



Research article

Can retail investors induce corporate green innovation? -Evidence from Baidu Search Index

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ABSTRACT

China's rapid economic development has caused some environmental damage in recent years. The popularity of the Internet has enriched the ways for investors to obtain information, which would exert an impact on corporate environmental behavior. Focusing on micro-enterprise green innovation from the perspective of informal regulation, this paper investigates the impact of investor attention on corporate green innovation. This study takes Chinese A-share listed companies from 2011 to 2018 as samples, constructs panel fixed-effects models and adopts multiple linear, Logistic and Tobit regressions. This article finds that investor attention, measured by the web search index, can significantly improve corporate green innovation. The conclusion is still valid after a series of robust tests. Besides, mechanism tests reveal that investor attention can promote corporate green innovation by improving the implementation efficiency of punitive environmental regulation, the use efficiency of environmental subsidies, and by increasing the reputation cost of enterprises. In additional tests, this paper further clarifies that investors' attention to negative public opinion can play a better role in environmental governance, and reveals the reason why investors are motivated to improve corporate green innovation. This research puts forward a unique perspective, which extends the understanding of informal environmental regulation and enriches research on green innovation at the micro-enterprise level, promoting the cross research of finance and environmental protection.

1. Introduction

After 40 years of rapid economic development, China has made remarkable achievements. From 1978 to 2018, China's GDP grew from less than 0.15 trillion dollars to more than 13.89 trillion dollars, increasing nearly 92.6 times. China has become the world's second-largest economy, the largest trader in goods, and the largest manufacturing country, with a per capita GDP of more than 8,000 dollars and a contribution rate of over 30% to global economic growth. However, the rapid economic growth has come at the cost of long-term high energy consumption and high pollution. The situation of environmental quality in China is currently devastating. According to the "2018 China Environmental Bulletin" issued by the Ministry of Environmental

Protection, the proportion of prefecture-level cities with excessive air pollution in China was as high as 64.2% in 2018. Among 10,168 groundwater quality monitoring points, 86.2% of them were of poor or very poor grade. The ecological and environmental protection situation, which is still very severe, has exerted severe impacts on the lives and health of residents. Breaking the "either/or" situation between economy and environment is essential for building a socialist economy and ecological civilization with Chinese characteristics.

Unlike direct pollution control and direct environmental investment, green innovation can not only reduce environmental pollution and improve environmental performance but also enable enterprises to produce green differentiated products and stimulate new market demand (Hess et al., 2016; Kotarba, 2018; Hinterhuber and Nilles, 2021;

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Jafari-Sadeghi et al., 2021; Rezaei et al., 2021), which can effectively improve the green competitiveness of enterprises (Porter and Vanderlinde, 1995; Saunila et al., 2018; Cai et al., 2020; Quan et al., 2021). Therefore, green innovation can truly achieve the “win-win situation” between corporate economic efficiency and environmental protection (Xie et al., 2016; Huang and Li, 2017). It is an inevitable choice for listed enterprises in China to carry out green innovation activities and realize green transformation (Xie et al., 2016; Huang and Li, 2017; Saunila et al., 2018; Cai et al., 2020; Quan et al., 2021).

So far, scholars have paid more and more attention to discussing the determinants of corporate green innovation, including environmental regulation (Brunnermeier and Cohen, 2003; Acemoglu et al., 2016; Stucki et al., 2018; Borsatto and Amui, 2019; Huang et al., 2019; Petroni et al., 2019; Fan et al., 2021), bank-firm relationship (Falcone, 2018), social trust (Pan et al., 2021), stakeholders (Abbas and Sagsan, 2019; Zhang and Zhu, 2019; Chen and Liu, 2020), corporate governance (Gauthier and Genet, 2014), technological capability (Chen, 2008; Horbach, 2008; He and Jiang, 2019), etc. It can be seen that most of the existing literature focuses on the impact of formal institutional constraints generally faced by enterprises on green innovation. Redding (2005) divided the institution into formal institution and informal one. Informal environmental regulation is often seen as a powerful complement to formal environmental regulation, especially in developing countries where formal environmental regulation is generally less effective (Blackman, 2010). With the popularity of the Internet and the increasing awareness of environmental protection (Sun et al., 2016), retail investors, as dual stakeholders of enterprises and the external environment (Hu et al., 2017), can obtain and disseminate information more conveniently through the Internet (Rezaei et al., 2020) and form public opinion pressure (Dyck et al., 2008). Therefore, as an informal environmental regulation, it also plays an increasingly important role in corporate environmental governance. It is a pity that few studies have confirmed the impact of retail investors on green innovation. Assuming this effect is verified in this paper, this paper will be the first stepping stone to explore how investor attention affect corporate green innovation and clarify the internal mechanism in the context of China. So this study is of a critical theoretical value.

There has been a lot of literature on the economic consequences of formal environmental regulation from various aspects compared to informal environmental regulation. The impact on corporate financial behavior is mainly reflected in the level of corporate investment behavior (Leiter et al., 2011), involving human capital investment (Berman and Bui, 2001; Liu et al., 2017), export investment (Shi and Xu, 2018), investment region selection (Chen et al., 2018; Wu et al., 2020) and so on. Specific to corporate environmental governance, existing literature has discussed the impact of environmental regulation on pollution emissions (He and Pan, 2017; Shapiro and Walker, 2018), green investment (Liao and Shi, 2018; Falcone, 2020), green innovation, etc. In terms of informal environment regulation, many scholars have discovered the positive roles of the media (Jia et al., 2016; Tang and Tang, 2016; Dang et al., 2021), the public (Pan et al., 2021; Zhao et al., 2022), ENGOs (Tian et al., 2016; Li et al., 2018; Tu et al., 2019), etc., in corporate governance and regional environmental governance. However, little literature has discussed the impact of investor attention at the firm level. Previous studies on the economic consequences of investor attention mainly focused on the stock market (Barber and Odean, 2008; Vozlyublennaiia, 2014; Andrei and Hasler, 2015; Sun et al., 2016; Wang et al., 2021). Only Quan and Wu (2012) explored the impact of investor attention on management behavior, using turnover rate to measure investor attention. More empirical evidence is needed on the role of investor attention in corporate governance.

In recent years, Internet has developed rapidly and has become an essential medium in addition to television, radio, and newspaper. The number of Internet users in China has reached 829 million as of December 2018, according to the 43rd Statistical Report on Internet Development in China released by the China Internet Network

Information Center. Unlike the mature stock markets in Europe and America, retail investors are the primary fund providers and traders in China's stock market (Snyder and Stromberg, 2010; Chen et al., 2021). Believed to be less informed and professional (Chen et al., 2021), they tend to use the Internet to obtain stock investment information under the condition that professional investment software cannot wholly replace network search software. When investors type a stock's code, abbreviation, or full name into the search engine, it means that investors are trying to get information about the company. Therefore, the web search index can represent investors' attention to a certain company (Da et al., 2011). The convenience of online publishing and the extensiveness and rapidity of online dissemination have reduced the cost of obtaining and using information for retail investors and facilitated them to spread public opinion through the Internet (Rezaei et al., 2020). This allows retail investors to band together and put pressure on specific companies they focus on and local administrative regulators. The general rise of Internet attention can also reduce the probability of information asymmetry and increase the visibility of enterprises (Lou, 2014). As a result, reputation punishment (Dyck et al., 2008) and administrative intervention (Snyder and Stromberg, 2010) may be triggered for corporate violations. That is, to some extent, investor network attention may play the role of media coverage and publicity, supervising and restraining corporate operation and management and internalizing the externalities of corporate environmental pollution, thus, encouraging enterprises to participate in environmental governance. Based on this, this paper raises these questions: can investor promote corporate green innovation? If yes, what about the underlying mechanisms? And further, considering that investors' attention to corporate environmental issues is mostly on negative information (Nguyen, 2015), does the attention on negative public opinion have a stronger environmental governance effect? And why do these retail investors care about corporate green innovation?

In order to fill the research gap and answer the above questions, this paper utilizes a sample of publicly traded firms listed on Shanghai and Shenzhen stock exchanges in China during 2011–2018 to study the impact of investor attention on corporate green innovation by constructing panel fixed-effects models and adopting multiple linear, Logistic and Tobit regressions. The results show that investor attention, measured by the web search index, can significantly improve corporate green innovation. For each additional unit of investor attention (IA), the corporate green innovation output increases by 0.154 on average. The conclusion is still valid after a series of robust tests, such as alternative measures of key variables, changing econometric models, propensity score matching (PSM), and placebo, etc. In addition, mechanism tests reveal that investor attention can promote the green innovation level of enterprises by improving the implementation efficiency of punitive environmental regulation, the use efficiency of environmental subsidies, and increasing the reputation cost of enterprises. In additional tests, this paper further clarifies that investors' attention to negative public opinion can play a better role in environmental governance, and the reason why investors are motivated to improve corporate green innovation is that green innovation can create wealth for investors.

The contributions to the current literature are as follows. Firstly, this paper is the first to focus investor attention on corporate green behavior. Most of the existing studies on the economic consequences of investor attention focus on the stock market (Vozlyublennaiia, 2014; Peng et al., 2015; Chen et al., 2021). This article takes the lead in analyzing the functional effect of investor attention on corporate environmental governance from the perspective of corporate green innovation, which undoubtedly broadens the research on the economic consequences of investor attention. Secondly, previous studies mainly examine the impact of formal environmental regulations on green innovation (Brunnermeier and Cohen, 2003; Acemoglu et al., 2016; Stucki et al., 2018; Borsatto and Amui, 2019; Huang et al., 2019; Petroni et al., 2019; Fan et al., 2021), but relatively ignore the role of the informal institution. This paper makes up for the deficiency of relevant research and offers a new perspective for studying the antecedents of corporate green innovation. Thirdly, this

paper proposes and supports the mechanism of “punitive regulation”, “incentive regulation”, and “reputation cost”, which can help to unfold the “black box” of how investor attention promotes corporate green innovation and provide some more valuable experience and inspiration for other studies in this field. Fourthly, this paper empirically affirms that green innovation can increase corporate financial performance, providing empirical evidence for the theoretical expositions in the existing literature (Jafari-Sadeghi and Biancone, 2018; Garousi Mokhtarzadeh et al., 2020a, 2020b; Sukumar et al., 2020).

The rest of the paper is organized as follows: Section 2 briefly reviews relevant literature and develops the main hypothesis, Section 3 describes the sample and empirical design, Section 4 reports the empirical results, and Section 5 concludes.

2. Literature review

2.1. Corporate green innovation

Currently, in the context of increasingly fierce market competition, it is essential for firms to enhance their innovative capacities to obtain sustainable competitive advantage and long-term growth, and finally improve the corporate performance (Jafari-Sadeghi and Biancone, 2018; Garousi Mokhtarzadeh et al., 2020a, 2020b; Sukumar et al., 2020). Green innovation can realize the greening of the whole product life cycle and achieve a “win-win situation” between economic and environmental benefits (Xie et al., 2016; Huang and Li, 2017; Saunila et al., 2018; Cai et al., 2020; Quan et al., 2021). It can reduce the adverse impact on the environment and continuously improve the competitiveness of enterprises (Xie et al., 2016; Huang and Li, 2017; Saunila et al., 2018; Cai et al., 2020; Quan et al., 2021).

Therefore, the research on corporate green innovation has gradually become the focus of academic circles. Most of the previous literature discusses the impact on corporate green innovation from the perspective of environmental regulation, which is an exogenous policy force. However, the conclusions are not consistent. Among them, most scholars support the “Porter hypothesis” and believe that environmental regulation can promote green innovation (Brunnermeier and Cohen, 2003; Acemoglu et al., 2016; Stucki et al., 2018; Borsatto and Amui, 2019; Huang et al., 2019; Petroni et al., 2019; Fan et al., 2021). However, some scholars deny the “Porter hypothesis”, arguing that environmental regulation will hinder green innovation (Dean and Brown, 1995; Clarkson et al., 2004; Petroni et al., 2019). Some scholars believe that the “Porter hypothesis” is not necessarily valid: there is uncertainty in the relationship between environmental regulation and green innovation (Brunnermeier and Cohen, 2003). In addition, existing literature also found that bank-firm relationship (Falcone, 2018), social trust (Pan et al., 2021), stakeholders (Abbas and Sagsan, 2019; Zhang and Zhu, 2019; Chen and Liu, 2020), corporate governance (Gauthier and Genet, 2014) and technological capability (Chen, 2008; Horbach, 2008; He and Jiang, 2019) can influence enterprises’ green innovation. It can be seen that there is obviously insufficient literature on the impact of informal institutions on corporate green innovation, and there is still no literature discussing it from the perspective of investor attention.

2.2. Environmental regulation

Redding (2005) divided the institution into formal and informal institution. There has been a lot of literature on the economic consequences of formal environmental regulation from various aspects compared to informal environmental regulation. From the perspective of corporate financial behavior, environmental regulation can increase corporate investment (Leiter et al., 2011), including human capital investment (Berman and Bui, 2001; Liu et al., 2017), export investment (Shi and Xu, 2018), investment region selection (Chen et al., 2018; Wu et al., 2020) and so on. And from the perspective of corporate environmental governance, existing literature has discussed the impact of

environmental regulation on pollution emissions (He and Pan, 2017; Shapiro and Walker, 2018), green investment (Liao and Shi, 2018; Falcone, 2020), green innovation (Hattori, 2017; Cai and Li, 2018; Klemtsen et al., 2018; Ramanathan et al., 2018), etc.

In terms of informal environment regulation, many scholars have discovered the positive roles of the media (Jia et al., 2016; Tang and Tang, 2016; Dang et al., 2021), the public (Pan et al., 2021; Zhao et al., 2022), NGOs (Tian et al., 2016; Li et al., 2018; Tu et al., 2019), etc. in corporate governance and regional environmental governance. However, little literature has discussed the impact of retail investors, who are dual stakeholders of both enterprises and the external environment (Hu et al., 2017), on corporate decision-making, especially environmental protection behavior.

2.3. Investor attention

The so-called investor attention refers to the active processing of the information captured by investors under the joint action of perceptual system and reaction system (Daniel and Amos, 1973). Existing literature mainly focuses on the correlation between investor attention and asset pricing. Scholars at home and abroad have made rich and detailed discussions on this issue from theoretical and empirical perspectives (Seasholes and Wu, 2007; Barber and Odean, 2008; Barber et al., 2009a, 2009b; Foucault et al., 2011; Andrei and Hasler, 2015; Peng et al., 2015). In earlier studies, financial operations of listed companies (Graham and Kumar, 2006; Chemmanur and Yan, 2009), exchange-specific rules (Seasholes and Wu, 2007; Feng, 2017), stock turnover rate (Loh, 2010), stock trading volume (Barber and Odean, 2008), media coverage (Yuan, 2015), and other market behaviors have all been used as indicators to represent investor attention.

Recent popularisation of the network and advances in mobile communication technologies have significantly reduced the cost of information searching (Rezaei et al., 2020), and the Internet has become a significant information source in contemporary society. Investors mainly trade stocks online (especially in China), and web users often use search engines to obtain information. When an investor searches for information about a stock, there is no doubt that the investor has paid attention to the stock. As a result, the web search volume index - the number of times a particular keyword (company information/ticker symbol) is retrieved in search engines - can directly and accurately measure investors’ attention to a specific stock.

In the research about measuring investor attention, Da et al. (2011) found that the Google search index can better reflect investor attention on time, especially that of individual investors. Drake et al. (2012) also proved that Google search could reflect investors’ demand for public information. The Internet plays a pivotal role in the process of information collection. Therefore, the attention based on Internet search has already aroused intense interest in academic circles. Among them, the influence of investor attention on the securities market is still a hot issue that scholars at home and abroad pay attention to (Vozlyublennai, 2014; Chen et al., 2021).

In sharp contrast to the high focus of existing research on “how investor attention affects asset prices”, few pieces of literature explore the effect of investor attention at the micro-enterprise level. Quan and Wu (2012) used turnover rate to represent investor attention, and tested the relationship between investor attention and subjective earnings manipulation of management, and found that investor attention has “cognitive effect” and “governance effect”. However, there is limited literature investigating the influence of investor attention, indicated by the web search index, on corporate policies.

Given the deficiency of the existing literature and under the national environmental protection trend, this study strives to explore the effect and mechanism of investor attention on green innovation activities of enterprises from the perspective of corporate external informal governance mechanism. This is also of great theoretical guiding significance for forming a new pattern of environmental protection under the joint

management of the whole society by coordinating all forces in the current new development stage.

3. Theoretical basis and research hypothesis

3.1. Theoretical basis

3.1.1. Externality theory

“Externality” refers to an economic behavior of an economic entity that brings benefits to others but is not paid, or that costs others without compensation. When externalities exist, the market will be in a state of low efficiency.

Take pollution and technological innovation as an example. Environmental pollution has negative externalities, because enterprises have obtained value returns from economic activities, but the pollution discharge in the process has caused losses to the public and the ecological environment (without compensation). Technological innovation has positive externalities, because innovation achievements are easily shared by others, so it is difficult for innovation subjects to obtain all the benefits brought by technological innovation. In the absence of effective mechanism, the positive externality of technological innovation will lead to the insufficient social supply of technological innovation. As a kind of technological innovation that can reduce environmental pollution, green innovation has double externalities.

For the correction of externalities, the economic circles have mainly formed two schools of thinking: neoclassical economics and new institutional economics. Pigou proposed in his book *The Economic of Welfare* that the government should add the costs of externalities to the costs (or benefits) of those economic entities that produce externalities through pigovian taxes (fines, levies, or subsidies). However, Coase opposed this approach. In his book *The Problem of Social Cost*, he pointed out that externalities result from unclear definition of property rights. The government only needs to reasonably define property rights and guarantee their operation (such as carbon emission right trading, etc). Externality theory explains the internal reason why investor attention, as an external constraint, promotes green technology innovation.

3.1.2. Informal institution and formal institution theory

Institutions are mainly composed of formal institutions and informal institutions. Institutions constitute the incentive structure of social exchange relationship and have the function of restricting and influencing organizational behavior (North, 1981). Formal institutions include political, legal and economic rules and contracts. Informal institutions include the following three levels: (1) As the extension of formal institutions, they are unwritten constraints on the interactions among social members; (2) they are codes of conduct for people in public places; (3) They are the individual's subjective action preference, such as ideas, ideology and beliefs (Pargal and Wheeler, 1996).

The investor attention studied in this paper belongs to the first level of informal institutions. Pargal and Wheeler (1996) believe that informal environmental regulation is a supplement to the government's formal environmental regulation. And it is the efforts made by social groups to participate in environmental protection (including negotiations with polluting enterprises or governments). The formal system endows the informal system with legitimacy and effectiveness, while the informal system forms a supplement to the formal system to make it more effective. Therefore, institutional theory can explain the internal mechanism of investor attention on corporate green innovation. The analysis in this part establishes the theoretical basis for the role of external pressure in enterprises' choice of green innovation, and also constitutes one of the mechanisms of investor attention on corporate green innovation.

3.1.3. Porter Hypothesis

Porter proposed the “Porter Hypothesis”. He believes that reasonable environmental regulation can motivate enterprises to carry out technological innovation and enable enterprises to compensate the costs of

complying with the government environmental regulation with saved costs and increased profits (Porter and Vanderlinde, 1995). This hypothesis denies the long-standing research hypothesis that “environmental regulation can only increase the compliance cost of enterprises”. It affirms the incentive effect of government environmental intervention on enterprises. “Porter Hypothesis” shows in detail the internal mechanism of government environmental regulation on corporate green innovation and also constitutes one of the mechanisms of investor attention on corporate green innovation.

3.1.4. Corporate reputation theory

In the 1960s, corporate reputation theory began to take shape. On the one hand, a good reputation will form the competitive advantage of the enterprise, which will put the enterprise in a favorable position in the process of game. On the other hand, enterprises will consider the cost of reputation damage when making business decisions, so a good reputation can effectively restrain the behavior of enterprises. Fombrun and Shanley (1990) pointed out that reputation is not invariable and will change with the change of corporate behavior. Therefore, enterprises need to make continuous efforts to maintain or even strengthen the existing reputation.

As the main body of pollution, enterprises must assume environmental responsibility, convey to the outside world that they attach importance to the environment, establish and maintain the existing reputation, so as to effectively alleviate the external pressure faced by enterprises. Therefore, corporate reputation theory can provide theoretical support for the impact of investor attention on corporate green innovation. To sum up, the externality theory reveals the fundamental reason why green innovation needs to be driven by external forces, which constitutes the fundamental starting point of this paper. Informal institution and formal institution theory provides a theoretical basis for this paper to study the impact of investor attention on corporate green innovation. “Porter Hypothesis” and corporate reputation theory constitute the mechanisms of investor attention on corporate green innovation.

3.2. Research hypothesis

Green innovation can reduce environmental pollution, save energy, and realize the green and sustainable development coordinated between environmental protection and corporate competitiveness (Xie et al., 2016; Huang and Li, 2017). However, innovation activities are characterized by a long cycle, high investment, and high risk. Therefore, the intensity of corporate innovation activities depends on managers' judgment of the risks and the expected benefits of innovation (Brav et al., 2018). In the Internet era, investor attention, based on the web search index, is becoming an emerging force that can exert public influence on listed companies and play the role of external governance mechanism that cannot be ignored (Quan and Wu, 2012). Thus, this paper, referring to the existing literature, will elaborate on the promoting effect of investor attention on corporate green innovation from the following three dimensions.

Firstly, improve the implementation efficiency of punitive environmental regulation. Most Chinese studies have found that introducing administrative intervention is essential for the media to improve corporate governance. Dyck et al. (2008) pointed out that the traditional media plays the role of corporate governance mainly through the intervention of relevant administrative agencies. And under the intervention of the government or administrative agencies, media supervision can promote executive compensation to be reasonable. Under traditional media, it is difficult for regulators to determine how many people are interested in relevant events. While, in the network environment, this attention can be reflected in the number of Internet searches. As the regulatory authorities may deal with public opinion events of a particular scale, the risk of regulatory intervention would be significantly increased when the network attention to enterprises' pollution behavior rises to a certain level. Departments of local government will inevitably investigate and

punish the polluting companies for showing that the government is capable of good governance and preventing being held accountable by the central government (Snyder and Stromberg, 2010). The universality of investor attention also greatly reduces the rent-seeking space of enterprises. Moreover, investor attention may lead to the intervention of higher-level administrative agencies (Dai et al., 2015), which are more likely to improve the efficiency of local environmental regulation. Based on the “Porter hypothesis”, appropriate environmental regulation helps to “force” enterprises to undertake green innovation. By using green innovation achievements to improve the production process, enterprises can reduce their dependence on the original polluting production mode, which effectively avoids the cost of environmental supervision (Berrone et al., 2013) and helps companies to obtain “compensatory benefits” that exceed the costs (Porter and Vanderlinde, 1995). Many pieces of literature have shown that environmental regulation can induce the green innovation behavior of enterprises (Porter and Vanderlinde, 1995; Huang et al., 2019).

Secondly, improve the use efficiency of government environmental subsidies. It has been found in the literature that environmental subsidies may have a “crowding-out effect” on corporate green innovation (Auty, 1993; Brollo et al., 2013), while investor attention can improve the use efficiency of environmental subsidies (Snyder and Stromberg, 2010; Liao and Shi, 2018). The “crowding-out effect” is caused by the opportunistic behavior induced by government support, which often distorts the optimal allocation of funds. There is information asymmetry between the government and enterprises (Jensen and Meckling, 1976; Fang et al., 2014), so it is difficult for the government to directly supervise enterprises’ use of environmental subsidies. It is even difficult to determine whether enterprises are eligible for environmental subsidies (Brollo et al., 2013). In this case, management’s opportunistic motives tend to result in resources flowing into areas that bring private benefits to management rather than those that create corporate value and social benefits (Roychowdhury, 2006), thus “crowding out” corporate green innovation. While investor attention, to a certain extent, may be able to weaken this effect. As Internet access has spread, people increasingly use it to search for information of interest. The search volume records the search behavior of Internet users from all cities in China. And retail investors usually search for information about individual firms using the stock name (including abbreviations and full name) or code, as keywords (Cheng and Liu, 2018). Therefore, Internet search can fully reflect investors’ attention to enterprises. However, on the Internet, netizens are not only the receivers of information, but also the disseminators of information. Since the Internet has the advantages of convenient information release as well as rapid and extensive information transmission, in the process of information diffusion, the propagation speed increases exponentially. As a result, via the Internet, investors can adequately transmit asymmetric information (e.g. about corporate violations) to the relevant authorities (Lou, 2014; Wang et al., 2021) and arouse their attention to strengthen the initial review and follow-up supervision of these enterprises (Snyder and Stromberg, 2010), promoting their rational use of environmental subsidies, and finally enhancing corporate green innovation ability.

Thirdly, improve the reputation cost of enterprises. In network communication, the phenomenon of “group polarization” is severe (Wang et al., 2018). The propagation of a small amount of negative news about the company or its executives may lead to the rapid spread of negative investor emotions, which can cause a devastating blow to the company’s reputation (Dyck et al., 2008; Wu et al., 2020). Negative information on the Internet often has a more severe impact on the reputation of companies and their executives than positive information (Nguyen, 2015). It may take a long time to build a positive reputation, but only one or two pieces of negative news are enough to destroy it. And the negative reputational impact of the Internet is hard to eliminate; even after things calm down, people can still search for these negative comments on the Internet. When investors begin to pay attention to the environmental protection information of listed companies, if an

environmental pollution accident happens to an enterprise, not only will it seriously damage the image and reputation of the enterprise, but the capital market will also make a negative response to the enterprise quickly.

Moreover, major environmental accidents are usually accompanied by fines, compensation, litigation, etc., which all would affect investors’ expectations of the enterprises’ future earnings for a long time after the accidents and then negatively impact the firm value (Konar and Cohen, 1997). More and more enterprises are aware that the most severe consequence of being sued for violating environmental protection standards is the loss of reputation, which would reduce corporate profitability (Dyck et al., 2008; Wu et al., 2020). The threat of such losses is more than simple legal costs or expected penalties. To stabilize the market position, enterprises will strive to meet the demands of sustainable development put forward by stakeholders. Responsible enterprises tend to focus on the advantages of green innovation in environmental protection and increase the intensity of green technology innovation (Hou et al., 2020).

Given the above analysis, researchers propose the following hypothesis:

H1. Investor attention can improve corporate green innovation level.

4. Empirical design

4.1. Sample construction and data source

This paper focuses on A-share companies listed on Shanghai and Shenzhen Exchanges over the period of 2011–2018 to investigate the impact of investor attention, indicated by the Internet search index, on corporate green innovation. Researchers collect green patent information from the State Patent and Property Office (SIPO) and obtain the web search index from the China research data service platform (CNRDS). Researchers started the sample period from 2011 because Internet search index information was not available before. Other financial data are from the CSMAR database and CNRDS database. According to the existing literature, the initial samples are processed as follows: (1) exclude financial firms; (2) eliminate ST and *ST firms; (3) remove samples with missing values, and abnormal data (such as those with an asset-liability ratio greater than 1). All related continuous variables are winsorized at 1st and 99th percentiles to minimize the effects of potential outliers. After the above screening process, the final sample contains 19,385 firm-year observations.

4.2. Variable construction and description

4.2.1. Explained variable (corporate green innovation)

Referring to Fang et al. (2014), the number of green patent applications is used to measure the green innovation level of the enterprise. Considering the time lapse between the research and development (R&D) and obtaining the patent output, the natural logarithm of 1 plus the number of the green patent applications in the next year is used to measure the green innovation behavior. Previous research mainly measures corporate innovative behavior by investment in R&D or the number of patents. The reasons for this paper choosing the number of patents are as follows: Firstly, R&D input only represents the innovation resource invested by the enterprise but cannot directly reflect the output results. By contrast, the number of patent applications can directly reflect the achievement and performance of the enterprise’s innovation activities (Du et al., 2019). Secondly, the chances are that the information is lost because the input in R&D is disclosed by enterprises voluntarily. No input in R&D disclosed does not necessarily mean that no innovation activities are going on. However, the information of the number of patents is always complete, which can accurately reflect the innovation level of the enterprise (Fang et al., 2014).

Referring to the practice of Amore and Bennesen (2016), researchers first manually search for the information of the corporate patent

application, authorization and IPC classification number from the search page of SIPO. Then match the firm-level patent types retrieved from SIPO with the green patent IPC classification number in the “International Patent Green Classification List” launched by the World Intellectual Property Organization (WIPO) in 2010. And further, distinguish between green invention patents and green utility model patents. Finally, researchers obtain the number of green patents applied and granted by firms every year. This paper eliminates the appearance design patents with a low innovation level by drawing on previous research approaches and uses the natural logarithm of the total number of green invention patents and green utility model patents added by 1 (Gpatent) to construct the proxy indicator of corporate green innovation. Researchers also use green granted patents to measure green innovation in the robustness tests.

4.2.2. Explanatory variables (investor attention)

Referring to the research of Da et al. (2011) and Drake et al. (2012), this paper uses the web search index to measure investor attention. Researchers do not use the Google Search Index commonly used in the international literature (Ettredge et al., 2005; Da et al., 2011; Drake et al., 2012); instead, they adopt the Baidu Index to measure investor attention. This is mainly because: firstly, Google's development in China has not been very smooth. Since Google withdrew from mainland China in April 2010, the public rarely used Google (Du et al., 2019). Secondly, Baidu's market share is much bigger than Google's in terms of Chinese search. Baidu search is the world's leading Chinese search engine, accounting for more than 70% of China's search engine market share. It responds to billions of search requests from more than 100 countries and regions every day, and is the main entry point for netizens to obtain Chinese information. Originally developed on the basis of Google, Baidu has now shaken off the shadow of Google through years of efforts, and the search service experience it provides has won the love of the majority of users.

Researchers argue that Baidu Index can depict investors' information acquisition behavior. Baidu index is based on the search volume of Internet users in Baidu, taking keywords as the statistical object, scientifically analyzing and calculating the weighted sum of each keyword's search frequency in Baidu web search (Du et al., 2019). Searches for individual firms may use the stock number or code, including abbreviations and full names as keywords. And the main purpose of network users to input stock abbreviations in Baidu is to obtain information related to the individual stock. Therefore, Baidu Index is an explicit index to describe investors' interest in a certain company.

Researchers admit that the Baidu index may be affected by other factors. Still, in any case, the index comes from the search results of investors, so it objectively records the information acquisition behavior of investors about the companies they follow. Specifically, researchers obtain the total search value from the Chinese listed companies web search volume index (WSVI) database in the CNRDS database, which takes stock code, company abbreviation, and complete company names as keywords. This index is a comprehensive search index calculated based on various Internet search data on the Baidu platform. It can reflect netizen sentiment and corporate search popularity, which is a key indicator to measure the attention to listed companies. This study takes the natural logarithm of the index as the explanatory variable. Researchers also use the natural logarithm of the search value with stock code as a keyword to represent investor attention in the robustness tests.

4.2.3. Control variables

Following He and Tian (2013), Fang et al. (2014), and other previous literature, this paper includes the following control variables: firm size (Size), return on assets (ROA), leverage ratio (Lev), free cash flow (CF), R&D Intensity (R&D), financial distress (Loss), ownership of the largest shareholder (Tophold), the proportion of independent directors (Indep), CEO duality (Dual), institutional ownership (Inshold), analyst coverage

(Analyst), media coverage (Media), firm Age (Age), and the Herfindahl-Hirschman Index (HHI). See Appendix 1 for the definition and measurement of specific variables.

4.3. Empirical method

Firstly, this paper uses multiple linear regression analysis to investigate the impact of investor attention on corporate green innovation, which allows researchers to control many other factors that may simultaneously affect the explained variable.

Secondly, based on the hypothesis proposed above, this paper examines three mechanisms to explore the underlying mechanisms by which investor attention affects corporate green innovation.

In robustness tests, in order to solve endogeneity problems such as missing variables as much as possible, researchers use alternative measures of investor attention and green innovation, change econometric models and employ propensity score matching (PSM) method and placebo test. Since the distribution of the dependent variable (green innovation) piles up at zero and is roughly continuously distributed on positive values, the Tobit model is adopted for this situation.

Finally, in additional analysis, this article further investigates the impact of investor attention caused by negative public opinion on firms and the economic consequence of corporate green innovation.

4.3.1. Model selection

Multiple regression is a model to study the regression relationship among various variables, that is, one variable is taken as the dependent variable, and the other variables are taken as the independent variables for regression analysis. The relationship between variables can be linear or nonlinear. In the linear variable relationship, the multiple regression model is a system of linear equations. While in the nonlinear variable relationship, the multiple regression model can be exponential, power, or logarithmic functions.

According to He and Tian (2013), Fang et al. (2014) and other existing literature, this paper first uses a multiple linear regression model for the main test. Since the data used in this paper are panel data, the Hausman test is used to determine whether to use a random-effects model or a fixed-effects model for estimation (Fageda, 2014). The results of the Hausman test are shown in Table 1. It can be seen from the results that the statistic of the Hausman test is 627.98, and the concomitant probability is 0, which means the null hypothesis is rejected at the 1% level of significance, and the fixed-effect model can be selected for model estimation.

4.3.2. Model construction

Then, the following model is built to examine the impact of investor attention on corporate green innovation.

$$Gpatent_{i,t+1} = \beta_0 + \beta_1 IA_{i,t} + \beta_2 Controls_{i,t} + Year_{FE} + Ind_{FE} + Prov_{FE} + \varepsilon_{i,t} \quad (1)$$

The dependent variable is corporate green innovation ($Gpatent_{i,t+1}$), which is the sum of the number of green invention patent applications and green utility model patent applications plus 1, and then takes the natural logarithm. Considering there is a time lag between the R&D input and the patent output, this paper utilizes the patent applications in $t+1$ year to measure the green innovation activities of the company i in year t . The main independent variable investor attention ($IA_{i,t}$) is the natural logarithm of total search value with the keywords of stock code, company abbreviation, and company's full name. $Controls_{i,t}$ is a group of control variables representing the characteristics of companies and industries. As there may be omitting variables at the provincial level (e.g., regional environmental policy), which can also affect corporate green innovation, this paper includes province fixed effects in the regressions besides year and industry fixed effects. At the same time, to solve the heteroscedasticity of residuals and time-series correlation problems,

Table 1. Hausman test.

	(b) FE1	(B) RE1	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
IA	-0.001	0.034	-0.035	0.007
Size	0.275	0.360	-0.085	0.009
ROA	0.260	-0.035	0.295	0.033
Lev	-0.082	-0.044	-0.038	0.028
CF	-0.154	-0.127	-0.027	0.026
R&D	4.483	8.535	-4.052	0.231
Loss	-0.069	-0.088	0.019	0.008
Tophold	-0.149	-0.395	0.246	0.067
Indep	0.092	0.264	-0.172	0.071
Dual	-0.051	-0.051	-0.001	0.008
Inshold	-0.222	-0.155	-0.067	0.030
Analyst	0.045	0.052	-0.007	0.003
Media	-0.004	-0.013	0.009	0.003
Age	0.502	0.150	0.353	0.019
HHI	-0.047	-0.331	0.285	0.066
Test: Ho: difference in coefficients not systematic				
chi2(16) = (b-B)' [(V_b - V_B) ⁻¹](b-B)				
= 627.98				
Prob > chi2 = 0.0000				

This table reports the results of Hausman test. The statistic of the Hausman test is 627.98 and the concomitant probability is 0, which means the null hypothesis is rejected at the 1% level of significance and the fixed-effect model can be selected for model estimation.

researchers use heteroscedasticity-robust standard errors clustered at the firm level. Researchers predict β1 to be positive and statistically significant, as stated in the above hypothesis.

5. Results

5.1. Summary statistics

Panel A of Table 2 reports the descriptive statistics of the above variables used in this analysis. The number of observations, mean, standard deviation, 5th percentile, 25th percentile, median, 75th percentile, and 95th percentile are shown in the table. The average green innovation level (Gpatent) of A-share listed enterprises in China is 0.950, and the median is 0. More than half of the listed companies have no green innovation output in the sample period, indicating that A-share listed companies' overall green innovation level in China is low. The average of investor attention (IA) is 12.824, and the median is 12.751. The descriptive statistics of the remaining control variables are consistent with the existing studies (He and Tian, 2013; Fang et al., 2014). According to the annual median of investor attention, this paper further divides the sample firms into the high investor attention and low investor attention groups. The results in panel B of Table 2 show that the average value of Gpatent in the group with low investor attention is 0.715, while the average value of Gpatent in the group with high investor attention is 1.184. The difference between the two groups is significant at the level of 1%, indicating that firms with more investor attention tend to apply for more green patents than those with less investor attention. This preliminarily supports H1 that investor attention can promote enterprises to carry out more green innovation activities.

5.2. Baseline findings

Table 3 reports the results for the baseline model. The impact of investor attention on green innovation. Column (1) shows the result of univariate regression, and column (2) includes firm and industry control variables. As seen from columns (1) and (2), IA has a positive and

statistically significant impact on corporate green innovation at the 1% level, indicating that investor attention can magnificently promote corporate green innovation. This effect is economically significant as well. For example, in column (2), each unit increase in investor attention (IA) is associated with an average increase of 0.154 in a firm's green innovation output. Given that the average level of green innovation is 0.944, an increase of 0.154 represents a 16.3% improvement in innovation, which is of magnificent economic significance. In a word, the results in Table 3 support the hypothesis that investor attention can significantly improve green innovation.

In terms of control variables, Size, Lev, R&D, Inshold, Analyst and HHI are all significantly positively correlated with Gpatent, implying that the larger the firm scale is, the higher the leverage and the R&D intensity is, the more the institutional ownership and analyst coverage is and the bigger the HHI is, then the stronger the green innovation capability of the enterprise is. On the other hand, Loss is significantly negatively related to Gpatent, indicating that the more serious the loss is, the lower the green innovation level is. Most of the above conclusions are in line with this paper's theoretical expectations.

5.3. Potential mechanisms

The above results show that investor attention can significantly improve green innovation, then what is the influence mechanism behind it? This paper attempts to put forward and examine the impact paths from the following three aspects.

5.3.1. Punitive regulation mechanism

As theoretically analyzed above, when the retail investors' attention to corporate pollution behavior increases to a certain extent in the network environment, it would easily trigger the intervention of regulatory authorities or even higher-level administrative agencies (Dai et al., 2015). It would significantly improve the enforcement of formal environmental regulation and thus promote corporate green innovation (Porter and Vanderlinde, 1995; Huang et al., 2019). If this mechanism holds, researchers will observe that investor attention significantly enhances the positive impact of environmental regulation on corporate green innovation.

Environmental regulation refers to all the laws, policies, measures, and implementation processes adopted by the state to regulate economic activities to protect the environment. According to the ways and means of regulation, environmental regulation can be divided into three types: order control environmental regulation, market incentive environmental regulation, and voluntary environmental regulation. The order control environmental regulation refers to the laws, regulations, policies, and systems formulated by the legislative or administrative departments that directly affect the environmental protection choices of those polluters. Market incentive environmental regulation refers to systems designed by the government using market mechanisms. It aims to guide corporate emission behavior with the help of market signals, encourage polluters to reduce their emission level, or control and optimize the overall pollution situation of the society. Voluntary environmental regulation refers to the agreements, commitments, or plans proposed by industry associations, enterprises themselves, or other subjects. It aims to protect the environment, which enterprises can choose to participate in or not.

In this part, researchers believe that investor attention affects the green innovation of enterprises through leading to the intervention of administrative agencies (Dai et al., 2015). Therefore, this study focuses on the order control type of environmental regulation, also known as the punishment type. Based on the studies of Levinson (1996), researchers use the amount of environmental administrative legislation issued by local government and the ratio of revenue from sewage fee to gross industrial output value to proxy the punitive environmental regulation. Researchers collect the above data from the China Environment Yearbook of each province over the years and further sort them out by hand. And then researchers match the provincial-level data with the firm-level

Table 2. Summary statistics.

Panel A Summary statistics of the full sample								
Variable	N	Mean	Std	P5	P25	Median	P75	P95
Gpatent	16,445	0.950	1.263	0.000	0.000	0.000	1.609	3.584
IA	16,445	12.824	0.653	11.891	12.356	12.751	13.215	13.995
Size	16,445	22.230	1.315	20.378	21.304	22.070	23.002	24.706
ROA	16,445	0.039	0.058	-0.040	0.015	0.036	0.065	0.124
Lev	16,445	0.440	0.215	0.106	0.269	0.434	0.600	0.797
CF	16,445	0.041	0.072	-0.079	0.003	0.041	0.083	0.159
R&D	16,445	0.019	0.023	0.000	0.000	0.014	0.029	0.063
Loss	16,445	0.018	0.133	0.000	0.000	0.000	0.000	0.000
Tophold	16,445	0.350	0.151	0.137	0.230	0.331	0.452	0.625
Indep	16,445	0.374	0.054	0.333	0.333	0.333	0.429	0.500
Dual	16,445	0.735	0.441	0.000	0.000	1.000	1.000	1.000
Inshold	16,445	0.068	0.070	0.000	0.014	0.047	0.101	0.212
Analyst	16,445	1.744	1.057	0.000	0.693	1.792	2.565	3.367
Media	16,445	4.587	1.205	1.946	4.078	4.796	5.380	6.138
Age	16,445	2.248	0.688	0.969	1.738	2.349	2.858	3.116
HHI	16,445	0.065	0.097	0.009	0.016	0.017	0.072	0.320

Panel B Summary statistics grouped by the median of investor attention			
Variables	Low investor attention	High investor attention	T test
Gpatent	0.715	1.184	0.469***
Size	21.676	22.785	1.109***
ROA	0.039	0.038	-0.001
Lev	0.394	0.486	0.091***
CF	0.038	0.044	0.006***
R&D	0.020	0.018	-0.002***
Loss	0.015	0.021	0.006***
Tophold	0.351	0.349	-0.001
Indep	0.373	0.374	0.001
Dual	0.699	0.772	0.073***
Inshold	0.064	0.072	0.009***
Analyst	1.555	1.933	0.377***
Media	4.205	4.969	0.764***
Age	2.059	2.437	0.378***
HHI	0.061	0.068	0.007***
N	8,222	8,223	—

Panel A reports the summary statistics of the variables.

Panel B reports the results of mean difference test. We split the sample based on the annual median of investor attention. The column “T test” reports the mean differences of variables between low investor attention and high investor attention.

data by year using the provinces where the companies are registered. Two dummy variables are introduced: *Env_std* and *Env_tax*. If the number of environmental administrative legislation issued by a region in a given year is greater than the sample median, *Env_std* is assigned to 1; otherwise, *Env_std* is assigned to 0. If the ratio of pollution fee income to total industrial output value in a district of a given year is greater than the sample median, *Env_tax* is assigned to 1; otherwise, *Env_tax* is assigned to 0. As can be seen from column (1) and (2) of Table 4, the coefficients of $Env_std \times IA$ and $Env_tax \times IA$ are both significantly positive, demonstrating that given the degree of regional environmental regulation, the higher the investor attention enterprises receive, the considerably higher the average number of green patents applied for in the future will be. That is to say, investor attention enhances the “reversed transmission” effect of environmental regulation on corporate green innovation and proves that investor attention can positively promote environmental regulation and induce more green innovation activities.

5.3.2. Incentive regulation mechanism

From the perspective of government incentive effect, investors' extensive attention can transfer asymmetric information to relevant

departments, prompting them to strengthen the qualification review of those enterprises applying for environmental subsidies and enhance the supervision on their subsequent use. This can ultimately promote enterprises' rational use of environmental subsidies and enhance their green innovation ability.

Therefore, this paper examines the impact of investor attention on the use efficiency of environmental subsidies, that is, whether investor attention can positively affect the relationship between environmental subsidies and corporate green innovation. Considering that the environmental innovation subsidies in environmental subsidies are clearly used to support corporate environmental R&D and innovation, this study further subdivides the environmental subsidies to investigate the impact of investor attention on the efficiency of environmental innovation subsidies. Researchers sort out the environmental subsidies by hand from the detailed subject of “government subsidies” in the notes to the financial statements of listed companies and define the subsidies directly applied to environmental R&D and innovation as environmental innovation subsidies. Then, referring to the practice of previous studies, this paper standardizes the environmental subsidies and environmental innovation subsidies with total revenue, which are recorded as *Env_sub*

Table 3. The impact of Investor attention on corporate green innovation.

Dep var.=	Gpatent _{t+1}	
	(1)	(2)
IA	0.566*** (15.812)	0.154*** (4.660)
Size		0.320*** (15.568)
ROA		0.271 (1.304)
Lev		0.382*** (4.629)
CF		-0.591*** (-3.794)
R&D		10.258*** (12.285)
Loss		-0.158*** (-2.900)
Tophold		-0.081 (-0.711)
Indep		-0.066 (-0.240)
Dual		0.026 (0.812)
Inshold		0.366* (1.799)
Analyst		0.035** (2.213)
Media		0.014 (1.047)
Age		-0.019 (-0.703)
HHI		0.477** (2.050)
Constant	-6.305*** (-13.924)	-8.581*** (-17.183)
Year F.E.	Yes	Yes
Industry F.E.	Yes	Yes
Province F.E.	Yes	Yes
N	16445	16445
Adj. R ²	0.291	0.385

Column (1) shows the result of univariate regression, and column (2) includes firm and industry control variables. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

and Env_innovsub, respectively. The results in Table 5 show that both the regression coefficient of Env_sub × IA and that of Env_innovsub × IA are significantly positive at the level of 5%, which indicates that when enterprises get the same environmental subsidies (environmental innovation subsidies), compared with other firms, the firms that receive more attention from investors will have a higher level of green innovation in the next year, that is, investor attention effectively improves the incentive effect of environmental subsidies and then exerts a positive impact on corporate green innovation activities. What's more, as can be seen from Table 5, the coefficient of Env_sub is significantly negative at the level of 5%. While only the coefficient of Env_sub cannot accurately represent the relationship between environmental subsidies and green innovation. The coefficient of Env_sub × IA should also be taken into

Table 4. Punitive regulation mechanism.

Dep var.=	Gpatent _{t+1}	
	(1)	(2)
IA	0.070* (1.746)	0.122*** (2.888)
Env_stdd × IA	0.176*** (3.649)	
Env_stdd	-2.138*** (-3.488)	
Env_tax × IA		0.098** (2.048)
Env_tax		-1.217** (-1.987)
Constant	-7.695*** (-13.622)	-7.590*** (-12.378)
Controls	Yes	Yes
Year F.E.	Yes	Yes
Industry F.E.	Yes	Yes
Province F.E.	Yes	Yes
N	16107	16033
Adj. R ²	0.387	0.366

This table reports the results of punitive regulation mechanism tests. Env_stdd takes the value of 1 if the number of environmental administrative regulations issued by the region in the given year is greater than the median of the sample, and 0 otherwise. Env_tax takes the value of 1 if the ratio of the pollution fee income to the total industrial output value in the current year of a district is greater than the median of the sample, and 0 otherwise. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

account. Therefore, taking the mean of IA, the marginal effect of Env_sub on Gpatent_{t+1} can be calculated as 0.002 (0.004*12.824-0.049), which demonstrates that environmental subsidies actually have a positive impact on green innovation.

5.3.3. Reputation cost mechanism

From the perspective of corporate reputation cost, investors' attention on corporate environmental issues mainly focuses on the negative news, and investor attention is characterized by universality and dissemination, which can significantly broaden the range of target audience and enhance the influence of the companies' pollution incidents. Thus, this attention can easily lead to the decline of corporate reputation, which would induce the punishment mechanism of the capital market, shake investors' confidence in the enterprise and its products, and finally lead to a long-term seriously negative impact on the firm value (Dyck et al., 2008; Wu et al., 2020). In order to prevent a sharp drop in stock prices in the capital market or avoid greater pressure from public opinion, responsible enterprises that attach importance to long-term corporate reputation among stakeholders will focus on long-term competitive advantage and increase the intensity of green technology innovation (Hou et al., 2020). Researchers in this paper argue that the reputational costs of corporate environmental violations are higher in regions with higher public awareness of environmental protection. The public who have higher demands for environmental protection tend to pay closer attention to corporate environmental problems and resist the enterprises that cause pollution accidents more strongly. In addition, enterprises with higher social responsibility scores have higher reputation costs caused by environmental pollution accidents. Based on the stakeholder theory, enterprises tend to perform corporate social responsibility for

Table 5. Incentive regulation mechanism.

Dep var.=	Gpatent _{t+1}	
	(1)	(2)
IA	0.151*** (4.573)	0.152*** (4.650)
Env_sub × IA	0.004** (2.449)	
Env_sub	-0.049** (-2.406)	
Env_innovsub × IA		0.018** (1.964)
Env_innovsub		0.079 (1.334)
Constant	-8.564*** (-17.127)	-8.687*** (-17.520)
Controls	Yes	Yes
Year F.E.	Yes	Yes
Industry F.E.	Yes	Yes
Province F.E.	Yes	Yes
N	16439	16439
Adj. R ²	0.385	0.394

This table reports the results of incentive regulation mechanism tests. Env_sub refers to environmental protection subsidies standardized with total revenue. Env_innovsub refers to environmental protection innovation subsidies standardized with total revenue. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

image building and reputation maintenance. Such enterprises usually attach more importance to their reputation. Thus, environmental pollution incidents would cause a more massive contrast in their firm image and significantly negatively impact corporate stakeholders.

Therefore, this study examines whether public awareness of environmental protection in different regions and corporate social responsibility scores can affect the promotion effect of investor attention on green innovation to test whether the reputation cost mechanism is established.

This paper uses the enthusiasm of public participation in environmental protection in the World Values Survey (WVS) as a proxy variable for public environmental protection awareness. WVS is a world survey funded by the world bank and implemented by the University of Michigan. The Chinese Mainland Research Center is responsible for implementing the Chinese component of the survey. The sampling method has the characteristics of multiple stages and probability proportional to population size. The target group covers adults aged between 18 and 75 in 31 provinces, municipalities, and autonomous regions in the Chinese mainland. The survey sample is reasonably constituted in terms of regional scope, income distribution, age structure, gender, and other aspects, which is highly representative. According to this paper's sample period and data availability, researchers select the survey data of the Sixth Wave (2010–2014) in China for empirical analysis. The question closely related to the public awareness of environmental protection is “Are you an active member of an environmental protection organization?”. The respondents can choose how actively they participate in environmental protection from 0 to 2, 0 for non-members, 1 for non-active members, 2 for active members. The higher the scores are, the more actively the respondents participate in environmental protection. In order to measure the public awareness of environmental protection in each region, this research takes the annual average of the scores by

Table 6. Reputation cost mechanism.

Dep var.=	Gpatent _{t+1}	
	(1)	(2)
IA	0.085* (1.833)	-0.054 (-0.496)
Env_awa × IA	0.217*** (3.432)	
Env_awa	-2.592*** (-3.221)	
CSR × IA		0.013** (2.155)
CSR		-0.146* (-1.895)
Constant	-6.076*** (-9.625)	-7.763*** (-4.822)
Controls	Yes	Yes
Year F.E.	Yes	Yes
Industry F.E.	Yes	Yes
Province F.E.	Yes	Yes
N	7882	4718
Adj. R ²	0.322	0.536

This table reports the results of reputation cost mechanism tests. Env_awa represents public environmental awareness and takes the value of 1 if the respondents' rating of the question “Are you an active member of an environmental protection organization?” in WVS in a given province is greater than the sample median, and 0 otherwise. CSR equals to the corporate social responsibility scores from Hexun divided by 100. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

province, and further divides the public environmental protection awareness of the province where the enterprise is registered into the higher group and lower group according to the sample median. Researchers then match the provincial-level data with the firm-level data by year using the provinces where the companies are registered. A dummy variable, Env_awa, is introduced, with values of 1 and 0 assigned to the high and low groups, respectively.

The corporate social responsibility (CSR) scores are derived from Hexun, who scores the social responsibility report of listed companies. This evaluation system examines the disclosure and performance of corporate social responsibility from five aspects: shareholder responsibility, employee responsibility, supplier, customer and consumer responsibility, environmental responsibility, and social responsibility. The higher the CSR scores are, the stronger the CSR awareness and the better the CSR performance is. In order to enhance the readability of this paper, researchers divide the CSR scores by 100 and record them as CSR.

According to the results in Table 6, both of the coefficients of Env_awa × IA and CSR × IA are significantly positive, implying that if companies pay more attention to their reputation—the reputation cost caused by adverse events is higher. Then investor attention will play a more significant role in promoting corporate green innovation, confirming that investor attention can greatly improve the reputation cost of enterprises and then promote firms to carry out green innovation activities actively. Besides, as shown from Table 6, both of the coefficients of Env_awa and CSR are significantly negative. While only the coefficient of the single variable (Env_awa/CSR) cannot accurately show its influence on green innovation. The coefficient of the cross-product term (Env_awa × IA/CSR × IA) should also be considered. Therefore, taking the mean of IA, the marginal effect of Env_awa/CSR on Gpatent_{t+1} can be calculated as

Table 7. Alternative measures of green innovation.

Dep var.=	Gpatent_uti _{t+1}	Gpatent_inv _{t+1}	Gpatent _{t+2}	Gpatent_grt _{t+1}	Gpatent_cit _{t+1}
	(1)	(2)	(3)	(4)	(5)
IA	0.072*** (2.675)	0.174*** (5.983)	0.159*** (4.702)	0.096*** (3.363)	0.206*** (6.438)
Constant	-6.016*** (-13.848)	-7.829*** (-16.812)	-8.706*** (-16.995)	-7.055*** (-15.374)	-8.063*** (-14.522)
Controls	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes
Province F.E.	Yes	Yes	Yes	Yes	Yes
N	16445	16445	16445	16445	16445
Adj. R ²	0.345	0.345	0.370	0.359	0.271

This table reports the results from the regressions with alternative measures of green innovation. Gpatent_uti_{t+1} is the natural logarithm of 1 plus the number of green utility model patent applications. Gpatent_inv_{t+1} is the natural logarithm of 1 plus the number of green invention patent applications. Gpatent_{t+2} is the natural logarithm of 1 plus the number of green patent applications in year t+2. Gpatent_grt_{t+1} is the natural logarithm of 1 plus the number of green patents granted (green utility model patent and green invention patent). Gpatent_cit_{t+1} is the natural logarithm of 1 plus the number of green patent citations which are within 5 years after the beginning of the patent application period. IA is the natural logarithm of 1 plus annual web search index of firms. All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

0.191 (0.217*12.824–2.592) and 0.021 (0.013*12.824–0.146), which demonstrates that both public environmental protection awareness and CSR actually have a positive effect on green innovation.

5.4. Robustness tests

The robustness tests are carried out to ensure the reliability of the conclusions from the following aspects.

5.4.1. Alternative measures of green innovation

Firstly, distinguish the types of green patents. A considerable number of enterprises carry out innovation activities not to improve competitiveness, create differentiated products or promote a change in production methods, but simply as a “strategic” activity, pursuing the quantity of innovation one-sidedly instead of focusing on the quality of innovation. Compared with invention patents, utility novel patents have lower technical levels and are easier to learn and imitate. Moreover, many studies have shown that only invention patent is the actual embodiment of corporate innovation strength (He and Tian, 2013). Therefore, researchers further divide the green innovation patents into green invention patents and green utility model patents and use model (1) to re-test. It can be seen from columns (1) and (2) of Table 7 that investor attention (IA) and corporate green innovation (Gpatent) are correlated positively and significantly as before; the above results are consistent with the conclusions of this paper.

Secondly, change the measurement period of green innovation. Given that it takes some time for enterprises to form green innovation achievements, this study extends the measurement period of green innovation, using the green innovation (Gpatent) in the year t+2 to measure the level of corporate green innovation and carry out the regression again. The result in column (3) of Table 7 shows that investor attention (IA) has a significantly positive impact on corporate green innovation (Gpatent), which is consistent with the conclusion of this paper.

Thirdly, considering that the amount of patent granted and cited can more directly measure the corporate innovation level, this paper further takes the natural logarithm of 1 plus the number of green patents granted in the next year to re-measure corporate green innovation. As for the number of cited patents applied by enterprises, there may be problems if the number of cited patents is directly adopted. For example, the patents applied in 2000 may be cited by other patents longer than those applied in 2008. Therefore, referring to the practice of Akcigit et al. (2016), this

paper only counts the number of patent citations which are within 5 years after the beginning of the patent application period. Then, the main regression analysis is performed again. Columns (4) and (5) of Table 7 show that there is still a positive and statistically significant relationship between investor attention (IA) and corporate green innovation (Gpatent), which does not change the main conclusion of this paper.

5.4.2. Alternative measures of investor attention

Firstly, it may be sometimes misleading to compare the search volume among stocks in absolute numbers. Referring to previous literature, this paper adopts the relative number processing method dividing the annual search volume of sample firms by the annual average search volume within the sample period to construct the network search intensity (SI) index. Secondly, the search volume may rely on firm characteristics that correlate with corporate green innovation. For instance, it is natural to argue that larger firms are owned by more individuals, so their firm names or stock codes are more frequently searched. Meanwhile, larger firms can afford more green innovation expenditures and achieve more green innovation patents. This paper regresses the search volume on a set of firm characteristics included in the baseline model to address this concern. It uses the residuals (Ehat) as the proxy of investor attention. Thirdly, this paper uses the search value with the stock code as the keyword and takes the natural logarithm as another measure of investor attention (IA_code). Fourthly, in order to measure investor attention about environmental pollution more accurately, referring to Zheng et al. (2012), this paper uses Baidu search index to construct the public environmental concern index (EA) by year and city with the keyword “environmental pollution”. Fifthly, drawing on Huang et al. (2016), this study takes Oriental Fortune, the most visited and influential online stock forum in China's stock market, as the object to measure investors' online attention (Post). Researchers take the natural logarithm of 1 plus the total amount of forum posts of each company in each year. In addition, investors are publishers of information on social networking platforms and are involved in interactive behaviors such as receiving and exchanging information. The more views or comments a post gets, the more attention it attracts and the greater its market influence is. Therefore, this paper further uses the logarithm of the page views (Read) and the number of comments (Comment) on the posts to measure the intensity of investor attention. Sixthly, “Shenzhen Interactive Exchange” and “Shanghai E Interactive” platforms are launched by the Shenzhen and Shanghai stock exchanges respectively for direct interaction between investors and listed companies. Investors can directly ask questions to listed companies, and

Table 8. Alternative measures of investor attention.

Dep var.=	Gpatent _{t+1}							
	SI	Ehat	IA_code	EA	Post	Read	Comment	Qnumb
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IA	0.129*** (4.923)	0.085** (2.499)	0.235*** (6.338)	0.089*** (3.923)	0.109*** (5.799)	0.140*** (7.550)	0.088*** (5.944)	0.035*** (2.907)
Constant	-6.639*** (-15.561)	-8.353*** (-17.648)	-9.223*** (-17.326)	-7.933*** (-17.739)	-7.922*** (-18.090)	-9.048*** (-18.380)	-7.830*** (-18.060)	-7.930*** (-17.846)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	16445	14348	16445	16089	16445	16445	16445	15648
Adj. R ²	0.387	0.393	0.386	0.384	0.385	0.386	0.385	0.381

This table reports the results from the regressions with alternative measures of investor attention. SI is the ratio of the annual search volume of sample firms to the annual average search volume within the sample period. Ehat is the residuals from the regressions of the search volume on a set of firm characteristics included in the baseline model. IA_code is the natural logarithm of search value with the stock code as the keyword. EA is the annual average value of Baidu search index in each city with the keyword “environmental pollution”. Post is the natural logarithm of 1 plus the total amount of forum posts of each company on Oriental Fortune in each year. Read is the logarithm of 1 plus the page views on the forum posts. Comment is the logarithm of 1 plus the number of comments on the forum posts. Qnumb is the logarithm of 1 plus “times of listed companies being questioned by investors” provided by “Shenzhen Exchange Interactive” and “Shanghai Exchange E Interactive”. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

then listed companies answer investors' questions online. Therefore, this paper uses “times of listed companies being questioned by investors” provided by “Shenzhen Exchange Interactive” and “Shanghai Exchange E Interactive” to construct investor attention variable (Qnumb). Columns (1)–(8) of Table 8 present the re-test results after changing the investor attention variables, as can be seen from these results, the regression coefficients of IA are all significantly positive at the level of 1%, the conclusion remains unchanged.

5.4.3. Alternative econometric models and fixed effects

Firstly, researchers re-test using alternative econometric models. On the one hand, researchers use the Tobit model to control the errors of those samples intercepted on the left side of green innovation. On the other hand, researchers use the Logit model to regress again. The results in columns (1) and (2) of Table 9 show that no matter which econometric model is selected, the regression coefficients of investor attention (IA) are significantly positive. The results are consistent with the research conclusion of this paper.

Secondly, to mitigate the concerns of omitted variables, this paper includes firm fixed effects in the regressions to control the time-invariant unobserved firm characteristics. And then, model (1) is re-examined. The results are reported in column (3) of Table 9. In the presence of firm fixed effects, investor attention (IA) is significantly positively correlated with corporate green innovation (Gpatent).

5.4.4. Propensity score matching (PSM)

In order to further remove the concern of possible omitted variables in the empirical analysis and enhance the reliability of the conclusions, this paper uses the propensity score matching (PSM) method to retest model (1). Firstly, referring to Ni and Zhu (2016), researchers take the median of investor attention (IA) of listed companies as the benchmark, divide all samples into two categories: high investor attention vs. low investor attention and set a dummy variable IA_dummy. If the value of investor attention (IA) is greater than the benchmark, then IA_dummy equals 1, denoted as the treatment group; otherwise, marked as the control group. Secondly, following the ideas and methods of Bartram et al. (2012) and Cao et al. (2018), based on the control variables in the model (1), researchers use the logit model to calculate the probability of sample companies entering the treatment group, namely propensity scores. Then, researchers match the individuals with the slightest

difference in propensity scores between the control and treatment groups using 1:1 nearest neighbor matching method. Finally, researchers retain samples that satisfy the common support hypothesis. That is to say, to improve the quality of matching, this paper only keeps individuals with overlapping scores (although it will reduce the sample size). Specifically, the scores of any individual in the common support set must be greater than the larger one of the minimum propensity scores of the control group and the treatment group, and also less than the smaller one of the

Table 9. Alternative econometric models, fixed effects and PSM.

Dep var.=	Gpatent _{t+1}	Green _{t+1}	Gpatent _{t+1}	Gpatent _{t+1}
	Tobit	Logit	Fixed effect	PSM
	(1)	(2)	(3)	(4)
IA	0.179*** (3.202)	0.174*** (2.762)	0.058** (2.095)	0.113*** (3.217)
Constant	-16.862*** (-22.222)	-15.769*** (-17.183)	-3.972*** (-6.252)	-8.119*** (-14.472)
Controls	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Firm F.E.	No	No	Yes	No
Industry F.E.	Yes	Yes	No	Yes
Province F.E.	Yes	Yes	Yes	Yes
N	16445	16445	16330	10185
Adj. R ²	0.169	0.241	0.745	0.387

Column (1) reports the results from the Tobit model. Column (2) reports the results from the Lobit model. Column (3) reports the results from the OLS regression with firm fixed effects. Column (4) reports the results from the OLS regression with the propensity score matching (PSM) method. Green_{t+1} takes the value of 1 if the number of green patent applications is greater than 1, and 0 otherwise. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions except column (3) include year, industry, and province fixed effects. Regressions in column (3) include year, firm, and province fixed effect. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

maximum propensity scores of the control group and the treatment group. If the common range of propensity scores is too small, then it will lead to deviation. The PSM procedure alleviates the endogenous problem caused by unobservable variables to a certain extent. The results are shown in column (4) of Table 9, that the coefficient of IA is still significantly positive at the level of 1%, which does not change the main conclusion of this paper.

5.4.5. Placebo test

In order to exclude the possible influence of other unobservable variables and random noise, this paper conducts 500 random assignments and transformation of investor attention among samples (Cornaggia et al., 2015; Bernile et al., 2017) and re-regress model (1). The variable of investor attention after random transformation is SIMAttention. Suppose that the improvement of green innovation output is not caused by investor attention but is affected by other unobserved factors related to investor attention, then SIMAttention will still be significantly positive. On the contrary, if it is investor attention that causes the improvement of innovation output, then SIMAttention will not be significant after the randomization of Attention. Figure 1 shows the distribution of 500 coefficients of investor attention (IA), β_1 , estimated by the placebo test. The mean value of β_1 in Figure 1 is 0.0006 ($t = 0.044$), close to zero compared to the benchmark result of 0.154. Moreover, the β_1 in Figure 1 is concentrated around 0. The above results align with this paper's expectation, indicating that the positive impact of investor attention (IA) on green innovation (Gpatent) is highly reliable.

5.5. Additional analysis

5.5.1. The influence of negative investor attention

Negative network public opinion usually attracts investors' attention more easily. It spreads more widely (Nguyen, 2015), causing regulators to step in to strengthen their supervision and scrutiny on companies, prompting more retail investors to vote with their feet, which brings greater external pressure to enterprises. Therefore, considering that investors' attention to corporate environmental issues is mostly on negative information (Nguyen, 2015), this paper further refines investor attention and examines whether investors' attention to the negative public opinion on enterprises has a more obvious promotion effect on green innovation. In this paper, researchers define the negative posts as negative online public opinion, and the data are derived from the CNRDS stock bar review database of Chinese listed companies. Specifically, this paper uses the natural logarithm of 1 plus the number of views (comments) on negative posts to indicate the market power of negative public opinion on enterprises, denoted as Neg.gb1 (Neg.gb2). The regression results are shown in Table 10. The regression coefficients of Neg.gb1 \times IA and Neg.gb2 \times IA are both significantly positive, indicating that investor

Table 10. The influence of negative investor attention on corporate green innovation.

Dep var.=	Gpatent _{t+1}	
	(1)	(2)
IA	-0.823***	-0.124
	(-3.710)	(-0.945)
Neg.gb1 \times IA	0.061***	
	(4.092)	
Neg.gb1	-0.685***	
	(-3.666)	
Neg.gb2 \times IA		0.028*
		(1.849)
Neg.gb2		-0.308
		(-1.626)
Constant	2.716	-5.330***
	(0.994)	(-3.318)
Controls	Yes	Yes
Year F.E.	Yes	Yes
Industry F.E.	Yes	Yes
Province F.E.	Yes	Yes
N	16445	16445
Adj. R ²	0.388	0.386

Neg.gb1 is the natural logarithm of 1 plus the number of views on negative posts. Neg.gb2 is the natural logarithm of 1 plus the number of comments on negative posts. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent_{t+1} is the natural logarithm of 1 plus the number of green patent applications (green utility model patent and green invention patent). All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

attention caused by negative corporate news has a more significant role in promoting corporate green innovation.

5.5.2. The influence of corporate green innovation on financial performance

Researchers found that investor attention can significantly improve enterprises' green innovation level in the above examination. While the premise, that the result is true, is that investors attach importance to corporate green innovation. So, there is the question: can enterprises carrying out green innovation bring higher returns to investors? In order to answer this question, this paper investigates the impact of corporate green innovation on ROA and ROS in the next year to explore the economic consequences of green innovation. The results are shown in Table 11. It can be seen that the regression coefficients between Gpatent and ROA or ROS are both significantly positive, indicating that corporate green innovation can improve financial performance and create more wealth for investors.

6. Discussions

In this paper, researchers construct panel fixed-effects models and employ multiple linear, Logistic and Tobit regressions along with PSM and placebo tests to identify the relationship between investor attention and corporate green innovation. Using Chinese firms listed in the Shanghai and Shenzhen stock exchanges from 2011 to 2018, this paper finds that investor attention can significantly enhance the level of corporate green innovation. And each unit increase in investor attention (IA) is associated with an average increase of 0.154 in a firm's green innovation output. This result further confirms the corporate governance effect of investor attention from the perspective of green innovation (Quan and Wu, 2012).

In mechanism tests, this paper reveals the logic chains that investor attention promotes corporate green innovation level: First, when retail

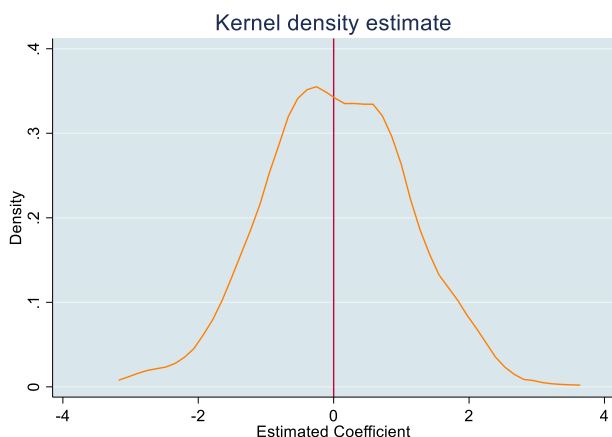


Figure 1. β_1 of 500 placebo tests.

Table 11. The influence of corporate green innovation on financial performance.

Dep var.=	ROA _{t+1} (1)	ROS _{t+1} (2)
Gpatent	0.003*** (3.556)	0.009*** (3.377)
Constant	0.064*** (3.140)	0.044 (0.527)
Controls	Yes	Yes
Year F.E.	Yes	Yes
Industry F.E.	Yes	Yes
Province F.E.	Yes	Yes
N	16441	16432
Adj. R ²	0.144	0.091

ROA_{t+1} is the ratio of net income to total assets in year t+1. ROS_{t+1} is the ratio of net income to total revenue in year t+1. IA is the natural logarithm of 1 plus annual web search index of firms. Gpatent is the natural logarithm of 1 plus the number of green patent applications in year t. All regressions include year, industry, and province fixed effects. The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

investors' attention to corporate pollution increases to a certain extent, it is easy to trigger the intervention of regulatory authorities or even higher-level administrative agencies (Dai et al., 2015), which significantly improves the enforcement of formal environmental regulation and thus promotes corporate green innovation (Porter and Vanderlinde, 1995; Huang et al., 2019). This is consistent with "Porter Hypothesis" (Porter and Vanderlinde, 1995). Secondly, from the perspective of the government incentive effect, investors' extensive attention can transfer asymmetric information to relevant departments (Lou, 2014). It can prompt them to strengthen the initial review and follow-up supervision on these enterprises (Snyder and Stromberg, 2010). It ultimately promotes enterprises' rational use of environmental subsidies and enhances their green innovation ability. Finally, from the perspective of corporate reputation cost, investors' attention on corporate environmental issues mainly focuses on the negative news, which can significantly increase the negative impact of the companies' pollution incidents. Thus, investor attention can easily lead to the decline of corporate reputation (Dyck et al., 2008; Wu et al., 2020). In order to prevent a sharp drop in stock prices and maintain a good corporate image, responsible enterprises will focus on long-term competitive advantage and increase the intensity of green technology innovation (Hou et al., 2020).

In additional tests, firstly, this paper further refines investor attention. Considering that investors' attention to corporate environmental issues is mostly on negative information (Nguyen, 2015), this paper explores whether investors' attention to negative public opinion can play a better governance effect. And the results confirm the conjecture. Besides, given that investor attention can improve corporate green innovation level through the above three mechanisms, the premise is that investors attach importance to corporate green innovation. Therefore, this paper further explores the economic consequences of corporate green innovation. And results show that enterprises carrying out green innovation can create investor wealth, which provides empirical evidence for previous conclusions that green innovation can improve the competitiveness of enterprises (Xie et al., 2016; Huang and Li, 2017; Saunila et al., 2018; Cai et al., 2020; Quan et al., 2021).

7. Conclusions

7.1. Research findings and implications

As an informal regulation, investor attention is becoming a hot topic in academia, and this research extends its consequences to corporate

green innovation. In this paper, researchers examine whether and how investor attention affects the green innovation of listed firms in China.

This paper utilizes a sample of publicly traded firms listed on Shanghai and Shenzhen stock exchanges in China during 2011–2018 to study the impact of investor attention on corporate green innovation. Researchers construct panel fixed-effects models and adopt multiple linear, Logistic and Tobit regressions. The results show that investor attention, measured by the web search index, can significantly improve corporate green innovation. The conclusion is still valid after a series of robust tests, such as alternative measures of key variables, changing econometric models, propensity score matching (PSM), and placebo, etc. In addition, mechanism tests reveal that investor attention can promote the green innovation level of enterprises by improving the implementation efficiency of punitive environmental regulation, the use efficiency of environmental subsidies, and increasing the reputation cost of enterprises. In additional tests, this paper further clarifies that investors' attention to negative public opinion can play a better role in environmental governance, and the reason why investors are motivated to improve corporate green innovation is that green innovation can create wealth for investors.

This paper contributes to the current literature in at least four ways.

Firstly, to our knowledge, this work is the first to explore the impact of investor attention on firm green innovation, contributing to the studies on the relationship between investor attention and corporate policies, especially green strategies. Previous literature on the economic consequences of investor attention mainly focuses on the stock market (Barber and Odean, 2008; Andrei and Hasler, 2015; Wang et al., 2021). There are limited studies discussing the impacts of investor attention on corporate decision-making behavior as an important informal institution. Some scholars have found the "governance effect" of investor attention on management earnings manipulation (Porter and Vanderlinde, 1995). This paper takes the lead in focusing on the environmental policies at the micro-enterprise level. It deeply analyzes the role of investor attention, measured by web search index, in corporate green innovation, which undoubtedly broadens the research scope of economic consequences of investor attention and provides new empirical evidence for the "governance effect" of investor attention.

Secondly, this study enriches the research on green innovation at the micro-firm level from the perspective of informal institutions. Most of the existing literature on corporate green innovation focuses on formal environmental regulation (Brunnermeier and Cohen, 2003; Acemoglu et al., 2016; Stucki et al., 2018; Borsatto and Amui, 2019; Huang et al., 2019; Petroni et al., 2019; Fan et al., 2021), but relatively ignores the role of informal institutions. In this paper, researchers take investor attention, measured by web search index, as the entry point to study the impact of this informal system on corporate green innovation. This study further breaks the previous single research perspective based on formal systems. It also expands the research scope of environmental governance and provides new micro-evidence for informal institutions' role in environmental governance.

Thirdly, this paper proposes and supports the mechanism of "punitive regulation", "incentive regulation", and "reputation cost" based on the empirical results. The conclusions can help unfold the "black box" of how investor attention promotes corporate green innovation and offer some valuable experience and inspiration for other studies in this field.

Fourthly, in order to confirm that investors are motivated to participate in improving the level of corporate green innovation, this paper tests the economic consequences of green innovation and finds that green innovation can increase corporate financial performance. In the past, most of the literature directly or indirectly discussed the positive impact of green innovation on enterprises' economic benefits from a theoretical perspective (Jafari-Sadeghi and Biancone, 2018; Garousi Mokhtarzadeh et al., 2020a, 2020b; Sukumar et al., 2020). This paper empirically verifies the great advantages of green innovation in coordinating economic development and environmental protection, which complements existing research and would help motivate companies to carry out green innovation.

7.2. Policy recommendations

The findings also have important practical implications. China is now in the new normal of economic structural transformation and upgrading. To a certain extent, the paper's conclusions provide a good reference value for the government to guide the public, enterprises, and other organizations to participate in environmental protection supervision and form a new pattern of environmental protection under the multi-governance of the whole society. Based on the conclusions of this research, the following policy recommendations are proposed.

7.2.1. Advice for the government

Firstly, attach importance to the power of retail investors. Investor attention is an expression of public opinion, which has a certain guiding role in government work. The results of this paper show that investor attention is conducive to promoting enterprises to improve green innovation and actively undertake the responsibility of environmental protection, which is conducive to the development of environmental governance. Historical experience tells us that it is far from enough to rely only on the power of the government to protect the environment and carry out environmental governance. Based on this, the government should give full play to the advantages of investor supervision, vigorously publicize the concept of "environmental protection is everyone's responsibility", and actively guide retail investors to pay attention to environmental issues.

Secondly, attach importance to the power of the Internet and optimize the construction of the online political platform. With the increasing popularity of the Internet, the Internet is playing an increasingly important role in the political, economic, and social life of the Chinese people. The Internet has become an important way for citizens to exercise their right to know and supervise (Rezaei et al., 2020). The conclusion of this paper confirms the amplification effect of network development on the influence of retail investors. The establishment of an online political platform provides a platform for investors to express their environmental demands. However, the construction of the online political platform in China is not perfect, and the coverage of the platform is low. The government should optimize the construction of network political platforms and realize environmental supervision on enterprises with the help of investors (Falcone and Sica, 2019).

7.2.2. Advice for the companies

Enterprises should actively shoulder their environmental responsibilities and carry out green innovation. As China's economy has entered a new normal, the concept of green development has gained popular support. As an important source of environmental problems, enterprises should assume the responsibility of environmental governance. And green innovation can reduce enterprises' environmental pollution and effectively improve enterprises' green competitiveness (Porter and Vanderlinde, 1995; Saunila et al., 2018; Cai et al., 2020; Quan et al., 2021). The conclusions of this paper also show that green innovation can increase corporate financial performance. Therefore, for enterprises, implementing green innovation is not only conducive to their own long-term development, but also can protect the environment, establish a green image, and win the support of stakeholders.

7.3. Limitations and directions for future research

7.3.1. The following limitations should be considered

Firstly, the indicators used to measure green innovation need to be improved. Although patent data can reflect innovation output to some extent, it cannot explain the improvement of process innovation in environmental protection cases (Liao and Shi, 2018; Falcone, 2020). Due to the availability of data, this paper failed to study this issue. Future research can try to dig for more detailed green innovation data from the two dimensions of industry and region, so that we can judge the innovation effect more clearly and accurately.

Secondly, the theoretical framework needs to be extended. Due to limited space, this research only discusses the role of investor attention as an informal regulation in the context of information asymmetry and ignores the role of mandatory environmental regulation. While there is a complementary relationship between informal and formal institutions and few studies has combined the two institutions. In consideration of this, future studies can introduce such mandatory environmental regulations into the framework to explore their comprehensive effects and the internal mechanisms.

Finally, due to the availability of data and insufficient understanding of other emerging markets, this research does not consider the special situations of other emerging market economies and only takes China's domestic listed companies as a sample. Although the findings demonstrate a positive correlation between investor attention and corporate green innovation, this may be related to the selection of companies influenced by traditional Chinese culture. Thus, the applicability of the results remains to be seen. Therefore, in the future research, it will be of great significance to analyze the relationship between investor attention and green innovation under other EME's national conditions.

Declarations

Author contribution statement

Min Li: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Nian Li: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Muhammad Asif Khan, Faheem Ur Rehman: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Noshawan Khaliq: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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The authors declare no conflict of interest.

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