

The effects of option incentive compensation on corporate innovation: The case of China

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Highlights

- Option incentives stimulate corporate innovation inputs and outputs.
- Innovations driven by option incentives promote invention patents rather than utility model patents.
- High-tech firms benefit more from option incentives for their innovations.

Abstract

This study aims to examine the impact of option incentives on corporate innovations in the representative emerging and transition economy. By utilizing the Chinese dataset, we find a noteworthy positive impact of option incentives on two dimensions of innovation: inputs and outputs. These positive effects remain valid after controlling for potential endogeneity problems using difference-in-differences with propensity score matching. Option incentives have a more pronounced effect in high-tech firms but underperform in non-high-tech firms. Therefore, it is necessary to consider the different characteristics and needs of firms when developing their incentive policies. Our results provide useful insights for corporate managers

and policymakers in developing option incentive programs to promote innovations in emerging economies.

Keywords: Compensation structure; Corporate innovation; Chinese market; Option incentives; R&D

Subject classification codes: G30, G32, O31, O32

1. Introduction

Innovation is central to economic growth and long-term corporate competition (Chkir, Hassan, Rjiba, and Saadi, 2021; He and Tian, 2018). Schumpeter (2017) introduces the “theory of innovation” in his book, *The Theory of Economic Development*. This perspective provided the basis for the corporate innovation theory, attracting many scholars. Innovation activities are high-cost investments with long duration and high risks. Therefore, innovation at the company level is subject to agency problems, where managers prefer projects with small cash flow fluctuations to reduce the risk of damaging their wealth or losing their job (Lu and Wang, 2018). Promoting corporate innovation activity while reconciling the interests of managers and shareholders has become an increasingly important topic.

In their classical principal-agent framework, Jensen and Meckling (1976) argue that equity incentives can effectively improve management’s appetite for innovation. Equity incentives also alleviate agency conflicts between corporate managers and owners (Ryu and Ryu, 2017). Moreover, the risk-taking incentives provided by equity incentives can reduce management’s risk aversion (Smith and Stulz, 1985). Specifically, stock option incentives, such as those based on restricted stocks and option incentive compensation, serve as primary mechanisms for aligning management behavior with shareholder objectives (Biggerstaff, Blank, and Goldie, 2019).

Many empirical studies focus on whether option incentives influence a firm’s innovation activities. However, the impact of option incentives on corporate innovation in the Chinese market needs to be studied. In recent years, the economic development of China enters a new high-speed and high-quality stage, especially as Chinese companies transform from low- to high-end manufacturing (Cheng, Kim, and Ryu, 2023; Ham, Cho, Kim, and Ryu, 2019; Luo,

Cai, and Ryu, 2022).¹ Thus, industrial upgrading through technological innovation has become an inevitable choice for national economic development. In addition, with the formal implementation of relevant regulations such as the *Measures for the Administration of Equity Incentives for Listed Companies* between 2005 and 2008, the conditions for granting and exercising equity incentives are further clarified, making the implementation of equity incentives for listed companies more operative. Since 2010, more and more Chinese A-share companies have started to implement equity incentive plans, and generally adopt the lower-cost stock options model. Therefore, we believe that the study of the relationship between option incentives and corporate innovation at this stage is very meaningful in the current institutional context.

Executive stock options (ESOs) are a common incentive in enterprise management. ESOs originated in the US in the 1950s and have seen widespread usage since the early 1990s. Due to the growth and development of high-tech companies, option incentive compensation is also being offered to non-executive employees (Chang, Fu, Low, and Zhang, 2015; Core and Guay, 2001). The number of listed companies implementing equity incentives has continued to increase annually in China since the China Securities Regulatory Commission (CSRC) promulgated the *Measures for the Administration of Equity Incentives of Listed Companies* (for Trial Implementation) in 2006. Presently, equity incentives in China are primarily based on option incentive compensation and restricted stocks, with a few companies adopting stock appreciation rights as an incentive method. As of December 31, 2020, more than 2,100 companies listed in China indicated implementing equity incentive plans.

In this study, we investigate the impact of option incentive schemes on corporate innovation. Many studies to date have focused on the impact of financial market development (Hsu, Tian, and Xu, 2014), conglomerate organizations (Seru, 2014), share pledges of controlling shareholders (Pang and Wang, 2020), and other factors on corporate innovation. However, the empirical literature on the relationship between option incentive compensation and firm innovation has not reached a consensus. Mao and Zhang (2018) use the 2005 FAS 123R²

¹ Some topics are frequently studied in the developed markets, however, further empirical studies are still required considering the unique characteristics of emerging and transition economies (Azari, Kim, Kim, and Ryu, 2016; Chun, Cho, Ryu, 2020; Kim, Cho, Ryu, 2018; Song, Ryu, 2016).

² FAS 123R is a financial accounting standard in the U.S. introduced by the Financial Accounting Standards Board (FASB) in 2006 that requires stock options to be expensed.

accounting regulations in the U.S. to establish causality and report that the diminished incentive for management to take risks inhibits innovative activities after the policy is implemented. Chang and Garen (2004), and Lin, Lin, Song, and Li (2011) find a strong positive relationship between option incentive compensation and research and development (R&D) expenditure. Chang, Fu, Low, and Zhang (2015) point out that implementing option incentives for non-executive employees positively impacts corporate innovation in terms of innovation output and improves the competitiveness of the company. Bens, Nagar, and Wong (2002) argue that since the benefits received from equity incentives are closely related to R&D investment, too much equity given to executives through equity incentives does not increase R&D investment. Zhou, Li, Sun, and Zhou (2021) find that executive equity compensation negatively affects innovation investment when corporate risk is high. Moreover, in the choice of equity-based incentive approaches, stock options play a more significant role in innovation incentives than restricted stocks.

This investigation contributes to the existing literature in that examines the relationship between option incentives and corporate innovation in more detail. First, this study comprehensively examines two aspects of innovation – innovation inputs and outputs. Most of the existing research mainly focuses on the unilateral impact of option incentives on corporate innovation output. Using only the corporate innovation output as an indicator does not show the whole picture of corporate innovation. We also include the R&D expenditure to total assets ratio, which measures corporate innovation input. This methodology helps to avoid the potential impact stemming from the varying sizes and economic foundations of different firms, thus providing a more accurate reflection of their actual R&D investment. Secondly, we employ two distinct methods to investigate firm innovation. We begin by applying a commonly used linear regression model to analyze our data. Subsequently, in order to more precisely assess the influence of option incentives on firm innovation, we implement a propensity score matching (PSM) and generate a PSM-paired sample. By controlling for year and industry effects, this paper uses a difference-in-differences (DID) model to test the impact of option incentive programs on firm innovation, thereby providing more compelling evidence. And we analyze the effects of option incentives in firms with different sector characteristics. Finally, this study examines the most recent data available for Chinese-listed companies after 2012. With the formal implementation of regulations related to equity incentives from 2005 to 2008, the implementation of equity incentives in listed companies has been standardized. Consequently, Chinese listed companies have refrained from considering equity incentives

merely as a supplement to employees' salaries. Furthermore, the *Accounting Standards for Business Enterprises* mandate the disclosure of R&D investment information, but initially, compliance with this requirement is limited to only a few listed companies. After 2012, the disclosure of R&D expenditure information became normalized, leading to more credible data. Therefore, this study uses data from 2012 onwards to accurately assess the impact of option incentives on corporate innovation.

Our results with linear regression show that option incentives have a positive impact on both innovation inputs and outputs of firms. However, after performing PSM-DID analysis, the positivity is significantly reduced in both cases. We also find that the effect of option incentives is more significant in high-tech firms. The remainder of this paper is organized as follows. In Section 2, we provide some background information and discuss the related literature. We describe the data and empirical methodology in Section 3 and present our results in Section 4. We discuss our results in Section 5. Finally, Section 6 concludes.

2. Background and Related Literature

Extant literature documents three main positive effects of option incentive compensation on corporate innovation. First, stock options usually have an extended exercise period such that early innovation failure can be tolerated and long-term success can be promoted. When an innovation activity fails, the incentive recipient can forgo exercising the option; thus, the loss in the option incentive value is limited. Conversely, when the innovation activity is successful, the stock price rise can realize rich returns, which is beneficial to the option value (Manso, 2011). Chava and Purnanandam (2010) indicate that the risk-seeking incentives provided by key corporate managers' stock and option holdings are strongly linked to corporate risk-taking. Second, an option incentive plan can encourage the company's executives to undertake technological innovation activities with long-term characteristics toward the company's extensive development and reduce the probability of executives leaving (Balsam and Miharjo, 2007). Compared with general compensation methods, option incentive compensations encourage manager who wants to receive option incentives to stay with the company during the exercise period. Retaining executives is an essential characteristic that distinguishes option incentive compensation from other compensation methods (Oyer, 2004). Finally, option-based compensation incentive plans connect management compensation with the company's stock price fluctuation, motivating executives to take risks and engage in innovation. Francis, Hasan, Sharma, and Waisman (2019) study the relationship between CEO compensation and

innovation. They find that option compensation induces corporate innovation.

Option-based compensation incentives may also inhibit corporate innovation. Coles, Daniel, and Naveen (2006) argue that linking manager compensation to the company's stock price will increase the dependence of managers' wealth on the company's stock price, which will make managers more risk-averse and reduce R&D expenditure. Fang, Tian, and Tice (2014) suggest that short-term pressure in the stock market might limit management's horizons and impede corporate innovation. In China, the effect of option-incentive compensation plans is also unclear. Fang, Nofsinger, and Quan (2015) point out that, in China, stock option incentive plans have both incentive and welfare effects. They find that some Chinese listed companies use option incentives for executive compensation, but that compensation loses its original purpose and even reduces corporate performance.

Some scholars conclude that option incentives and corporate innovations are unrelated. Himmelberg, Hubbard, and Palia (1999) report an insignificant correlation between stock option compensation incentives and operating efficiency. Nguyen (2018) investigates the relationship between CEO equity-based incentives and corporate innovation. He finds that short-term incentives are not associated with greater innovation output, while long-term incentives are only effective for firms in highly innovative industries. Biggerstaff, Blank, and Goldie (2019) use the FAS 123R regulations as a quasi-natural experiment to examine the impact of option compensation on corporate innovation and conclude that option-based remuneration does not promote corporate innovation. Tien and Chen (2012) use a sample of high-tech firms to test the moderating effect of CEO compensation on the technological dynamics of R&D innovation. They show that there is no positive effect on the behavioral dynamics of R&D innovation regardless of the compensation structure.

In sum, there is no consensus on the relationship between option compensation and innovation of listed companies. Corporate innovation in emerging economies may be of a different nature from that in developed countries (Fedyunina and Radosevic, 2022; Yano and Shiraishi, 2020). Unlike the capital markets of developed countries, China's capital market is undergoing rapid development and transformation. Chinese market's various rules and regulations are imperfect, and supervision is not strict, which can affect the effectiveness of equity-based compensation incentives. Studies on Chinese companies, including Heitzman (2011), show that some companies use incentive stock options to benefit executives, resulting in the loss of their effectiveness. Specifically, when the design of performance appraisal indicators is too loose, this is conducive to obtaining and exercising stock options by the

management. However, these studies mainly use data before 2011, as the formal implementation of the *Measures for the Administration of Equity Incentives of Listed Companies* (for Trial Implementation) is promulgated by the CSRC in 2006. In 2008, a series of three memoranda is issued on matters related to equity incentives. Subsequently, the Measures for the Administration of Equity Incentives for Listed Companies are officially promulgated in 2016. They further clarify the grant and exercise conditions of equity incentives and effectively limited the implementation of a pure welfare equity incentive plan. In sum, due to policy changes, data after 2011 are much more reliable.

Based on the discussion above, our study addresses the limitations of previous research. First, previous studies have often neglected important considerations such as sample selection issues and the unilateral use of only inputs or outputs as measures in measuring corporate innovation (Heckman, 1979; Sunder, Sunder, and Zhang, 2017). Second, as the conditions of equity incentive grants and exercises become more stringent between 2005 and 2008, the implementation of purely welfare-based equity incentive plans has been more limited than before. Therefore, a new empirical study is needed to consider the policy changes. Third, despite being evident and straightforward, a simple count of patents is insufficient to separate breakthrough technologies from incremental technical breakthroughs. Patent citations are a more accurate indicator of the importance and quality of a company's innovation output (Nguyen, 2018). Most studies in China only use the number of patent applications to measure innovation output, but many company patents are not used for production activities. Some studies find that to show their competitive advantages, firms ignore the patent quality and achievement transformation, which leads to the low quality of corporate patents (Trappey, Trappey, Wu, and Lin, 2012). This ignorance indicates that the number of patents used to measure corporate innovation results cannot fully reflect the actual corporate innovation situation. These limitations in prior research may have led to an incomplete or inaccurate assessment of the relationship between equity incentives on corporate innovation.

This study uses more detailed innovation analysis indicators to reflect Chinese corporate innovation capabilities better. The number of patent applications, patent citations, and R&D expenditures are used to measure the innovation abilities of companies. Furthermore, building upon the framework of ordinary least squares regression, we employ the PSM-DID approach to address any potential biases resulting from sample selection issues. Specifically, we conduct matching between firms that implement stock option incentives and those that do not and subsequently use the DID method to compare the changes in innovation inputs and outputs

between the treatment and control groups before and after the intervention. This approach helps to alleviate any potential biases stemming from sample selection issues and increases the robustness of our findings.

3. Data and Methodology

3.1 Sample description

Our sample covers the period from 2012 to 2021. Kondo (1999) finds that the time lag between research and development and the resulting patent applications is found to be about one and a half years. In a similar vein, we examine companies implementing option incentives between 2013 and 2020 to consider the time lag between introducing an option incentive compensation and the impact on innovation output. To select companies that implemented option incentives in 2013, the observation period in this study begins in 2012. Data on R&D expenditures and patents, representing innovation inputs and outputs, are observed up to 2021. Our dataset includes annual book value data at the end of December, while our industry classification follows the CSRC 2012 Standard Industry Classification codes. R&D expenses and patent data of listed companies come from the Chinese Research Data Services database, option incentive data, and company financial data from the China Stock Market & Accounting Research database. To avoid the adverse effects of abnormal data and enhance comparability between samples, we screen our sample using the following criteria: (1) Exclude financial companies and companies subject to special regulatory measures due to financial distress or non-compliance with listing requirements; (2) companies with debt ratios over 100% are excluded because they may be insolvent; (3) cross-listed companies that issue B or H shares at the same time are excluded³; and (4) observations with missing major research variables are excluded. To mitigate the effect of extreme observations, the continuous variables used in the regression analysis are winsorized at the first and 99th percentiles.

3.2 Variable selection

3.2.1 Corporate innovation

³ B shares, officially known as Renminbi special shares, are foreign shares denominated in Renminbi, subscribed and traded in foreign currency, and listed and traded on the stock exchanges in China (Shanghai and Shenzhen). H shares refer to the shares of Chinese companies registered in the Mainland and listed in Hong Kong.

In this study, we incorporate innovation inputs and outputs to measure corporate innovation performances. Innovation inputs are typically measured by R&D expenditures (Chang and Garen, 2004). In terms of R&D expenditures and innovation performance, Hazarika, Karpoff, and Nahata (2012) believe that increasing R&D investment can improve a company's stock price. Falk (2012) finds that a company's R&D expenditures are conducive to improving technological innovation output. To effectively control for the impact of company size on R&D expenditures, we utilize the publicly disclosed ratio of R&D expenditures to total assets in annual reports as the primary indicator for this study (Biggerstaff, Blank, and Goldie, 2019). To better capture the changing trend of R&D expenditures and mitigate the data compression effect caused by linear changes, we also employ the logarithm of R&D expenditures as an indicator of a firm's innovation investment. This approach ensures that our study considers the complex relationship between R&D investment and company performance, providing a more thorough and nuanced analysis. Based on extant literature, missing values of all R&D expenses are taken as zero (Mao and Zhang, 2018).

Several studies on innovation performance examine innovation output capacity from the number of patents and citations (Liu, Du, Zhang, Tian, and Kou, 2021; Chang, Fu, Low, and Zhang, 2015; Hochberg and Lindsey, 2010). These studies measure the quantity and quality of innovation output. Based on this literature, we use the number of patent applications and citations to investigate the output capacity of corporate innovation. According to the Patent Law of the People's Republic of China, applied patents are divided into three types: invention, utility model, and design. Among them, invention and utility model patents represent new technological innovations, while design patents create unique aesthetic designs of product shapes or patterns. Hence, we select the number of invention and utility model patent applications as the indicator of innovation output since it provides a more comprehensive and accurate reflection of the quality of corporate innovation. We define the patent variable as the application date rather than the grant date because there is a considerable gap between application and authorization dates. The application date is considered closer to when innovation occurs. Patents take a longer time from application to grant, and the filing date is considered closer to the time when the innovation occurs (Biggerstaff, Blank, and Goldie, 2019). Patent data count the number of patents of listed companies and those of their subsidiaries and associated companies. We use the number of citations for each year, excluding self-citations, in our calculation for patent citation data. Given that the number of patents of some companies is zero, the number of patent applications and citations is increased by one to

take the logarithm. The number of citations is calculated by dividing the actual number of citations of each patent by the average number of citations of granted patents in the same year for normalization of the number of citations.

3.2.2 Option incentive compensation

We focus on companies that announce their option incentive programs from 2013 to 2020 since the implementation of the *Measures for the Administration of Equity Incentives of Listed Companies*. Programs that passed the board of directors' proposal but have not yet been implemented and the programs that passed the shareholders' meeting but have not yet been implemented and terminated are excluded. We select the date of the first announcement as the benchmark time for the listed companies that issue and implement the incentive compensation plan, and the incentive objects are executives and core employees. The years before implementing its first option incentive are defined as the pre-event period (Post = 0). The years in which option incentives are implemented and the following years are defined as the post-period (Post = 1). Firms that implement option incentives are the treatment group (Treatment = 1), and firms that do not are the control group (Treatment = 0).

3.2.3 Control variables

Following the practice of Biggerstaff, Blank, and Goldie (2019) and Seru (2014), we select company size, company value, capital structure, profitability, company age, and tangible asset ratio to control company characteristics. Table 1 provides definitions of our variables in detail. According to Hall and Ziedonis (2001), large and capital-intensive companies generate more patents and citations. We use $\ln(TA)$, the natural logarithm of total assets, to control for firm size. *Tobin's Q* is a frequently used measure of firm value in the international finance and economics literature. We adopt it as our measure of company value (Bryant-Kutcher, Guenther, and Jackson, 2012). The company's debt-to-asset ratio, *Debt_Ratio*, measures capital structure as low-leverage firms are more conducive to innovation activities. We use *ROA*, the return on total assets, as an indicator of profitability. $\ln(Age)$ is the natural logarithm of the business's age, which is the number of years since the firm has been founded. This variable is adopted to control for the influence of the firm's life cycle on its innovation capability. We also control the tangible assets to total assets ratio, *Tangible*, because profitability is associated with the availability of internal funds. We also add the nature of property rights and firm characteristics as matching control variables. Owing to differences in corporate property rights and operating

environments, state-owned enterprises (SOEs) and non-SOEs have different innovation incentives and efficiencies (Lin, Lu, Zhang, and Zheng, 2020). Enterprises with different property rights may have different impacts on innovation. Therefore, we adopt the property right nature of the ultimate controller of the enterprise as the explanatory variable. The high-tech industry is a knowledge- and technology-intensive economic entity. Compared with traditional sectors, the impact on innovation is very different. Investigating the relationship between stock option incentives and innovation in high-tech companies has practical significance and research value. Patent growth is measured as the average annual growth rate in the number of patents preceding the option incentive's occurrence for three years.

[Insert Table 1 about here]

Table 2 provides summary statistics and a univariate comparison of patent applications, patent citations, R&D expenditure, and firm characteristics used in later models as dependent and control variables. Our final sample contains 12,166 observations after the screening. There are 1,352 listed companies in our observations. In the sample, 336 listed companies have adopted option incentive plans, which is 24.85% of the total number of listed companies.

[Insert Table 2 about here]

3.3 Methodology

We utilize a generalized linear regression approach to compare and analyze the innovation inputs and outputs of companies that implement stock option incentives. To test the effect of option incentives on the innovation inputs, we test the following linear regression model:

$$Input_{i,t+1} = \beta_0 + \beta_1 Option_{i,t} + \beta_2 Control_{i,t+1} + Year_dum + Indus_dum + \varepsilon_{i,t}, \quad (1)$$

where $Input_{i,t+1}$ denotes the innovation inputs of firm i in period $t+1$, which is measured by $R\&D_{i,t+1}/TA_{i,t+1}$ and $\ln(R\&D_{i,t+1})$. $Option_{i,t}$ is a dummy variable that has a value of 1 at the time of introduction of option incentives and thereafter, and 0 otherwise. $Control_{i,t+1}$ is the set of the control variable that influences corporate innovation. $Year_dum$ and $Indus_dum$ are dummy variables to control fixed effects. And the effect of option incentives

on the innovation outputs is tested as follows:

$$Output_{i,t+3} = \beta_0 + \beta_1 Option_{i,t} + \beta_2 Control_{i,t+3} + Year_dum + Indus_dum + \varepsilon_{i,t}, \quad (2)$$

where $Output_{i,t+3}$ denotes the innovation outputs of firm i in period $t+3$, which is measured by $\ln(Patent_{i,t+3} + 1)$ and $\ln(Citation_{i,t+3} + 1)$. $Patent_{i,t+3}$ and $Citation_{i,t+3}$ are the number of patent applications and citations of firm i in period $t+3$, respectively.

By estimating the coefficients in Equations (1) and (2), we can derive the level of innovation inputs and outputs for companies implementing option incentives and companies not implementing them, and compare the differences and impacts between the two groups of companies. As there is typically a time lag between the implementation of option incentives and the resulting changes in innovation inputs and outputs, we have delayed the measurement of innovation inputs by one year and innovation outputs by three years. It is important to acknowledge that the model has certain limitations, such as the potential presence of endogeneity issues between study variables. Therefore, we further test the PSM-DID approach to overcome those limits.

There are two important issues when studying the impact of option incentives on corporate innovation. One is the problem of sample selection bias, and the other is endogeneity issues due to omitted variables. In order to alleviate the bias caused by these two problems, we use a combination of PSM and DID analysis. First, the PSM calculates the propensity score of the companies implementing option incentives and matches the companies that have the same probability of implementing option incentives. Thus, we obtain two groups of individual companies with similar characteristics, transforming from a quasi-natural experiment into a randomized experiment. Then, DID is used to control individual and time effects and eliminate the endogeneity problem caused by omitted variables.

We first estimate a logistic regression on companies with and without option incentives and calculate the propensity score of each company. We perform the matching process using firm characteristic variables and patent increments, the details of which are shown in Table 3. Except for the variable measuring the increase in the number of patents, all other variables use the observed values one year before implementing the option incentive. The average annual growth in the number of patents ensures the validity of the difference-in-differences model parallel path hypothesis (Crown, 2014). We use the nearest neighbor matching method, where the samples of companies implementing option incentives and those that do not match the

nearest propensity score according to the same industry and year. Finally, we conduct a sample matching effect test. Figure 1, Panel A, shows the propensity score values of the treatment and control groups before matching, while Panel B shows the propensity score value-fitting results based on the nearest neighbor matching method. We find that the propensity score matches of the two groups after matching are significantly better than those before matching.

[Insert Figure 1 about here]

Table 3 shows the balance test of the treatment (option incentive firms) and control group (non-option incentive firms). Column (1) shows the summary statistics of companies in the treatment group in the year before implementing option incentives. Column (2) provides the summary statistics of companies that do not implement option incentive control groups. Column (3) reports the summary statistics of the control group companies matched by propensity scores in the year before the implementation of option incentives. Column (4) shows the *t*-statistic of the mean difference of each variable before sample matching. There are significant differences between firms that implement option incentives (treatment group) and those that do not (control group) on the indicators of tangible asset ratio, capital structure, profitability, and firm age. This result indicates that there may be a selection bias if we conduct the analysis directly. Firms with high profitability and older firms are more likely to implement option incentives. Column (5) gives the *t*-statistics of whether there are significant differences in the mean values of the variables in Columns (1) and (3). We observe that all *t*-statistics are insignificant after sample matching, indicating no significant difference between the two data groups after matching. This suggests that the PSM method adopted in this study passes the balance test and matches well.

[Insert Table 3 about here]

After obtaining matched samples, we perform a multivariate DID regression. We refer to the firms implementing option incentives as the treatment group and the matched firms obtained using the PSM method as the control group. The treatment group firms have the same probability of implementing the option incentive as their control group firms in the year they implement it. If the treatment group does not implement the option incentive, the innovation

input and output will change according to the path of the control group. Specifically, we begin by examining the impact of option incentives on R&D expenditures by using the following regression with industry and time-fixed effects:

$$\begin{aligned}
 Input_{i,t+1} = & \beta_0 + \beta_1 Treatment_i + \beta_2 Post_{i,t} + \beta_3 Treatment_i \times Post_{i,t} + \delta Control_{i,t+1} \\
 & + Year_dum + Indus_dum + \varepsilon_{i,t},
 \end{aligned} \tag{3}$$

where $Input_{i,t+1}$ is either $R\&D_{i,t+1}/TA_{i,t+1}$ or $Ln(R\&D_{i,t+1})$. $Treatment_i$ is a dummy variable that has a value of 1 if the company is in the treatment group (i.e., companies with option incentives), and 0 otherwise. $Post_{i,t}$ represents the indicator variable of firm i in period t , the value of the current and subsequent years when the option incentive is implemented is 1, and the years before the option incentive are 0. Companies without option incentives that are matched to companies with option incentives will have the same value for the variable, $Post_{i,t}$. $Control_{i,t+1}$ is the set of the control variable that influences corporate innovation.

We also examine the impact of option incentive compensation on innovation output by running the following regressions:

$$\begin{aligned}
 Output_{i,t+3} = & \beta_0 + \beta_1 Treatment_i + \beta_2 Post_{i,t} + \beta_3 Treatment_i \times Post_{i,t} + \delta Control_{i,t+3} \\
 & + Year_dum + Indus_dum + \varepsilon_{i,t},
 \end{aligned} \tag{4}$$

where $Output_{i,t}$ denotes the innovation outputs of firm i in period t , which is measured by $Ln(Patent_{i,t+3} + 1)$ and $Ln(Citation_{i,t+3} + 1)$. $Control_{i,t+3}$ is the set of the control variable that influences corporate innovation. Moreover, we control for time and industry effects. We expect the coefficient estimate of β_3 to be significantly positive if option incentive payoffs catalyze corporate innovation.

4. Empirical Results

4.1 Impact of option incentive compensation on corporate innovation using linear regression

Our study utilizing general linear regressions has revealed a significant positive association between implementing option incentives and corporate innovations. Table 4 shows that firms with option incentives increase their innovation inputs which are measured by the R&D

expenditure to total assets ratio, and the logarithm of R&D expenditure. Table 5 shows that firms with option incentives also have significantly higher innovation outputs, which are measured by patent applications and patent citations. Our empirical results indicate that the implementation of option incentives has a positive impact on the innovation input and output of the company.

[Insert Table 4 about here]

[Insert Table 5 about here]

We include several control variables, such as firm size and industry type, in the linear regression models to mitigate the risk of omitted variable bias. However, we acknowledge that there may be interaction effects between the implementation of option incentives and innovation, which could potentially compromise the reliability of our regression results. To address possible endogeneity concerns, we refine linear research methodology by employing the PSM-DID model for further analysis.

4.2 Impact of option incentive compensation on corporate innovation using PSM-DID model

We use PSM to pair each firm that implements option incentives with the most similar firm that does not implement option incentives. Then we utilize DID model to examine the effect of option incentives on corporate innovation. Based on the PSM-DID model results in Table 6, the ratio of R&D expenditure to total assets has a significant positive impact. These findings suggest that firms are more willing to invest in R&D following the implementation of option incentive policies, which aligns with the policy's original intention. Additionally, we consider that the reason for the insignificant logarithm of R&D expenditures is that the implementation of option incentives indirectly encourages higher quality R&D rather than directly affecting the size of R&D expenditures.

[Insert Table 6 about here]

Regarding innovation output, Table 7 shows that invention patents and citations have a significant positive impact, while utility model patents and the total number of patents have no

significant effect. Similarly, the number of utility model citations and the number of total patent citations are not significant. This is because firms implementing option incentives focus more on technological innovation and research in frontier areas to obtain more invention patents and patent citations, thereby promoting innovation output. Obtaining utility model patents and total patents can enhance a company's commercial value and market competitiveness, but has relatively little effect on promoting technological innovation and innovation output of enterprises. Thus, companies that implement option incentives are more willing to invest more R&D resources in technological innovation and research in frontier areas.

[Insert Table 7 about here]

Upon comparing the two methods, we observe that the R&D expenditure to total assets ratio, patent applications for inventions, and patent citations show positive and significant results in both the PSM-DID model and the general linear regression model. However, the significance of these relationships decreased during the PSM-DID model analysis. This suggests that the effect of implementing option incentives on corporate innovation is not particularly strong. We believe that general linear regression models may suffer from selection and observation bias, which may overestimate the effect of option incentives.

4.3 Impact of option incentive compensation based on the technical characteristics of the industry.

Innovation and R&D activities in the high-tech industry are characterized by a greater degree of technical complexity and challenge. In high-tech firms, innovation is critical to the operation of the company. In order to further investigate the factors that lead to differences in the results of general linear regression and PSM-DID methods, we conduct an additional empirical study on the impact of stock options on promoting innovation in high-tech and non-high-tech firms.

According to the regression results in Tables 8, 9, and 10, the ratio of R&D expenditures to total assets in high-tech companies increases significantly after the implementation of option incentives. It shows the importance of innovation in high-tech companies. The ratio of R&D expenditures to total assets does not increase significantly in non-high-tech firms, but the logarithm of R&D expenditures is significantly positive. This suggests that although they also value R&D, they may prioritize other areas such as marketing, productivity improvements, or

equipment upgrades. The analysis based on the regression results shows that firms in different industries exhibit significant differences in R&D expenditures and capital allocation after implementing option incentives.

[Insert Table 8 about here]

[Insert Table 9 about here]

[Insert Table 10 about here]

The findings of our study indicate that option compensation serves as a motivating factor for high-tech companies to increase their investment in research R&D and innovation activities, leading to a positive effect on their asset base. As a result, these firms tend to produce more patent output with better quality patents. In contrast, option compensation does not appear to play a significant role in non-high-tech companies. While option compensation has a positive impact on R&D expenditures, this impact does not seem to translate into a significant impact on their assets. This finding is supported by the insignificant and negative effect of innovation output observed among non-high-tech firms.

5. Discussion

In this study, we test 1,352 A-share companies listed on the Shanghai Stock Exchange and Shenzhen Stock Exchange to assess the effect of option incentive compensations on corporate innovations in China, which represents emerging and transition economies. We categorize corporate innovation into two dimensions: inputs for corporate innovation and outputs from corporate innovation and analyze the impact of option incentives on each separately. We chose the ratio of R&D expenditures to total assets as a measure of innovation inputs, while using the number of patent applications and citations as an indicator of innovation outputs. We first use a general linear regression model to estimate the effect of option incentives on firm innovation. Then, to further determine the stability of the results, we perform further extensions using the PSM and DID methods, which reduces the effect of endogeneity bias. By comparing the differences between the experimental group and the control group, we can more accurately estimate the impact of option incentives on corporate innovation. Our results indicate a positive

effect of option incentives on both innovation inputs and outputs of the firm after conducting a general linear regression analysis. The results of PSM-DID analysis also show valid impacts of option incentives on corporate innovations, but there is a significant reduction in the positive effect of option incentives on both innovation inputs and outputs of the firm. Additionally, we also find that the role of option incentives differs across different types of firms.

Our findings have several implications for business managers and policymakers in developing option incentive programs to promote innovations in emerging markets. We find that firms that grant stock options have a positive impact on corporate innovation, but this impact is subject to certain limitations. And the degree of impact varies widely across sector types. Therefore, when investors assess a company's growth potential, it is important to understand the company's strategy in terms of technology and business innovation and to evaluate the allocation of investments in these areas. For business managers and policymakers, option incentive policies should focus on promoting corporate innovation, rather than simply serving as a motivational tool for employees. It is crucial to balance the relationship between option incentives and long-term corporate development, particularly in the organization and management of R&D activities to prevent resource over-concentration and waste. In summary, our study suggests that option incentive policies should be carefully designed and implemented to effectively stimulate innovations and promote long-term growth in emerging markets.

6. Conclusion

Innovation is one of the decisive factors that enhance a company's competitiveness. Designing an appropriate incentive mechanism to encourage innovation and productivity is challenging for businesses. Based on data from Chinese A-share-listed companies, we investigate the impact of option incentive compensation plans on corporate innovation. Different from previous literature, we examine innovation in terms of both innovation inputs and innovation outputs. We choose R&D expenditure to total assets ratio and the logarithm of R&D expenditure as measures of innovation inputs to comprehensively assess the relative and absolute scale of corporate innovation investment. We select the number of patent applications and patent citations as the index to measure the quantity and quality of corporate innovation outputs. In terms of research methodology, we conduct an initial analysis of firms that implement option incentives using general linear regression. Then, we apply the PSM-DID approach to mitigate potential self-selection issues that may arise when firms adopt option incentives and to compare the differences between the treatment and control groups around the

event date. By utilizing the above methods, we address the problems of sample selectivity bias and endogeneity. Our empirical findings indicate that, although the implementation of option incentives has a positive impact on corporate innovation inputs and outputs, the magnitude of the effect may not be as significant as initially anticipated. Subsequent research has revealed that the impact of option incentives varies across different types of firms. Specifically, option incentives are more effective in promoting innovation output in high-tech firms than in non-high-tech firms.

The study shows that option incentives encourage firms to invest more in R&D, particularly in frontier areas of technological innovation. This results in increased patenting of inventions and patent citations. However, there is no significant effect on utility model patents or total patent applications, suggesting that those firms focus more on technical inventions rather than their practical usage. Therefore, firms should aim to balance investment in technological and commercial innovation when implementing option incentives to improve their innovation performance and market competitiveness as a whole. We recommend that companies should adopt effective option incentive compensation and improve long-term incentives to enhance innovation incentives, while revising regulations to prevent manipulation of corporate earnings to obtain option incentives. Especially non-high-tech firms need to consider the characteristics of the firm and the needs of employees to choose the most suitable incentive method to promote innovation. Investors should focus on the balance between technological and commercial innovation in companies and review financial reports and R&D investment plans. Business managers and regulators should balance investment in technology innovation and business innovation and encourage employee communication and collaboration to create more opportunities and competitiveness. In addition, our study finds that the relationship between innovation inputs and outputs of firms is complex and diverse, and needs further research and exploration. These findings have some reference value for promoting innovation and improving the effectiveness of option incentives in emerging markets.

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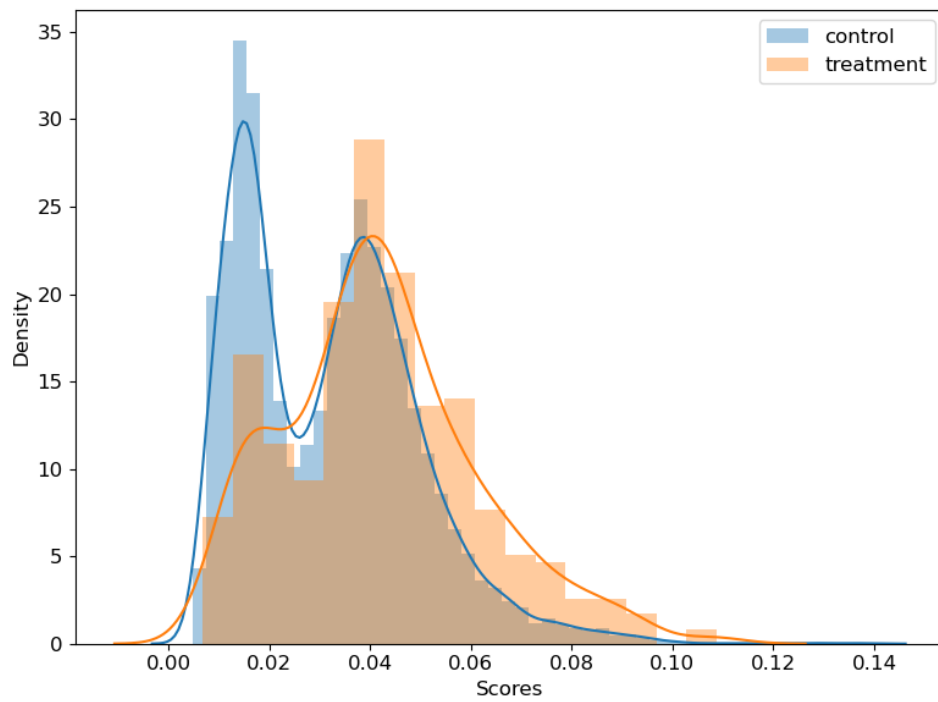
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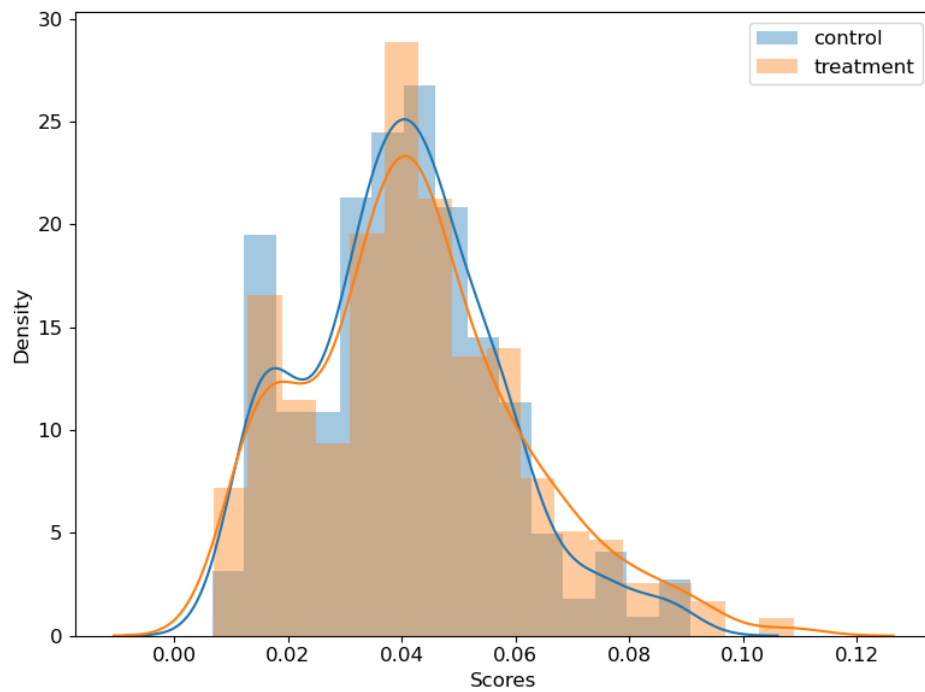
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Fig. 1. Fitting results of propensity score values.

Panel A



Panel B



Notes: Panel A shows the distribution of propensity scores before matching and panel B shows the distribution after matching.

Table 1
Variable definitions.

Abbreviation	Description
<i>N</i>	Number of observations
<i>R&D / TA</i>	R&D expenses as a percentage of total assets
<i>Ln(R&D)</i>	Natural log of R&D expenditure by firm <i>i</i> in year <i>t</i>
<i>Patent_I</i>	The number of invention patents of a company in one year plus 1 to take the logarithm
<i>Patent_U</i>	The number of utility model patents of a company in one year plus 1 to take the logarithm
<i>Patent_IU</i>	The sum of the number of invention patents and the number of utility model patents of the enterprise in one year plus 1 to take the logarithm.
<i>Citations_I</i>	The sum of invention patent citations within the fiscal year plus one is taken as a logarithm. The citation counts for each patent are scaled using the average number of citations obtained by patents awarded in the same fiscal year.
<i>Citations_U</i>	The sum of utility model patent citations within the fiscal year plus one is taken as a logarithm.
<i>Citations_IU</i>	The sum of invention and utility model patent citations in the fiscal year plus one, taking the logarithm.
<i>Ln(TA)</i>	Natural log of Total Assets by firm <i>i</i> in year <i>t</i> .
<i>Tobin's Q</i>	The ratio of market value to replacement cost of capital
<i>Debt_Ratio</i>	The ratio of total company debts to total assets
<i>Tangible</i>	The sum of net plant, property and equipment divided by total assets and expressed as a percentage.
<i>ROA</i>	Company net income divided by total assets
<i>Ln(Age)</i>	The current year minus the year of establishment of the company, plus 1 to take the logarithm
<i>SOE</i>	If the ultimate controller is state-owned, the value is 1; otherwise, the value is 0.
<i>High-tech</i>	If it is a high-tech firm, the value is 1, otherwise the value is 0.
<i>PatentI_AAGR</i>	Average annual growth rate of the number of invention patents in the past three years.
<i>PatentIU_AAGR</i>	Average annual growth rate of the total number of patents in the past three years.

Table 2

Descriptive statistics of the sample dataset.

Panel A: Full sample (N=12,166)							
	Mean	Std. Dev.	Min.	Max.	P25	Median	P75
<i>R&D / TA</i>	0.020	0.025	0.000	1.040	0.003	0.015	0.028
<i>Ln(R&D)</i>	15.654	6.578	0.000	25.025	16.584	17.986	19.018
<i>Patent_I</i>	2.260	1.716	0.000	9.074	0.693	2.303	3.401
<i>Patent_U</i>	2.268	1.780	0.000	8.598	0.693	2.303	3.526
<i>Patent_IU</i>	2.936	1.863	0.000	9.555	1.609	3.091	4.190
<i>Citations_I</i>	2.778	1.945	0.000	11.028	1.318	2.847	4.071
<i>Citations_U</i>	2.875	2.076	0.000	9.688	1.251	3.042	4.328
<i>Citations_IU</i>	3.433	2.248	0.000	11.152	1.938	3.785	4.962
<i>Ln(TA)</i>	22.657	1.340	19.729	26.398	21.714	22.474	23.447
<i>Tobin's Q</i>	2.224	9.669	0.856	729.629	1.196	1.607	2.366
<i>Debt_Ratio</i>	0.448	0.201	0.057	0.900	0.289	0.446	0.599
<i>Tangible</i>	0.921	0.093	0.502	1.000	0.906	0.952	0.976
<i>ROA</i>	0.033	0.063	-0.303	0.211	0.012	0.033	0.062
<i>Ln(Age)</i>	3.008	0.296	1.792	4.025	2.833	3.045	3.219

Panel B: Characteristics of firms with and without option incentives										
	Option incentive firms (N=381)					Non-option incentive firms (N=11,785)				
	Mean	Std. Dev.	Min.	Max.	Median	Mean	Std. Dev.	Min.	Max.	Median
<i>R&D / TA</i>	0.032	0.045	0.000	0.739	0.738	0.019	0.023	0.000	1.040	0.015
<i>Ln(R&D)</i>	17.585	4.644	0.000	25.025	18.529	15.591	6.622	0.000	24.410	17.968
<i>Patent_I</i>	2.742	1.779	0.000	8.688	2.773	2.245	1.712	0.000	9.074	2.197
<i>Patent_U</i>	2.563	1.803	0.000	7.528	2.485	2.259	1.779	0.000	2.303	2.303
<i>Patent_IU</i>	3.314	1.754	0.000	8.707	3.434	2.774	1.853	0.000	3.045	3.091

<i>Citations_I</i>	3.284	2.073	0.000	11.028	3.261	2.762	1.938	0.000	2.825	2.847
<i>Citations_U</i>	3.151	2.221	0.000	8.999	3.204	2.866	2.071	0.000	3.042	3.042
<i>Citations_IU</i>	3.898	2.393	0.000	11.152	3,434	4.226	2.242	0.000	3.772	3.785
<i>Ln(TA)</i>	22.726	1.396	19.729	26.398	22.554	22.655	1.338	19.729	26.398	22.472
<i>Tobin's Q</i>	2.247	1.535	0.856	9.885	1.726	2.223	9.820	0.856	729.629	1.605
<i>Debt_Ratio</i>	0.436	0.186	0.057	0.900	0.429	0.448	0.202	0.057	0.900	0.446
<i>Tangible</i>	0.902	0.114	0.502	1.000	0.948	0.921	0.092	0.502	1.000	0.952
<i>ROA</i>	0.043	0.059	-0.303	0.211	0.041	0.033	0.063	-0.303	0.211	0.032
<i>Ln(Age)</i>	2.962	0.324	1.946	3.892	2.996	2.873	0.323	1.792	4.025	3.045
<i>SOE</i>	0.218	0.413	0.000	1.000	0.000	0.432	0.495	0.000	1.000	0.000
<i>High-tech</i>	0.882	0.323	0.000	1.000	1.000	0.788	0.409	0.000	1.000	1.000
<i>PatentI_AAGR</i>	0.473	1.460	-0.592	18.667	0.000	0.449	1.903	-0.691	60.066	0.000
<i>PatentIU_AAGR</i>	0.744	1.552	0.500	14.496	0.259	1.002	6.832	-0.725	378.000	0.268

Notes: The sample periods of R&D expenditure, patent, and citations are from January 2013 to December 2021.

Table 3
Matching enterprise balance test.

	Option incentive firms (1)	Non-option incentive firms (2)	Matched firms (3)	Mean difference (4)	Mean difference (5)
	Mean (Std. Dev.)	Mean (Std. Dev.)	Mean (Std. Dev.)	t-value (p-value) (1)-(2)	t-value (p-value) (1)-(3)
<i>Ln(TA)</i>	22.516 (1.435)	22.493 (1.331)	22.427 (1.302)	-0.385 (0.700)	-0.841 (0.401)
<i>Tobin's Q</i>	2.129 (1.691)	2.227 (10.511)	1.988 (1.450)	0.142 (0.887)	-1.159 (0.247)
<i>Debt_Ratio</i>	0.418 (0.200)	0.440 (0.206)	0.409 (0.200)	1.593 (0.111)	-0.958 (0.339)
<i>Tangible</i>	0.896 (0.121)	0.923 (0.091)	0.904 (0.112)	5.298*** (0.000)	0.954 (0.340)
<i>ROA</i>	0.042 (0.061)	0.036 (0.059)	0.043 (0.056)	-1.247 (0.212)	0.286 (0.775)
<i>Ln(Age)</i>	2.877 (0.354)	2.931 (0.314)	2.896 (0.340)	2.815** (0.005)	0.694 (0.488)
<i>SOE</i>	0.220 (0.415)	0.433 (0.496)	0.229 (0.421)	8.576*** (0.000)	0.277 (0.782)
<i>High-tech</i>	0.878 (0.328)	0.788 (0.409)	0.890 (0.313)	-4.567*** (0.000)	0.481 (0.631)
<i>PatentI_AAGR</i>	0.619 (2.083)	0.448 (1.921)	0.507 (1.583)	-0.153 (0.248)	-0.784 (0.434)
<i>PatentIU_AAGR</i>	0.841 (1.611)	1.063 (7.111)	0.814 (2.021)	0.723 (0.471)	-0.194 (0.846)

Notes: We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). We select 336 treatment groups with option incentive compensation plans and match them with 336 control groups without option incentive compensation plans. Patents' average annual growth rate is measured at t , and all the other variables are measured at $t-1$. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 4

The effect of option incentive compensation on corporate innovation inputs using linear regression.

	R&D / TA	Ln (R&D)
<i>Option</i>	0.0032*** (5.742)	0.7776*** (6.001)
<i>Ln(TA)</i>	0.0007 (-0.367)	1.2672*** (28.739)
<i>Tobin's Q</i>	0.00002 (1.310)	-0.0107** (-2.439)
<i>Debt_Ratio</i>	-0.0035** (-2.833)	-1.2788*** (-4.410)
<i>Tangible</i>	0.0007 (0.303)	-0.4591 (-0.886)
<i>ROA</i>	0.0359*** (10.752)	3.2538*** (4.180)
<i>Ln(Age)</i>	-0.0040*** (-5.754)	-2.2510*** (-13.977)
Fixed effects	Industry Year	Industry Year
Observations	12,163	12,163
Adjusted R-squared	0.344	0.504

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2020. R&D expenditure data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). R&D expenditure is measured at $t+1$, and all the control variables are measured at $t+1$. The missing values of all dependent variables are 0. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 5

The effect of option incentive compensation on the number of corporate patents and their citations using linear regression.

Variable	Panel A. Patents			Panel B. Citations		
	Patent I	Patent U	Patent IU	Citations I	Citations U	Citations IU
<i>Option</i>	0.1721*** (4.151)	0.0793* (1.867)	0.1755*** (4.072)	0.2126*** (4.370)	0.2460*** (5.264)	0.2962*** (5.701)
<i>Ln(TA)</i>	0.6845*** (52.664)	0.5604*** (42.071)	0.6792*** (50.264)	0.6973*** (45.741)	0.6996*** (47.754)	0.7716*** (47.384)
<i>Tobin's Q</i>	0.0029** (2.428)	0.0026** (2.135)	0.0025** (2.017)	0.0033** (2.353)	0.0023* (1.711)	0.0030** (2.041)
<i>Debt_Ratio</i>	-0.4317*** (-4.949)	0.1319 (1.476)	-0.2546** (-2.808)	-0.2479** (-2.423)	0.0555 (0.564)	-0.0476 (-0.436)
<i>Tangible</i>	0.7205*** (4.660)	0.2831* (1.787)	0.5577** (3.469)	0.6120** (3.375)	-0.0313 (-0.180)	0.0702 (0.363)
<i>ROA</i>	3.0358*** (11.984)	2.5720*** (9.907)	3.2601*** (12.378)	3.2665*** (10.993)	0.8768** (3.071)	2.2077*** (6.956)
<i>Ln(Age)</i>	-0.2373*** (-5.536)	-0.3412*** (-7.766)	-0.3359*** (-7.536)	-0.4776*** (-9.498)	-0.1259** (-2.605)	-0.2639*** (-4.912)
Fixed effects	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year
Observations	9,460	9,460	9,460	9,460	9,460	9,460
Adjusted R-squared	0.494	0.502	0.526	0.460	0.553	0.523

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2018. patent data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). The patent and citation variables are measured at $t+3$, and all the control variables are measured at $t+3$. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 6

The effect of option incentive compensation on innovation inputs using the PSM-DID model.

	R&D / TA	Ln (R&D)
<i>Treatment</i>	0.0037* (4.287)	0.2862* (1.720)
<i>Post</i>	0.0011 (1.419)	0.2739* (1.802)
<i>Treatment × Post</i>	0.0025** (2.385)	0.2263 (1.123)
<i>Ln(TA)</i>	-0.0008** (-2.596)	0.9366*** (16.733)
<i>Tobin's Q</i>	0.00003* (1.807)	0.0007 (0.177)
<i>Debt_Ratio</i>	-0.0001 (-0.057)	0.4792 (1.332)
<i>Tangible</i>	0.0092*** (3.615)	-1.6233** (-3.328)
<i>ROA</i>	0.0402*** (10.402)	3.3603*** (4.520)
<i>Ln(Age)</i>	-0.0041*** (-4.255)	-1.2556*** (-6.585)
Fixed effects	Industry, Year	Industry, Year
Observations	6,530	6,530
Adjusted R-squared	0.429	0.487

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2020. R&D expenditure data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). R&D expenditure is measured at $t+1$, and all the control variables are measured at $t+1$. The missing values of all dependent variables are 0. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 7

The effect of option incentive compensation on the number of corporate patents and their citations using the PSM-DID model.

Variable	Panel A. Patents			Panel B. Citations		
	Patent I	Patent U	Patent IU	Citations I	Citations U	Citations IU
<i>Treatment</i>	0.0675 (1.287)	0.0790 (1.511)	0.1046* (1.983)	0.2650*** (4.587)	0.2028** (3.328)	0.3047*** (4.562)
<i>Post</i>	0.0361 (0.711)	-0.0754* (-1.491)	0.0134 (0.262)	0.0960* (1.717)	-0.0805 (-1.364)	0.0358 (0.554)
<i>Treatment × Post</i>	0.1492** (2.185)	0.0102 (0.150)	0.1091 (1.589)	0.1565** (2.080)	-0.0910 (-1.147)	0.0611 (0.703)
<i>Ln(TA)</i>	0.8731*** (43.331)	0.6411*** (31.939)	0.8260*** (40.767)	0.8424*** (37.958)	0.7095*** (30.310)	0.8795*** (34.291)
<i>Tobin's Q</i>	0.0469** (2.941)	-0.0082 (-0.518)	0.0220 (1.403)	0.0565** (3.212)	-0.0628** (-3.389)	0.0126 (0.619)
<i>Debt_Ratio</i>	-0.5986** (-4.578)	0.4344** (3.335)	-0.2023 (-1.539)	-0.4280** (-2.972)	0.3958** (2.606)	0.0649 (0.390)
<i>Tangible</i>	0.2082 (1.191)	0.0262 (0.150)	0.1580 (0.898)	0.7165*** (3.720)	0.2054 (1.011)	0.6351** (2.853)
<i>ROA</i>	-0.3187 (-1.317)	0.4305* (1.657)	0.3681 (1.403)	-0.6884** (-2.397)	-1.0169** (-3.356)	-1.1662*** (-3.513)
<i>Ln(Age)</i>	-0.1232* (-1.739)	-0.1013 (-1.436)	-0.1656** (-2.325)	-0.0682 (-0.874)	-0.0693 (-0.843)	-0.0406 (-0.450)
Fixed effects	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year
Observations	4,828	4,828	4,828	4,828	4,828	4,828
Adjusted R-squared	0.546	0.581	0.578	0.582	0.581	0.561

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2018. patent data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). The patent and citation variables are measured at $t+3$, and all the control variables are measured at $t+3$. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 8

The impact of option incentives on R&D expenditures in high-tech and non-high-tech firms.

Variable	High-tech firms		Non- High-tech firms	
	R&D / TA	Ln (R&D)	R&D / TA	Ln (R&D)
<i>Treatment</i>	0.0042*** (4.220)	0.1359 (1.093)	0.0012* (1.836)	2.8991*** (3.712)
<i>Post</i>	0.0011 (1.308)	0.1254 (1.133)	0.0001 (0.202)	-0.3821 (-0.467)
<i>Treatment × Post</i>	0.0025** (2.089)	0.0659 (0.444)	0.0009 (1.162)	1.6343* (1.707)
<i>Ln(TA)</i>	-0.0007** (-2.394)	0.8887*** (21.550)	-0.0005** (-2.223)	0.9705** (3.448)
<i>Tobin's Q</i>	0.0003** (1.722)	-0.0018 (-0.606)	-0.0007** (-2.867)	0.5430* (1.955)
<i>Debt_Ratio</i>	-0.0005 (-0.259)	-0.2912 (-1.114)	-0.0003 (-0.163)	5.6124** (2.883)
<i>Tangible</i>	0.0111*** (4.035)	-0.9966** (-2.857)	0.0022 (0.791)	6.6910** (1.971)
<i>ROA</i>	0.0418*** (9.973)	2.3434*** (4.427)	0.0038 (0.926)	7.0401 (1.436)
<i>Ln(Age)</i>	-0.0034** (-3.210)	-0.6198*** (-4.611)	-0.0062*** (-6.203)	-1.1487 (-0.963)
Fixed effects	Industry Year	Industry Year	Industry Year	Industry Year
Observations	5,818	5,818	712	712
Adjusted R-squared	0.370	0.364	0.511	0.503

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2020. R&D expenditure data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). R&D expenditure is measured at $t+1$, and all the control variables are measured at $t+1$. The missing values of all dependent variables are 0. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 9

The impact of option incentives on the number of patents in high-tech and non-high-tech firms.

Variable	High-tech firms			Non- High-tech firms		
	Patent I	Patent U	Patent IU	Patent I	Patent U	Patent IU
<i>Treatment</i>	0.0520 (0.947)	0.0796 (1.445)	0.0927* (1.737)	0.6764*** (4.580)	0.4720** (3.114)	0.6522*** (3.785)
<i>Post</i>	0.0136 (0.263)	-0.0920* (-1.779)	0.0018 (0.036)	0.1726 (1.035)	0.1170 (0.683)	0.1531 (0.787)
<i>Treatment × Post</i>	0.1725** (2.462)	0.0393 (0.560)	0.1362** (2.001)	-0.1379 (-0.676)	-0.5322** (-2.541)	-0.3199 (-1.344)
<i>Ln(TA)</i>	0.9224*** (44.715)	0.6585*** (31.825)	0.8492*** (42.364)	0.6186*** (10.172)	0.6267*** (10.041)	0.7966*** (11.228)
<i>Tobin's Q</i>	0.0226 (1.424)	-0.0208 (-1.306)	0.0012 (0.076)	0.2455*** (3.579)	0.2339** (3.323)	0.2744** (3.430)
<i>Debt_Ratio</i>	-0.6150*** (-4.650)	0.4590** (3.460)	-0.2025 (-1.575)	-0.4088 (-0.948)	-0.3700 (-0.836)	-0.7580* (-1.507)
<i>Tangible</i>	0.4592** (2.620)	0.1857 (1.056)	0.3940** (2.313)	-0.4052 (-0.556)	0.1861 (0.249)	-0.0932 (-0.110)
<i>ROA</i>	0.0750*** (0.288)	0.3981 (1.527)	0.3673 (1.454)	-0.3721 (-0.377)	0.0807 (0.080)	-0.7724 (-0.671)
<i>Ln(Age)</i>	-0.0765 (-1.072)	-0.0045 (-0.064)	-0.0732 (-1.056)	-0.3889 (-1.458)	-0.9178*** (-3.353)	-0.7923** (-2.547)
Fixed effects	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year
Observations	4,312	4,312	4,312	516	516	516
Adjusted R-squared	0.537	0.587	0.575	0.415	0.408	0.443

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2018. patent data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). The patent variables are measured at $t+3$, and all the control variables are measured at $t+3$. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.

Table 10

The impact of option incentives on the number of patent citations in high-tech and non-high-tech firms.

Variable	High-tech firms			Non- High-tech firms		
	Citations I	Citations U	Citations IU	Citations I	Citations U	Citations IU
<i>Treatment</i>	0.2320*** (3.903)	0.1947** (3.081)	0.2659*** (3.915)	1.0817*** (6.617)	0.6840*** (3.997)	1.1405*** (5.861)
<i>Post</i>	0.0628 (1.126)	-0.0748 (1.260)	0.0434 (0.681)	0.3668* (1.987)	0.0076 (0.040)	0.1161 (0.528)
<i>Treatment × Post</i>	0.2133** (2.812)	-0.0780 (-0.967)	0.0966 (1.114)	-0.4857** (-2.150)	-0.5016** (-2.122)	-0.4872* (-1.812)
<i>Ln(TA)</i>	0.8962*** (40.126)	0.7527*** (31.699)	0.9299*** (36.425)	0.5896*** (8.759)	0.6011*** (8.532)	0.7353*** (9.177)
<i>Tobin's Q</i>	0.0381** (2.214)	-0.0767*** (-4.189)	-0.0003 (-0.017)	0.2263** (2.980)	0.2113** (2.659)	0.1887** (2.089)
<i>Debt_Ratio</i>	-0.4256** (-2.972)	0.4590** (3.460)	-0.0222 (-0.135)	-0.3844 (-0.805)	-0.0661 (-0.132)	-0.0417 (-0.073)
<i>Tangible</i>	1.0181*** (5.364)	0.5782** (2.865)	0.5782*** (5.078)	0.6297 (0.781)	-0.4290 (-0.508)	-0.1772 (-0.185)
<i>ROA</i>	-0.7336** (-2.606)	-1.2112*** (-4.047)	-1.3834*** (-4.299)	-0.9740 (-0.892)	0.7884 (0.689)	-0.2594 (-0.199)
<i>Ln(Age)</i>	-0.0039 (-0.050)	-0.0045 (-0.064)	0.1017 (1.152)	-0.4972* (-1.684)	-1.7392*** (-5.629)	-1.3254*** (-3.772)
Fixed effects	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year	Industry Year
Observations	4,312	4,312	4,312	516	516	516
Adjusted R-squared	0.581	0.587	0.549	0.449	0.475	0.491

Notes: The sample period is from January 2013 to December 2021. Among them, the time range of option data is 2013-2018. Citation data is from 2013 to 2021. We include industry fixed effects based on the China Securities Regulatory Commission 2012 industry classification codes (2-digit). The citation variables are measured at $t+3$, and all the control variables are measured at $t+3$. t -statistics are reported below the coefficient estimates. *, **, and *** denote the significance at the 10%, 5%, and 1% levels, respectively.