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Research on incentive and technological innovation models of biopharmaceutical companies

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Abstract. This article selects biopharmaceutical enterprises listed in high-tech industry as samples, using the Heckman selection model effectively avoid sample bias and according to linear analysis, this research tests the influence between senior management incentives and technological innovation based on the Chinese biopharmaceutical enterprises listed in high tech industry in a certain period. The empirical research results indicate that there is not a simple linear correlation between short-term salary incentives and technological innovation, and there is a curve relationship that first decreases and then increases among them; Long term equity incentives have a significant positive impact on technological innovation. This research aimed to find the maximum value of incentives, propose countermeasures and suggestions to avoid excessive salary incentives, appropriately improve the level of stock-based compensation, and establish a reasonable senior management incentive system for insight. Keywords: Heckman selection model, biopharmaceutical industry, technological innovation, executive incentive

1 Introduction

Technological innovation is a dynamic process, perhaps the most dynamic of all industrial activities. Schumpeter with his “gales of creative destruction” shows how innovation is creative, bring new industries for competitive survival (Dodgson, Gann, 2010) [1]. Scientific and technological innovation is an effective way for enterprises not only to gain a competitive advantage but also to promote sustainable economic development. However, the innovation process in enterprises faces serious risks including high uncertainty, a high investment failure rate, and the long investment cycle of enterprise innovation investment [2]. The biopharmaceutical industry, as a typical technology intensive and knowledge intensive industry, represents the high-end technology and economic development level of a country and region. It’s directly influenced to the life and health of the people and the harmony and stability of society. Therefore, the biopharmaceutical industry has become a strategic pillar industry that China is focusing on developing [1-22]. For the biopharmaceutical industry, technological innovation is a key factor in forming the core competitiveness of enterprises. The biopharmaceutical industry today is of vital importance due to the drive towards

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technological innovation solutions to new medical challenges [3]. Innovative drugs and other new products or processes help enterprises form competitive advantages and achieve sustainable development. However, currently, there is a significant lack of innovation investment from Chinese biopharmaceutical enterprises. How to improve the overall innovation capability of the industry has become a hot research topic for Chinese scholars.

Due to the particularity of the biopharmaceutical industry, its technological innovation has the feature of high technology, high risk, high value and long cycle. Causing serious principal-agent problems in the process of innovation activities for enterprises. Therefore, executive incentives have become one of the main factors affecting corporate technological innovation activities [4]. Through research literature on the relationship between senior management incentives and technological innovation in foreign and Chinese countries, it was found that there are still some problems in research in this field. (1) In terms of general theoretical research, at present, academia remains a greater dispute and still has the space for further research; (2) for the biopharmaceutical sector, more academic achievements are needed as a research foundation; (3) for the methods using aspect, scholars focus on regression analysis in order to get further empirical analysis in the chosen area but ignoring observations without innovative behavior, which may lead to sample bias. From this perspective, this article takes listed companies in the biopharmaceutical industry as an example and creatively uses the Heckman selection model to control for sample selection bias, once again exploring the effect of the senior management incentives on technological innovation.

2 Literature review and research hypotheses

Senior management incentive’s structure can facilitate enterprises innovation performance [5]. As the decision-makers and implementers of the enterprise, senior management determine the direction of the enterprise's long-term resource allocation. Long-term and stable support from executives is crucial for the enhancement of firms' innovation performance; therefore, how to design a reasonably structured and externally competitive incentives system to reduce executives' short-sighted behavior and enhance enterprises' innovation performance is a core issue that must be addressed by corporate governance (Si et al., 2020). The senior management of a biopharmaceutical company not only hold the strategic decision-making power of enterprises but also keep the main force driving the development of technological innovation in the enterprise. However, there is an inconsistent benefit function between executives and shareholders. If there is a lack of effective incentive mechanisms, senior management sector usually give up investing in high investment, high-risk, and long-term innovation projects in order to maximize their own interests. This will affect the long-term development of the enterprise and harm the interests of the company's shareholders. Therefore, how to use reasonable incentive measures to guide executives towards innovation, effectively allocate internal and external resources of the company, and improve the technological innovation capability of the enterprise has become an important research area for scholars at home and abroad. Scholars mainly conduct research on the relationship between senior management incentives and corporate innovation from two dimensions: salary incentives and equity incentives.

2.1 Salary incentives and technological innovation

Most research on salary incentives and technological innovation is based on the theory of salary contracts. The impact of an industry salary incentives on corporate innovation is a topic that has attracted great interest [6]. According to the theory of compensation contracts, there is a certain relationship between senior management and business performance, and the degree of correlation is reflected in the sensitivity of compensation performance. Most scholars believe that executives in China's pharmaceutical industry are currently in the stage of wealth accumulation and have high sensitivity to salary and performance. Being able to make innovative decisions that benefit the company. therefore, salary incentives can significantly enhance the company's technological innovation capabilities. Chen Xiao hui and Wang Zhen jie [4] found through regression analysis that in A-share manufacturing listed companies, executive compensation incentives are significantly positively correlated with private enterprises' technological innovation investment. Li Yao and Wang Wei (2015) argue in their research that salary incentives can promote R&D investment in companies listed on the ChiNext board. Xu Ning and Wu Chuang [7] combined linear regression and nonlinear regression to explore the positive effect on the inspire of the senior management sector on the innovation drive of private small and medium-sized enterprises, and the inverted U-shaped relationship with the selection tendency of internal independent research and development. However, according to the expectancy theory, the effectiveness of compensation incentives largely depends on the perceived attractiveness of compensation by executives. When executive wealth is at a low stage, compensation can have a strong motivating effect. But with the continuous increase of executive wealth, salary incentives have shifted from incentive factors to health factors, and their incentive effect has gradually declined, resulting in a diminishing marginal be

2.2 Equity Incentives and technological innovation

The research on stock-based compensation incentive effects in China and overseas is based on two hypotheses: the convergence of interest hypothesis and the manager's defense hypothesis. Jensen and Meckling [8] proposed the convergence of interest hypothesis, which suggests that implementing incentive methods such as stock options on corporate agents can promote alignment of benefit for senior management and stockholders, greatly reducing agency costs. Based on the convergence of interest hypothesis, many scholars have confirmed a significant pertinence relation on stock-based compensation and enterprises technological innovation. Lerner and Wulf [9] used American high-tech companies as samples and ultimately found that implementing incentives such as stock or options for executives can significantly increase the number of patents in the company. In addition, scholars such as Zahra [10], Bulan and Sanyal [11], Huang Yuan and Chen Kun yu [12] also believe that the proportion of executive shareholding is significantly positively correlated with the technological innovation activities of high-tech enterprises, especially those in the pharmaceutical industry. However, the "Manager Defense Hypothesis" suggests that granting incentives to executives enhances their ability to resist internal and external regulatory pressures, thereby strengthening their opportunistic behavior. Subsequently, scholars such as Xu Ning [13], Wang Jianhua [14], supported the manager's defense hypothesis, stating that the long-term equity incentive contracts between high-tech enterprises and executives of GEM companies exhibit an inverted U-shaped relationship with technology innovation indicators such as R&D investment and patent authorization. It’s also pointed out that when the management's shareholding ratio exceeds 30.37%, an increase in management's shareholding ratio is actually not conducive to the company's investment in technology innovation and R&D. In summary, scholars from China and overseas have conducted extensive study about a certain relation between senior management incentives and innovation. But so far, no consensus has been reached. The reason for this may be that (1) the selected research samples are different. Some scholars use all listed companies as samples, while others use GEM, SME board, high-tech enterprises or private enterprises, and state-owned enterprises as samples; (2) More literature is limited to the linear correlation between the two, neglecting the research on the nonlinear relationship between senior management incentives and technological innovation. As a high-tech enterprise, the biopharmaceutical industry in China is rarely studied by scholars. Consequently, this research selects the current listed companies in the biopharmaceutical industry in China as a sample and innovatively uses the Heckman selection model for empirical research. Meanwhile, this article combines linear and nonlinear research, and the defensive effect of managers has not yet emerged.

According to these two aspects, the following assumptions are proposed:

H1: There is an inverted U-shaped relationship between short-term salary incentives and the technological innovation capability of biopharmaceutical enterprises.

H2: There is a positive correlation between long-term equity incentives and the technological innovation capability of biopharmaceutical enterprises.

3 Research Design

3.1 Sample selection and data sources

This article selects biopharmaceutical enterprises listed in high-tech industry as samples, selects 2018-2022 as the research interval, and examines the impact of short-term salary incentives and long-terms stock-based compensation on technological innovation ability in the Chinese biopharmaceutical industry, providing decision-making basis for the improvement of innovation ability in future biopharmaceutical enterprises. To ensure the reliability and effectiveness of the empirical results, ST, * ST, and PT companies were removed, resulting in 95 biopharmaceutical listed companies with a total of 475 observations. Incentive data and financial data are all from CS-MAR database, and patent data are from China Patent Database of China National Intellectual Property Administration. The data processing and analysis were completed using STATA and SPSS.

3.2 Variable Definition and Measurement

The dependent variable of this article is the technological innovation index of biopharmaceutical enterprises. The existing literature mainly measures the technological innovation capability of enterprises from two aspects: innovation input and innovation output. The former is usually represented by R&D investment intensity, while the latter is mostly influenced according to the quantities of patents or the output value of new drugs.

Due to many listed companies not disclosing R&D investment data in their annual reports, the lack of R&D data does not mean that the company has no R&D investment. It is difficult to ensure the scientific and accuracy of research conclusions if only data from listed companies that disclose their R&D investment is used for research. Therefore, this article chooses the quantities of patent application in order to find innovation ability of listed companies in the biopharmaceutical industry.

The explanatory variables are senior management incentives and stock-based compensation. Short-term compensation incentives are measured by the total compensation located in the first, second, and third senior manageme.

Table 1. Variable Description

Variable Declaration		Variable code	Definition
Dependent variable	Number of patent applications	PA	Number of applications for three types of patents
Independent variable	Compensation	EP	The natural logarithm of the total compensation of the top three executives
	Equity incentive	ES	Total number of shares held by executives/total number of shares
Control variable	Nature of Property Rights	EN	Virtual variable, state-owned enterprises assigned a value of "1"
Control variable	Growth potential	GR	Revenue growth rate
	Company size	SIZE	Natural logarithm of total assets
	Corporate performance	EPS	Earnings per share
	Capital structure	LEV	Total liabilities/total assets
	Ownership concentration	EC	The shareholding ratio of the company's largest shareholder
	Equity balance	EB	The shareholding ratio of the largest shareholder/the shareholding ratio of the second largest shareholder, which is actually the reciprocal of equity balance
	Duality	PT	Dummy variable, the general manager concurrently serves as a director, assigned a value of "1"

4 Research Methods and Model Construction

4.1 Research method

This article selects the Heckman two-stage model proposed by Heckman [15] to address sample selection bias. Due to the fact that some biopharmaceutical companies in the Chinese patent database have zero patent applications, using the ordinary least squares method for regression estimation will inevitably exclude observations without innovative output, and ultimately only estimate a portion of the samples with innovative output, resulting in sample selection bias. This is because only when the occurrence of non-innovative output is random, ignoring or excluding biopharmaceutical companies without innovative output may not cause bias. In this article we use the Heckman two-stage model to avoid sample selection bias.

The Heckman model is divided into two steps. The first step is to select the innovation model, and the second step is to analyze it through the Probit model:

$$Y_{i1} = X_{i1}\delta_1 + \alpha + \varepsilon_i \tag{1}$$

Formula(1) indicates that whether biopharmaceutical companies choose to useY_i1 to represent technological innovation is determined by the observable related variableX_i1and the unobservable variable α . If a company chooses technological innovation, thenY_i1=1, otherwise Y_i1=0. ε _i is the error term. According to formula(1), obtain the estimated value δ ̂_11, and then calculate the inverse Mills ratio for each sample individual i:

$$\lambda_i = \frac{\phi\left(X_{i1}\hat{\delta}_1\right)}{\varphi\left(X_{i1}\hat{\delta}_1\right)} \tag{2}$$

In Formula(2), $\phi\left(X_{i1}\hat{\delta}_1\right)$ and $\varphi\left(X_{i1}\hat{\delta}_1\right)$ represent the density function and cumulative density function of the standard normal distribution with $X_{i1}\hat{\delta}_1$ as the variable, respectively. The second step is the innovation quantity model, which uses $Y_{i1} = 1$ to select samples for regression:

$$Y_{i2} = X_{i2}\delta_2 + \lambda_i + \mu_i \tag{3}$$

In Formula(3), Y_{i2} is the dependent variable for the second stage, which is the number of patent applications from biopharmaceutical listed companies. X_{i2} is the explanatory variable for the second stage. λ_i is the inverse Mills ratio calculated based on the first stage, used to correct for sample selection bias. If λ is significantly non-zero, it indicates the existence of selectivity bias, and therefore the Heckman model is effective. μ_i is the error term.

4.2 Modelling

This study uses the Heckman model to examine the impact of senior management incentives on technological innovation in biopharmaceutical listed companies from two stages: innovation selection and innovation quantity. Firstly, by constructing a Heckman selection model, the non-linear relationship formula between salary incentives and technological innovation in biopharmaceutical enterprises is verified:

$$\begin{aligned} Probit(PATENT) &= \beta_0 + \beta_1 EP + \beta_2 EP^2 + \beta_3 EN + \beta_4 GR + \beta_5 SIZE + \beta_6 EPS + \beta_7 LEV \\ &\quad + \beta_8 EC + \beta_9 EB + \beta_{10} PT + \varepsilon_i \end{aligned} \tag{4}$$

$$\begin{aligned} PA = \gamma_0 + \gamma_1 EP + \gamma_2 EP^2 + \gamma_3 EN + \gamma_4 GR + \gamma_5 SIZE + \gamma_6 EPS + \gamma_7 LEV + \gamma_8 EC + \gamma_9 EB \\ + \gamma_{10} PT + \gamma_{11}\lambda_1 + \varepsilon_2 \end{aligned} \tag{5}$$

Meanwhile, to verify the linear relationship between equity incentives and technological innovation, the following model formula is constructed:

$$\begin{aligned} Probit(PATENT) &= \beta'_0 + \beta'_1 ES + \beta'_2 EN + \beta'_3 GR + \beta'_4 SIZE + \beta'_5 EPS + \beta'_6 LEV \\ &\quad + \beta'_7 EC + \beta'_8 EB + \beta'_9 PT + \varepsilon'_1 \end{aligned} \tag{6}$$

$$\begin{aligned} PA = \gamma'_0 + \gamma'_1 ES + \gamma'_2 EN + \gamma'_3 GR + \gamma'_4 SIZE + \gamma'_5 EPS + \gamma'_6 LEV + \gamma'_7 EC + \gamma'_8 EB \\ + \gamma'_9 PT + \gamma'_{10}\lambda_2 + \varepsilon_2 \end{aligned} \tag{7}$$

Equations (4) and (6) are innovation selection equations that examine the effects of salary incentives, equity incentives, and other factors on whether pharmaceutical companies choose technological innovation. If the number of patent applications for pharmaceutical companies is greater than zero, then $PATENT = 1$; If the number of applications is zero, then $PATENT = 0$. Equations (5) and (7) are innovation quantity equations, and regression

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estimation is conducted using a selection sample with $PATENT = 1$ to examine the effects of salary incentives, equity incentives, and other factors on the technological innovation capability of pharmaceutical enterprises. Among them, EP is a short-term compensation incentive, measured by the natural logarithm of the total compensation of the top three executives, ES is a long-term equity incentive, measured by the executive shareholding ratio, λ is the inverse Mills ratio, ε varepsilon is the error term, and the rest are control variables used to control the impact of other variables on technological innovation capability.

4.3 Empirical results and analysis

Before conducting empirical analysis, first conduct correlation analysis and collinearity testing. There is a positive correlation between the number of patents and the proportion of executive shareholding, as well as the total compensation of the top three executives, which is consistent with the previous analysis The Pearson correlation coefficient between the explanatory variable and the control variable is relatively small, mostly around 0.1. Only the correlation coefficient between equity concentration and equity balance is relatively large, reaching 0.51, indicating that the model does not have serious multicollinearity issues. In addition, the VIF figures below 2. Through comprehensive judgment, it is concluded that the model setting in this study is relatively reasonable and there is no multicollinearity problem, making it suitable for further statistical analysis.

4.4 Descriptive statistics

Table 2 presents the descriptive statistical analysis results of each variable shows there are 101 observations with zero patent numbers in all samples, indicating that some biopharmaceutical companies in China have not produced innovation output in certain years, and the overall innovation capacity of the biopharmaceutical industry is relatively weak. The average value of the compensation incentive variable (EP) in China is 14.28, indicating that the total compensation located in the first, second, and third positions is as high as 1.6 million yuan, with a standard deviation of less than 1, indicating that the compensation level of executives in Chinese biopharmaceutical enterprises is high and the difference is not significant; The highest paid individual even reached 19 million yuan. The highest shareholding ratio (ES) is 13.8%, it’s remaining that stock-based compensation in Chinese biopharmaceutical enterprises keeping a low level in recent years.

Table 2. Descriptive Statistics

Variable	Minimum value	Maximum value	Average value	Standard deviation	N
PA	1	500	22.05	40.72	374
EP	12.49	16.76	14.28	0.75	475
ES	0	0.84	0.05	0.13	475
EN	0	1	0.12	0.32	475
GR	-0.88	4.96	0.18	0.38	475
SIZE	19.54	24.36	21.83	0.90	475
EPS	-1.14	4.10	0.59	0.63	475
LEV	0.07	0.88	0.30	0.19	475
EC	7.93	71.56	35.30	14.22	475
EB	1	109.40	7.89	10.29	475
PT	0	1	0.29	0.45	475

Sources: by author.

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5 Results and analysis of Heckman's selection model

5.1 Empirical Results and Analysis of the Relationship between Salary Incentives and Technological Innovation

Table 3 shows the Heckman two-step analysis results of compensation incentives and technology innovation in Chinese biopharmaceutical enterprises. To verify the non-linear relationship between salary incentives and technology innovation, first examine the linear correlation between the two. Table 3 shows both the linear and nonlinear models of salary incentives and technological innovation and the ratio significant at 5% refers to sample bias existing. The Heckman model is effective.

From Table 3, the linear correlation between salary incentives and the number of patent applications of biopharmaceutical listed companies in Model (1) is not significant. Therefore, it is necessary to verify the nonlinear relationship between the two. After adding the square term to Model (2), both the salary incentive and its square term are significant at the 5% level, and the salary incentive is positively correlated with the number of patents, while the square term of the salary incentive is negatively correlated with the number of patents. Therefore, it can be concluded that the salary incentive of biopharmaceutical listed companies has an curve relationship with their technological innovation capabilities. Hypothesis 1 is verified. Meanwhile, using EP coefficients, the inflection point of the salary incentive variable (EP) is calculated to be 14.20. Therefore, it can be inferred that when the total salary of the top three senior management sector in the Chinese biopharmaceutical industry did not reach 1.48 million, the technological innovation ability of the enterprise continued to improve with the improvement of income levels; After the total compensation located in the first, second, and third senior management positions reaches 1.48 million yuan, the promoting effect of salary incentives on technological innovation gradually decreases. The reason for this may be that when the salary reaches a certain level, the attractiveness generated gradually decreases. Enterprises are more inclined to use redundant resources to maintain existing performance and give up investing in high-risk, long-term innovation activities.

In the controlled variables, we can find a significant positive correlation between enterprise scale and performance and the choice of technological innovation at the 5% level, and a significant positive correlation with the number of technological innovations at the 1% level. That is to say, both enterprise scale and performance can promote biopharmaceutical companies to choose technological innovation and significantly improve their technological innovation capabilities. The larger the scale of enterprises (SIZE), the higher the ability to diversify innovation activity risks, greatly reducing the risk of R&D project failure, and therefore, the more likely it is to engage in technological innovation; In addition, large-scale enterprises have advanced research and development equipment and strong research teams, with high innovation efficiency, and usually can obtain more innovative results. The better the company's performance (EPS), the more likely it is to choose technological innovation, because the company can provide sufficient funds and personnel for R&D investment. Higher R&D investment will inevitably bring relatively high innovation output. Duality (PT) is significantly negatively correlated with the innovation choices and the number of technological innovations at the 1% and 5% level differently. This conclusion indicates that even if the chairman concurrently serves as a senior management of the company, the goal is not to maximize the interests of the company's shareholders. The technological innovation ability of biopharmaceutical companies has not been improved as a result, and it is highly likely that senior management sector has used their power to pursue their own interests and abandoned the opportunity to invest in research and development projects.

In addition, other control variables failed the significance test and require further investigation and analysis. The asset liability ratio (LEV) is positively correlated with the technological innovation choices and capabilities of biopharmaceutical companies, indicating that executives have realized that technological innovation capabilities are the core competitiveness of biopharmaceutical companies. Even if they bear a high level of debt, they will still choose technological innovation to improve the company's technological innovation capabilities. However, the relationship between capital structure and technological innovation is not significant, indicating that senior management sector considers the rights and interests of corporate creditors when making technological innovation decisions, in order to avoid excessive asset liability levels caused by technological innovation investment. The growth potential (GR) of enterprises is negatively correlated with technological innovation choices and technological innovation capabilities, but it is not significant. Fast growing companies may often focus on the development of various aspects of the enterprise, going over more focus and financial resources to other businesses. The nature of property rights (EN), concentration of equity (EC), and technological innovation are all negatively correlated. Due to low competitive pressure, state-owned biopharmaceutical listed companies are usually unwilling to choose technological innovation, and their technological innovation capabilities lag behind non-state-owned enterprises. The concentration of equity has a negative impact on the technological innovation of biopharmaceutical enterprises. Generally speaking, if a company wants to achieve or realize its long-term benefits and development goals, it needs to have a relatively concentrated share of shareholders' equity within the company, which is more advantageous. At the same time, the development of the regulatory system should be strengthened, and effective incentive measures should be formulated to encourage company operators to enhance their competitiveness by improving their technological innovation capabilities. However, at the same time, major shareholders will also avoid investment risks and avoid short-term damage to their profits. Therefore, when making technological innovation decisions, they are more cautious and may inhibit the company's investment in technological innovation. The reciprocal of equity balance (EB) is negatively correlated with technological innovation, indicating that equity balance can promote biopharmaceutical enterprises to choose technological innovation and improve their technological innovation capabilities. Equity balance can avoid "one shareholder dominating", allowing multiple major shareholders to constrain each other and make scientific technological innovation decisions.

Table 3. Empirical Analysis Results of Salary Incentives and Technological Innovation

Variable	**Linear model 1**		**Non-linear model 2**	
	Phase 1	**Phase 2**	**Phase 1**	**Phase 2**
Constant term	-6.270*** (-2.87)	-292.378*** (-3.64)	-9.505 (-0.50)	-1611.9** (-2.48)
EP	-0.089 (-0.81)	-2.349 (-0.64)	0.368 (0.14)	179.306** (2.02)
EP^2	-	-	-0.016 (-0.17)	-6.310** (-2.04)
EN	-0.144 (-0.66)	-10.113 (-1.38)	-0.147 (-0.67)	-11.173 (-1.47)
GR	-0.156 (-0.89)	-3.361 (-0.57)	-0.156 (-0.89)	-4.335 (-0.70)
$SIZE$	0.256** (2.45)	14.905*** (3.90)	0.255** (2.44)	15.466*** (3.90)
EPS	0.384** (2.00)	16.587*** (3.27)	0.384** (2.00)	16.913*** (3.20)
LEV	0.327 (0.73)	17.197 (1.18)	0.331 (-0.55)	2.566 (1.35)
EC	-0.003 (-0.40)	-0.075 (-0.39)	-0.003 (-0.55)	-0.045 (-0.23)
EB	-0.003 (-0.40)	-0.140 (-0.53)	-0.003 (-0.41)	-0.153 (-0.56)

PT	-0.415*** (-2.78)	-12.839** (-2.05)	-0.416*** (-2.79)	-13.991** (-2.15)
Λ	-	42.736** (1.98)	-	48.365** (2.16)

Note: The values in parentheses represent the Z values corresponding to the estimated coefficients of the variables. *, * *, * * * respectively represent significant values at the 10%, 5%, and 1% levels.

5.2 Empirical Results and Analysis of the Relation on Stock-based Compensation and Enterprises Technological Innovation

The Heckman two-step analysis results of stock-based compensation incentives and technological innovation in Chinese biopharmaceutical enterprises are shown in Table 4. As shown in Table 4, λ Significant non zero indicates that the Heckman selection model is effective. The empirical results show that equity incentives (ES) are positively correlated with technological innovation choices, but have not passed the significance test; It shows a positive pertinence relation at the 1% level with the number of technological innovations. Stock-based Compensation do not significantly promote biopharmaceutical enterprises to choose technological innovation, indicating that not companies with a higher proportion of senior management shareholding are more likely to choose technological innovation. However, due to the stock-based compensation incentives can promote alignment of interests between executives and shareholders, generating a strong incentive effect, the higher the proportion of executive shareholding, the more the efficient enterprise technology production. Therefore, H2 has been validated. The research results of Wang Wen Hua [16] indicate that there exist a first decreasing and then increasing curve relation between salary incentives and technology innovation ability among high tech enterprises. Therefore, compared with the entire high-tech industry, the equity incentive level of China's biopharmaceutical industry is generally lower and has not yet reached its extreme value. Therefore, it still shows a linear correlation with technological innovation ability and there is no "manager defense effect".

In the controlled variables, firm scale (SIZE) and company performance (EPS) have a positive relationship with technological innovation choice and the number of innovations at the 5% and 1% levels respectively.

The larger the scale and better the performance of biopharmaceutical enterprises, the more inclined they are to choose technological innovation, and their technological innovation capabilities are obviously improving compared with other small-scale and low performing enterprises. The duality (PT) is significantly negatively correlated with technological innovation choices and the number of technological innovations at the 1% level, indicating that executives serving as directors have a negative impact on technological innovation in biopharmaceutical enterprises.

Table 4 Empirical Analysis Results of Equity Incentives and Technological Innovation

Variable	Phase 1	Phase 2
Constant term	-6.882*** (-3.22)	-374.197*** (-3.50)
ES	0.702 (1.29)	86.931*** (3.15)
EN	-0.165 (-0.94)	-10.681 (-1.10)
GR	-0.165 (-0.94)	-0.327 (-0.80)
$SIZE$	0.229** (2.43)	16.500*** (3.51)

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EPS	0.378** (1.99)	19.185*** (2.82)
LEV	0.536 (1.17)	32.470 (1.64)
EC	-0.004 (-0.64)	-0.152 (-0.60)
EB	-0.001 (-0.09)	0.072 (0.20)
PT	-0.490*** (-3.02)	-24.638*** (-2.63)
Λ	-	62.202** (2.13)

Note: The values in parentheses represent the Z values corresponding to the estimated coefficients of the variables. *, * *, * * * respectively represent significant values at the 10%, 5%, and 1% levels.

5.3 Robust Test

To verify the non-linear relationship between salary incentives and technological innovation, this paper conducted a robustness test. Replace the salary incentive variable (EP) with "the natural logarithm of the total compensation of the top three directors, supervisors, and executives" instead of "the natural logarithm of the total compensation of the top three executives" for retesting, and the regression results are basically consistent with the previous text.

6 Conclusion and countermeasures

This article selects biopharmaceutical enterprises listed in high-tech industry as samples and innovatively uses the Heckman two-step method to correct sample selection bias from a combination of linear and nonlinear perspectives, to empirically test the relationship between senior management incentives and technological innovation in the biopharmaceutical industry during the 2018-2022 period. The research results indicate that there is no significant linear correlation between salary incentives and technological innovation capabilities in Chinese biopharmaceutical companies, but an curve relationship; There is a maximum value in salary incentives, with a turning point of 1.48 million; Stock-based compensation incentives can significantly enhance the technological innovation capabilities of biopharmaceutical companies. With the continuous increase of executive wealth, compensation has shifted from incentive factors to health factors, and the attractiveness to executives has gradually decreased. That is, there is a marginal diminishing effect of compensation incentives, which has a curve relationship with the company's technological innovation ability. The promotion effect of salary incentives on technological innovation in biopharmaceutical enterprises has a maximum value. When the executive compensation level is low, salary incentives can promote technological innovation in the enterprise. When the salary level reaches the maximum value, salary incentives will actually inhibit technological innovation in the enterprise. According to data from Chinese biopharmaceutical companies during the 2018-2022 period, when the total compensation located in the first, second, and third senior management positions reaches 1.48 million yuan, it has the strongest incentive effect on technological innovation. The average level of equity incentives for Chinese biopharmaceutical companies is 5.9%, indicating that the proportion of shareholding among companies is generally low. Currently, this is manifested as a convergence of interest effect, and the defensive effect of managers has not yet been manifested. Therefore, stock-based compensation incentives have played a significant promoting role in technological innovation of enterprises. This article uses the Heckman selection model to empirically demonstrate the linear and nonlinear correlation between senior management incentives and technological innovation in the biopharmaceutical industry, avoiding sample bias caused by directly excluding listed companies without patent data. Meanwhile, this study breaks the limitation of previous research that only focused on linear relationships, enriches the empirical data between executive incentives and technological innovation in the Chinese biopharmaceutical industry, and provides biopharmaceutical enterprises with "14th Five Year Plan" provide a basis for technological innovation decision-making during this period.

Based on the empirical research findings of this article, in order to improve the technological innovation capability of Chinese biopharmaceutical enterprises, the following countermeasures and suggestions are proposed: (1) Due to The curve relationship of first decreasing and then increasing between incentives and technology innovation indicated that Chinese biopharmaceutical enterprises have already developed incentive problems. Therefore, when designing salary contracts, the executive compensation level should be controlled within an appropriate range to prevent higher compensation levels from causing short-sighted effects on senior managers. At the same time, the quantity of innovation output can be used as one of the evaluation indicators for executive business performance, which can encourage executives to make scientific technological innovation decisions and avoid giving up investing in high-risk innovation activities to maintain short-term performance. (2) Executive equity incentives can significantly improve the technological innovation level of biopharmaceutical companies, but have not yet reached the critical point of convergence of interests and manager defense effects. As a result, we suggest to appropriately increase the proportion of senior management shareholding and further leverage the convergence of interest effect of incentives. (3) Establish a reasonable senior management incentive system, effectively combining short-term salary incentives with long-term stock-based compensation incentives. By setting an appropriate income or salary level to incentivize senior management sector, short-term and operational benefits can be improved. While achieving short-term benefits, greater emphasis should be placed on the long-term development and goal realization of the enterprise to achieve better corresponding incentive effects.

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