Investor Attention and Corporate Innovation Performance: Evidence from Web Search Volume Index of Chinese Listed Companies

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Abstract: Leveraging from the online search index of Chinese listed companies from 2012 to 2018, we empirically test the relationship between investors’ attention and corporate innovation performance for the first time. The main results are as follows: (1) investors’ attention significantly improves listed companies’ innovation performance, which is reflected in the increase of patent applications. This indicates that investors’ active information collection behaviour affects China’s economic development by promoting enterprise innovation. (2) This paper’s conclusion remains intact after a battery of robustness checks, such as alternative measures of key variables and empirical specifications and a series of endogenous treatment. (3) The mechanisms tests show that: “information asymmetry”, “financing constraint”, and “agency cost” are supported. In other words, with the increase of investors’ attention, not only the information asymmetry is reduced, which greatly improved the information environment of the capital market, but also the external financing constraints of enterprises are alleviated. The opportunistic management behaviour is effectively suppressed, thus motivating the corporate innovation incentives and improving the corporate innovation of input, output and quality. (4) Further research shows that investor attention to listed companies also improves the efficiency of capital allocation. This paper’s conclusion shows that investors’ initiative information acquisition behaviour can improve enterprises innovation performance, thus providing a driving force for China’s economic development.

Keywords: innovation; investor attention; information disclosure quality; financing constraints

1. Introduction

According to the view of behavioural finance, individual investors are often described as “noise traders” [1], who often passively receive information and trading on newspapers, TV and other traditional media, etc. [2–4]. In these cases, only when public information comes, investors will notice it and start acting. In fact, in addition to receiving public information through corporate disclosure and financial media, investors will also take the initiative to obtain more valuable private information through other channels (such as site visit, online consultation, etc.), reducing the degree of information asymmetry with listed companies, to occupy a dominant position in trading [5]. Although investors’ proactive information acquisition behaviour is essential [6–8], the existing literature has not fully discussed this topic due to data access limitation [9].

The enthusiasm of investors in information search depends on the cost and benefit of information search. If the benefit of searching for information is greater than the cost, investors will actively search for information. When the marginal benefit of information...
search equals the marginal cost, it is the optimal information search scale for investors [5]. In recent years, based on the advancement of network technology, the Internet has rapidly become the first source of institutional investors’ information [10]. The Internet is generally considered to provide individuals with rich and useful information in various fields [11], thus providing convenience for studying investors’ active information acquisition behaviour and improving the cost-benefit ratio of information searching. Firstly, based on the richness of network resources, ordinary investors can freely collect, read, analyse, and exchange various information about listed companies on the Internet, thereby significantly reducing the cost of information acquisition and improving the knowledge about listed companies [11,12]. Secondly, unlike traditional information acquisition channels, the Internet can accurately record people’s inquiries and usage, thus providing the possibility for academic research. Da et al. [13] believe that Google search volume index data (SVI) can effectively measure investors’ attention because Google search volume measures investors’ behaviour actively acquiring information. Similarly, this paper argues that using the Web Search Volume Index provided by the Chinese Research Data Services Platform (CNRDS) as a substitute variable for investors’ attention to listed companies can effectively measure investors’ active information acquisition behaviour of listed companies.

Previous researches have revealed the impact of investor attention on capital market efficiency [6,14]. And it is also found that investors’ attention to listed companies and active information collection have improved the efficiency of instant interpretation of corporate information [15] and the quality of corporate information disclosure, thus significantly improving market resources allocation efficiency. For example, Rakowski et al. [16] document that Twitter activity is a unique and meaningful measurement of investor attention. Compared with the traditional investor attention index, twitter can more effectively capture the information dissemination among investors. They found that the impact of the Twitter activity on individual stock trading volume and pricing has statistical and economic significance. However, the existing research does not test whether the improvement of capital market efficiency by investors’ attention further affects the development of the real economy. In other words, the current understanding of the role of investors is limited to the capital market. Still, it is unclear whether it promotes the real economy’s development by alleviating information asymmetry and improving the capital market’s efficiency. Undoubtedly, corporate innovation is an essential driving force for developing the real economy and a source of competitive advantage for enterprises [17]. However, a large number of studies have shown that agency problems [18,19] and financing constraints [20–22] are the key factors that distort managers’ decisions and lead corporates to deviate from the optimal innovation level [23]. By actively increasing their attention to listed companies, investors can help alleviate the degree of information asymmetry with companies, supervise managers’ opportunistic behaviours, and alleviate corporate financing constraints, thereby affect corporate innovation activities and the development of the real economy. This article will empirically test the relationship between investor attention and corporate innovation performance to reveal the vital role that investors play in developing China’s real economy.

This paper takes all A-share listed companies from 2012 to 2018 as samples to test investor attention’s impact on enterprise innovation performance. The results show that: (1) Investor attention is significantly positively correlated with listed companies’ innovation level, indicating that external investors’ active information search behaviour positively influences corporate innovation behaviour. (2) This paper’s conclusion is still valid after a series of robust tests, such as alternative measures of key variables and empirical specifications, propensity score matching (PSM), Heckman two-stage method, multiple-period lagged independent variable, instrumental variable method (IV) and placebo test. (3) This article proposes and confirms the three possible mechanisms of “information asymmetry”, “financing constraints”, and “agent costs”. (4) Additional analysis indicates
that investor attention to listed companies improves firms’ capital allocation efficiency in investment-Tobin’s Q sensitivity.

This paper’s improvement and innovation are reflected in the following three aspects: Firstly, this paper contributes to the burgeoning literature on the positive effect of the capital market on a firm’s real investment decisions, such as capital allocation efficiency and enriches the literature on the influencing factors of corporate innovation. Specifically, this article complements this literature by linking market level factors to long-term, intangible assets such as corporate innovation, which is vital for nations’ economic growth and competitive advantage [24]. To the best of our knowledge, this paper is the first to empirically test the impact of investor attention on corporate innovation. From the perspective of investors’ active information acquisition process, this paper discusses the relationship between investors’ attention and corporate innovation and confirms that investor attention is one of the fundamental reasons for corporate innovation of Chinese listed companies.

Secondly, this paper adds to the literature about the vital role of investors in promoting the real economy. The previous literature mainly focuses on the impact of institutional investors’ ownership on corporate innovation [25–27], the economic consequences of institutional investors’ corporate site visits [7] and the impact of investors’ attention on capital market information environment [28,29]. This paper expands the literature about the influence dimension of investor, uses the online search index of listed companies as the proxy variable of investor’s attention for the first time and reveals the positive impact of investor’s attention on corporate technology innovation. The conclusions of this article prove that investors play an important role in promoting China’s real economic development.

Finally, this article this paper enriches the relevant literature about the economic consequences of Internet search technology. In the field of corporate finance, the literature mainly focuses on the impact of Internet search technology on the stock market. For example, Da et al. (2011) [13] believed that search frequency in Google (SVI) could predict product sales and potentially impact stock price changes. Bollen et al. (2011) [30] further found that twitter’s sentiment index significantly impacted the Dow Jones Industrial Index trend. Blankespoor et al. (2014) [31] also pointed out that IT companies’ use of Twitter can reduce information asymmetry in the stock market. In response to these studies, this article reveals the influence of Internet technology development on corporate innovation and its internal mechanism.

The paper’s structure is as follows: the second part is a literature review and research hypothesis; the third part is research design; the fourth part is empirical results; the fifth part is a conclusion.

2. Literature Review and Research Hypothesis

2.1. Literature Review

Unlike developed western economies, China’s capital market is still dominated by small and medium-sized investors [15]. Due to the low transparency of China’s information environment [32], investors are more active in collecting and interpreting information. For example, a corporate site visit becomes an essential channel for investors to obtain company information [7,28]. Site visits help investors obtain companies’ information timely and accurately and confirm the uncertain information they have obtained [28], thereby making better investment decisions. Besides, the rapid development of information technology can optimize the ways and methods of information acquisition and interpretation of investors [33] and improve investors’ ability to obtain and interpret information [31,34]. Especially in the “information age”, the Internet has become the most crucial information acquisition channel for investors [35]. Da et al. (2011) [13] and Drake et al. (2012) [34] use the search volume for listed companies on the Internet to measure investors’ information demand. Internet search volume is an explicit measure of investor
attention. It indicates that the investor is paying attention to a stock when he or she searches that stock. Therefore, the aggregated information search volume can directly and clearly measure the investor’s information needs [36]. Quan and Wu (2012) [35] found that investor attention has a cognitive effect. The increase in investors’ attention can significantly improve their cognition efficiency of earnings composition information. As a result, the corporate information environment will change. In particular, the degree of internal and external information asymmetry will be reduced, the earnings manipulation behaviour of listed companies’ management will be effectively restrained, the proportion of manipulable earnings will be significantly reduced, and the quality of accounting information will be significantly improved.

Many studies have shown that information asymmetry and financing constraints, and agency problems in an information asymmetry environment are three important factors that distort enterprise innovation [21,37–39]. Therefore, we argue that there are three conceptual underpinnings for the impact of investor attention on corporate innovation performance. Firstly, investors can alleviate information asymmetry and financing constraints in corporate innovation activities by actively collecting information, which may enhance managers’ willingness and ability to invest in innovation. Second, investors’ continued attention to enterprises and their supervisory role may also reduce agency problems in using innovation funds, thereby increasing fund use efficiency and creating more innovation output.

2.2. Research Hypothesis

Scholars have found that financing constraints under asymmetric information are an important factor affecting corporate innovation [40–43]. Because corporate innovation itself has the characteristics of high professionalism, confidentiality and uncertainty, these will undoubtedly increase the degree of information asymmetry, making it difficult for investors to judge the future earnings of the company accurately, so they tend to underestimate those innovations value of more active companies [44,45]. This may form a negative incentive for managers and employees and reduce their willingness to invest in innovation [37]. At the same time, investors’ adverse selection behaviour will aggravate the financing constraints faced by innovative companies and increase the difficulty of obtaining funds, which may lead to companies having to cut or even abandon their innovation investments. Since innovation activities require many human and material resources, sufficient funds are crucial for enterprises to obtain various production resources needed for innovation [41,46]. Therefore, the financing constraints caused by information asymmetry may restrict the innovation ability of enterprises.

The increase in investors’ attention can enhance investors’ understanding of the value of future innovation activities, reduce information asymmetry, and avoid the value of innovative enterprises being underestimated. At the same time, investor attention can further alleviate the problem of investors’ adverse selection, improve the financing constraints faced by enterprises to a certain extent, and strive for more financial support for enterprises’ innovative projects, thereby enhancing managers’ innovation capabilities and willingness [37]. Therefore, this paper argues that there are two important mechanisms for investors’ attention to promote enterprise innovation. One is alleviating the information asymmetry between enterprises and investors, and the other one is reducing the degree of financing constraints faced by enterprises.

The process of corporate innovation is also easy to aggravate the agency problem of the enterprise. The professionalism of innovation activities increases the cost of shareholders supervision on the innovation process; simultaneously, the uncertainty of innovation activities also makes it difficult for shareholders to evaluate managers’ efforts [47]. When an innovation project fails to achieve the expected performance, it is difficult for shareholders to judge whether it should be attributed to the project’s risk or the managers’ shoddy work. Therefore, managers have greater autonomy in innovation, which may lead to serious agency problems [48]. For example, in the 1980s, General Motors invested
nearly $400 billion in innovation, but the profit was minimal. And the innovation activity even caused a huge loss in the early 1990s and a loss of opportunity worth $100 billion [49]. Investors’ continuous attention to enterprises and their supervisory role are likely to reduce the agency problems in using innovation funds, thus improving fund use efficiency and creating more innovation output. The alleviation of agency conflict by investors’ attention is likely another important mechanism that affects enterprises’ innovation performance. Under this mechanism, the supervision of investors can significantly inhibit the opportunistic behaviour of managers.

Based on the above analysis, this paper puts forward the following main hypothesis:

**Hypothesis 1 (H1).** The higher the investors’ attention, the better the corporate innovation performance.

In addition, the above theory and logical reasoning are captured in the following hypotheses about three important mediation effects:

**Hypothesis 2 (H2).** Investors’ attention to the promotion of corporate innovation may be achieved by alleviating information asymmetry.

**Hypothesis 3 (H3).** Investors’ attention to the promotion of corporate innovation may be achieved by reducing financing constraints.

**Hypothesis 4 (H4).** Investors’ attention to the promotion of corporate innovation may be achieved by mitigating agency conflicts.

3. Research Design

3.1. Sample Data

This paper takes the impact of the Internet search index of listed companies on corporate innovation as the research object. The sample screening procedures are as follows: (1) Excluding financial listed companies; (2) Sample observations with negative or greater than 100% financial leverage ratio are removed; (3) Eliminating firms with missing financial characteristics; (4) All continuous variables are winsorized at 1% and 99% quantiles to eliminate the influence of outliers. After the above sample screening, 16,608 firm-year observations from 2012 to 2018 were finally retained.

The online search index of listed companies, the number of patent applications and the citation number of patent applications are all from the China research data service platform (CNRDS). The research and development (R&D) data of listed companies are from the WIND database. Other financial data and special company indicators are mainly from the CSMAR database or the China research data service platform (CNRDS) database.

3.2. Selection and Design of Major Variables

3.2.1. Explained Variable

The explained variable is corporate innovation performance, proxied by the number of patent applications (Patent). Technological innovation is the ultimate embodiment of resource input and utilization efficiency. The existing literature mainly used R&D input and patent output to measure corporate innovation [50,51] and regarded the number of patents as the output of corporate R&D activities [26,52,53]. Compared to the high failure rate and intense uncertainty of R&D activities, patents reflect the corporate innovation level more intuitively. The number of patent applications can be used as a leading indicator of social science and technology’s progress and predict the economic development prospect [54]. Therefore, the number of patent applications representing innovation output can better reflect enterprises’ innovation capability [55,56]. According to China’s pa-
tent law, patents are divided into invention patents, utility model patents, and design patents. Following Custódio et al. (2019) [57] and Ovtchinnikov et al. (2020) [58], this article uses the total number of the above three types of patent applications to measure the corporate innovation capabilities. Specifically, the natural logarithm is taken after the total number of patent applications is added by 1, which is used as the proxy index of corporate innovation output [59], to alleviate the obvious right-skewness of the sample and avoid the interference caused by heteroscedasticity [60,61].

3.2.2. Explanatory Variables

The explanatory variable (Attention) is the online search index of listed companies. The index is from CNRDS’ network search index database. The database comprehensively collects news and public opinion, and other information, which can reflect netizens’ sentiment and the popularity of company searches, thereby effectively measuring investor attention.

This paper also uses the search index of listed companies to proxy investors’ active information acquisition behaviour, mainly based on the following points [9]: Firstly, as a convenient information acquisition tool, the search engine has become an indispensable part of people’s work and life. Secondly, different from television, newspapers and other information access channels, an Internet search can better reflect people’s active information acquisition behaviour. Finally, although investors can obtain information through other ways, such as telephone conversation, online chat, etc., the only search engine can record people’s daily use more comprehensively and objectively, which simplifies the complexity of research work.

3.2.3. Control Variables

Following He and Tian (2013) [52], Fang, Tian and Tice (2014) [62] and Shen and Yuan (2020) [63] and other previous literature, this paper controls the following important factors that may affect corporate innovation, including firm size (Size), firm Age (Age), capital intensity (Capital), Tobin’s Q (Q), return on assets (ROA), leverage ratio (Lev), free cash flow (CF), firm growth (Growth), financial distress (Loss), CEO duality (Duel), board size (Board), the proportion of independent directors (Indd), major shareholder’s shareholding ratio (TOPHOLD) and the Herfindahl-Hirschman Index (HHI). Appendix A presents detailed definitions of all variables.

3.3. Multiple Regression Model

This paper uses the following multiple regression model to examine the impact of investor attention on corporate innovation performance:

$$Patent_{i,t+1} = \beta_0 + \beta_1 Attention_{i,t} + \eta_1 + \eta_{ind} + \epsilon_{i,t+1},$$  \hspace{1cm} (1)

$$Patent_{i,t+1} = \beta_0 + \beta_1 Attention_{i,t} + \beta_2 Controls_{i,t} + \eta_1 + \eta_{ind} + \epsilon_{i,t+1},$$  \hspace{1cm} (2)

The explained variable is the corporate innovation performance, Patent. Since Patent is a non-negative censored variable with continuous values, there is a zero-deletion problem. It is more appropriate to use the Tobit model for regression analysis [50,64,65]. The explanatory variable is investor attention, Attention. Controls represent a batch of control variables. a represents three types of fixed effects, including the year(η), industry(η_ind) level fixed effects, respectively [50,55]. The fixed effects at different levels can effectively alleviate the endogenous problems caused by missing variables [66]. Besides, to ensure the conclusion’s robustness, this paper further follows Petersen (2009) [67] and clusters the standard errors at the firm level [68–70]. If hypothesis H1 is supported, it is expected that \( \beta_i \) should be significant and positive.
4. Results and Discussion

4.1. Summary Statistics and Correlation Analysis

Table 1 reports the results of the summary statistics of the main variables. The mean (median) of explained variables Patent is 1.435 (1.099) and the standard deviation is 1.613, indicating that there is a considerable variation of Patent among firms. This is consistent with the findings of He, Yu, Dai and Wang (2019) [68] and Wang and Wish (2018) [60]. The mean (median) of explanatory variables Attention is 12.860 (12.780), and the standard deviation is 0.649. The summary statistics of the control variables are consistent with the previous literature [71].

Table 1. Summary statistics.

| Variable  | N   | Mean | Std  | P5  | Q1  | Median | Q3   | P95  |
|-----------|-----|------|------|-----|-----|--------|------|------|
| Patent    | 16,608 | 1.435 | 1.613 | 0.000 | 0.000 | 1.099 | 2.639 | 4.454 |
| Attention | 16,608 | 12.860 | 0.649 | 11.930 | 12.390 | 12.780 | 13.250 | 14.020 |
| Size      | 16,608 | 22.100 | 1.291 | 20.290 | 21.190 | 21.940 | 22.840 | 24.540 |
| Age       | 16,608 | 2.261 | 0.694 | 0.962 | 1.751 | 2.401 | 2.871 | 3.114 |
| Capital   | 16,608 | 12.520 | 1.134 | 10.630 | 11.860 | 12.510 | 13.200 | 14.420 |
| Q         | 16,608 | 0.585 | 0.199 | 0.224 | 0.448 | 0.603 | 0.737 | 0.880 |
| ROA       | 16,608 | 0.036 | 0.054 | -0.050 | 0.012 | 0.034 | 0.062 | 0.120 |
| Lev       | 16,608 | 0.440 | 0.219 | 0.103 | 0.264 | 0.432 | 0.602 | 0.806 |
| CF        | 16,608 | 0.038 | 0.073 | -0.085 | 0.000 | 0.038 | 0.081 | 0.157 |
| Growth    | 16,608 | 0.226 | 0.784 | -0.116 | 0.017 | 0.101 | 0.237 | 0.861 |
| Loss      | 16,608 | 0.025 | 0.155 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Dual      | 16,608 | 0.273 | 0.441 | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 |
| Board     | 16,608 | 2.141 | 0.198 | 1.792 | 1.946 | 2.197 | 2.197 | 2.398 |
| Indep     | 16,608 | 0.374 | 0.054 | 0.333 | 0.333 | 0.333 | 0.429 | 0.500 |
| TOPHOLD   | 16,608 | 0.348 | 0.151 | 0.136 | 0.228 | 0.327 | 0.450 | 0.624 |
| HHI       | 16,608 | 0.064 | 0.097 | 0.009 | 0.017 | 0.018 | 0.071 | 0.333 |

Table 2 shows the correlation coefficients between the main variables. The explanatory variable Attention is significantly positively correlated with the explained variable Patent at the 1% level. The above results preliminarily indicate the rationality of hypothesis H1 in this article, that is, the increase in investor attention (Attention) is likely to promote the improvement of corporate innovation performance (Patent). In addition, the correlation coefficients between the control variables are all less than 0.6, except for one (the correlation coefficient between lev and Q is 0.630 > 0.6), which indicates that there is no multicollinearity in the multiple regression model (2).

Table 2. Correlation analysis.

| Variable  | Patent  | Attention | Size  | Age  | Capital | Q | ROA | LEV |
|-----------|---------|-----------|-------|------|---------|---|-----|-----|
| Patent    | 1       | 0.139 *** | 1     | 1    | 1       | 1 | 1   | 1   |
| Attention | 0.117 ***| 0.521 *** | 1     | 1    | 1       | 1 | 1   | 1   |
| Size      | -0.244 ***| 0.277 *** | 0.308 ***| 1     | 1       | 1 | 1   | 1   |
| Age       | -0.042 ***| 0.095 *** | 0.298 ***| 0.149 ***| 1     | 1 | 1   | 1   |
| Capital   | -0.021 ***| -0.043 ***| 0.227 ***| -0.134 ***| -0.010 | 1 | 1   | 1   |
| Q         | 0.130 ***| -0.006 | 0.029 ***| -0.184 ***| -0.120 ***| -0.193 ***| 1 | 1   |
| ROA       | -0.092 ***| 0.196 ***| 0.446 ***| 0.407 ***| 0.127 ***| 0.630 ***| -0.382 ***| 1 | 1   |
| Lev       | 0.083 ***| 0.090 ***| 0.075 ***| -0.006 | 0.120 ***| -0.157 ***| 0.354 ***| -0.163 ***| 1 | 1   |
| CF        | -0.036 ***| 0.005 | 0.095 ***| -0.033 ***| -0.068 ***| 0.190 ***| 0.133 ***| 0.006 | 1   |
| Growth    | -0.064 ***| 0.010 | -0.062 ***| 0.089 ***| 0.031 ***| 0.099 ***| -0.381 ***| 0.161 ***| 1   |
| Loss      |         |           |       |      |         |    |     |     |
Appendix B shows the results of the variance inflation factor (VIF) test. Generally, variance inflation factor (VIF) can be used to test the severity of collinearity. The empirical judgment method shows: when $0 < \text{VIF} < 10$, there is no multicollinearity. It can be seen from Appendix B that the VIF values of all variables are less than 5, indicating that the model does not have serious multicollinearity problems and the model is well constructed.

Overall, the results of correlation analysis have laid a good foundation for the following regression analysis.

### 4.2. Baseline Results

Table 3 reports the results of the main regression. In addition to the full Equation (2), a simplified regression model without control variables is designed as Equation (1). Column (1) is a univariate regression, and the coefficients of Attention is 0.654 ($t = 8.90$), which is significantly positive at the level of 1%. Column (2) is the regression result of the full model after adding control variables, and the coefficient of Attention is 0.255 ($t = 3.39$), which was still significantly positive at the 1% level. The results are economically significant. Using Equation (2), Given the coefficient of the Attention, for every additional unit of the Attention, a firm's Patent is, on average, 0.255 bigger than before. With the mean of Patent at 12.780, a 0.255 increase represents approximately a 1.995% increase in Patent relative to a mean firm. It shows that hypothesis H1 has been supported; that is, listed companies’ investor attention is significantly positively correlated with the number of patent applications. External investors may reduce the degree of information asymmetry, ease enterprises’ financing constraints, supervise the opportunistic behaviour of management, and stimulate enterprises’ innovation motivation, thereby increasing innovation output.

In terms of control variables, Size, ROA, Lev, CF, Board and HHI are significantly positively correlated with the number of patent applications (Patent), which indicates that enterprises with large scale, high rate of return on assets, high level of financial leverage, rich free cash flow, the large board of directors and higher market competition have higher patent applications (Patent). Age, Capital, Q, Growth and Loss were negatively correlated with a patent application. The results suggest that firms with a higher degree of these factors result in a lower patent application amount and innovation ability. The empirical results of these variables are consistent with previous literature [60,68].
Table 3. The impact of investor attention on corporate innovation.

|          | Y = Patent (1) | Y = Patent (2) |
|----------|----------------|----------------|
| Attention| 0.654 ***      | 0.255 ***      |
|          | (8.90)         | (3.39)         |
| Size     | 0.585 ***      |                |
|          | (11.79)        |                |
| Age      | -1.060 ***     |                |
|          | (-13.80)       |                |
| Capital  | -0.208 ***     |                |
|          | (-5.13)        |                |
| Q        | -1.538 ***     |                |
|          | (-6.70)        |                |
| ROA      | 2.791 ***      |                |
|          | (4.65)         |                |
| Lev      | 0.581 **       |                |
|          | (2.28)         |                |
| CF       | 1.287 ***      |                |
|          | (3.35)         |                |
| Growth   | -0.378 ***     |                |
|          | (-8.63)        |                |
| Loss     | -0.355 **      |                |
|          | (-2.05)        |                |
| Dual     | 0.004          |                |
|          | (0.06)         |                |
| Board    | 0.433 *        |                |
|          | (1.88)         |                |
| Independ | -0.025         |                |
|          | (-0.03)        |                |
| TOPHOLD  | 0.207          |                |
|          | (0.80)         |                |
| HHI      | 1.777 ***      |                |
|          | (3.47)         |                |
| Constant | -9.025 ***     | -12.290 ***    |
|          | (-9.23)        | (-9.72)        |
| Industry F.E. | Yes  | Yes  |
| Year F.E.    | Yes  | Yes  |
| N          | 16,608         | 16,608         |
| Pseudo R²  | 0.112          | 0.151          |

Note: All regressions include industry and year 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.

4.3. Potential Mechanisms

This section puts forward three possible mechanisms for the research findings: “information asymmetry”, “financing constraints”, and “agency costs”. Specifically, the information disclosure environment is an important factor affecting corporate innovation. For external investors, their perception of the corporate information disclosure environment will directly affect enterprises’ financing behaviour and investors’ recognition of innovation projects. The increase in investors’ attention to listed companies reduces information asymmetry and expected return risk [72] and alleviates enterprises’ financing constraints [73]. It provides financial support for corporate innovation [40] and improves the
innovation enthusiasm of enterprises. Simultaneously, the increase of investment attention can effectively restrain the management’s opportunistic behaviour, reduce the agency problem in using innovation funds, and improve capital use efficiency.

4.3.1. Information Asymmetry

Previous works of literature have discussed the impact of corporate characteristics on innovation. Although the research scenarios are different, they all show that information asymmetry is the root cause of distorting managers’ decision-making and leading enterprises to deviate from the optimal innovation level [37,38,47]. In terms of information interconnection, the Internet has natural advantages. Investors can obtain the information of listed companies timelier and more conveniently through the Internet. On the one hand, companies can use online social media platforms to directly disseminate information to many audiences, bypassing traditional media and other information intermediaries [74].

On the other hand, investors can use the Internet to obtain more financial news reports of listed companies actively and share them with friends and other followers in real-time, thus affecting the dynamics and nature of the company’s information disclosure [75]. All these show that the online search index of listed companies selected in this paper can be a good proxy for investors’ attention. The increase in investors’ attention to listed companies helps alleviate information asymmetry among market participants. On this basis, it can effectively alleviate enterprises’ financing constraints and supervise managers’ opportunistic behaviour. Therefore, it is likely to impact enterprises’ innovation activities, thus affecting the real economy’s development. With the improvement of companies’ information environment, managers who focus on their career will expect that the companies’ innovation behaviour will be reflected in the companies’ stock price and value in time and have stronger motivation to engage in innovative activities to improve their professional reputation [76].

Based on the above analysis, this article believes that investors’ attention to enhancing corporate innovation should first improve corporate information disclosure quality. With the improvement of enterprise transparency, the innovation investment and patent application volume will be increased rapidly [40]. Therefore, this paper uses a structural equation model (SEM) to test the mediation effect for the impact of Investor attention (Attention) on corporate innovation performance (Patent). The mediation variable is Evaluation. The specific results are shown in column (1) in Table 4.

The results of (1) in Table 4 show that the direct path for the impact of Attention on Patent is significant and positive (coefficient of P(Attention, Patent): 0.267; Z-values: 9.78). For the indirect path, Attention also has a significantly positive, indirect effect on Patent through Evaluation (coefficient of P(Attention, Path)* P(Path, Patent): 0.017; Z-values: 6.32). The results are consistent with the logic in the testable hypothesis. Collectively, we find that Attention has significant indirect effects on Patent through mediating variable of Evaluation.

Table 4. Potential mechanisms tests.

|                     | Path = Evaluation | Path = SA | Path = KZ | Path = Turnover |
|---------------------|-------------------|-----------|-----------|----------------|
| **Coefficient**     | **Z-Stat**        | **Coefficient** | **Z-Stat** | **Coefficient** | **Z-Stat** |
| Direct Path         |                   |           |           |                |           |
| P(Attention, Patent)| 0.267 ***         | 9.78      | 0.275 *** | 10.92          | 0.293 *** | 10.65 | 0.361 *** | 16.57 |
| Mediated Path       |                   |           |           |                |           |
| P(Attention, Path)  | 0.209 ***         | 9.46      | -0.834 ***| -8.21          | -0.04 *** | -3.64 | 0.253 *** | 3.10 |
| P(Path, Patent)     | 0.082 ***         | 8.48      | -0.075 ***| -21.28         | -0.177 ***| -7.63 | 0.007 *** | 3.84 |
| P(Attention, Path)* P(Path, Patent)| 0.017 *** | 6.32 | 0.062 *** | 7.66          | 0.007 *** | 3.28 | 0.002 ** | 2.41 |
| N                   | 11,337            | 13,898    | 11,333    | 16,608         |
| Standardized root mean squared residual | 0.036 | 0.071 | 0.073 | 0.023 |

Note: Based on Wei et al. (2014) [77], this paper redefines the KZ index as: KZ = 6.315*CF−39.356*DIV_N−3.494*Cash + 3.291*Lev + 0.460*Q. The empirical results after redefinition are consistent with column (3) in Table 4. The findings using bootstrap mediation tests yield a similar conclusion. * ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.
4.3.2. Financing Constraints

The first key feature of innovation activities is that the risk of failure is high, and the output is full of uncertainty [45,71]. This feature makes the innovation process contain information asymmetry and induces potential adverse selection and moral hazard problems. As a result, innovation activities often face severe financing constraints [41,46], and enterprise managers often lack sufficient motivation to innovate [78]. Secondly, another characteristic of innovation is long-term, which is a typical long-term and high-intensity capital intensive investment and requires a large amount of capital. Schumpeter (1934) [79] pointed out that innovation, as a resource-consuming activity, is an organic combination of creativity and capital. Without the support of capital, creativity will not form effective production. Subsequent literature has also generally confirmed that the financing constraints will inhibit companies' innovation activities [46,64,80]. When internal funds are not enough to support innovation projects, and external financing has serious constraints, corporate will have to postpone or give up innovation. Therefore, financing constraints limit the innovation initiative and become the primary problem hindering corporate innovation [41,81].

The existing studies believe that enterprises’ financing constraints under the environment of asymmetric information [21,39] are the key factors affecting corporate innovation. In an imperfect capital market, it is often difficult for corporations to obtain effective funds to support innovation from external channels, leading to insufficient investment in innovation [78]. The “information asymmetry” test results support investor attention’s role in alleviating information asymmetry. Through an in-depth understanding of enterprise information, external investors can get more initiative to evaluate enterprise innovation investment and decide whether to invest. This is a kind of protection for external investors, especially creditors. Jiang et al. (2017) [82] also found that the improvement of creditor protection level has a positive role in promoting enterprise innovation. Therefore, this paper verifies the “financing constraint” mechanism by examining investor attention’s impact (online search index of listed companies) on financing constraint index SA and KZ index.

The KZ index is currently a relatively common measure of corporate financing constraints [83]. However, the KZ index contains many endogenous financial variables, such as cash flow, financial leverage, etc. [84–86]. In addition to the KZ index, Hadlock and Pierce (2010) [85] constructed the SA index based on two variables that do not change much over time and have a strong exogeneity, namely, firm size and firm age, which is conducive to describing the characteristics of financing constraints from a long-term perspective. The financing constraint index SA can weaken the endogenous problems faced by the KZ index to a certain extent. Besides, previous studies have found that the SA index can reasonably measure Chinese enterprises’ degree of financing constraints [46,87]. To ensure the robustness of the test results of the “financing constraint” mechanism, this paper both tests the impact of investors’ attention on KZ and SA indexes. The specific definitions of the two indicators are as follows: firstly, $KZ = -1.001909*CF - 39.36780*DIV_N - 1.314759*Cash + 3.139193*Lev + 0.2826389*Q$. In the formula, $CF$ = Net cash flow from operating activities / total assets at the beginning of the period, $DIV_N$ = dividend per share, $Cash$ = balance of cash and cash equivalents / total assets at the beginning of the period, $Lev$ = financial leverage ratio and $Q$ is Tobin’s $Q$ value. Secondly, following Hadlock and Pierce (2010) [85], Ju et al. (2013) [46], Dou et al. (2014) [87], Berkowitz et al. (2015) [84], Liu et al. (2015) [88], Jiang et al. (2017) [82], Lu and Chen (2017) [86], this paper uses SA index to measure the degree of corporate financing constraint. $SA = -0.737 * (Total Assets) + 0.043 * (Total Assets) 2 - 0.040 * Age$, where $Total Asset s = ln (total assets (unit: 1 million yuan))$, $Age$ = Natural logarithm of 1 plus years of listing at the beginning of the year. As most of the SA indexes are negative, we further use Lu and Chen (2017) [86] for reference and use $SA_{index}$ (logarithm of the absolute value of the index of listed companies) to measure the degree of corporate financing constraints. The larger the $SA_{index}$ index, the
higher the degree of financing constraints. For the Financing constraints channel, we conduct similar analyses using an SEM in the information asymmetry channel. We use two variables: SA and KZ. We present the findings in columns (2) and (3) in Table 4.

The empirical results in Table 4 show that the coefficients of $P(Attention, Patent)$ are 0.275 ($Z = 10.92$) and 0.293 ($Z = 10.65$) in columns (2) to (3), which are both significantly positive at the 1% level. The above results indicate that Attention has significant and positive direct effects on Patent in columns (2) and (3). For the indirect path, the paths of SA and KZ in columns (2) and (3) in Table 4 have significant $Z$-values ($z = 7.66$ and 3.28) for the row of $P(Attention, Path) \times P(Path, Patent)$, suggesting that the impact of Attention on Patent through the channels of Financing constraints, SA and KZ.

4.3.3. Agency Cost

According to the existing research, the agency problem under asymmetric information [18,19] is the key factor affecting enterprise innovation. Managers’ preference for a comfortable life rather than striving to create value for shareholders is another important manifestation of agency conflict between shareholders and managers [89]. However, the enterprise innovation risk is high, and the task is complex, which belongs to non-procedural decision-making and usually requires managers to invest more energy. Besides, there is a mismatch between the time of economic inflow and cost expenditure, which usually has a negative impact on enterprises’ short-term performance. Managers are reluctant to implement innovation projects for the sake of safeguarding private interests and increasing private costs. In this case, enterprises need more supervision input to ensure the smooth development of innovation activities [19]. This paper argues that investors’ supervision can significantly inhibit managers’ opportunistic behaviour and empirically test the impact of investor attention (online search index of listed companies) on listed companies’ agency costs. As the total asset turnover rate can reflect the control efficiency and management efficiency of management of the agency cost caused by the substitution of leisure enjoyment for hard work [90,91], this paper uses the total asset turnover rate to proxy the agency cost of listed companies. For the agency cost channel, we also conduct a similar test using an SEM in the information asymmetry channel. The specific mediation test result of Turnover is reported in column (4) in Table 4.

For row $P(Attention, Patent)$ in column (4) in Table 4, the result shows that the coefficient is 0.361 ($Z = 16.57$), which is significantly positive at the 1% level. It suggests that Attention has a direct effect on Patent. For the indirect path, the coefficient of $P(Attention, Path) \times P(Path, Patent)$ is 0.002 ($Z = 2.41$) in column (4), which is significantly positive at the 5% level. Hence, Attention has significant indirect effects on Patent through all “agency cost” mediating variables. The results are consistent with the notion that investor attention significantly improves the turnover rate of listed companies’ total assets, reduces the agency cost between management and investors and provides evidence support for the “agency cost” mechanism.

4.4. Robustness Test

To ensure the robustness of the research conclusions, the following robustness tests are carried out.

4.4.1. Alternative Measures of Key Variables and Empirical Specifications

Firstly, according to innovation’s different motivation, patent applications are divided into substantive Innovation (invention patent applications) and strategic innovation (utility model patent applications and design patent applications). Substantive innovation can promote technological progress, which belongs to high-tech innovation, while strategic innovation is only to meet government policies, and generally requires small and low-tech innovation [55]. China’s patents can be divided into invention patents, utility models and appearance design. Invention patents refer to the new technical solutions proposed
for product development technology or its improvement. Compared with utility models and appearance designs, invention patents have higher technical content and innovation value [92]. In this sense, invention patents are the patents that can best reflect the actual technical level [93]. Based on the definition of China’s patent law and the discussion of existing research literature [94], the existing literature often regards the application of “high-quality” invention patent as substantive innovation, and the enterprise’s application for a utility model patent and appearance design patent as strategic innovation [55].

Secondly, this article further uses patent citations to represent the quality of corporate innovation. Specifically, Citation1 (the number of patent citations in each year) and Citation2 (the number of citations excluding self-citations in each year, namely, excluding the number of citations within the group including a patent company, subsidiaries, joint ventures and associates) are used to proxy the quality of innovation output of enterprises.

Thirdly, this paper uses R&D investment, R&D/Sale, to represent the intensity of corporate innovation investment and examines the impact of investor attention on corporate innovation investment. R&D/Sale is the ratio of current R&D investment to listed companies’ current sales revenue [64,66,69,95].

Finally, since the number of enterprises’ patent applications is a non-negative integer value, which is a typical counting variable. This paper follows the existing literature to retest the impact of investor attention on corporate innovation by using the negative binomial regression (NBreg) [96] and Poisson regression [71,97]. Besides, this paper also uses general linear regression (OLS) [98] to test Equation (2). The above robustness test’s empirical results are shown in columns (1)–(8) of Table 5.

| Y= | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|----|-----|-----|-----|-----|-----|-----|-----|-----|
| Attention Constant | 0.244 *** | 0.260 *** | 0.334 *** | 0.342 *** | 0.009 *** | 0.190 *** | 0.105 *** | 0.099 *** |
| (3.45) | (3.28) | (6.56) | (6.85) | (4.58) | (4.35) | (3.35) | (3.26) |
| Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| Year F.E. | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| N | 16,608 | 16,608 | 13,494 | 13,494 | 13,201 | 16,608 | 16,608 | 16,608 |
| Adj(Pseudo) _R^2_ | 0.142 | 0.147 | 0.190 | 0.192 | -0.136 | 0.339 | 0.146 | — |

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level in columns (1) to (4). ** and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

It can be seen from Table 5 that the regression coefficients of Attention in column (1)–(8) are significantly positive at the level of 1%, which is consistent with the results of the main regression. The baseline results are still robust after changing the measurements of innovation variables and using other regression methods.

4.4.2. Propensity Score Matching (PSM)

To alleviate omitting variables concern that may exist in the empirical research and enhance the validity of the research conclusions, this paper uses the propensity score matching (PSM) method to retest Equation (2).

Firstly, following the ideas and methods of Ni and Zhu (2016) [61] and He et al. (2019) [68], this paper takes the median of investors’ attention (Attention) of listed companies as the benchmark and divides all samples into two categories: high vs low subsample. Treat equals 1 if Attention’s value is greater than the benchmark, which means treatment group, and 0 otherwise.

Secondly, referring to Bartram et al. (2012) [99], Cao et al. (2018) [100], He et al. (2019) [68], this paper uses the 1:1 nearest neighbour matching method and keep the set of con-
trol variables in Equation (2) in the logit regression of PSM’s first step to calculate propensity score. The matching method with replacement is adopted to find the control group sample with each firm’s closest propensity score in the treatment group [68,99,100].

Finally, in the process of matching, it is required that the distributions of treatment and control firms meet the common support assumption [101]. Specifically, any observation’s propensity score in the common support set is located in the treatment group’s intersection and the control group. The PSM procedure mitigates the impact of unobservable variables on our findings to a certain extent. The regression results after treatment with propensity score matching (PSM) are shown in column (1) of Table 6.

The results of PSM are presented in column (1) in Table 6. The coefficient of Attention is still significantly positive at the level of 5%. After alleviating the endogenous problem, investors’ attention still helps increase the number of patent applications and improves the innovation level, proving the robustness of this paper’s baseline results.

| Table 6. Endogenous treatment. |
|-----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Y = Patent                  | (1)            | (2)            | (3)            | (4)            | (5)            | (6)            | (7)            |
|                             | PSM            | Heckman        | Forward2       | Forward3       | Forward4       | Attention      | Patent         |
| Attention                   | 0.214 **       | 0.286 ***      | 0.202 **       | 0.209 **       | 0.231 **       | 8.107 ***      |                |
|                            | (2.44)         | (5.67)         | (2.44)         | (2.26)         | (2.21)         | (9.02)         |                |
| IMR                         | 1.613***       |                |                |                |                |                |                |
|                            | (3.45)         |                |                |                |                |                |                |
| Patent_mean                 |                | 0.066 ***      |                |                |                |                |                |
|                            |                | (5.76)         |                |                |                |                |                |
| Internet                    |                | 0.250 ***      |                |                |                |                |                |
|                            |                | (9.18)         |                |                |                |                |                |
| Constant                    | Yes            | Yes            | Yes            | Yes            | Yes            | Yes            | Yes            |
| Industry F.E.               | Yes            | Yes            | Yes            | Yes            | Yes            | Yes            | Yes            |
| Year F.E.                   | Yes            | Yes            | Yes            | Yes            | Yes            | Yes            | Yes            |
| N                           | 11,067         | 9111           | 13,875         | 11,298         | 8855           | 11,064         | 11,064         |
| Adj(Pseudo)_R²             | 0.146          | 0.286          | 0.150          | 0.146          | 0.143          | 0.371          | 0.340          |

Note: All regressions include industry and year 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.

4.4.3. Heckman Two-Stage Model

Due to the missing or zero value of some firms’ patent application data, the sample selection bias may weaken the research conclusion. This paper uses the Heckman two-stage method to modify Equation (2) by following Shi and Wang (2017) [102]. Firstly, a probit regression is run by using Equation (3) to calculate the inverse mills ratio (IMR). Patent dummy, in Equation (3) is a dummy variable, which equals 1 if patent applications are greater than 0, and 0 otherwise. Controls are consistent with Equation (2). In the second stage of Heckman models, the selected sample of Patent dummy = 1 is used to perform the ordinary least square (OLS) regression on Equation (4), and other variables were still consistent with Equation (2). The empirical result of Heckman’s two-stage method is shown in column (2) in Table 6.

\[
\text{Patent dummy}_{i,t} = \alpha_0 + \alpha_1 \text{Attention}_{i,t} + \alpha_2 \text{Controls}_{i,t} + \eta_i + \eta_{id} + \epsilon_{i,t},
\]

\[
\text{Patent}_{i,t} = \beta_0 + \beta_1 \text{Attention}_{i,t} + \beta_2 \text{Controls}_{i,t} + \beta_3 \text{IMR}_{i,t} + \eta_i + \eta_{id} + \epsilon_{i,t},
\]

The results in column (2) in Table 6 show that the coefficient of inverse mills ratio (IMR) is 1.613 (t = 3.45), which is significantly positive at the level of 1%, indicating that there is indeed a sample selection bias in the data of patent applications. The Attention coefficient was 0.286 (t = 5.67), which was significantly positive at a 1% level, consistent
with the main regression. Once again, it is confirmed that investors’ attention is helpful to improve the output level of innovation patent of listed companies.

4.4.4. Multiple-Period Lagged Independent Variable

It takes a certain amount of time due to the impact of investor attention (listed company web search index) on enterprise innovation output (patent applications), the independent variable has already been lagged for a period to effectively alleviate the endogenous problem caused by reverse causality [66] by following Chen et al. (2016) [103], Adhikari and Agrawal (2016) [104]. It is also helpful to examine the long-term impact of investor attention on innovation output. Therefore, in the robustness test, this paper further follows He and Tian (2013) [52], Fang et al. (2014) [62], Jiang et al. (2017) [82], lags the independent variable to multiple periods, i.e., the independent variables are lagged by two periods, three periods and four periods respectively. The corresponding empirical results are shown in column (3)–(5) in Table 6.

The results of columns (3)–(5) in Table 6 show that the coefficients of Attention are 0.202 (t = 2.44), 0.209 (t = 2.26) and 0.231 (t = 2.21), all three of them are significantly positive at the 5% level. It proves that the research conclusion remains unchanged after alleviating the influence of reverse causality. Besides, this part’s empirical results also show that investor attention has a long-term impact on corporate innovation output.

4.4.5. Instrumental Variable Method (IV)

Equation (1) in this paper may have the reverse causality problem; that is, the companies with strong innovation ability are often paid more attention by investors. The positive correlation of Equation (2) may not mean that investors’ attention improves corporate innovation output. Aiming at this endogenous problem, this article uses the instrumental variable method to eliminate reverse causality interference.

By following Fisman and Svensson (2007) [105] and Shen and Yuan (2020) [63], this paper uses two Instrumental variables for Attention, the industry average of corporate Internet search index (Patent_mean) and the prefecture-level Internet penetration rate (Internet). Column (6) in Table 6 reports the regression results of the first stage of the two-stage least squares method (2SLS). This paper finds that the instrumental variables (Patent_mean and Internet) are significantly positively correlated with investor attention (Attention) at the level of 1%. The tested F value is 169.8, which is far greater than 10. In the second stage of regression, the predicted values of Attention are taken as explanatory variables into Equation (2) to retest the baseline result. The empirical result in column (7) of Table 6 shows that the predicted value of the Attention index is significantly positively correlated with Patent at the level of 1%, which indicates the regression results of instrumental variables are consistent with the main result. Investor attention can still better improve the level of innovation output of enterprises after considering the endogeneity.

4.4.6. Placebo Test

There is a possibility that the baseline findings in Table 3 are due to random noise. To eliminate the interference of the missing variables and random noise on the results, this article conducts a placebo test by following Chen et al. (2017) [47], Cornaggia et al. (2015) [39] and Bernile et al. (2017) [106]. Specifically, this paper conducts 500 random assignment and transformation of investor attention among samples and re-regression Equation (2). The variable of investor attention after random transformation is SIMAttention. Suppose the improvement of innovation output is not caused by investor attention but affected by other factors related to investor attention but not observed. In that case, SIMAttention will still be significantly positive. On the contrary, if investors’ attention causes the improvement of innovation output, then SIMAttention will not be significant after the randomization of Attention. The results are shown in Table 7.
Table 7 reports the placebo test’s empirical results: the mean of the coefficient of SIMAttention is 0.0003 (t = 0.133). Approximately 2.2% is positive, and 2.8% is negative and statistically significant at the 5% level. Besides, we compare the estimated coefficients in the placebo tests and the estimated coefficients in Table 3 and notice that none of the estimated coefficients for Attention is larger than the corresponding coefficients in Table 3. Besides, the proportion of SIMAttention’s estimated coefficients satisfying the following three conditions is 0%. The absolute value is greater than the absolute value of the coefficient in the main regression, and the signs of the two are the same and significant. It can be seen that the coefficient of SIMAttention obtained by the placebo test is significantly different from the real regression coefficient (0.255, t = 3.39), and it is not significant, which is in line with the expectation, indicating that the missing variables and random noise do not cause the conclusion of this paper.

4.5. Additional Analysis: Capital Allocation Efficiency

The results of the mechanism test show that “information asymmetry”, “financing constraint”, and “agency cost” have been empirically supported. That is, the increase of investors’ attention to listed companies reduces the information asymmetry of enterprises [72] and eases the financing constraints of enterprises [73], provides financial support for enterprise innovation [40], improves the supervision of opportunistic behaviour of managers and reduces agency costs [107,108]. This paper argues that with the improvement of corporate innovation enthusiasm, only by continuously increasing R&D investment and improving capital allocation can the enterprise’s innovation level be continuously improved. In the robustness test part, this paper has found that R&D has increased. In this part, this article further examines whether the company has improved its capital allocation efficiency because only in this way can the company’s innovation output level be continuously improved. In this section, this paper further examines this issue by using the specification of McLean et al. (2012) [109] to explore the impact of Attention on a firm’s investment-Tobin’s Q sensitivity. The specific model is as follows:

\[ INV_{it} = \alpha_1 + \beta_1 Q_{it-1} + \beta_2 CF_{it} + \beta_3 Attention_{it-1} \times Q_{it-1} + \beta_4 Attention_{it-1} \times CF_{it} + \beta_5 Lev_{it} + \beta_6 Size_{it} + \eta_1 + \eta_2 + \epsilon_{it} \]  

(5)

In model (5), Attention represents listed companies’ online search index, which is used to represent investors’ attention to listed companies. INV is the new investment amount, Q is the lagged Tobin’s Q value and CF is the enterprise’s free cash flow. We also control variables such as firm size (Size) and corporate leverage ratio (Lev). In Equation (5), we mainly examine whether the interaction term (Attention × Q) is significant. If investors’ attention improves the capital allocation efficiency of listed companies, it is expected that \( \beta_3 \) is significantly positive.

It can be seen from Table 8 that the coefficient of the interactive term Attention × Q is 0.004 (t = 13.63), which is significantly positive at the 1% level. This indicates that investors’ attention significantly improves the capital allocation efficiency of listed companies. That is to say, the improvement of investors’ attention to listed companies can
improve the quality of information disclosure, reduce information asymmetry, ease financing constraints and obtain funds needed for innovation and then reduce agency costs to improve the efficiency of capital allocation and improve the innovation level of enterprises.

Table 8. Test results of capital allocation efficiency.

| Y = INV | (I) |
|---------|-----|
| Q       | 0.171 *** | (22.08) |
| CF      | 0.152 *** | (6.74) |
| Attention×Q | 0.004 *** | (13.63) |
| Attention×CF  | 0.000 | (0.28) |
| Lev     | -0.206 *** | (-20.83) |
| Size    | 0.013 *** | (12.85) |
| Constants | -0.215 *** | (-10.82) |

Industry F.E. Yes
Year F.E. Yes
N 18,109
Adj_R² 0.198

Note: All regressions include industry and year 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.

5. Conclusions

This paper provides empirical evidence to the effect that investor’s initiative to collect information may foster corporate innovative activity. Consistent with Jensen and Meckling (1976) [108] and Jiang and Yuan (2018) [7], investors play an important role in improving the capital market information environment [28,29] and promoting corporate innovation. Specifically, leveraging from the online search index of Chinese listed companies from 2012 to 2018, this paper examines the impact of investor attention on corporate innovation. Firstly, our findings suggest that investor attention proxied by online search index enhances, on average, corporate innovation performance. It indicates that investors’ active information online search behaviour has a positive guiding effect on China’s real economic development by promoting corporate innovation. Next, our results are still valid after engaging in a battery of robustness tests, such as the redefinition of key variables, alternative empirical specifications and a series of endogenous treatment methods (propensity score matching, Heckman two-stage, multiple-period lagged independent variable, instrumental variable and placebo test). Then, this article proposes and confirms three types of possible mechanisms, namely, “information asymmetry”, “financing constraints” and “agent costs”. In other words, investor attention has effectively improved the corporate information disclosure environment, mitigated information asymmetry and finally alleviated firms’ external financing constraints. Moreover, Investors supervise the management more effectively, alleviate the agency conflict, prompt managers’ motivation for innovation input and improve the corporate innovation of output and quality. Finally, additional analysis indicates that investors’ network attention to listed companies does
have a positive effect on capital allocation efficiency and the development of the real economy.

Given the robust results of this article, our conclusions have several important theoretical and practical significance. Firstly, the literature is enriched on the relationship between capital market and firm’s real investment decisions, such as capital allocation efficiency, and the relationship between market-level factors to long-term, intangible assets such as corporate innovation, which is vital for nations’ economic growth and competitive advantage [24]. To the best of our knowledge, this paper is the first to empirically test the impact of investor attention, proxied by Internet search index, on corporate innovation. From the perspective of investors’ active information acquisition process, this paper reveals the positive impact of investor attention on corporate innovation performance, thus enriching the literature on the influencing factors of corporate innovation. Secondly, this article complements this literature about the vital role of investors in promoting the real economy. Previous literature mainly focuses on institutional investors’ ownership [25–27], institutional investors’ corporate site visits [7]. This paper expands the literature about the influence dimension of investors and proves that investor attention also plays an important role in promoting China’s real economic development by improving corporate technology innovation. In addition, the conclusions of this article reveal the specific ways that investor attention can enhance corporate value from the perspective of corporate innovation, and provides new empirical evidence for the corporate governance role of investor attention. Finally, this article this paper enriches the relevant literature about the economic consequences of Internet search technology. Previous literature mainly focuses on the impact of Internet search technology on the stock market [13,30,31], however, our paper reveals the influence of Internet technology development on corporate innovation and the real economy [110]. In addition, our conclusions also have certain reference significance for policymakers. While implementing the development strategy of “building an innovative country”, our country should also vigorously develop the Internet and other information and communication technologies to provide more convenient conditions for investors to search for information about enterprise information.

This article only focuses on the general innovation of enterprises. In view of the increasing importance of environmental protection, especially environmental protection is one of the common actions and main tasks of the governments and people of all countries in the world today, and it has become a basic national policy of China. Corporate green innovation has gradually become the focus of finance and practice. Therefore, research on the relationship between investor attention and environmental innovation is also an important topic worthy of an in-depth discussion in the future.

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### Appendix A

This table provides definitions of all variables used.

| Variable | Definition | Reference | Source |
|----------|------------|-----------|--------|
| **Explained variable:** |
| Patent | Natural logarithm of 1 plus total annual patent applications of listed companies | Custódio et al. (2019) [57]; Ovtchinnikov et al. (2020) [58] | CSMAR |
| **Explanatory Variables:** |
| Attention | Natural logarithm of 1 plus annual Internet search index of listed companies | Da et al. (2011) [13]; Drake et al. (2012) [34] | CNRDS |
| **Control Variables:** |
| Size | Natural logarithm of total assets at the beginning of the year. | Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Age | Natural logarithm of 1 plus years of listing at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Capital | Natural logarithm of 1 plus the ratio of fixed assets to the number of employees at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Q | Tobin’s Q value measured as the ratio of (stock price × shares of outstanding shares + net assets value per share × number of non-outstanding shares + book value of liabilities) to total assets at the beginning of the year. | Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| ROA | The ratio of net income to total assets at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Lev | Leverage computed as total liabilities divided by assets at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| CF | The ratio of net cash flow from operating activities to total assets at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Growth | The growth rate of total assets at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Loss | A dummy variable with a value of 1 if the company loses consecutively in the last two fiscal years, and 0 otherwise. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Dual | A dummy variable with a value of 1 if the firm’s chairman and CEO are held by the same person, and 0 otherwise. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Board | Natural logarithm of the number of board of directors at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| Indd | The ratio of the number of independent directors to the number of board of directors at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| TOPHOLD | The ratio of the number of shares held by the largest shareholder to total shares of the firm at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |
| HHI | Industry Herfindahl Index at the beginning of the year. | He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63]; Fang et al. (2014) [62]; He and Tian (2013) [52]; Shen and Yuan (2020) [63] | CSMAR |

Other variables:
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