Empirical Evidence on How CEO Option Incentives Spur Corporate Innovation from Panel Analysis with Lagged Incentives

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Abstract. This study examines the real effects of Chief Executive Officer (CEO) option incentives on corporate innovation output, assessing whether this contractual instrument can effectively bridge the inherent tension between managerial risk aversion and the uncertainty inherent in innovation activities. Based on data from U.S.-listed companies from 1993 to 2021, the research systematically investigates the immediate impact of option incentives on patent applications and their sustained, cross-period effect on patent grants. The empirical findings reveal that option incentives significantly promote corporate innovation, and this effect persists for up to two years after the grant. Further analysis shows that this effect is not universal but is strictly limited to industries with greater suitability for option contracts, such as technology-intensive sectors, and is more pronounced in sub-samples of larger firms and those with higher leverage. These findings confirm that the relationship between option incentives and innovation output is more likely to be a context-dependent causal relationship than a mere correlation. This study deepens the understanding of how executive compensation design influences corporate innovation strategy.

Keywords: CEO Option Incentives, Corporate Innovation, Panel Regression, Lagged Effects, Heterogeneity Analysis.

1 Introduction

Innovation has become the core engine for contemporary enterprises to build sustainable competitive advantages and drive long-term value growth. However, the inherent high risk, long-term uncertainty, and lagged value conversion of innovation activities naturally create a sharp conflict with managers' short-term performance orientation and career security concerns [1]. How to design effective compensation contracts to stimulate the Chief Executive Officer's (CEO) willingness to innovate and guide the allocation of resources to Research and Development (R&D) projects with strategic value has become a critical question in the field of corporate governance.

Traditional theory posits that equity incentives, by granting managers residual claim rights, can alleviate the risk-sharing divergence between shareholders and managers,

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thereby encouraging CEOs to undertake innovation investments with positive net present value but high short-term volatility [2]. Among these, stock options, due to their asymmetric payoff structure and long-term vesting arrangements, are considered a lower-cost incentive tool that can significantly enhance risk tolerance [3]. However, in practice, whether option incentives effectively drive innovation output or are merely an ideal theoretical construct remains a matter for rigorous empirical testing. Although theoretically superior, the effectiveness of option incentives in promoting corporate innovation is constrained by practical challenges. Firstly, the success rate of innovation is generally low. The transformation pathway from R&D investment to patent output is fraught with uncertainty, with only a few technological explorations yielding patentable outcomes [1]. Secondly, even after obtaining patent grants, converting them into market-recognized commercial value and financial performance is more difficult, as it involves multiple obstacles, including technology commercialization, market acceptance, and competitive dynamics [4]. This dual uncertainty, from input to output, means that the realized value of option incentives is highly dependent on the company's future stock price performance, which often reflects innovation success with a lag and incompletely. Consequently, a rational CEO may not significantly increase innovation efforts due to option incentives: they may fear that high-risk R&D failure could damage personal reputation and career security, or they may opt to strategically increase low-quality patent applications to boost the stock price short-term, rather than engage in genuinely value-creating breakthrough innovation [5]. Whether option incentives can penetrate this transformation black box and substantially enhance a firm's capacity for innovation constitutes the core research question of this study.

To systematically address the above question, this study selects U.S.-listed companies from 1993 to 2021 as the research sample, integrating the *Duke DISCERN* patent database, the *ExecuComp* executive compensation database, and the *Compustat North America* financial database to construct a panel dataset comprising 23,567 firm-year observations. The research adopts a multivariate regression framework, controlling for both firm and year fixed effects to control for unobservable individual heterogeneity and macroeconomic shocks. It further introduces lagged (1-2 periods) variables of option incentives to capture the long-cycle nature of innovation activities and mitigate reverse causality issues. To enhance the robustness of causal inference, the study implements two mechanism tests: first, a grouped placebo test based on industry-level economic characteristics to rule out industry self-selection bias; second, an interaction-term model incorporating firm size and leverage to test the moderating effects predicted by agency theory. The empirical results show that the intensity of option incentives is significantly positively correlated with innovation output, and this effect persists in the 1-2 lagged periods. The placebo test confirms that this effect exists only in high-tech and growth industries suitable for option incentives and is insignificant in traditional sectors, thereby strengthening the credibility of causal identification.

The main contributions of this study are reflected in two aspects. First, in the field of CEO incentive effects, this study, through independent measurement of option incentives and a multi-dimensional testing framework, precisely identifies the net causal effect of option contracts on corporate innovation output. The research not only provides direct empirical evidence for the theoretical chain of "incentive - risk-taking -

innovation" but also reveals differential response mechanisms across stages of the innovation value chain, deepening understanding of how compensation structures shape managerial strategic behavior. Second, in the field of determinants of corporate innovation, this study addresses the gap in the causal chain from option incentives to innovation output. By introducing lagged dynamic tests, industry-suitability placebo tests, and heterogeneity analysis, the research effectively addresses the three major challenges posed by the long-term nature of innovation activities, the endogeneity of option incentives, and industry heterogeneity. It provides more robust empirical evidence for regulatory bodies designing differentiated incentive policies and for firms optimizing compensation contracts. These findings help guide the allocation of incentives toward substantive technological innovation rather than short-term strategic patenting, with important policy implications for promoting high-quality corporate development.

2 Literature Review

The inherent high risk, long-term uncertainty, and lagged value conversion of innovation activities naturally create a sharp conflict with managers' short-term performance orientation [1]. At the macro level, the strength of intellectual property protection and the level of capital market development directly affect the appropriability of innovation returns and financing constraints [6]. At the meso level, industry technological opportunities and the structure of market competition determine the marginal returns to innovation incentives [6]. At the micro level, a firm's internal R&D investment intensity and human capital density constitute the fundamental guarantee for innovation activities [7]. However, the transformation path from R&D investment to patent output is fraught with uncertainty, with only a few technological explorations yielding patentable outcomes; even after obtaining patent grants, converting them into market-recognized commercial value is more difficult, as it entails multiple obstacles, including technology commercialization, market acceptance, and competitive dynamics. This dual uncertainty from input to output means that the innovation success rate is generally low, and the stock market's reflection of innovation success is often lagged and incomplete. Hence, innovation is inherently a long-term investment requiring high risk tolerance.

The risk-taking propensity of senior corporate managers is a core driver of innovation, resource allocation, and value creation. In the realm of innovation, a moderate tolerance for risk is a necessary prerequisite for breaking organizational routines, increasing R&D expenditure, and pursuing breakthrough innovation. CEOs with higher risk preferences are more likely to significantly enhance both the quantity and quality of their firms' patent output. However, risk-taking exhibits diminishing marginal effects and boundary conditions: excessive risk-taking may lead to overinvestment, diversification discount, or financial distress. Particularly in firms with ample free cash flow and weak oversight, CEOs may engage in value-destroying aggressive expansion to build an empire [8]. Career concerns and reputational considerations also significantly influence risk-taking. Younger CEOs, seeking to establish industry reputation, often favor high-risk strategies, whereas managers nearing retirement tend to avoid risk to preserve their established reputations [9]. Therefore, the CEO's level of risk-taking has a decisive impact on innovation output, but individual characteristics and the corporate governance environment constrain its effect.

From a contract design perspective, compensation structure is a key mechanism for adjusting managerial risk preferences. Equity incentives, such as stocks and options, by granting managers residual claimant rights, can effectively alleviate the risk-sharing conflict between shareholders and managers, prompting CEOs to adopt long-term investment projects with positive net present value but high short-term volatility [2]. Among these, option incentives, due to their asymmetric payoff structure and long-term vesting arrangements, are considered more capable than restricted stock of stimulating the tolerance for trial and error required for breakthrough innovation [3]. In addition to explicit incentives, the corporate governance environment plays an important role: board independence, the monitoring intensity of institutional investors, and the ability of controlling shareholders to provide checks and balances all constrain or incentivize the CEO's willingness to take risks [10]. Notably, compensation incentives may induce unintended consequences, such as earnings management to meet performance targets, cutting discretionary expenditures, or even financial fraud, or strategically increasing low-quality patent applications to boost the stock price in the short term [11].

Synthesizing the above findings, although the existing literature provides multidimensional perspectives on the relationship between compensation incentives and innovation, the core research gap lies in the incomplete specification of the causal chain linking CEO option incentives to corporate innovation output. Most existing studies treat option incentives as a component of equity incentives and examine only the impact of the proportion of equity-based compensation on R&D input or patent quantity. They fail to isolate the unique asymmetric payoff structure and intertemporal commitment attributes of options, resulting in ambiguity regarding the mechanism of the incentive tool. More crucially, the long-term nature of innovation activities and the endogeneity of option incentives remain underexplored. By constructing a lagged testing framework for option incentives, implementing grouped placebo tests by industry, and conducting heterogeneous interaction analysis, this study aims to precisely identify the net effect of option incentives on innovation output, fill the aforementioned research gaps, and provide more rigorous empirical evidence for understanding how compensation contracts shape corporate innovation strategy.

3 Data and Methodology

This study selects relevant data from U.S.-listed companies for the period 1993 to 2021 as the initial sample. Data sources include the *Duke DISCERN* database, *ExecuComp*, and *Compustat North America*. Industry classification follows the U.S. Standard Industrial Classification (SIC) code standards. To ensure the comparability of the empirical research, the initial sample is filtered according to the following criteria: selecting data in Standard Format (not Summary Format), from North American domestic companies, with consolidated statement data in U.S. dollars. Financial institution data are excluded, with attention limited to industrial company formats.

3.1 Explanatory Variables – CEO Option Incentives

Data for the option incentives is sourced from *ExecuComp*. First, the original ratio $Option\ Awards\ Pct$ is calculated by dividing $Option\ Awards$ (the value of option awards granted in the year) by $TDC1$ (total compensation). This metric directly measures the relative weight of options in the CEO's overall compensation contract, with a theoretical range of 0 to 1. Subsequently, strict outlier removal is performed: observations with missing, non-positive, or $TDC1$ values that are less than the $Option\ Awards$ values are deleted to avoid logical contradictions, such as negative compensation or options exceeding total compensation. Missing values for $Option\ Awards$ are treated as 0, which aligns with the reality for CEOs who were not granted options and avoids sample selection bias. Thereafter, both $Option\ Awards$ and $Option\ Awards\ Pct$ are winsorized at the 1st and 99th percentiles to mitigate the influence of tail outliers arising from data-entry errors or special cases (e.g., startup CEOs with option proportions close to 1), thereby making the distributions more nearly normal and strengthening coefficient interpretation.

Building on this, the lagged terms of $Option\ Awards\ Pct$, $Option\ Awards\ Pct\ (Lagged\ 1\ year)$ and $Option\ Awards\ Pct\ (Lagged\ 2\ years)$, are calculated. These capture the inter-temporal persistence of option incentives and are used to test the delayed effects or dynamic adjustment mechanisms of incentive policies on corporate innovation, thereby mitigating reverse causality. Additionally, the standardized variable $Option\ Awards\ div1000$ converts the unit of option value from dollars to thousands of dollars. This reduces the numerical magnitude to improve coefficient readability, meets the sensitivity requirements of some econometric models regarding variable scale, and presents the economic significance of incentive intensity more intuitively in descriptive statistics. These supplementary variables collectively support a multi-dimensional, long-cycle empirical testing framework.

3.2 Explained Variables – Enterprise Innovation Output

This study uses the number of patent applications and the number of patent grants from the *Duke DISCERN* database to measure the level of corporate innovation. Specifically, compared with input-oriented indicators such as R&D investment or expenditure, patent data more directly capture the substantive outputs of innovation activities, reflecting the firm's actual ability to transform R&D resources into protectable technological achievements [12]. The number of patent applications reflects the total scope of a firm's innovation effort in a given year, indicating the level of R&D activity and the breadth of technological exploration, with the advantage of strong timeliness [13]. Concurrently, the number of patent grants reflects technological achievements that have obtained legal validation following substantive examination, with a higher quality threshold and more stable legal status, thereby better reflecting the real contribution and technological value of innovation [13]. However, it exhibits significant lag: the process from application to grant typically takes 1-3 years, meaning grants in a given year may reflect prior rather than current innovation effort. Considering that application numbers capture the intensity of innovation attempts and grant numbers reflect the quality of innovation success, the study incorporates both dimensions.

Both variables undergo a "adding 1 and taking the natural logarithm" transformation. This aims to address common issues, such as zero values and right skewness, in patent-count data. The logarithmic transformation can mitigate non-normality and heteroscedasticity of the distribution. Thereafter, both variables are winsorized at the 1% and 99% levels to treat outliers. The final variable names are $Log\ (Patent\ Application + 1)$ and $Log\ (Patent\ Grant + 1)$.

3.3 Control Variables - Financial Variables

The study controls for other corporate financial factors that may influence innovation. It considers the impact of firm size (logarithm of total assets, denoted $Size$), return on assets (ROA), asset-to-liability ratio ($Leverage$), cash-holding ratio ($Cash\ Ratio$), and sales growth rate ($Sales\ Growth$). Data comes from *Compustat North America*. Observations with total assets less than 10 million dollars are excluded to ensure sample stability. All ratio variables are scaled by total assets to eliminate size effects and ensure cross-firm comparability. All financial variables are winsorized at the 1st and 99th percentiles to ensure robust estimation results.

3.4 Descriptive Statistics

After processing the aforementioned variables, the study ultimately obtains 23,567 firm-year observations. Table 1 presents descriptive statistics for the core variables used in the study. Count indicates the number of non-missing observations. The table also reports the variable's mean and standard deviation derived from these observations, as well as the minimum, 25th, 50th, 75th percentiles, and the maximum.

Regarding innovation output indicators, the mean of $Log\ (Patent\ Application + 1)$ is 1.754, corresponding to approximately 4.8 patent applications. Its median is only 1.386 (approximately 3.0 applications), indicating that innovation output for most firms is concentrated at low levels, with the mean elevated by a few highly innovative firms. The mean of $Log(Patent\ Granted + 1)$ is 2.143 (approximately 7.5 grants), higher than the application mean. This is primarily due to the time lag in patent examination, where patents applied for earlier might be concentratedly granted within the sample observation period. Their 75th percentiles are 3.091 and 3.367, respectively (corresponding to approximately 21 and 29 items), while the maximum values are both approximately 5.8 (330 items), indicating that innovation activity is highly concentrated among technology-intensive leading firms and exhibits significant tail characteristics.

CEO option incentives exhibit the typical pattern of low prevalence but high intensity. The mean of $Option\ Awards\ Pct$ is 0.101, meaning options on average constitute 10.1% of the CEO's total compensation. However, the median and the 25th percentile are both 0, indicating that at least a quarter of firms did not grant options in a given year, showing structural differences in the use of this incentive tool. The standard deviation of 0.177 exceeds the mean, indicating a highly dispersed intensity distribution. The mean of $Option\ Awards\ div1000$, is approximately 617 thousand dollars; the

75th percentile is 571 thousand dollars, and the maximum is 7,247 thousand dollars. This indicates that a few firms grant extremely high option values, producing a pronounced right-skewed, heavy-tailed distribution, consistent with the practice of intensive use of option incentives in high-tech firms.

Control variables indicate that sample firms are medium- to large- sized and have robust financial conditions. With a mean $Size$ of 7.251 and a standard deviation of 1.726, there is considerable cross-sectional dispersion in firm scale. The mean ROA of 0.120 indicates an average asset return rate of 12.0%, showing good profitability. Mean $Leverage$ of 0.185 and mean $Cash\ Ratio$ of 0.196 reflect average leverage and cash holding ratios of 18.5% and 19.6% respectively, indicating overall controllable financial risk. A mean $Sales\ Growth$ of 13.6% shows relatively high growth, but the standard deviation of 0.440 indicates volatility, with some firms experiencing negative growth (minimum -70.2%). The above analysis validates the effectiveness of data cleaning and outlier treatment.

Table 1. Descriptive statistical results.

Variable	Count	Mean	Std.	Min.	25%	50%	75%	Max.
Log (Patent Application +1)	23567	1.754	1.791	0.000	0.000	1.386	3.091	5.561
Log (Patent Grant +1)	23567	2.143	1.731	0.000	0.693	1.946	3.367	5.768
Option Awards Pct	23567	0.101	0.177	0.000	0.000	0.000	0.166	0.740
Option Awards div1000	23567	0.617	1.362	0.000	0.000	0.000	0.571	7.247
Size	23567	7.251	1.726	3.380	6.021	7.116	8.365	11.576
ROA	23567	0.120	0.129	-0.756	0.081	0.129	0.180	0.411
Leverage	23567	0.185	0.178	0.000	0.013	0.159	0.288	0.936
Cash Ratio	23567	0.196	0.196	0.000	0.044	0.127	0.289	0.921
Sales Growth	23567	0.136	0.440	-0.702	-0.013	0.075	0.188	4.857

3.5 Empirical Model

To examine the impact of CEO option incentives on a firm's innovation output capacity, this study employs multivariate regression analysis, constructing the following baseline regression model.

$$Innovation\ Output_{i,t} = \beta_0 + \beta_1 Option\ Awards_{i,t} + \boldsymbol{\beta_2 Controls'}_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t} \quad (1)$$

Here, i denotes the firm, and t denotes the year. β_0 is the constant term (intercept), representing the baseline level. The variable $Innovation\ Output$ includes $Log\ (Patent\ Application + 1)$ and $Log\ (Patent\ Grant + 1)$. $Option\ Awards$ includes $Option\ Awards\ Pct$ and $Option\ Awards\ div1000$. The vector $\boldsymbol{Controls'}$ represents all firm-level control variables. α_i is the firm fixed effect, capturing time-invariant individual heterogeneity, including inherent corporate governance structures, geographical location, corporate culture, and other unobservable or difficult-to-quantify firm characteristics. γ_t is the year fixed effect, controlling for macroeconomic environment, policy shocks, market cycles, and other time-varying factors affecting all firms, eliminating systematic interference in the time series. $\varepsilon_{i,t}$ is the random error term, containing other unobserved disturbance factors at the firm-year level.

4 Research Results and Analysis

4.1 Baseline Regression and Lagged Effect Analysis

To systematically identify the correlation between CEO option incentives and corporate innovation output, and to address the identification challenges posed by the long-cycle nature of innovation activities and endogenous incentive arrangements, this study employs a multidimensional lagged-effects testing framework. Controlling for two-way fixed effects to eliminate unobservable heterogeneity, it simultaneously examines the differential impact of current and lagged incentives on patent applications and grants, effectively isolating immediate responses from long-term commitment effects.

Table 2. Baseline regression results.

	Log (Patent Application +1)			*Log (Patent Grant +1)*		
	(1)	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Option Awards div1000	0.091*** (10.155)			0.015* (1.886)		
Option Awards Pct		0.276*** (4.527)	0.175*** (3.547)		0.103* (1.835)	0.063 (1.334)
Option Awards Pct (Lagged 1 year)			0.118*** (2.921)			0.089** (2.378)
Option Awards Pct (Lagged 2 year)			0.116** (2.517)			0.095** (2.156)
Size	0.398*** (13.772)	0.419*** (14.499)	0.459*** (14.926)	0.464*** (19.478)	0.467*** (19.602)	0.455*** (17.632)
ROA	-0.057 (-0.483)	-0.009 (-0.079)	-0.071 (-0.554)	-0.651*** (-6.575)	-0.643*** (-6.479)	-0.638*** (-5.714)
Leverage	-0.132 (-0.151)	-0.129 (-1.481)	-0.111 (-1.217)	-0.118 (-1.499)	-0.118 (-1.498)	-0.091 (-1.074)
Cash Ratio	0.159* (1.687)	0.171* (1.786)	0.100 (1.011)	-0.269*** (-3.295)	-0.268*** (-3.277)	-0.236*** (-2.778)
Sales Growth	-0.015 (-1.012)	-0.015 (-0.979)	-0.035** (-2.225)	-0.131*** (-6.546)	-0.131*** (-6.558)	-0.086*** (-4.142)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.821	0.819	0.835	0.873	0.873	0.886
N	23567	23567	20225	23567	23567	20225

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

The results in Table 2 show that option incentives have a significant immediate and sustained positive effect on innovation output, but the magnitude and intensity of the effect differ. For every $1,000 increase in the current option value, the number of patent applications increases by 9.1%, whereas the number of patent grants increases by only 1.5%. Meanwhile, the coefficient of $Option\ Awards\ Pct$ is 0.276 in the application model and 0.103 in the grant model. This indicates that for each one-standard-deviation increase (approx. 0.177) in current option incentive intensity, a firm at the average innovation level expects its number of patent applications to increase by about 5.0% (exp(0.276×0.177)−1), while the number of patent grants increases by only 1.84% (exp(0.103×0.177)−1). This confirms that options primarily affect the R&D investment, with a greater marginal effect on innovation effort than on validated outcomes.

At the dynamic level, the lagged term coefficients for patent applications decrease slightly from 0.118 to 0.116, indicating mild attenuation: the stimulating effect of incentives on innovation attempts weakens over time, consistent with the "diminishing returns" pattern [14]. In contrast, the lagged term coefficients for patent grants increase marginally from 0.089 to 0.095, inversely trending upward. This precisely validates a characteristic of the patent examination cycle: applications driven by current incentives are concentratedly granted 1-3 years later, thereby marginally strengthening the incentive effect in lagged periods due to examination completion, reflecting the delayed genuine contribution of option incentives to high-quality innovation. This differential pattern accurately depicts stage-specific response differences in the innovation value chain: strong-then-weak for the application side and weak-then-strong for the grant side. This finding underscores the necessity of the research design: relying solely on contemporaneous regression would severely underestimate the real innovation premium of option incentives. Option incentives bind managerial wealth to long-term technological value through intertemporal bundling mechanisms, rather than merely inducing short-term strategic innovation behavior.

4.2 Placebo Test

The placebo test aims to rule out the possibility that inherent industry characteristics drive the baseline results and to verify whether the innovation effect of option incentives exists only in industries theoretically expected to be suitable for using this contractual tool. Specifically, the implementation of option incentives exhibits industry selectivity: high-tech, high-growth firms are more likely to grant options, and these firms inherently exhibit stronger innovation tendencies. If industry heterogeneity is ignored, the baseline regression may capture the industry's inherent innovation environment rather than the true causal effect of the incentive contract. Therefore, this study divides the sample into two groups based on industry economic characteristics: "Industries should not be affected by option incentives" and "Industries suitable for option incentives". The former group includes industries in which, due to strict regulation, stable growth, low equity liquidity, or thin profit margins, there is, in theory, no reliance on options as a core incentive tool. These specifically include mining, utilities, transportation, services, agriculture, forestry, fishing, construction, food, tobacco, textile manufacturing, wholesale trade, and retail trade [15]. If the option incentive variable continues to affect innovation in these industries, it would indicate spurious correlation in the baseline results. Conversely, if not, it strengthens the robustness of causal inference.

Table 3. Regression results for the placebo test.

	Log (Patent Application +1)		*Log (Patent Grant +1)*	
	(1) Industries should not be affected by option incentives	(2) Industries suitable for option incentives	(1) Industries should not be affected by option incentives	(2) Industries suitable for option incentives
Option Awards Pct	0.074	0.301***	-0.015	0.144***
	(0.686)	(4.183)	(-0.127)	(2.281)
Size	0.372***	0.453***	0.385***	0.517***
	(7.776)	(13.435)	(8.348)	(19.113)
ROA	-0.110	0.014	-0.240	-0.876***
	(-0.481)	(0.101)	(-1.060)	(-7.887)
Leverage	-0.023	-0.199**	0.029	-0.205**
	(-0.148)	(-1.962)	(0.173)	(-2.318)
Cash Ratio	-0.029	0.167	-0.307**	-0.259***
	(-1.170)	(1.528)	(-2.004)	(-2.756)
Sales Growth	-0.048	-0.022	-0.207***	-0.089***
	(-1.543)	(-1.376)	(-5.146)	(-3.824)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R-squared	0.786	0.835	0.836	0.870
N	6875	16692	6875	16692

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

Table 3 shows that the innovation-driving effect of option incentives is strictly limited to certain industries, with significant inter-group heterogeneity. In unsuitable industries, the coefficients of $Option\ Awards\ Pct$ on both patent applications and grants are not statistically significant. In the appropriate sectors, all coefficients are significant at the 1% level. This pattern of differentiation confirms that option incentives are not a universally applicable innovation tool; their effectiveness depends on matching industry characteristics. The causal identification of the baseline regression is strongly supported, confirming that the innovation-promoting effect of option incentives is a causal return to the contract design itself, rather than an artifact of industry self-selection. This provides evidence for regulatory bodies regarding differentiated incentive policies.

4.3 Heterogeneity Analysis

The core purpose of the heterogeneity test is to strengthen the causal chain of option incentives driving innovation by testing the moderating effects predicted by theory. According to Agency Theory, the effectiveness of option incentives often depends on the inherent intensity of agency conflicts and the degree of information asymmetry within the firm [16]. First, in large firms, due to organizational complexity and severe information asymmetry, monitoring costs rise sharply. Options can effectively bind managerial wealth to shareholder value, thereby forming an interest-alignment mechanism that bridges hierarchical levels and significantly amplifies their incentive effect on innovation. In contrast, in small firms, where managerial ownership is often higher and monitoring costs are lower, excessive option grants may distort risk-taking, leading to insufficient investment in strategic innovation. Second, the synergistic effect of option incentives is particularly pronounced in high-leverage firms because debt contracts intensify short-term performance pressure, thereby inclining managers to reduce high-risk R&D expenditure. Options, as a risk-compensating tool, can counteract the adverse incentives of debt constraints, restoring investment in innovation to an optimal level. If option incentives indeed drive innovation by reducing agency costs, their effect should be significantly stronger in subsamples with more severe agency problems. This type of mechanism test constitutes evidence for causal inference. If the baseline effect stems from unobservable industry trends or reverse causality, it should not exhibit systematic differentiation on moderating variables consistent with theoretical predictions. Therefore, this study constructs interaction-term moderation models to test if the effect of option incentives on innovation is more likely to operate through a causal channel.

Table 4. Heterogeneity test using $Log\ (Patent\ Application + 1)$ as the explained variable.

	Corporate Size Moderation	**Corporate Leverage Moderation**
*Option Awards Pct * Large Size*	1.099*** (9.986)	/
Large Size	-0.180*** (-4.105)	/
*Option Awards Pct * High Leverage*	/	0.284*** (2.985)
High Leverage	/	-0.043 (-1.246)
Option Awards Pct	-0.250*** (-3.495)	0.151** (2.204)
Size	0.431*** (14.156)	0.421*** (14.532)
ROA	-0.043 (-0.369)	-0.015 (-0.124)
Leverage	-0.130 (-1.508)	-0.110 (-1.060)
Cash Ratio	0.162* (1.715)	0.167* (1.748)
Sales Growth	-0.012 (-0.796)	-0.015 (-1.001)
Firm FE	Yes	Yes
Year FE	Yes	Yes
R-squared	0.821	0.819
N	23567	23567

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

Specifically, the industry-year medians of $Size$ and $Leverage$ are used to construct dummy variables, $Large\ Size$ and $High\ Leverage$, assigning 1 to industry-year samples exceeding the median and 0 otherwise. Furthermore, interaction terms of $Option\ Awards\ Pct * Large\ Size$ and $Option\ Awards\ Pct * High\ Leverage$ are constructed. Table 4 shows that the coefficient of $Option\ Awards\ Pct * Large\ Size$ is 1.099. This indicates that when option incentive intensity reaches the mean level (0.101), the growth rate of patent applications for large firms is approximately 11.8 percentage points higher than that for small firms (exp(1.099×0.101)−1), demonstrating the strong effect of options in organizations with sufficient innovation resources. The coefficient of $Option\ Awards\ Pct * High\ Leverage$ is 0.284. This indicates that in high-leverage firms, for each one-standard-deviation increase (0.177) in option incentive intensity, the number of patent applications increases by approximately 5.2% (exp(0.284×0.177)−1) more than in low-leverage firms.

5 Conclusion

This study, by constructing a multi-dimensional testing framework for option incentives, systematically reveals the significant driving effect of CEO option incentives on corporate innovation activities. Dynamic tests show that the policy effect exhibits intertemporal commitment efficacy lasting more than two years. The significant impact of lagged terms on patent grants accurately captures the examination-cycle characteristic, thereby mitigating managerial myopia. Heterogeneity tests further reveal that the strength of this incentive is enhanced in larger firms and those with higher leverage. These findings collectively support the conclusion that the relationship between option incentives and innovation output is more likely causal than correlational.

The above conclusions have dual implications for corporate compensation design and regulatory policy. First, companies should abandon a one-size-fits-all option-granting strategy. They should prioritize the use of option incentives in high-tech, high-growth industries with equity appreciation potential and dynamically adjust the granting intensity based on their own size and leverage levels. Second, regulators need to be vigilant about the risk of option mismatches in incentive plans. They should strengthen the rationality review of listed companies' use of options in unsuitable industries and require disclosure of the justifications for aligning incentives with industry characteristics and corporate strategy. Simultaneously, they should encourage continuous rather than one-time grants, link option plans to intertemporal assessment of innovation performance, prevent strategic patenting behavior and short-term earnings manipulation, and guide incentive resources toward substantive technological innovation.

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