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# Game Analysis on the Executives' Private Earnings and R&D Investment in Equity Incentive Process of High-tech Enterprises

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**Abstract:** Abundant R&D investment plays an important role in the success of high-tech enterprises' innovation, it is also the key point to improve the high-tech enterprises' core competitiveness. In this paper, a game model is built to study the executives' private earnings from R&D investment and R&D investment level theoretically, considering that executives acquire private earnings from the R&D investment and should afford the corresponding costs when the private earnings exceed a certain threshold value. The following conclusions can be drawn: the ratio of the executives' R&D private earnings is positively connected with the threshold value which the executives grab private earnings freely, is negatively connected with the equity incentive level, is non-linear connected with the R&D investment; R&D investment have a positive relationship with the ratio of free private earnings, the relationship between R&D investment and equity incentive depends on whether the executives acquiring private earnings from R&D investment or not and the corresponding punishment.

**Key words:** High-tech enterprises, equity incentive, private earnings, R&D investment

## INTRODUCTION

With the accelerated process of economic globalization, the market competition grows increasingly fierce. As for the high-tech enterprises, a short product life cycle, fast product replacement and fast technology alternation are all their characters. Facing the rapid change of market demand, only the high-tech enterprises have their own creative ability and core technology, can they gain their own place in the market and maintain long-term competitive strength which needs the research and development expenditures. R&D investment is the basic power of the high-tech enterprises' R&D innovation. Whether R&D expenditure is adequate or not plays a key role in the success or failure of the high-tech enterprises' R&D innovation. Thus, the R&D effort is the most important driving force of the high-tech enterprise' successful innovation (Wang *et al*., 2013).

Because of the separation of ownership and management in modern enterprises, the shareholder's and the manager's aims are inconsistent which leads to the principal-agent problem. The principal-agent problem causes over-investment or under-investment.

Jensen (1986, 1993) present that managers will invest the projects which have negative net present value, because they can gain more benefits from controlling more assets, this formed over-investment. On the contrary, managers will probably forgo some projects which have positive net present value, since the investment will cost the managers' time and energy, the managers usually hope to work less, so the under-investment comes into being. For the high-tech enterprises which competitive advantage mainly comes from the R&D investment. However, since the R&D investment results are uncertainty and high-risk which lead shareholders not to evaluate managers objectively by R&D activities. So, it is probably to reduce the manager' s enthusiasm in R&D investment which results in inadequate R&D investment. In order to reduce or even eliminate the executives' non-efficiency investment behavior caused by the agency problem, the equity incentive plan has been widely adopted.

The scholars have carried out some research on the relationship between the executive equity incentive and the corporate R&D investment. Ryan and Wiggins (2001) points out that the executives' compensation connects with R&D investment, different type of compensation lead to different change direction of R&D. Zara *et al.* (2000) empirically find that the stake of executives has a significant positive correlation with technology innovation by studying medium-sized enterprises' innovation activities. Wu and Tu (2006) test the relationship between the CEO's stock option and R&D investment. They find that stock options have a positive impact on R&D investment. Xu and Liu (2002) thinks that raising the executives' stock holding can improve the

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level of enterprise technology innovation. Liu and Liu (2007),Yun and Qingquan (2008), Tang *et al*. (2009) and Chen (2011) show that executives' equity incentives and R&D spending have a significant positive correlation relationship. The greater the executives' equity incentives the more R&D expenditure will be spent. According to the above literatures, literatures about theoretically inferring the relationship between executives of high-tech enterprises' equity incentive and R&D investment are rare. Executives can get private interests from the sub-optimal investment decision. Currently, there is no literature which takes executives' private interests, equity incentive and R&D investment into a same framework and analyses them theoretically.

At present, China's high-tech enterprises generally face the under-investment problem in research and development. In order to reduce or even eliminate the agency costs of R&D investment, equity incentive plan has been implemented or intend to be implemented in many high-tech enterprises. Under this background, it is necessary to study how executives conduct R&D investment decisions in the process of the high-tech enterprises' executive equity incentive. What's more, how to prevent the executives from obtaining R&D investment private earnings is necessary to be studied too. Plus the problem that how the executives' private interest from R&D investment affect the R&D investment expenditure in high-tech enterprises is also need to be observed. The solutions to these problems are very important to promote the high-tech enterprises' development and enhance the high-tech enterprises' core competitiveness.

In this study, the fact that the high-tech enterprises' R&D investment in China is not sufficient has been focused on. A game model is constructed to deduce the relationship between executives' R&D investment private earnings and R&D spending in equity incentive process. The model is different from other models. This model considers that executives can acquire private earnings from R&D investment and afford corresponding cost when the R&D investment private earnings exceed a certain threshold value (proportion). This study can provide micro theoretical basis for the under-investment of high-tech enterprises' R&D investment and also provide practical reference for high-tech enterprises' equity incentive plan.

## MODEL CONSTRUCT

We assume that the shareholders of high-tech enterprises hire senior executives to run the company and the senior executives make R&D investment decisions. Due to asymmetric information, shareholders take executive equity incentive plan to induce the executives to make the best R&D investment decisions.

Assume the equity ratio that the shareholders give to the managers is $\theta$ $0\langle\theta\langle 1$ and also give some fixed salary $\omega_0$ to the managers. Shareholders are risk neutral while senior executives are risk-averse and the managers have a negative exponential utility function $U(\omega) = -e^{-\gamma\lambda}$, in which $\gamma(\gamma\langle 0)$ indicates the managers' absolute risk aversion, $\omega$ is the managers' actual money revenue.

Assume the executives can make R&D investment decisions independently and the company has abundant cash flows for R&D investment. According to De Motta (2003), similar to Wang and Sun (2005), the form of the profit from executives' R&D investment is:

$$\pi = I - \frac{1}{2}\alpha I^2 + \varepsilon, \varepsilon \sim N\left(0, \delta^2\right)$$

Managers can get private interests through R&D investment decision. For example, they may spend more money on themselves such as luxury office by over-investment and may also entrench their position by making proprietary investments decisions, or they may take under-investment decisions to obtain more leisure. It is supposed that managers' private benefits seized from R&D investment equal to fI, $f(0 \le f\langle 1)$ shows the managers' private interests proportion obtained from R&D investment. Stulz (2005) for reference, assume that the executives can acquire private interests without any cost within the scope of threshold $c(0 \le c\langle 1)$ but if f is bigger than c, then the executives' private interests will afford the corresponding cost of shareholders' punishment. And the cost of executives' private interests is:

$$\frac{1}{2}\left[\max\left(f - c, 0\right)\right]^2 I$$

Based on the above assumption, senior executives' revenue consists of three parts: fixed salary, net profit of private interests from R&D investment and returns on common stock right. So senior executives' actual money revenue is:

$$\omega = \omega_0 + \theta(\pi - \omega_0 - fI) + fI - \frac{1}{2}\left[\max\left(f - c, 0\right)\right]^2 I$$

According to the conclusion of Arrow-Pratt, senior executives' risk cost is $1/2\gamma\theta^2\delta^2$, their certainty equivalent revenue is:

$$\omega_0 - \theta\omega_0 + \theta I - \frac{1}{2}\alpha\theta I^2 - \theta fI + fI - \frac{1}{2}\left[\max\left(f - c, 0\right)\right]^2 I - \frac{1}{2}\gamma\theta^2\delta^2$$

Executives maximize expected utility function $EU = -Ee^{-\gamma\omega}$ which is equal to maximizing the certainty equivalent revenue, then the certainty equivalent revenue is used to take the place of expected utility.

As shareholders are risk-neutral, the expected utility is equal to expected revenue:

$$EU(p) = (1-\theta)(\pi-\omega_0-fI)$$

Assume when senior executives' reserve revenue is 0 and their certainty equivalent revenue is less than 0, they will not accept the contract. Senior executives' participation constraint is:

$$\omega_0 + fI + \theta(\pi - \omega_0 - fI) - \frac{1}{2}\left[\max(f-c,0)\right]^2 I - \frac{1}{2}\gamma\theta^2\delta^2 \geq 0$$

According to the assumptions and analysis above, the model can be constructed below:

$$\max_{\theta}(1-\theta)(\pi-\omega_0-fI) \tag{1}$$

$$\begin{aligned}&\omega_0 - \theta\omega_0 + \theta I - \frac{1}{2}\alpha\theta I^2 - \theta fI + fI \\ &-\frac{1}{2}\left[\max(f-c,0)\right]^2 I - \frac{1}{2}\gamma\theta^2\delta^2 \geq 0\end{aligned} \quad \text{(IR)} \tag{2}$$

$$\begin{aligned}\max_{f,I}\quad &\omega_0 - \theta\omega_0 + \theta I - \frac{1}{2}\alpha\theta I^2 - \theta fI + fI \\ &-\frac{1}{2}\left[\max(f-c,0)\right]^2 I - \frac{1}{2}\gamma\theta^2\gamma^2\end{aligned} \quad \text{(IC)} \tag{3}$$

Usually, the managers obtain private earnings from R&D investment and afford the corresponding punishing cost. It means $f-c\rangle 0$.

The keys to Eq. 3 are:

$$f = 1-\theta+c \tag{4}$$

$$I = \frac{\theta - \theta f + f - \frac{1}{2}(f-c)^2}{\alpha\theta} \tag{5}$$

In the optimal, Eq. 2 is equality, take 2 into 1, there is:

$$\max_{\theta} I - \frac{1}{2}\alpha I^2 - \frac{1}{2}(f-c)^2 I - \frac{1}{2}\gamma\theta^2\delta^2 \tag{6}$$

Take (4) and (5) into (6), to solve $\theta$. The result is $\theta^*$, $\theta^*$ meet the conditions below:

$$\begin{aligned}&2\theta^{*4} - 3(1-\theta^*)^2(\theta^* - \theta^{*3}) - 2(1-\theta^*)^3 - 2(c+1)(1-\theta^*)^2 \\ &-(c+1)(\theta^* - \theta^{*3})(1-\theta^*) - 2c(1-\theta^*) + c(\theta^* - \theta^{*3}) - 4\theta^*(1-\theta^*)^3 \\ &+(2-5\theta^*)(1-\theta^*)^4 + 2(1-\theta^*)^5 - 2\alpha\gamma\theta^{*4}\delta^2 = 0\end{aligned}$$

let:

$$\begin{aligned}f(\theta) = {}& 2\theta^{*4} - 3(1-\theta^*)^2(\theta^* - \theta^{*3}) - 2(1-\theta^*)^3 - 2(c+1)(1-\theta^*)^2 \\ &-(c+1)(\theta^* - \theta^{*3})(1-\theta^*) - 2c(1-\theta^*) + c(\theta^* - \theta^{*3}) - 4\theta^*(1-\theta^*)^3 \\ &+(2-5\theta^*)(1-\theta^*)^4 + 2(1-\theta^*)^5 - 2\alpha\gamma\theta^{*4}\delta^2\end{aligned}$$

We can see: $f(0) = -4c\langle 0$, $f(1) = 2-2\alpha\gamma\delta^2$, if $\alpha\gamma\delta^2$, in that way, $f(1) = 2-2\alpha\gamma\delta^2\rangle 0$, so the $\theta^*$ exists in theory.

## COMPARATIVE STATIC ANALYSIS

**Analysis on the executives' R&D investment private earnings:** We can see from Eq. 4 that the proportion f of executives' private earnings seized from R&D investment is negative connected with equity incentive level $\theta$. In other words, the higher the managers' equity incentive is, the smaller the proportion f of executives' private earnings seized from R&D investment is. It is clear that the managers' equity incentive can prevent executives from grabbing personal R&D investment private interests; the proportion f of executives' private earnings seized from R&D investment is positive connected with the threshold value that the managers can gain R&D investment private interests without any cost. That's to say, the larger the threshold value that the managers can gain R&D investment private interests freely is, the larger the proportion f of executives' private earnings seized from R&D investment is. The lighter the punishment to executives' R&D investment private earnings is, the larger the proportion f of executives' private earnings seized from R&D investment is. So, to punish the managers heavily when they grab R&D investment private benefits is one of the efficient ways to prevent executives from seizing R&D investment private benefits.

**Analysis on the executives' R&D expenditures:** By the Eq. 5, 7, 8, 9 can be get:

$$\frac{\partial I}{\partial c} = \frac{1}{\alpha\theta}(f-c)\rangle 0 \tag{7}$$

$$\frac{\partial I}{\partial f} = \frac{1+c-(\theta+f)}{\alpha\theta} \tag{8}$$

$$\frac{\partial I}{\partial \theta} = \frac{(f-c)^2 - 2f}{2\alpha\theta^2} \tag{9}$$

Some conclusions can be drawn by the Eq. 7: R&D investment is positive connected with the proportion that the executives can acquire private gains without cost. The more managers acquire free R&D investment private gains are, the more the executives' R&D expenditures are; The

lighter of the punishment given to managers because of their acquiring R&D investment private interests is, the more the executives' R&D expenditures are. This demonstrates that punishing the managers heavily when they grab R&D investment private benefits can inhibit the executives' over- investment.

We can also draw some conclusions by the Eq. 8: if $1+c\rangle\theta+f$, that $\partial I/\partial f\rangle 0$, the R&D investment has a positive relationship with the executives' private interests proportion but if $1+c\rangle\theta+f$, that $\partial I.\partial f\langle 0$, the R&D investment has a negative relationship with the executives' private interests proportion. Therefore, the proportion of executives' R&D investment private interests is non-linear connected with R&D expenditures, the managers' acquiring R&D investment private interests may lead to inefficient investments (both over-investment and under- investment). It is visible that the executives getting R&D investment private interests is not only the reason to over-investment but also to under-investment which type of inefficient investment appears depending on the executive equity incentive, the ratio of getting R&D investment private gains and the degree of getting R&D investment private gains without any cost; At the same time, we can also draw some conclusions by theEq. 9: if $f = 0$, $c\neq 0$, that $\partial I/\partial\theta\rangle 0$, the R&D expenditures are positive connected with the executive equity incentive. If $f\neq 0$, $c\neq 0$, since $-1\langle f-c\langle 1$, so $(f-c)^2\langle 2f$, that $\partial I/\partial\theta\langle 0$, the R&D expenditures are negative connected with the executive equity incentive. Therefore, the implementation of executive equity incentive in high-tech enterprise can promote R&D expenditures when the executives do not grab private gains but if the executives grab private gains and are punished by the shareholders, the executive equity incentive inhibit R&D spending. In this case, equity incentive level given to executives in high-tech enterprises should be low, only in this way can the R&D expenditures be promoted.

## NUMERICAL SAMPLES

**Determination on the executives' personal gain from R&D investment:** By the State Council, the SASAC and the Ministry of Finance jointly issued the "State Holding Listed Companies (offshore) the Implementation of Equity Incentive Pilot Scheme" came into effect on March 1, 2006 in China. The number of equity incentive granted to the managers was limited in the "Measures". Total equity which granted to the executives, accumulative total may not exceed 10% of the total share capital of the Company. The first option grant number should be controlled within 1% of the total share capital of the listed company. In addition, the equity incentive plan within the validity period in any 12-month period granted any person shares (including exercised and unexercised options) more than 1% of the total shares, the managers should not be granted equity.

According to the provisions of the "measures", assumed that two different executive equity incentive intensity are, respectively $\theta_1 = 0.050$ and $\theta_2 = 0.080$. The threshold values that executives acquire personal gain from R&D investment without any cost are respectively 0.020 and 0.008. That is to say, the proportion of executives getting private benefits from R&D investment is larger than 0.020 or 0.008, the executives will afford the cost of being punished by the shareholders for getting R&D investment private benefits. Substituting the two groups of data into Eq. 4, when $\theta_1 = 0.050$, $c_1 = 0.020$, therefore, $f_1 = 0.0970$; when $\theta_1 = 0.050$, $c_2 = 0.008$, that $f_2 = 0.958$, we can see that the larger the threshold value of the executives acquiring private benefits without any cost is, the larger the proportion of executives acquiring private benefits is. When $\theta_1 = 0.050$, $c_1 = 0.020$, $f_1 = 0.970$; when $\theta_2 = 0.080$, $c_1 = 0.020$, that $f_2$, it is can be seen that the higher the equity incentive level is, the smaller the executives acquire private benefits from R&D investment is.

**Determination on the executives' R&D expenditures:** Firstly, how to the threshold value c of the executives' free R&D investment private interests influence on the R&D expenditures is studied. Assumed that $\alpha = 1$, $\theta_1 = 0.050$, $f = 0.500$, the threshold value c of the executives' free R&D investment private interests are $c_1 = 0.020$, $c_2 = 0.100$, respectively. Substituting them into Eq. 5, $I_1 = 8.196$, $I_2 = 8.900$ can be obtained. So the larger the threshold value of the executives' R&D investment private interests without any cost is, the more the R&D expenditures are.

Secondly, the effect of equity incentive on R&D expenditures is examined. If $\alpha = 1$, $f = 0$, $c_1 = 0.020$, two different equity incentive are $\theta_1 = 0.050$, $\theta_2 = 0.080$, Substituting them into Eq. 5, $I_1 = 0.996$, $I_2 = 0.998$ can be obtained. Thus it can be seen, if $f = 0$, $c\neq 0$, the higher the equity incentive is, the more the R&D expenditures are; if $\alpha = 1$, $f = 0.030$, $c_1 = 0.020$, two different equity incentive are $\theta_1 = 0.050$, $\theta_2 = 0.080$, respectively, substituting them into Eq. 5, then $I_1 = 1.569$, $I_2 = 1.344$. We can see that if $f\neq 0$, $c\neq 0$, the higher the equity incentive is, the less the R&D expenditures are.

At last, the ratio of the executives getting R&D private benefits influencing on R&D expenditures is also focused on. If $\alpha = 1$, $\theta_1 = 0.050$, $c_1 = 0.020$, the ratio of the executives getting R&D private benefits are $f_1 = 0.600$, $f_2 = 0.800$, respectively, Substituting them into Eq. 5, then

$I_1$ = 3.672, $I_2$ = 10.120. It is thus evident that, when $1+c\rangle\theta+f$, the larger the ratio of the executives grabbing R&D private benefits is, the more the R&D expenditures are. If $f_3$ = 0.980, $f_4$ = 0.990, substituting them into Eq. 5,then $I_3$ = 10.404, $I_4$ = 10.401, it is obvious that, when $1+c\langle\theta+f$, the larger the ratio of the executives grabbing R&D private benefits is, the less the R&D expenditures are. In summary, the ratio of the executives grabbing R&D private benefits is non-linear connected with R&D expenditures. The proportion of the executives grabbing R&D private benefits is one of the reasons for both over-investment and under-investment.

## CONCLUSION

A game model is built to analysis the relationship between the executives' private benefits from R&D investment and R&D expenditures. Many conclusions can be drawn as follow: the ratio of the executives' R&D private earnings is positively connected with the threshold value which the executives grab private earnings freely, is negatively connected with the equity incentive level, is non-linear connected with the R&D investment.

The following conclusions can be drawn: the ratio of the executives' R&D private earnings is positively connected with the threshold value which the executives grab private earnings freely, is negatively connected with the equity incentive level, is non-linear connected with the R&D investment; R&D investment have a positive relationship with the ratio of free private earnings, the relationship between R&D investment and equity incentive depends on whether the executives acquiring private earnings from R&D investment or not and the corresponding punishment. The results of this study reveal the factors which affect the executives' R&D expenditures in the process of executive equity incentive in high-tech enterprises, they can also provide reference for the high-tech enterprises to implement equity incentive plan. These results may provide theoretic base for relevant empirical test.

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