period from October 2020 to November 2021 (after the dual-carbon goals). The unit of observation is a month. All variables are defined in Table 2. All regressions include year-month fixed effects. Columns (2) and (4) also include industry-fixed effects. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

dual carbon goals, the impact of the climate-policy index on environmentally responsible firms' excess stock returns in the Chinese market can be mainly attributed to a change in green preferences. However, following the announcement of the dual carbon goals, with the acceleration of climate-policy implementation, climate policies strengthen the market pricing of carbon risk and thus decrease the excess stock returns of firms with sound environmental performance.

## Additional analysis

### Confounding factors

Although we control for several important corporate characteristics, excess stock returns may be affected by other confounding factors, such as leverage (Bhandari 1988), cash flow (Lakonishok et al. 1994), sales growth (Lakonishok et al. 1994), turnover volatility (Chordia et al. 2001), return volatility (Ang et al. 2006), and research and development (R&D) expenses (Guo et al. 2006). We address the potential omitted-variable bias by adding more control variables, including the asset-liability ratio (LEVERAGE), ratio of cash flow to market capitalization (CASHFLOW), logarithmic growth rate of sales (SALESGR), standard deviation of returns over the previous 12 months (RET-VOL), standard deviation of turnover over the previous 12 months (TURNVOL), and ratio of R&D expense to market capitalization (R&D). We also use firm-fixed effects to control for unobserved heterogeneity at the firm level. The results following the additional control variables and firm-fixed effects are shown in Columns (1)–(2) and (3) of Table 11, respectively. Table 11 shows that all the additional control variables have a significant impact on excess stock returns and that the adjusted R<sup>2</sup> for all the regression results increases, indicating that additional control variables and firm-fixed effects can

**Table 11** Additional control variables

	(1)	(2)	(3)
LOGGREEN	0.013*** (10.90)	0.010*** (8.16)	0.015*** (7.78)
BETA	− 0.003*** (− 3.48)	− 0.003*** (− 3.90)	− 0.005*** (− 4.10)
LOGSIZE	− 0.005*** (− 15.83)	− 0.005*** (− 14.15)	− 0.043*** (− 25.09)
BM	0.005*** (4.05)	0.014*** (10.16)	0.028*** (7.98)
MOM	− 0.003*** (− 2.60)	− 0.003*** (− 2.60)	0.000 (0.00)
ROE	− 0.004** (− 2.15)	− 0.002 (− 1.00)	− 0.003 (− 1.02)
INV	− 0.001 (− 0.77)	− 0.002** (− 2.27)	− 0.002 (− 1.51)
TURNOVER	− 0.020*** (− 21.69)	− 0.022*** (− 23.12)	− 0.021*** (− 20.64)
LEVERAGE	− 0.001 (− 0.43)	0.009*** (5.93)	0.026*** (6.00)
CASHFLOW	− 0.000 (− 0.11)	0.008*** (3.36)	0.012*** (2.64)
SALESGR	0.003*** (3.68)	0.002** (2.56)	0.005*** (4.69)
RETVOL	0.019*** (2.86)	0.014** (2.02)	0.041*** (4.78)
TURNVOL	− 0.005*** (− 3.16)	− 0.007*** (− 4.16)	− 0.011*** (− 5.51)
R&D	− 0.358*** (− 19.25)	− 0.674*** (− 25.33)	− 1.942*** (− 26.37)
Constant	− 0.189*** (− 24.75)	− 0.179*** (− 19.04)	0.641*** (16.28)
Firm fixed effects	N	N	Y
Industry fixed effects	N	Y	Y
Year/month fixed effects	Y	Y	Y
Observations	221,356	221,356	221,356
Adjusted R <sup>2</sup>	0.3621	0.3655	0.3833

This table reports the results from regressing the excess stock returns (RET) on corporate environmental performance (LOGGREEN) and controls with robust standard errors clustered at the firm level. The sample period is March 2014 to November 2021, and the unit of observation is a month. LEVERAGE is the asset-liability ratio; CASHFLOW is the ratio of cash flow to market capitalization; SALESGR is the logarithmic growth rate of sales; RETVOL is the standard deviation of returns over the previous 12 months; TURNVOL is the standard deviation of turnover over the previous 12 months; and R&D is the ratio of R&D expense to market capitalization. All other variables are defined in Table 2. All regressions include year-month fixed effects. Columns (2) and (3) additionally include industry and firm fixed effects, respectively. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

control for heterogeneity at the firm level. More importantly, the coefficient of LOGGREEN remains significant and positive at the 1% level, or even greater. A one-standard deviation increase in the environmental score is related to an increase of 40 basis points in excess stock returns after additional control for firm-fixed effects. The positive green returns in the Chinese stock market over the period 2014–2021 illustrate the robustness of our results.

### Reverse causality

Waddock and Graves (1997) found a two-way causal relationship between corporate social performance and financial performance. On the one hand, sound financial performance enables companies to have more slack resources for improving corporate social performance. On the other hand, sound corporate social performance can improve the relationship between companies and stakeholders, thus improving financial performance. There may also be reverse causality in the study of the impact of corporate environmental performance on excess stock returns, and we use two-stage least squares regression to address this problem. Following El Ghouli et al. (2011, 2018), we use the industry average E-scores for the first year in the sample (E\_AVERAGE) and a dummy variable to measure whether the industry average E-score is higher than the median (E\_RANK) as instruments for corporate environmental performance. The average industry environmental performance may affect companies' environmental practices; however, the lag value and ranking of industry environmental performance are unlikely to affect contemporaneous excess stock returns. Columns (1) and (2) in Table 12 present the regression results for the first and second stages, respectively. In the first stage, t-tests and F-tests suggest that E\_AVERAGE and E\_RANK are significant determinants of corporate environmental performance. In the second stage, the p-value for the Sargan overidentification test is 0.71, indicating that our two instruments are exogenous. Environmental performance is significantly and positively related to excess stock returns at the 1% level, further indicating the robustness of our results.

### ESG-data replacement

We replace the ESG-data source with Refinitiv ESG and use environmental scores from Refinitiv ESG as a new proxy for corporate environmental performance. As the dataset is updated annually, we re-estimate the main regression models using annual data, and the results are presented in Table 13. Panel A of Table 13 shows no negative relationship between corporate environmental performance and excess stock returns, and thus H1 is rejected. The difference in significance from Table 7 may be due to the different samples. Within the limitation of data availability, the regressions using alternative E-scores cover only 617 A-share companies, while the regressions in Table 7 cover more than 3000 companies. In Panel B, the contemporaneous results show that climate-change concerns will increase market green returns and that stocks of firms with sound environmental performance outperform those of firms with poor environmental performance if people are not concerned about climate change. The interactions between one-year lagged climate-change concerns and corporate environmental performance are positive but nonsignificant, which suggests that climate -change concerns affect markets mainly in the short term. Panel C shows that in the short term, the moderating effect of the climate-policy index mainly reflects that the change in green preferences increases the market green returns, and that in the long term, climate policies reduce the market green returns by strengthening the pricing of carbon risk. Overall, the results using alternative data on ESG scores are close to the previous results, confirming the robustness of our findings.

**Table 12** Two-stage least squares regression

	First stage (1)	Second stage (2)
EVERAGE	0.009*** (28.95)	
ERANK	0.073*** (62.26)	
LOGGREEN		0.046*** (9.41)
BETA	0.005*** (4.12)	− 0.002*** (− 3.48)
LOGSIZE	0.076*** (155.53)	− 0.008*** (− 16.27)
BM	0.112*** (63.54)	− 0.004*** (− 3.56)
MOM	0.002 (1.46)	− 0.001 (− 1.29)
ROE	0.010*** (3.14)	− 0.002 (− 0.96)
INV	− 0.022*** (− 11.92)	0.002* (1.88)
TURNOVER	− 0.019*** (− 15.13)	− 0.021*** (− 32.92)
F-test of instruments (p-value)	1305.79 (0.00)	
Sargan overidentification test (p-value)		0.136 (0.71)
Constant	1.350*** (92.17)	− 0.244*** (− 24.53)
Year/month fixed effects	Y	Y
Observations	221,500	221,500
Adjusted R <sup>2</sup>	0.3730	0.3571

This table reports the results of a two-stage least squares regression of the excess stock returns (RET) on corporate environmental performance (LOGGREEN) and controls with robust standard errors clustered at the firm level. The sample period is March 2014 to November 2021, and the unit of observation is a month. EVERAGE is the industry average E-score for the first year in the sample. ERANK is a dummy variable that takes the value of 1 if the industry average E-score is higher than the median and 0 otherwise. All other variables are defined in Table 2. All regressions include year-month fixed effects. We use F-tests and the Sargan overidentification test to confirm the robustness of our instruments. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

### Firm-size effect

Large firms receive more attention from the market. Therefore, firm size can affect the relationship between corporate environmental performance and stock value (Cordeiro and Tewari 2015). The stocks in each year are sorted according to the market capitalization at the end of the previous year, and the stocks in the bottom 30%, middle 40%, and top 30% are recorded as small, middle, and big groups for subsample regression, respectively. The results are shown in Panel A of Table 14. Using the same approach, we divide the sample into three groups of stocks based on E-scores and observe the results of the subsample regression shown in Panel B of Table 14. We find a significant and positive relationship between corporate environmental performance and excess stock returns across different firm sizes and E-score levels.

**Table 13** Re-estimation of main regressions: alternative E-scores

	(1)	(2)		
Panel A: Environmental performance and excess returns				
LOGGREEN	0.008 (1.29)	0.002 (0.27)		
BETA	− 0.013 (− 0.61)	− 0.018 (− 0.77)		
LOGSIZE	− 0.030*** (− 4.05)	− 0.030*** (− 2.95)		
BM	− 0.044** (− 2.10)	− 0.010 (− 0.35)		
MOM	− 0.003 (− 0.10)	− 0.050 (− 1.63)		
ROE	0.000** (2.13)	0.000*** (2.98)		
INV	− 0.000* (− 1.66)	− 0.000 (− 0.96)		
TURNOVER	− 0.002 (− 0.56)	0.000 (0.04)		
Constant	− 1.363*** (− 7.31)	− 1.280*** (− 4.98)		
Control	N	Y		
Industry fixed effects	Y	Y		
Year fixed effects	Y	Y		
Observations	1877	1877		
Adjusted R <sup>2</sup>	0.3113	0.3366		
	(1)	(2)	(3)	(4)
Panel B: The moderating effect of climate-change concerns				
LOGGREEN	− 0.525* (− 1.68)	− 0.522 (− 1.45)	− 0.201 (− 0.52)	− 0.047 (− 0.10)
CONCERN	1.277*** (6.33)	1.335*** (5.87)		
L1.CONCERN			1.932*** (7.49)	2.081*** (6.78)
CONCERN*LOGGREEN	0.093* (1.71)	0.092 (1.46)		
L1.CONCERN*LOGGREEN			0.037 (0.54)	0.009 (0.10)
Constant	− 8.226*** (− 7.02)	− 8.432*** (− 6.30)	− 11.711*** (− 7.97)	− 12.439*** (− 7.04)
Control	Y	Y	Y	Y
Industry fixed effects	N	Y	N	Y
Year fixed effects	Y	Y	Y	Y
Observations	1877	1877	1877	1877
Adjusted R <sup>2</sup>	0.3120	0.3373	0.3110	0.3362
	(1)	(2)	(3)	(4)
Panel C: The moderating effect of climate policies				
LOGGREEN	− 0.033 (− 1.44)	− 0.042* (− 1.81)	0.134** (2.28)	0.150** (2.54)

**Table 13** (continued)

	(1)	(2)	(3)	(4)
POLICY	11.701*** (9.53)	12.028*** (9.36)		
L1.POLICY			− 195.909*** (− 15.01)	− 201.899*** (− 14.81)
POLICY*LOGGREEN	0.582** (2.00)	0.632** (2.13)		
L1.POLICY*LOGGREEN			− 2.206** (− 2.10)	− 2.598** (− 2.47)
Constant	− 1.965*** (− 9.32)	− 1.883*** (− 6.81)	8.849*** (13.51)	9.235*** (12.86)
Control	Y	Y	Y	Y
Industry fixed effects	N	Y	N	Y
Year fixed effects	Y	Y	Y	Y
Observations	1877	1877	1877	1877
Adjusted R <sup>2</sup>	0.3128	0.3385	0.3131	0.3393

This table reports the re-estimation results of the main regressions using alternative E-scores from Refinitiv. The sample period is 2014–2021, and the unit of observation is one year. Panel A shows the results of regressing the excess stock returns (RET) on corporate environmental performance (LOGGREEN) and the controls. Panel B shows the results of the regression tests of the moderating effect of climate-change concerns (CONCERN) on the relationship between environmental performance and excess stock returns with the controls. Panel C shows the results of the regression tests of the moderating effect of climate policy (POLICY) on the relationship between environmental performance and excess stock returns with the controls. In Panels B and C, columns (1) and (2) show the contemporaneous moderating effects of climate-change concerns or the climate-policy index, and columns (3) and (4) show the moderating effects of one-year lagged climate-change concerns or the climate-policy index. All regressions include year fixed effects, and selected columns additionally include industry fixed effects. We use robust standard errors clustered at the firm level. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively.

### Industry heterogeneity

Investors may have different environmental-responsibility fulfilment requirements for low- and high-carbon industries. We use Wind's renewable-energy stocks as representative of low-carbon industries. Furthermore, the eight sectors included in China's national carbon market are defined as high-carbon industries: petrochemicals, chemicals, building materials, steel, non-ferrous metals, papermaking, power generation, and aviation. We show how green returns vary across these two kinds of industries, and the results are presented in Table 15. There is no significant difference in the excess stock returns of renewable-energy companies with different environmental performances, and high-carbon industries have levels of green returns similar to those of the entire market. Due to the low-carbon characteristics determined by the nature of renewable-energy industries, investors are not sensitive to the difference in the environmental responsibility of new-energy companies, while they do pay more attention to the corporate environmental performance of high-carbon industries because stakeholders hope that companies in high-carbon industries will reduce their emissions.

### Green-technology innovation

In the energy-transition process, green technological innovation can increase future cash flows and reduce climate risks, which can induce investors' positive response toward green technological innovation (Srivastava et al. 1998, 2009; Ba et al. 2013). Dang and Xu (2018) found that high market sentiment could promote corporate innovation

**Table 14** Subsample analysis: market capitalization and E-score

	Small		Middle		Big	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: Grouping by market capitalization</i>						
LOGGREEN	0.005** (2.38)	0.005* (1.92)	0.007*** (4.17)	0.005*** (2.81)	0.007*** (4.11)	0.003* (1.78)
Constant	0.146*** (3.70)	0.185*** (4.57)	−0.027 (−0.94)	0.014 (0.47)	−0.246*** (−21.20)	−0.233*** (−17.02)
Control	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	N	Y	N	Y
Year/month FE	Y	Y	Y	Y	Y	Y
Observations	60,915	60,915	88,957	88,957	71,628	71,628
Adjusted R <sup>2</sup>	0.4118	0.4128	0.3866	0.3882	0.3308	0.3325
	Low		Middle		High	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel B: Grouping by E-scores</i>						
LOGGREEN	0.007*** (2.75)	0.006** (2.49)	0.014*** (6.36)	0.012*** (5.36)	0.005** (2.21)	0.003 (1.24)
Constant	−0.157*** (−8.45)	−0.125*** (−5.89)	−0.188*** (−15.15)	−0.176*** (−13.12)	−0.202*** (−17.40)	−0.176*** (−12.78)
Control	Y	Y	Y	Y	Y	Y
Industry FE	N	Y	N	Y	N	Y
Year/month FE	Y	Y	Y	Y	Y	Y
Observations	58,274	58,274	95,743	95,743	67,483	67,483
Adjusted R <sup>2</sup>	0.3515	0.3534	0.3797	0.3809	0.3490	0.3502

This table reports the subsample results from regressing the excess stock returns (RET) on corporate environmental performance (LOGGREEN) and controls with robust standard errors clustered at the firm level. The sample period is March 2014 to November 2021, and the unit of observation is a month. In Panel A, stocks are sorted by market capitalization, and the stocks in the bottom 30%, middle 40%, and top 30% are recorded as small, middle, and big groups, respectively. In Panel B, stocks are sorted by E-scores, and the stocks in the bottom 30%, middle 40%, and top 30% are recorded as low, middle, and high groups, respectively. All variables are defined in Table 2. All regressions include year-month fixed effects, and selected columns additionally include industry fixed effects. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

**Table 15** Industry heterogeneity analysis

	Low-carbon (1)	High-carbon (2)
LOGGREEN	−0.006 (−0.55)	0.007*** (3.25)
Constant	−0.157** (−2.55)	−0.157*** (−9.20)
Control	Y	Y
Year/month fixed effects	Y	Y
Observations	2786	36,489
Adjusted R <sup>2</sup>	0.4383	0.3572
Empirical p-value	−0.025**	

This table reports the results from regressing the excess stock returns (RET) on corporate environmental performance (LOGGREEN) and controls with robust standard errors clustered at the firm level in low- and high-carbon industries. The sample period is March 2014 to November 2021, and the unit of observation is a month. Columns (1) show the results for low-carbon industries, and columns (2) show the results for high-carbon industries. All variables are defined in Table 2. Both regressions include year-month fixed effects. We use seemingly unrelated estimation to test the difference in LOGGREEN coefficients between groups. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

**Table 16** Moderating effect of green technology innovation on the relationship between environmental performance and excess stock returns

	(1)	(2)
LOGGREEN	0.004** (2.49)	0.004*** (2.72)
L.PATENT	− 0.004** (− 2.15)	− 0.005** (− 2.03)
L.PATENT*LOGGREEN	0.001** (2.47)	0.001** (2.32)
Constant	− 0.132*** (− 13.40)	− 0.096*** (− 8.50)
Control	Y	Y
Industry fixed effects	N	Y
Year/month fixed effects	Y	Y
Observations	116,238	116,238
Adjusted R <sup>2</sup>	0.4609	0.4618

This table reports the results for the regression tests of the moderating effect of green technology innovation (PATENT) on the relationship between environmental performance (LOGGREEN) and excess stock returns (RET) with controls and robust standard errors clustered at the firm level. The sample period is March 2014 to October 2018, and the unit of observation is a month. PATENT is the number of green patent applications from the CSMAR database. All other variables are defined in Table 2. Both regressions include year-month fixed effects, and column (2) also includes industry fixed effects. \*, \*\*, and \*\*\* denote significance at the 10%, 5%, and 1% levels, respectively

activities. Do investors reward firms' green innovativeness in the form of higher green returns that reflect their deep concerns for climate change? We examine the economic impact of green returns on corporate green-technology innovation using data on the number of green patent applications from the CSMAR database. Table 16 indicates a positive moderating effect of green-technology innovation on the relationship between corporate environmental performance and excess stock returns. Green-technology innovation can improve corporate competitiveness in a low-carbon economy transition and reduce exposure to climate risks; thus, the market allocates higher green returns to companies with higher green-technology levels.

## Conclusion

To address the issue of climate change, a growing number of countries have pledged to achieve the goal of net-zero carbon emissions. The financial market can play an important role in the transition to a low-carbon economy, leading to the redistribution of capital between green and brown assets. This study aimed to investigate the impact of the low-carbon economy transition on China's stock market. Therefore, we examined the pricing of climate risk in China's stock market by analyzing the relationship between corporate environmental scores and excess stock returns; additionally, we explained the market pricing mechanism by analyzing the moderating effects of climate-change concerns and climate-policy stringency.

Using data on environmental scores for a sample of 3,326 Chinese listed companies between March 2014 and November 2021, we identified a positive impact of environmental performance on excess stock returns. On average, there was a 16-basis point rise in excess stock returns for each standard deviation increase in E-scores, indicating that sound environmental responsibility helped improve stock performance.

Green returns are largely due to heightened concerns about climate-change issues and investors' changing green preferences in recent years. When people are concerned about climate change, they tend to buy more stocks of companies with sound environmental performance, thus increasing the market's green returns, and investors' concerns can persistently affect their investment decisions, which is consistent with Ardia et al.'s (2020) and Pástor et al.'s (2022) findings in the US market. In addition, climate policies reduce green returns by improving the pricing of carbon risk in the long term. Climate policies, such as carbon-emissions trading and climate investment and financing, will increase carbon-intensive firms' costs of production and financing. Furthermore, investors will demand more carbon-risk compensation for stocks of companies with poor environmental performance and accept lower expected returns for stocks of those with sound environmental performance. We observe that after China's announcement of its dual carbon goals, the short-term impact of climate policies on green returns becomes more significant. Our findings about green returns differ from those regarding carbon premiums found by Bolton and Kacperczyk (2021b) in the Chinese market; however, our research on climate-change concerns and climate policies provides an avenue to reconcile the debate about the existence of a carbon premium or green returns in financial markets. We further analyze the firm-size effect, industry heterogeneity, and green-technology innovation effect. Last, our results remain robust to controlling for more variables, controlling for reverse causality, and replacing the ESG data.

Our evidence highlights, for investors, that the sound historical performance of green assets does not represent high expected returns in the future, but that corporate environmental performance can still be a useful criterion for managing climate-risk exposures. For companies, undertaking environmental responsibility has both short- and long-term benefits. When investors are deeply concerned about climate change, improving environmental performance can help increase equity value in the short term. If the government is determined to propel climate policies, companies can reduce their costs of capital through environmental-responsibility practices in the long term in any case. Our study also provides insights for policymakers. First, our evidence supports the government's promotion of climate policies, such as environmental-information disclosure and climate investing and financing, which will be helpful in strengthening the pricing of carbon risk in financial markets and reducing the costs of capital for green companies, thus facilitating the transition to a low-carbon economy more effectively. Second, our evidence suggests that policymakers should consider the market's response to climate policies, as investors price in climate-transition risks based on policy expectations. Therefore, policymakers should ensure the stability and continuity of climate policies to stabilize market participants' climate-policy expectations and thus reduce the uncertainty brought about by climate policies. Last, regulators should prohibit product managers' hyping up the expected returns of ESG products to prevent misleading advertising that could increase market uncertainty and to guide the rational development of ESG investing.

Due to the limited sample period, we did not consider the impact of the Covid-19 pandemic on the relationship between corporate environmental performance and excess stock returns. The Covid-19 pandemic has had complex and profound impacts

on climate change, such as changing the global carbon-emission path (Le Quéré et al. 2020), increasing fossil-fuel investments (Le Billon et al. 2021), and strengthening beliefs about climate change (Stefkovics and Hortay 2022). Future research can compare the relationship between corporate environmental performance and excess stock returns during the pre- and post-covid-19 pandemic periods to investigate the impact of the pandemic on climate-risk pricing. Moreover, our research can be extended to the international market. More important mechanisms of the relationship between corporate environmental performance and asset returns can be explored using a global sample. A significant difference among countries has been well documented by previous studies (e.g., Jakovljevic et al. 2020a, 2020b). Legal origin and language can influence corporate social responsibility (Liang and Renneboog 2017; Liang et al. 2018). Further discussions of country-level determinants (e.g., cross-cultural variations) that drive the divergence in the financial impacts of environmental performance among firms could be a fruitful area of study, and we would like to consider it as a potentially interesting direction for future research.

#### Abbreviations

CAPM	Capital asset pricing model
CSMAR	China Stock Market & Accounting Research
ESG	Environmental, social and governance
R&D	Research and development
US	United States

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#### Author contributions

DM: Conceptualization, Writing—Original Draft, Software, Calculation, Writing—Reviewing and Editing PZ: Conceptualization, Writing—Original Draft, Data curation DZ: Supervision, Writing—Reviewing and Editing QJ: Supervision, Writing—Reviewing and Editing, Funding acquisition.

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#### Availability of data and materials

The data that support the findings of this study are available from the authors upon reasonable request.

#### Declarations

##### Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors QJ and DZ had served as Guest Editor of *Financial Innovation* VSI: Climate-induced financial innovation: instruments and institutions, while this paper was not submitted to this VSI.

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