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Real options and earnings-based bonus compensation

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ABSTRACT

This study extends the works of Mauer and Sarkar (2005) and Andrikopoulos (2009) by incorporating a regime-dependent earnings-based bonus into managerial compensation. Examining the individual effects of ownership shares and earnings-based bonus compensation, we find that the former provides managers with incentives to issue debt, whereas the latter induces the opposite result, although consistent impacts are found for the two types of compensation on both agency costs and the optimal investment decisions of managers. When managerial compensation comprises both ownership shares and an earnings-based bonus, there are significant differences in the effects of these two types of performance compensation on managers' optimal investment and financing decisions, agency costs, optimal debt ratios and credit spreads, as a result of the specific interactions between the investment and financing decisions.

1. Introduction

The majority of prior studies examining executive compensation focus on the use of stock-based compensation to align the interests of managers with those of shareholders. However, there is little theoretical literature investigating the characteristics of earnings-based bonus compensation. This paper extends Mauer and Sarkar (2005) and Andrikopoulos (2009) by developing a real-options model where a manager's compensation includes cash salary, ownership shares and a regime-dependent earnings-based bonus. We complement the extant literature by addressing how earnings-based bonus compensation affects a manager's optimal investment and financing decisions, and why the impacts of ownership shares differ from those of earnings-based bonus compensation. To the best of our knowledge, this is the first paper that considers earnings-based bonus compensation in a real-options model and further clarifies the differences between the effects of ownership shares and earnings-based bonus compensation on firms' investment and financing decisions.

In a compensation plan contingent on earnings, no earnings-based bonus compensation is paid until earnings reach a threshold performance. Once earnings exceed this threshold, managerial compensation increases linearly with operating net incomes. In practice, earnings-based bonus compensation in CEO incentive contracts is rather commonly used. As pointed out by Murphy (1999) and emphasized in Câmara (2009), "virtually every for-profit company offers an annual bonus plan covering its top executives and paid annually based on a single-year's performance." Murphy (1999) reports that 91% of the sample firms use a measure of earnings performance in their annual bonus plans, based on the "Annual Incentive Plan Design Survey" conducted in 1996–1997 by Towers Perrin. As summarized in Duru et al. (2005), the amount of CEO earnings-based bonus compensation accounts for around 23% of total compensation in the sample of 1993–1997.[1]

Ownership shares and earnings-based bonus compensation are both performance-based compensation where the former is based on stock performance while the latter is directly linked to

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[1] The amount of managerial compensation accounts for a large proportion of a firm's operation. As pointed out by Lambrecht and Myers (2008), for example, General Electric's annual appropriation for management bonuses has been 10% of the amount by which earnings exceed 5% of invested capital. Banks routinely allocate substantial fractions of gross income to annual bonuses.

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operation performance. Nevertheless, the two types of compensation provide managers with opposite incentives to make decisions on optimal debt financing. When a firm faces a valuable investment project and its manager decides whether to employ debt financing or not, the manager tends to issue an optimal amount of debt to finance the project if she is totally compensated with ownership shares, since the benefits to bondholders could be easily exploited by the shareholders. On the other hand, if the manager is totally compensated with an earnings-based bonus, then she would not use any debt financing, because the coupon payments of debt would make the earnings-based bonus compensation less valuable by reducing a firm's net operating income. As a result, this paper attempts to fully investigate this difference by a real-options model and further examines a manager's investment and financing decisions when she is compensated with cash salary, ownership shares and earnings-based bonus compensation.

Since the two seminal papers of McDonald and Siegel (1986) and Majd and Pindyck (1987) and the pronounced book by Dixit and Pindyck (1994), the methodology of investment under uncertainty or real options has become the standard approach featuring a firm's irreversible investment flexibilities. The real-options-based theories investigating both of a firm's investment and financing decisions can date back to Mauer and Triantis (1994) and have been further advanced by Leland (1994, 1998), Leland and Toft (1996), Goldstein et al. (2001) and Lyandres and Zhdanov (2010). Following this line of research, Mauer and Sarkar (2005) establish a real-options framework that integrates a firm's investment and capital structure decisions in which the conflict between shareholders and bondholders is taken into consideration. Some research studies investigate the effects of managerial discretion on corporate decisions. For example, Cadenillas et al. (2004) examine shareholder–manager conflicts as well as the effect of managerial compensation on capital structure, where managers are only rewarded with stocks and are in charge of optimal corporate risk policy. Grenadier and Wang (2005) re-examine the investment timing for an option to invest, in the context of owner–manager contracts for an all-equity firm with the presence of asymmetric information and costly effort. Lambrecht and Myers (2008) show how managers' personal wealth constraints can lead to delayed investment and increased reliance on debt financing. Andrikopoulos (2009), which is the one most related to ours, examines a manager's investment and financing decisions when her compensation is composed of cash salary and ownership shares.

This paper extends Andrikopoulos (2009) and assumes that manager compensation consists of cash salary, ownership shares and an earnings-based bonus in order to analyze the manager's investment and financing decisions. We begin with examining the *individual* effects of ownership shares and earnings-based bonus compensation. When a manager is compensated with only cash and earnings-based bonus compensation, she has no incentive to conduct any debt financing, and the interaction between the optimal investment and financing decisions made by manager is trivial, thereby leading to an all-equity capital structure. On the other hand, she does have an incentive to issue debt when she is compensated with only cash and ownership shares. The individual effects of the ownership shares and earnings-based bonus compensation on a manager's investment decisions and agency costs are consistent.

When a manager is compensated with cash, ownership shares and earnings-based bonus compensation, the optimal coupon payment may not be equal to zero, and the particular interaction between the manager's investment and financing decisions leads to the following differences in the effects of ownership shares and earnings-based bonus compensation from our numerical results. The paper's main findings are summarized as follows. First, the manager's optimal investment trigger tends to increase and then decrease with a rise in earnings-based bonus compensation, but tends to decrease as the ownership shares increase. Second, the optimal coupon payment decreases to zero with an increase in earnings-based bonus compensation, but increases and then decreases as the ownership shares increase. Third, the agency costs of debt tend to increase, then decrease, and again increase as a manager's earnings-based bonus compensation rises, but the agency costs decrease and then increase with an increase in a manager's ownership shares. Finally, the optimal debt ratio and credit spreads decrease with an increase in earnings-based bonus compensation, but increase as a manager's ownership shares increase.

Our numerical findings are also related to the literature concerning the impacts of agency conflicts among shareholders, debt holders and managers on the association between capital structure and optimal managerial compensation. John and John (1993) and Douglas (2006) predict a negative relationship between pay-performance sensitivity and leverage. Duru et al. (2005) show that earnings-based cash bonus compensation is negatively related to corporate bond yields. Ortiz-Molina (2006) demonstrates that there is a positive relationship between managerial ownership and borrowing costs, and this relationship is weaker at higher levels of ownership. Ortiz-Molina (2007) particularly shows that firms trade-off shareholder–manager incentive alignment in order to mitigate shareholder–bondholder conflicts of interest. Our paper therefore makes three contributions to this line of literature. First, we employ the real options analysis to extend the discussion of this above literature by incorporating the firm's investment timing decision. Second, our numerical results clearly show that ownership shares and earnings-based bonus have different impacts on agency conflicts and capital structure, thereby demonstrating that the composition of managerial compensation does play a prominent role in a firm's optimal capital structure. Finally, we particularly demonstrate that the use of earnings-based bonus compensation is a disincentive to issuing debt, which may provide an explanation why debt ratios often appear lower relative to the prediction of the tradeoff theory.

The rest of this article is organized as follows. Section 2 introduces the real-options model with earnings-based bonus compensation. Section 3 conducts numerical analysis to illustrate the differences between the impacts of earnings-based bonus and ownership shares compensation. Section 4 concludes the paper.

2. The model

Based on the real options framework developed by Mauer and Sarkar (2005), we assume that a firm owns a monopolistic, perpetual right to exercise an investment project at cost I. Once the project is under way, it generates stochastic revenue P at a constant cost C per unit time. We assume that the dynamics of P can be replicated by forming a portfolio of traded assets in an economy with no opportunities for arbitrage, such that P is governed by the following stochastic differential equation under a risk-neutral probability measure:

$$\frac{dP}{P} = (r - \delta)dt + \sigma dW, \quad (1)$$

where r is the constant risk-free short rate δ is the constant convenience yield σ is the constant revenue return volatility and W is a risk-neutral Wiener process.

Similar to Andrikopoulos (2009), we assume that shareholders cannot manage the operational aspects of the projects themselves, and hence managers are hired for this purpose. We also assume that these managers are in pursuit of personal benefits, as opposed to pursuing the benefits of equity holders. Since managers do not have 100% ownership of this company, their decisions may deviate from the equity-value-maximizing policies, thereby leading to a principal agent problem. We further assume that managers have the discretion to decide when to invest in the project and how much debt to issue in order to finance the investment costs. Although the investment and financing decisions are observable, they are not verifiable and hence not contractible. Once the project starts, equity holders have control rights to decide whether or not to abandon the project or put the firm into default when financing with debt.

We can assume that originally the manager has existing income and after investment the manager must forego this previous income *PI*. Instead, the manager gets a new compensation offer consisting of a cash salary m_0 per unit time, a fraction (m_1) of equity, and an earnings-based bonus that is a proportion (m_2) of net profit after taxes per unit time. Notice that the cash salary is a part of the fixed cost, and therefore m_0 must be less than *C*. When bankruptcy occurs, managers could find alternative jobs providing them with some reservation income, *RI*. For simplicity, we follow Andrikopoulos (2009) to assume that *RI* = *PI*. When the option to invest is exercised, the manager can decide how much to finance this investment with equity and debt. If the amount for debt financing is *K*, then the shareholders contribute the remaining amount, $I-K$. As demonstrated by Mauer and Sarkar (2005), this assumption implies that this financing arrangement is a loan commitment, such that external funds (a specified committed amount) can be called upon in the future by the firm, as and when required.

2.1. Unlevered firm

The unlevered firm does not use debt to finance investment. In this case, the shareholders cannot decide to default the firm, but they do have the option of abandoning the project based upon excessive operating costs. Following Mauer and Sarkar (2005), the unlevered firm value $V^U(P)$ after the project has been exercised satisfies

$$\frac{1}{2}\sigma^2P^2V^U_{PP}+(r-\delta)PV^U_P-rV^U+(1-\tau)(P-C-m_2(P-C)^+)=0, \qquad (2)$$

and $V^U(P)$ has the following general solution:

$$V^U(P)=\begin{cases}(1-\tau)\left(\frac{P}{\delta}-\frac{C}{r}\right)+a_1P^{\beta_1}+a_2P^{\beta_2}, & P_A<P<C,\\ (1-\tau)(1-m_2)\left(\frac{P}{\delta}-\frac{C}{r}\right)+b_1P^{\beta_1}+b_2P^{\beta_2}, & P_A<C<P,\end{cases} \qquad (3)$$

where

$$\beta_1=\frac{1}{2}-\frac{r-\delta}{\sigma^2}+\sqrt{\left(\frac{1}{2}-\frac{r-\delta}{\sigma^2}\right)^2+\frac{2r}{\sigma^2}}>1,$$

$$\beta_2=\frac{1}{2}-\frac{r-\delta}{\sigma^2}-\sqrt{\left(\frac{1}{2}-\frac{r-\delta}{\sigma^2}\right)^2+\frac{2r}{\sigma^2}}<0,$$

$(X)^+ = \max(X, 0)$, and a_1, a_2, b_1 and b_2 are four constants to be determined, τ denotes the corporate effective tax rate, and P_A is the abandonment trigger.

In (3), only if *P* is greater than P_A can the investment project be exercised. The setting defined in (2) is different in our model from previous models through the presence of the operating cash flows, $(P-C-m_2(P-C)^+)$, reduced by the manager's earnings-based bonus compensation. Thus, once the project is under way, our model is dependent upon two regimes, $P > C$ and $P < C$. When *P* is greater than *C*, earnings-based bonus compensation is paid to managers; conversely, when *P* is less than *C*, managers will not be offered any earnings-based bonuses. That is to say, the earnings-based bonus compensation in our model is regime-dependent and determined by the relationship between *P* and *C*.

For solving the unlevered firm value, the Eq. in (3) is subject to the following boundary conditions: (i) $\lim_{P\uparrow\infty}V^U(P)/P<\infty$ (non-bubble condition); (ii) $\lim_{P\downarrow P_A}V^U(P)=0$ (value-matching at P_A); (iii) $\lim_{P\uparrow C}V^U(P)=\lim_{P\downarrow C}V^U(P)$ (value-matching at *C*); and (iv) $\lim_{P\uparrow C}\frac{\partial V^U(P)}{\partial P}=\lim_{P\downarrow C}\frac{\partial V^U(P)}{\partial P}$ (smooth-pasting at *C*). We respectively derive our solutions according to the cases of two regimes as follows.

For $P_A < P < C$,

$$\begin{aligned}V^U(P)&=(1-\tau)\left(\frac{P}{\delta}-\frac{C}{r}\right)-(1-\tau)\left(\frac{P_A}{\delta}-\frac{C}{r}\right)\left(\frac{P}{P_A}\right)^{\beta_2}-m_2(1-\tau)\\&\quad\times\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P}{C}\right)^{\beta_1}\\&\quad+\left(m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P_A}{C}\right)^{\beta_1}\right)\left(\frac{P}{P_A}\right)^{\beta_2}. \qquad (4)\end{aligned}$$

The first term is the individual unlevered firm value when shareholders do not have any flexibility to abandon the project. The second shows the expected loss of the individual unlevered firm value when the project has been abandoned. The third demonstrates the expected net loss of the unlevered firm value when the manager is paid the earnings-based bonus by the firm which operates at a loss now and might run at a profit in the future. The last term shows the expected profit from the reduction in the manager's bonus after the project is abandoned.

For $P_A < C < P$,

$$\begin{aligned}V^U(P)&=(1-\tau)(1-m_2)\left(\frac{P}{\delta}-\frac{C}{r}\right)-(1-\tau)\left(\frac{P_A}{\delta}-\frac{C}{r}\right)\left(\frac{P}{P_A}\right)^{\beta_2}\\&\quad-m_2(1-\tau)\left(\frac{1-\beta_1}{\beta_1-\beta_2}\frac{C}{\delta}+\frac{\beta_1}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P}{C}\right)^{\beta_2}\\&\quad+\left(m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P_A}{C}\right)^{\beta_1}\right)\left(\frac{P}{P_A}\right)^{\beta_2}.\end{aligned} \qquad (5)$$

The first term is the individual unlevered firm value if shareholders do not have any flexibility to abandon the project. The second term shows the expected net loss of the unlevered firm value when the project is abandoned. The third demonstrates the expected net loss of the unlevered firm value when the manager is paid the earnings-based bonus by the firm which operates at a profit now and might run at a loss in the future. The last term shows the expected profit of the reduction in the manager's bonus when the project is abandoned. The optimal abandonment strategy, chosen by shareholders to maximize equity value, is determined by the following smooth-pasting condition:

$$\lim_{P\downarrow P_A}\frac{\partial V^U(P)}{\partial P}=0.$$

We would justify why the abandonment decision is made by the shareholders instead of the manager. We recall that our real options model is similar to the structural model of Goldstein et al. (2001), where the shareholders have to inject extra cash (negative dividends) to recover the deficit of the firm. The cash payment to the manager, considered as the firm's costs, is always prior to the dividends payments, and the owner would therefore not allow the manager to make the abandonment decision. In addition, lots of structural models (e.g., Leland, 1994) as well as real options models (e.g., Mauer and Sarkar, 2005) assume that the shareholders are in charge of the bankruptcy and abandonment decisions of the firm. This assumption is also in line with that of Kanagaretnam and Sarkar (2011), which investigates managerial compensation in a real options framework.

The compensation package of the manager in an unlevered firm (Com^U) can be expressed by:

$$Com^U = m_0 + m_1[(1-\tau)(P-C-m_2(P-C)^+)] + m_2(1-\tau)(P-C)^+$$
$$= m_0 + m_1(1-\tau)(P-C) + m_2(1-m_1)(1-\tau)(P-C)^+. \quad (6)$$

In Eq. (6), the manager's compensation package is composed of fixed salary m_0, ownership shares $m_1[(1-\tau)(P-C-m_2(P-C)^+)]$ and earnings-based bonus compensation $m_2(1-\tau)(P-C)^+$.[2] Notice that earnings-based bonus compensation is based on after-tax net "positive" profits, while ownership shares are based on after-tax, after-bonus net "positive" or "negative" profits.

If the firm is unlevered, then the total value of the manager's wealth, $M^U(P)$, satisfies:

$$\frac{1}{2}\sigma^2P^2M^U_{PP} + (r-\delta)PM^U_P - rM^U + Com^U = 0, \quad (7)$$

and $M^U(P)$ has the following general solution:[3]

$$M^U(P) = \begin{cases} \frac{m_0}{r} + m_1(1-\tau)\left(\frac{P}{\delta}-\frac{C}{r}\right) + d_1P^{\beta_1} + d_2P^{\beta_2}, & P_A < P < C, \\ \frac{m_0}{r} + (m_1+m_2-m_1m_2)(1-\tau)\left(\frac{P}{\delta}-\frac{C}{r}\right) + e_1P^{\beta_1} + e_2P^{\beta_2}, & P_A < C < P, \end{cases} \quad (8)$$

d_1, d_2, e_1 and e_2 are constants and can be solved by the following four boundary conditions: (i) $\lim_{P\uparrow\infty} M^U(P)/P < \infty$ (non-bubble condition); (ii) $\lim_{P\downarrow P_A} M^U(P) = RI$ (value-matching at P_A); (iii) $\lim_{P\uparrow C} M^U(P) = \lim_{P\downarrow C} M^U(P)$ (value-matching at C); (iv) $\lim_{P\uparrow C}\frac{\partial M^U(P)}{\partial P} = \lim_{P\downarrow C}\frac{\partial M^U(P)}{\partial P}$ (smooth-pasting at C).

For $P_A < P < C$,

$$M^U(P) = \left(\frac{m_0}{r} + m_1(1-\tau)\left(\frac{P}{\delta}-\frac{C}{r}\right)\right) - \left(\frac{m_0}{r} + m_1(1-\tau)\left(\frac{P_A}{\delta}-\frac{C}{r}\right) - RI\right)\left(\frac{P}{P_A}\right)^{\beta_2}$$
$$+ (1-m_1)m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C}{\delta} + \frac{\beta_2}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P}{C}\right)^{\beta_1}$$
$$- \left((1-m_1)m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C}{\delta} + \frac{\beta_2}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P_A}{C}\right)^{\beta_1}\right)\left(\frac{P}{P_A}\right)^{\beta_2}. \quad (9)$$

The first term is the manager's compensation value when the shareholders do not have flexibility to abandon the project. The second term shows the expected net loss of the manager's compensation value when the project is abandoned. The third term, named as bonus flexibility value, demonstrates the expected present value of the future bonuses that the manager could obtain when the firm now operates at a loss and might run at a profit in the future. The last term shows the expected loss of the bonus flexibility when the project is abandoned.

For $P_A < C < P$,

$$M^U(P) = \left(\frac{m_0}{r} + (m_1+m_2-m_1m_2)(1-\tau)\left(\frac{P}{\delta}-\frac{C}{r}\right)\right) - \left(\frac{m_0}{r} + m_1(1-\tau)\left(\frac{P_A}{\delta}-\frac{C}{r}\right) - RI\right)\left(\frac{P}{P_A}\right)^{\beta_2}$$
$$+ (1-m_1)m_2(1-\tau)\left(\frac{1-\beta_1}{\beta_1-\beta_2}\frac{C}{\delta} + \frac{\beta_1}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P}{C}\right)^{\beta_2}$$
$$- \left((1-m_1)m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C}{\delta} + \frac{\beta_2}{\beta_1-\beta_2}\frac{C}{r}\right)\left(\frac{P_A}{C}\right)^{\beta_1}\right)\left(\frac{P}{P_A}\right)^{\beta_2}. \quad (10)$$

The first term is the manager's compensation value when the shareholders do not have flexibility to abandon the project. The second term shows the expected net loss of the manager's compensation value when the project is abandoned. The third term demonstrates the expected present value of the future bonuses that the manager could obtain when the firm now operates at a profit and might run at a profit in the future. The last term shows the expected loss of the bonus flexibility when the project is abandoned.

2.2. Levered firm

If the firm is levered with a perpetual coupon bond with coupon flow R per unit time, then equity value $E(P)$, after the project has been exercised, satisfies:

$$\frac{1}{2}\sigma^2P^2E_{PP} + (r-\delta)PE_P - rE + (1-\tau)(P-C-R-m_2(P-C-R)^+) = 0, \quad (11)$$

and $E(P)$ has the following general solution:

$$E(P) = \begin{cases} (1-\tau)\left(\frac{P}{\delta}-\frac{C+R}{r}\right) + h_1P^{\beta_1} + h_2P^{\beta_2}, & P_D < P < C+R. \\ (1-\tau)(1-m_2)\left(\frac{P}{\delta}-\frac{C+R}{r}\right) + i_1P^{\beta_1} + i_2P^{\beta_2}, & P_D < C+R < P. \end{cases} \quad (12)$$

Again, h_1, h_2, i_1 and i_2 can be solved by the following four boundary conditions: (i) $\lim_{P\uparrow\infty} E(P)/P < \infty$ (non-bubble condition); (ii) $\lim_{P\downarrow P_D} E(P) = 0$ (value-matching at P_D); (iii) $\lim_{P\uparrow C+R} E(P) = \lim_{P\downarrow C+R} E(P)$ (value-matching at $C+R$); and (iv) $\lim_{P\uparrow C+R}\frac{\partial E(P)}{\partial P} = \lim_{P\downarrow C+R}\frac{\partial E(P)}{\partial P}$ (smooth-pasting at $C+R$).

For $P_D < P < C+R$,

$$E(P) = (1-\tau)\left(\frac{P}{\delta}-\frac{C+R}{r}\right) - (1-\tau)\left(\frac{P_D}{\delta}-\frac{C+R}{r}\right)\left(\frac{P}{P_D}\right)^{\beta_2}$$
$$- m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C+R}{\delta} + \frac{\beta_2}{\beta_1-\beta_2}\frac{C+R}{r}\right)\left(\frac{P}{C+R}\right)^{\beta_1}$$
$$+ \left(m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C+R}{\delta} + \frac{\beta_2}{\beta_1-\beta_2}\frac{C+R}{r}\right)\left(\frac{P_D}{C+R}\right)^{\beta_1}\right)\left(\frac{P}{P_D}\right)^{\beta_2}. \quad (13)$$

[2] This setting of an earnings-based bonus is similar to that of Câmara (2009).

[3] In the case of $P_A > C$, the manager will always obtain the bonus. That means the earnings-based bonus is equivalent to a fraction of equity, and hence the model will reduce to that of Andrikopoulos (2009). Hereafter, we assume $P_A < C$.

For $P_D < C+R < P$,

$$E(P) = (1-\tau)(1-m_2)\left(\frac{P}{\delta}-\frac{C+R}{r}\right) - (1-\tau)\left(\frac{P_D}{\delta}-\frac{C+R}{r}\right)\left(\frac{P}{P_D}\right)^{\beta_2} - m_2(1-\tau)\left(\frac{1-\beta_1}{\beta_1-\beta_2}\frac{C+R}{\delta}+\frac{\beta_1}{\beta_1-\beta_2}\frac{C+R}{r}\right)\left(\frac{P}{C+R}\right)^{\beta_2} + \left(m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C+R}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C+R}{r}\right)\left(\frac{P_D}{C+R}\right)^{\beta_1}\right)\left(\frac{P}{P_D}\right)^{\beta_2}. \quad (14)$$

The optimal default policy, chosen by shareholders to maximize equity value, is determined by the following smooth-pasting condition: $\lim_{P\downarrow P_D}\frac{\partial E(P)}{\partial P}=0$.

As for the debt value, we assume that if the firm goes bankrupt and the creditor becomes the sole owner (Leland, 1994), then the creditor could hire another ability-identical manager to run the unlevered firm since it is more efficient for the new owners to continue operating the project with managers who have more firm-specific knowledge and value (Andrikopoulos, 2009). Debt value $D(P)$ after the exercise of the project satisfies:

$$\frac{1}{2}\sigma^2P^2D_{PP}+(r-\delta)PD_P-rD+R=0, \quad (15)$$

and $D(P)$ has the following general solution:

$$D(P)=\frac{R}{r}+j_1P^{\beta_1}+j_2P^{\beta_2}, \quad P_D<P, \quad (16)$$

where j_1 and j_2 can be solved by the following two boundary conditions: (i) $\lim_{P\uparrow\infty}D(P)/P<\infty$ (non-bubble condition); and (ii) $\lim_{P\downarrow P_D}D(P)=(1-\alpha)V^U(P_D)$ (value-matching at P_D) where a bankruptcy cost amounting to a fraction α ($0\leqslant\alpha\leqslant1$) of the unlevered firm value. The debt value is therefore given by:

$$D(P)=\frac{R}{r}-\left(\frac{R}{r}-(1-\alpha)V^U(P_D)\right)\left(\frac{P}{P_D}\right)^{\beta_2}, \quad P_D\leqslant P. \quad (17)$$

The compensation of the manager is now modified as:

$$Com^L = m_0+m_1[(1-\tau)(P-C-R-m_2(P-C-R)^+)] + m_2(1-\tau)(P-C-R)^+ = m_0+m_1(1-\tau)(P-C-R) + m_2(1-m_1)(1-\tau)(P-C-R)^+. \quad (18)$$

The total value for the manager in a levered firm $M^L(P)$ satisfies the following ordinary differential equation (ODE):

$$\frac{1}{2}\sigma^2P^2M^L_{PP}+(r-\delta)PM^L_P-rM^L+Com^L=0, \quad (19)$$

and $M^L(P)$ has the following solution form:

$$M^L(P)=\begin{cases}\frac{m_0}{r}+m_1(1-\tau)\left(\frac{P}{\delta}-\frac{C+R}{r}\right)+f_1P^{\beta_1}+f_2P^{\beta_2}, & P_D<P<C+R.\\ \frac{m_0}{r}+(m_1+m_2-m_1m_2)(1-\tau)\left(\frac{P}{\delta}-\frac{C+R}{r}\right)+g_1P^{\beta_1}+g_2P^{\beta_2}, & P_D<C+R<P.\end{cases} \quad (20)$$

For $P_D < P < C+R$,

$$M^L(P) = \left(\frac{m_0}{r}+m_1(1-\tau)\left(\frac{P}{\delta}-\frac{C+R}{r}\right)\right) - \left(\frac{m_0}{r}+m_1(1-\tau)\left(\frac{P_D}{\delta}-\frac{C+R}{r}\right)-RI\right)\left(\frac{P}{P_D}\right)^{\beta_2} + (1-m_1)m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C+R}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C+R}{r}\right) \times\left(\frac{P}{C+R}\right)^{\beta_1} - \left((1-m_1)m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C+R}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C+R}{r}\right)\left(\frac{P_D}{C+R}\right)^{\beta_1}\right)\left(\frac{P}{P_D}\right)^{\beta_2}. \quad (21)$$

For $P_D < C+R < P$,

$$M^L(P) = \left(\frac{m_0}{r}+(m_1+m_2-m_1m_2)(1-\tau)\left(\frac{P}{\delta}-\frac{C+R}{r}\right)\right) - \left(\frac{m_0}{r}+m_1(1-\tau)\left(\frac{P_D}{\delta}-\frac{C+R}{r}\right)-RI\right)\left(\frac{P}{P_D}\right)^{\beta_2} + (1-m_1)m_2(1-\tau)\left(\frac{1-\beta_1}{\beta_1-\beta_2}\frac{C+R}{\delta}+\frac{\beta_1}{\beta_1-\beta_2}\frac{C+R}{r}\right) \times\left(\frac{P}{C+R}\right)^{\beta_2} - \left((1-m_1)m_2(1-\tau)\left(\frac{1-\beta_2}{\beta_1-\beta_2}\frac{C+R}{\delta}+\frac{\beta_2}{\beta_1-\beta_2}\frac{C+R}{r}\right)\left(\frac{P_D}{C+R}\right)^{\beta_1}\right)\left(\frac{P}{P_D}\right)^{\beta_2}. \quad (22)$$

2.3. Options to invest

After exercising the investment option, the manager starts receiving a cash salary, being rewarded a fraction of the equity (thus sharing the same portion of investment cost), and receiving the earnings-based bonus compensation, but giving up the previous income. Similar to Andrikopoulos (2009), we define this case as "Manager-Best (MB)". For comparison, following Mauer and Sarkar (2005), we define "Firm-Best (FB)" when the optimal investment decision is chosen to maximize the total value for all stakeholders of the firm, which is the sum of equity value (excluding the fraction held by managers), debt value and managers' compensation value.

If the manager has the right to choose the time of project implementation, then the value of the option to invest $MB(P)$ satisfies the following ODE:

$$\frac{1}{2}\sigma^2P^2MB_{PP}+(r-\delta)PMB_P-rMB=0, \quad P<P_I^M, \quad (23)$$

and $MB(P)$ has the following general solution:

$$MB(P)=k_1P^{\beta_1}+k_2P^{\beta_2}, \quad P<P_I^M. \quad (24)$$

According to the following two boundary conditions: (i) $\lim_{P\downarrow0}MB(P)<\infty$; and (ii) $\lim_{P\uparrow P_I^M}MB(P)=\lim_{P\uparrow P_I^M}M^L(P)-m_1(I-K^M)-PI$, we have

$$MB(P)=(M^L(P_I^M)-m_1(I-K^M)-PI)\left(\frac{P}{P_I^M}\right)^{\beta_1}, \quad P<P_I^M, \quad (25)$$

Again, $M^L(P)$ must satisfy the following boundary conditions: (i) $\lim_{P\uparrow\infty}M^L(P)/P<\infty$ (non-bubble condition); (ii) $\lim_{P\downarrow P_D}M^L(P)=RI$ (value-matching condition at P_D); (iii) $\lim_{P\uparrow C+R}M^L(P)=\lim_{P\downarrow C+R}M^L(P)$ (value-matching condition at $C+R$); and (iv) $\lim_{P\uparrow C+R}\frac{\partial M^L(P)}{\partial P}=\lim_{P\downarrow C+R}\frac{\partial M^L(P)}{\partial P}$ (smooth-pasting condition at $C+R$), where RI is the reservation income.

where P_I^M is the manager's investment trigger and $K^M = D(P_I^M)$ is the equilibrium value of debt under the investment policy that maximizes the manager's wealth.

In (25), the manager's option to invest can be shown as the expected present value of the manager's net gains after investment. The manager's net gain after investment can be defined as the benefit from compensation, $M^L(P_I^M)$, minus the total cost of investment, $m_1(I - K^M) + PI$, where $m_1(I - K^M)$ is the investment cost contributed by the manager as a shareholder and PI is the manager's foregone reservation income. The optimal investment and financing decisions, chosen to maximize the manager's wealth, are jointly determined by $\lim_{P\to P_I^M} \frac{\partial MB(P)}{\partial P} = \lim_{P\to P_I^M} \frac{\partial M^L(P)}{\partial P}$ and $R^M \equiv \arg\max_R MB(P)$. The associated credit spreads of debt (CS) and optimal debt ratios (DR) are therefore defined as:

$$CS = \frac{R^M}{D(P_I^M; R^M)} - r \quad \text{and} \quad DR = \frac{D(P_I^M; R^M)}{D(P_I^M; R^M) + E(P_I^M; R^M)}.$$

If the option is granted to all stakeholders of a firm, then the value of the option to invest for all stakeholders, $FB(P)$, satisfies the following ODE:

$$\frac{1}{2}\sigma^2 P^2 FB_{PP} + (r - \delta)PFB_P - rFB = 0, \quad P < P_I^F, \tag{26}$$

and $FB(P)$ has the general solution as below:

$$FB(P) = q_1 P^{\beta_1} + q_2 P^{\beta_2}, \quad P < P_I^F. \tag{27}$$

According to the following two boundary conditions: $\lim_{P\downarrow 0} FB(P) < \infty$ and $\lim_{P\uparrow P_I^F} FB(P) = \lim_{P\uparrow P_I^F} F(P) - I - PI$, where $F(P) = D(P) + (1 - m_1)E(P) + M^L(P)$, we therefore have

$$FB(P) = (F(P_I^F) - I - PI)\left(\frac{P}{P_I^F}\right)^{\beta_1}, \quad P < P_I^F. \tag{28}$$

Similarly, in (28) the firm's all stakeholders' option to invest can be shown as the expected value of the stakeholders' net gains. The stakeholders' net gains after investment are defined as the benefit from compensation, $F(P_I^F)$, minus the net cost of investment, I, and the manager's past income, PI. The optimal investment and financing decisions, chosen to maximize all stakeholders' wealth, are jointly determined by $\lim_{P\to P_I^F} \frac{\partial FB(P)}{\partial P} = \lim_{P\to P_I^F} \frac{\partial F(P)}{\partial P}$ and $R^F \equiv \arg\max_R FB(P)$.

We next define the agency cost as the proportional value difference of the option to invest between the Firm-Best case and the Manager-Best case:

$$AC = \frac{FB(P; P_I^F, R^F) - FB(P; P_I^M, R^M)}{FB(P; P_I^M, R^M)}, \tag{29}$$

where $FB(P; P_I^F, R^F)$ is the value of the option to invest for the firm in which the abandon and default options are given to shareholders, while the investment and financing decisions are given to all stakeholders. Moreover, $FB(P; P_I^M, R^M)$ denotes the value of the option to invest for the firm, whereby the abandon and default options are also given to shareholders, and the investment and financing decisions are chosen by the manager. The agency costs can thus measure the deviations of a manager's optimal investment and financing decisions from the Firm-Best's choices.

3. Numerical analysis[4]

We begin in this section with an examination of the individual effects of ownership shares and earnings-based bonus compensation on a manager's optimal investment and financing decisions under two cases: (1) managers are compensated with only cash and ownership shares; (2) managers are compensated with only cash and earnings-based bonus compensation. In the latter case, managers have no incentive to use debt financing, and the optimal investment decision thus will not interact with the optimal financing decision. We further compare the effects of ownership shares and earnings-based bonus compensation when the manager is compensated with cash, ownership shares, and earnings-based bonus compensation. Because the optimal coupon payment may not be equal to zero in this case, the interaction between the manager's optimal investment and financing decisions leads to significant differences in the effects from these two types of performance compensation on the manager's optimal investment and financing decisions, agency costs, optimal debt ratios, and credit spreads. Finally, we report numerical results when the manager's expected wealth of compensation is fixed.[5]

For numerical analysis, we employ the following base-case parameters which are similar to those in Mauer and Sarkar (2005) and Andrikopoulos (2009). The production costs, C, are \$0.75 per unit time; the cost of exercising the investment option, I, is \$10; the volatility of the output price, σ, is 30%; the convenience yield of the output price, δ, is 2%; the risk-free rate, r, is 4%; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, PI, and reservation income, RI, are the same at \$1.5; the cash salary per unit time, m_0, is \$0.04; a fraction of equity, m_1, is 3% and a fraction of an earnings-based bonus, m_2, is 0.3%.[6]

3.1. The individual effects of ownership shares and earnings-based bonus compensation

To investigate the similarities and differences between ownership shares and earnings-based bonus compensation, we first analyze two special cases: the manager is compensated with only a cash salary and ownership shares ($m_2 = 0$), and then with only a cash salary and an earnings-based bonus ($m_1 = 0$).

Since the optimal investment and financing decisions are jointly determined by the manager, we use Figs. 1 and 2 to simultaneously explore her optimal investment and financing decisions. In the left panels of Figs. 1 and 2 ($m_2 = 0$), more ownership shares make manager starting from investing too late relative to the case of Firm-Best (underinvestment) to investing too early (overinvestment), and at the same time reducing optimal coupon payments.[7] On the other hand, the right panels of Figs. 1 and 2 ($m_1 = 0$) show that the optimal investment trigger is decreasing as more earnings-based bonus compensation is paid, and no debt is issued to finance the investment.

When the manager is compensated with more ownership shares or earnings-based bonus, her expected wealth increases and the optimal investment trigger thus decreases. However, the manager's optimal financing decisions are rather different. When she holds

4 We thank the referee for the constructive suggestions, which absolutely improve the presentation in this section.

5 Notice that all the numerical results in this paper are robust when the investment, financing, abandonment and bankruptcy decisions are all made by the manager.

6 The parameter values of m_1 and m_2 employed in our numerical examples can be justified by our unreported empirical results from the data of ExecuComp and Compustat between 1992 and 2010. We thank the referee's suggestion for this justification.

7 Optimal investment and financing decisions of a manager will converge to those of equity holders when a large fraction of ownership shares is paid.

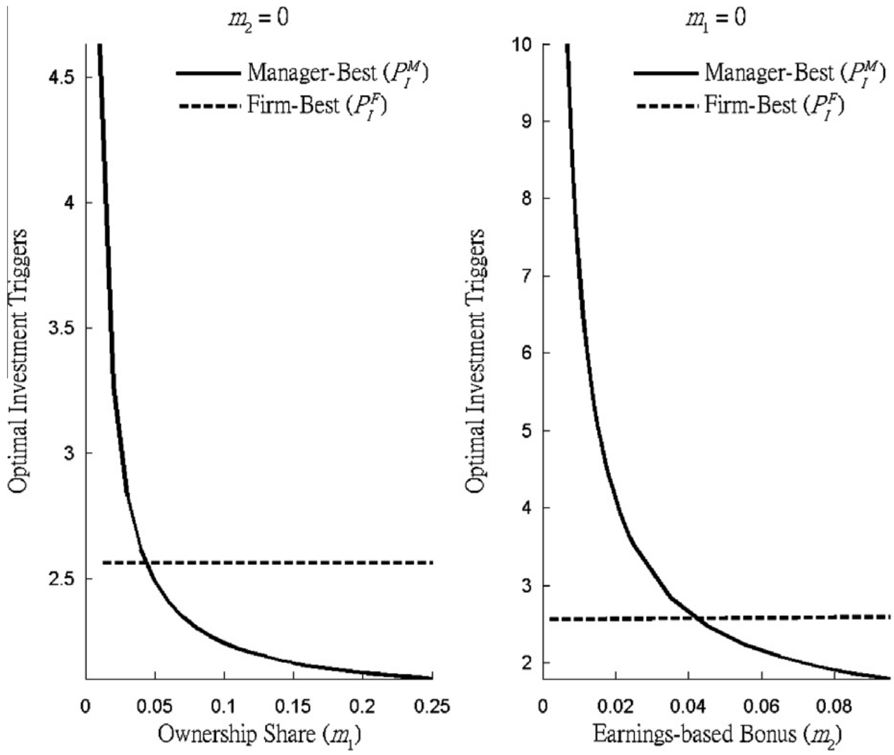

Fig. 1. Individual effects of ownership shares and earnings-based bonus compensation on optimal investment triggers. In the Firm-Best case, the investment decision is made by all stakeholders. In the Manager-Best case, the investment decision is made by the manager. In both cases, the abandonment and bankruptcy decisions are chosen by shareholders. Parameters of this figure are given as follows: the production costs, C, are \$0.75 per unit time; the cost of exercising the investment option, I, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, r, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, PI, is \$1.5; reservation income, RI, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

more ownership shares, this increased default risk resulting from accelerating investment leads to a higher cost of debt and motivates her to reduce debt issuance and the optimal coupon payment. Therefore, when the manager is compensated with only cash and ownership shares, her optimal coupon payment decreases as more ownership shares are paid. However, the manager optimally chooses zero debt financing when she is compensated with only cash and earnings-based bonus compensation, because earnings-based bonus compensation does not offer the manager any firm ownership and thus she gets no benefit from debt financing. Moreover, coupon payments will reduce the firm's net profit per unit time, thereby reducing the manager's bonus compensation.[8]

In Fig. 3 we examine agency costs where the left panel shows the case of $m_2 = 0$ and the right shows the case of $m_1 = 0$. Both the two cases demonstrate a U-shaped agency cost curve, because that manager's investment decision changes from underinvestment to overinvestment, and the agency cost reaches the lowest when the optimal investment timing of manager is equal to that of the First-Best case.[9] The manager's optimal financing decision also deviates from the Firm-Best case, leading to agency costs, but the effect of the optimal financing decision is dominated by that of the optimal investment decision.

In sum, although the manager's optimal investment decisions (Fig. 1) and the agency costs (Fig. 3) of the two cases share the same shapes, the manager's optimal financing decisions (Fig. 2) in those two cases are significantly different. In particular, the manager who is compensated only with a cash salary and an earnings-based bonus will not use any debt to finance the investment.

3.2. Optimal investment and financing decisions when the manager is compensated with cash salary, ownership shares and earnings-based bonus compensation

This subsection compares the effects of ownership shares and earnings-based bonus compensation on the firm's optimal investment and financing decisions by considering the particular interaction between the two decisions when the manager is compensated with cash, ownership shares, and earnings-based bonus compensation.

In the left panels of Figs. 4 and 5, we investigate the manager's optimal investment triggers and optimal coupon payments when $m_2 = 0.3\%$ and $m_1 \in [0, 25\%]$. The optimal investment triggers are monotonically decreasing with the increase of ownership shares. On the other hand, the manager's optimal coupon payments are zero when m_1 is less than 0.55%, increases rapidly when m_1 is between 0.55% and 0.95%, and decreases when m_1 is larger than 0.95%. The above numerical results can be explained as below. When the manager is only offered small ownership shares (less than 0.55%), she will not use any debt. This is because the incentive provided by 0.3% earnings-based bonus compensation not to use debt financing dominates that provided by the ownership share which is less than 0.55%. When the manager is offered a little more ownership shares (between 0.55% and 0.95%), she is motivated to issue more debt since the incentive provided by earnings-based bonus now are dominated by that provided by the ownership

[8] In this subsection, we omit the analysis of the optimal debt ratio and credit spread, since the manager does not have any incentive to issue any debt if only compensated with an earnings-based bonus and a cash salary.

[9] The lowest agency cost is still positive, because the optimal abandonment and bankruptcy decisions are determined by shareholders and the manager's financing decision is not the same as the firm-Best one.

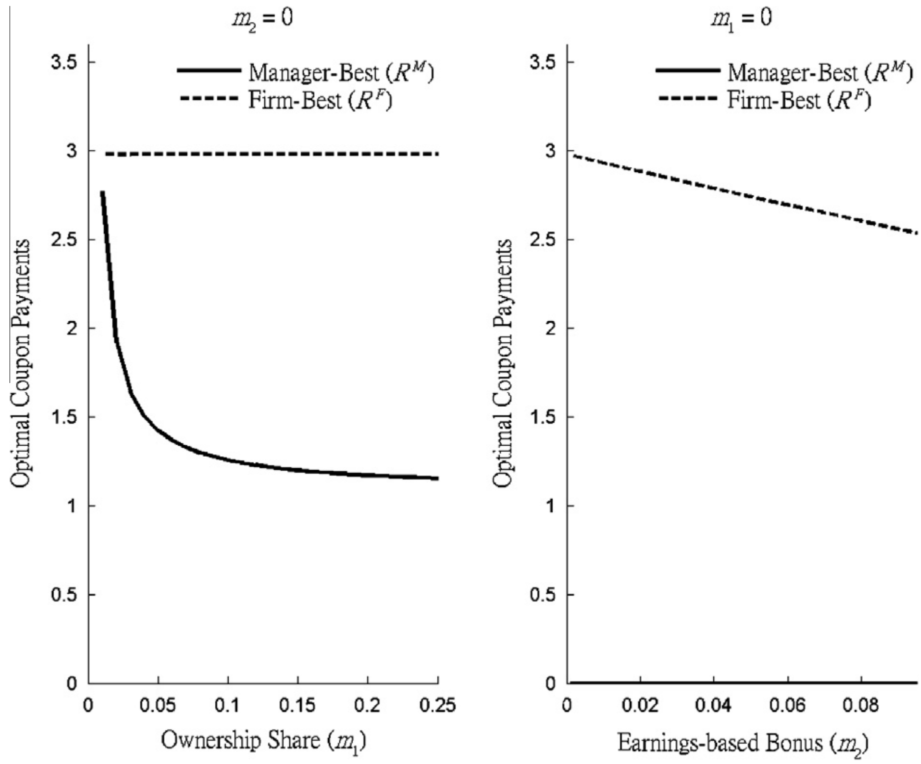

Fig. 2. Individual effects of ownership shares and earnings-based bonus compensation on optimal coupon payments. In the Firm-Best case, the financing decision is made by all stakeholders. In the Manager-Best case, the financing decision is made by the manager. In both cases, the abandonment and bankruptcy decisions are chosen by shareholders. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

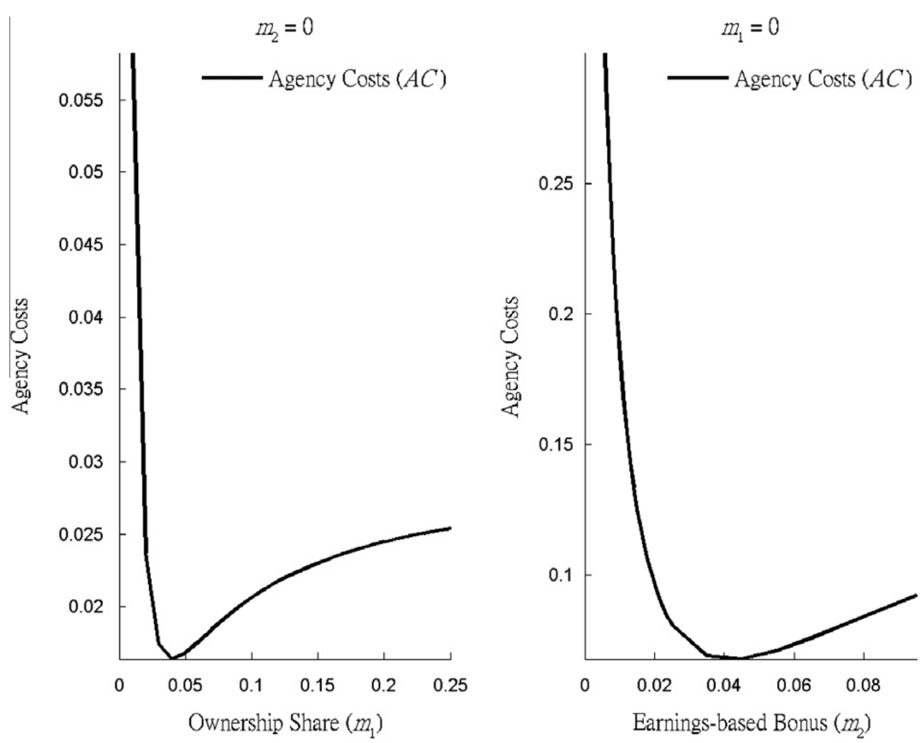

Fig. 3. Individual effects of ownership shares and earnings-based bonus compensation on agency costs. In the Firm-Best case, the investment and financing decisions are made by all stakeholders. In the Manager-Best case, the investment and financing decisions are made by the manager. In both cases, the abandonment and bankruptcy decisions are chosen by shareholders. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

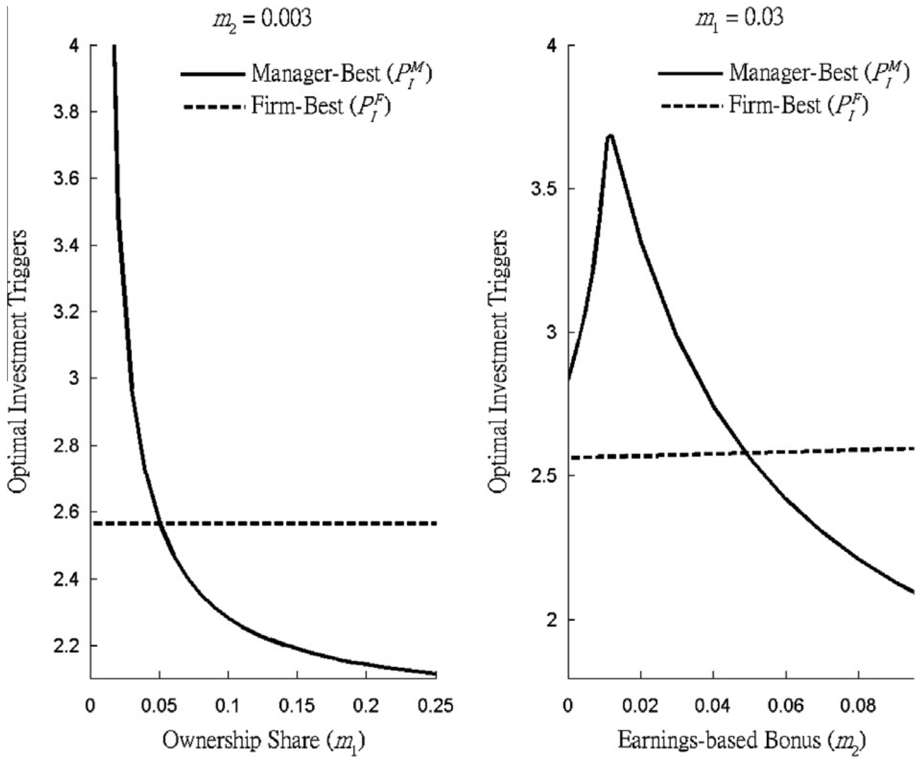

Fig. 4. Optimal investment triggers when the manager is compensated with a cash salary, ownership shares and an earnings-based bonus. In the Firm-Best case, the investment decision is made by all stakeholders. In the Manager-Best case, the investment decision is made by managers. In both cases, the abandonment and bankruptcy decisions are chosen by shareholders. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

shares. When the manager holds more ownership shares (larger than 0.95%), the increased default risk resulting from accelerating investment leads to a higher cost of debt and motivates the manager to reduce debt issuance and the optimal coupon payment. In addition, the result that the optimal investment trigger is monotonically decreasing as the ownership shares increase is exactly the same as that in Fig. 1. Even though the manager is compensated with not only ownership shares but also earnings-based bonuses, the relationship between the optimal investment decisions and the manager's holding position of ownership shares is not affected.

In the right panels of Figs. 4 and 5 we investigate the manager's optimal investment triggers and optimal coupon payments when m_1 = 3% and $m_2 \in [0, 10\%]$. We observe that the manager tends to defer and then accelerate investment as m_2 increases, while at the same time reduce the optimal coupon payment and then use zero debt financing. The above numerical results can be explained as below. First, when the manager holds 3% ownership shares and is compensated with zero or a relatively small fraction of earnings-based bonus (less than 1.2%), she has an incentive to use debt to partially finance the investment since the incentive provided by ownership shares to use debt financing dominates that provided by earnings-based bonus not to use debt. Moreover, the incentive to issue debt sharply reduces (the greater reduction of optimal coupon payments) when she is compensated with a greater fraction of earnings-based bonus, and this incentive will disappear when she is compensated with a relatively large fraction of earnings-based bonus (larger than 1.2%). The greater reduction of the optimal coupon payment is accompanied by an increase in the optimal investment trigger. The reason is that the reduction of the optimal coupon payment will lower down the benefits of debt, thus deferring investment, and this effect dominates the effect when the manager who is compensated with more earnings-based bonuses tends to reduce the optimal investment trigger due to an increase in compensation values. As a consequence, the range of earnings-based bonus when the manager's optimal coupon payment is decreasing is exactly the same as that when the manager's optimal investment trigger is increasing. Finally, when m_2 increases and is greater than 1.2%, the manager tends not to use any debt financing, and therefore the optimal investment triggers decrease, which is similar to the case when m_1 = 0.

In sum, Fig. 4 shows that the manager tends to accelerate investment as m_1 increases. However, she tends to defer and then accelerate investment as m_2 increases when she holds a given amount of ownership shares. On the other hand, Fig. 5 demonstrates that the manager tends to increase and then decrease the optimal coupon payments as m_1 increases when she holds a given earnings-based bonus. However, she tends to lower down the optimal coupon to zero as m_2 increases when she holds a given amount of ownership shares.

3.3. Agency costs, optimal debt ratios and credit spreads when the manager is compensated with a cash salary, ownership shares and an earnings-based bonus

Fig. 6 presents the agency costs where the investment and financing decisions are simultaneously made by the manager, and the abandonment and bankruptcy decisions are made by the shareholders. Although the manager's investment and financing decisions both deviate from the Firm-Best ones, the shapes of agency costs can be mainly explained by the deviations between the Manager-Best's and Firm-Best's optimal investment triggers. The left panel shows a U-shaped curve of agency costs when

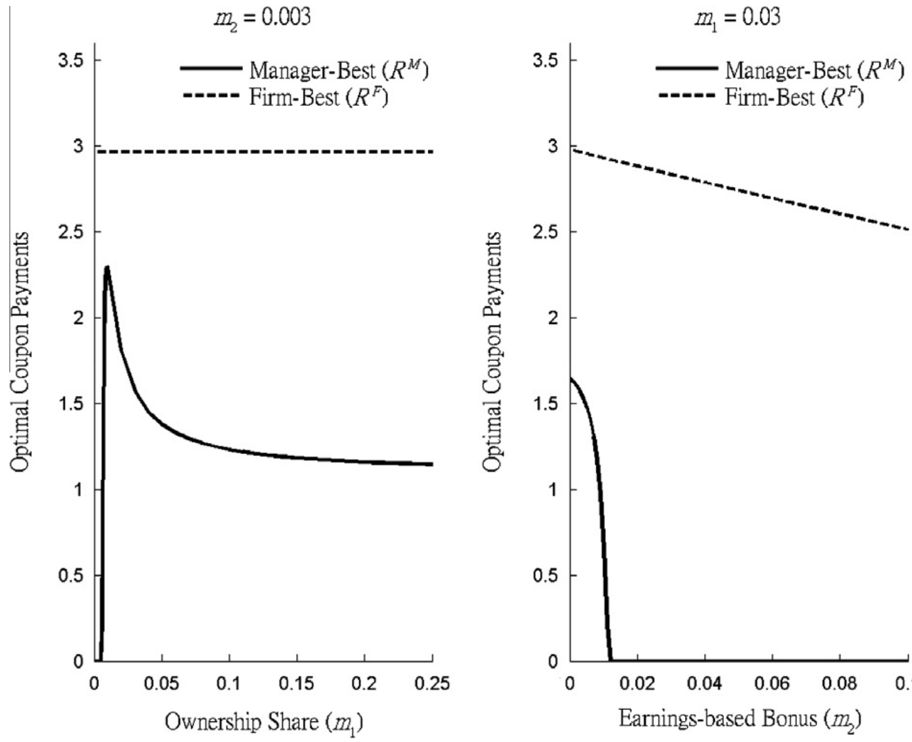

Fig. 5. Optimal coupon payments when the manager is compensated with a cash salary, ownership shares and an earnings-based bonus. In the Firm-Best case, the financing decision is made by all stakeholders. In the Manager-Best case, the financing decision is made by the manager. In both cases, the abandonment and bankruptcy decisions are chosen by shareholders. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

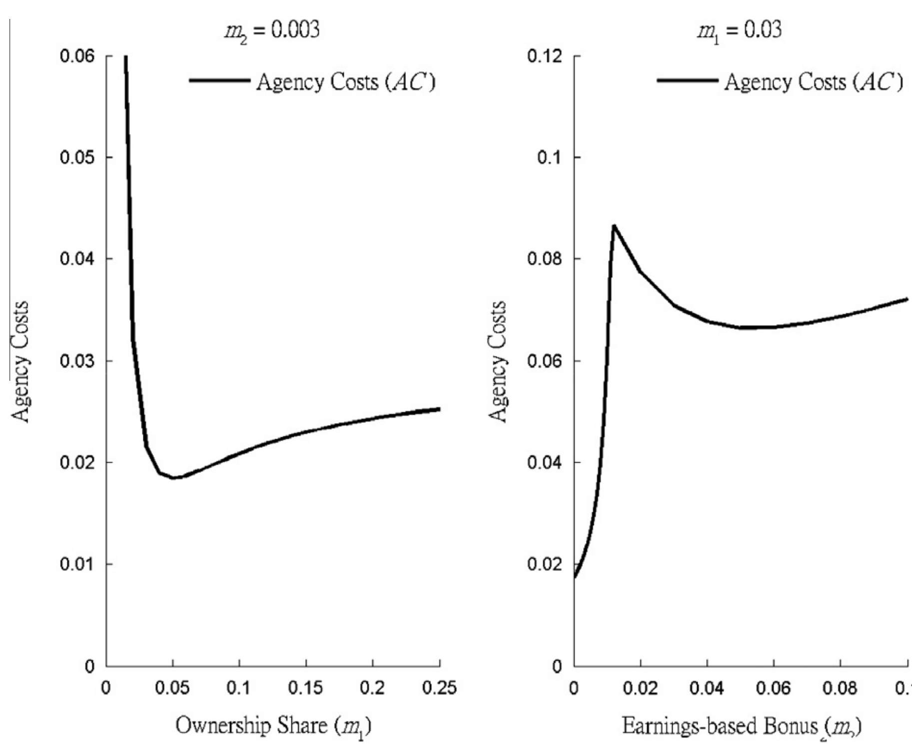

Fig. 6. Agency costs when the manager is compensated with a cash salary, ownership shares and an earnings-based bonus. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

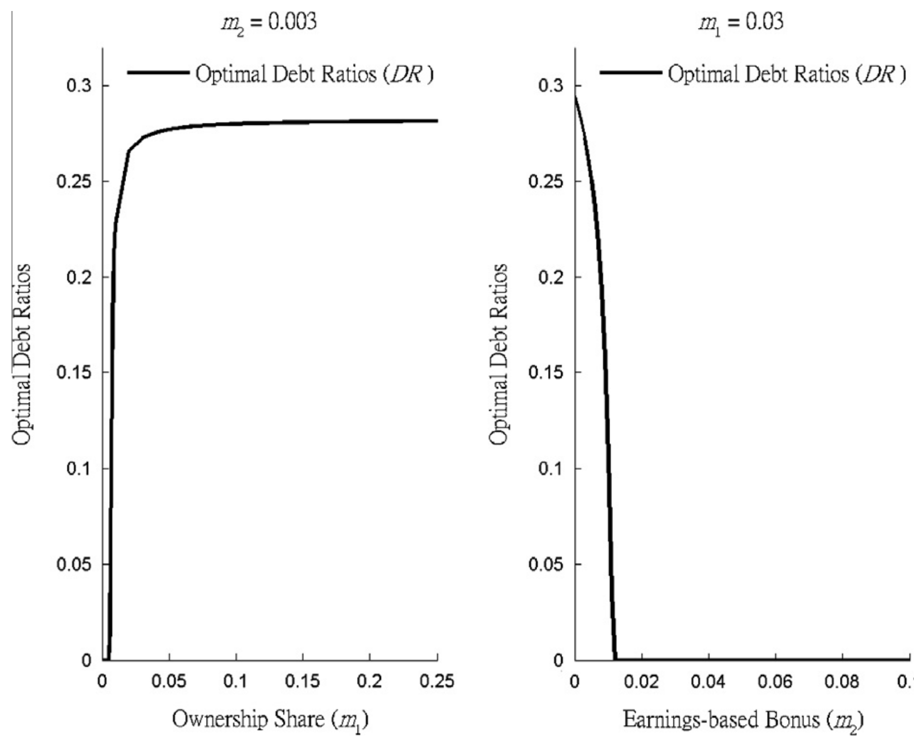

Fig. 7. Optimal debt ratios when the manager is compensated with a cash salary, ownership shares and an earnings-based bonus. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds.

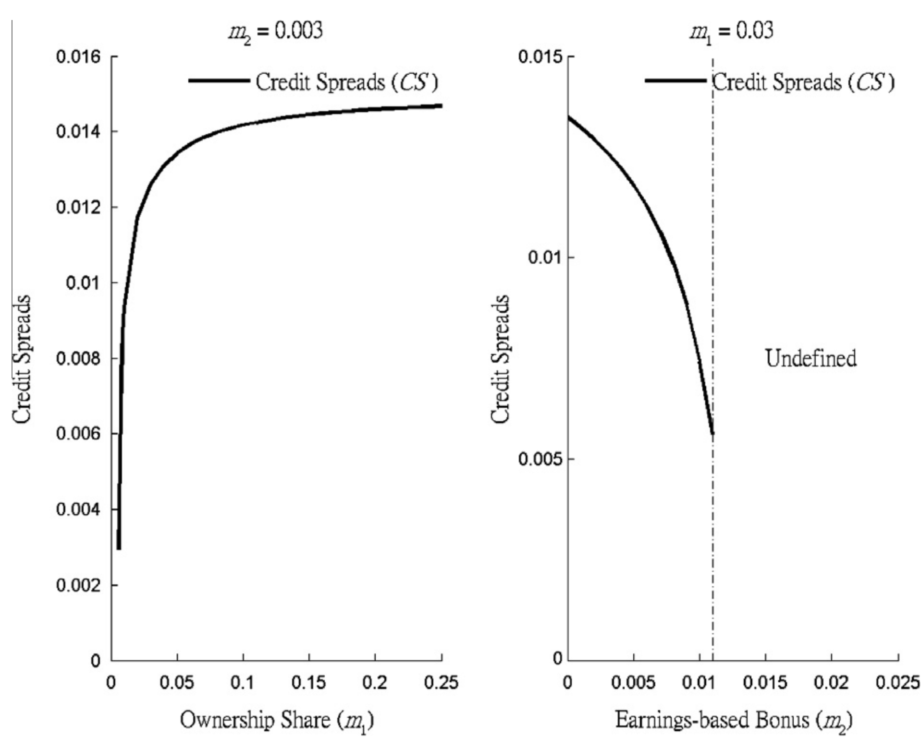

Fig. 8. Credit spreads when the manager is compensated with a cash salary, ownership shares and an earnings-based bonus. Parameters of this figure are given as follows: the production costs, *C*, are \$0.75 per unit time; the cost of exercising the investment option, *I*, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, *r*, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, *PI*, is \$1.5; reservation income, *RI*, is \$1.5; and the initial cash salary, m_0, is \$0.04, where m_1 is a fraction of ownership shares and m_2 is a fraction of earnings-based bonus that the manager holds. “Undefined” denotes the area where the optimal coupon payment is zero.

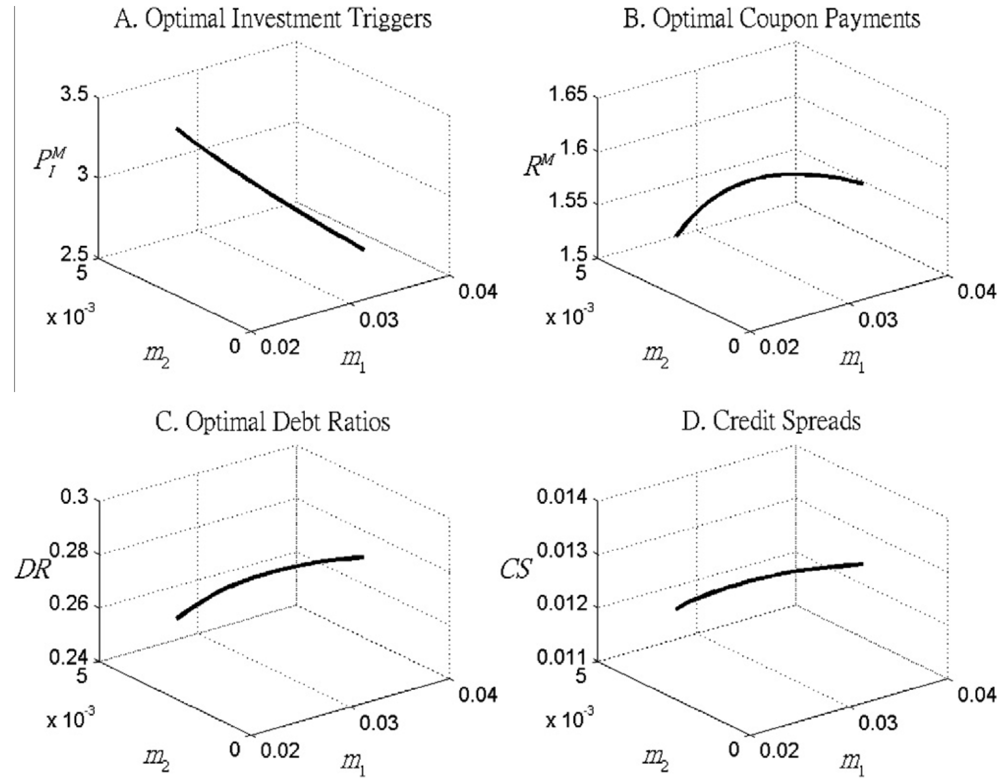

Fig. 9. Optimal investment triggers, coupon payments, debt ratios and credit spreads when the manager's expected wealth compensation is fixed. We fixed the manager's expected wealth of compensation to be \$1.2 and change the combination of ownership shares m_1 and earnings-based bonus compensation m_2. The initial output price, P, is \$1.5 per unit time; production costs, C, are \$0.75 per unit time; the cost of exercising the investment option, I, is \$10; the volatility of the output price, σ, is 30% per year; the convenience yield of the output price, δ, is 2% per year; the risk-free rate, r, is 4% per year; the corporate tax rate, τ, is 20%; and bankruptcy costs, α, are 35% of the value of unlevered assets at the time of bankruptcy. Previous income, PI, is \$1.5; reservation income, RI, is \$1.5; and the initial cash salary, m_0, is \$0.04.

$m_2 = 0.3\%$ and $m_1 \in [0, 25\%]$. This can be explained by the manager's decreasing optimal investment triggers, from underinvestment to overinvestment, as displayed in the left panel of Fig. 4. On the other hand, the right panel demonstrates that agency costs are increasing, then decreasing, and finally increasing when $m_1 = 3\%$ and $m_2 \in [0, 10\%]$, which can be similarly explained by the manager's increasing and then decreasing optimal investment triggers as shown in the right panel of Fig. 4. Duru et al. (2005) suggest that earnings-based bonus plans are an explicit role in reducing the agency costs of debt. Our numerical results support this finding when earnings-based bonus is paid in median range, and further demonstrate that the agency conflict may be deepened when earnings-based bonus is rather small or large.

In Fig. 7, we explore the effects of the two types of compensation on optimal debt ratios where the investment and financing decisions are jointly made by the manager, and abandonment and bankruptcy policies are chosen by the shareholders. The left panel shows optimal debt ratios are zero when m_1 is less than 0.55% and are then sharply increasing and finally slowly increasing as m_1 rises. The right panel, on the other hand, demonstrates that the optimal debt ratios sharply decrease when m_2 increases and become zero when m_2 is greater than 1.2%. Fig. 7 clearly displays the different financing incentives provided by the ownership shares and earnings-based bonus compensation, where ownership shares motivate the manager to raise the firm leverage, but the earnings-based bonus induces the manager to lower down the leverage.

The above numerical results can be explained as follows. There are two main impacts on the optimal debt ratios. One is the optimal coupon payment, and the other is the optimal investment trigger. Intuitively, the higher the optimal coupon payment is, the larger the optimal debt ratio will be. To investigate the effect of optimal investment trigger, we first recall that the optimal debt ratios are defined as the debt value divided by the total firm value, which are all calculated at the time when the manager initiates the project and makes financing decision (at $P = P_I^M$). It can be shown that the equity, managerial compensation and debt values are positively related to P_I^M, whereas the equity value is much more sensitive to P_I^M than the debt value.[10] As a result, the larger the optimal investment trigger is, the lower the optimal debt ratio will be. In the left panel of Fig. 7, when the ownership share is very small, the optimal debt ratio is zero since the optimal coupon payment is zero. As the ownership share gets larger, the optimal investment trigger becomes lower and the optimal coupon payment becomes higher, both leading to a higher debt ratio and thus demonstrating a sharply increasing optimal debt ratio curve. When the ownership share is relatively higher, the optimal investment trigger is still decreasing and the optimal coupon payment begins to decrease. The effect of optimal investment trigger dominates that of optimal coupon payment, thereby displaying a smoothly increasing optimal debt ratio curve. The positive relation between leverage ratio and managerial ownership share is consistent with John and John (1993) and Douglas (2006), and agrees with the empirical evidence from Chemmanur et al. (2010). In the right panel of Fig. 7, when the earnings-based bonus is small, the optimal debt ratio is sharply decreasing as earnings-

[10] After the project is initiated by the manager, our model is reduced to standard structural models (e.g., Leland, 1994). The optimal investment trigger before investment is just the initial revenue after investment. Similar to Leland (1994), the equity value in our model is convex in the initial revenue, while the debt value is concave in the initial revenue. Accordingly, the equity value is much more sensitive to the optimal investment trigger than the debt value.

based bonus increases since the optimal investment trigger becomes larger while the optimal coupon payment is decreasing. As the earnings-based bonus is larger than 1.2%, the optimal coupon payment becomes zero, leading to a zero optimal debt ratio.

The determinant of optimal leverage in this paper is relevant to the traditional tradeoff theory. Empirically, debt ratios often appear lower relative to the prediction of the tradeoff theory, thereby indicating that the magnitude of bankruptcy costs is too low to be a sufficient disincentive to issuing debt (e.g., Graham, 2000; Fama and French, 2002). Recently, Berk et al. (2010) theoretically show that human capital costs associated with financial distress and bankruptcy are large enough to be a disincentive to issuing debt. The left panel of Fig. 7 particularly demonstrates that the use of earnings-based bonus compensation offers the manager a disincentive to issuing debt, which may be an explanation why debt ratios often appear lower relative to the prediction of the tradeoff theory.

Fig. 8 demonstrates the effects of credit spreads of debt where the investment and financing decisions are made by the manager, and the abandonment and bankruptcy decisions are decided by shareholders. The left panel shows that credit spreads are not defined due to zero debt financing when m_1 is less than 0.55% and are then sharply increasing and finally slowly increasing as m_1 rises. This is consistent with the evidence from Ortiz-Molina (2006), showing that there is a positive relationship between managerial ownership shares and borrowing costs, and this relationship is weaker at higher levels of ownership. The credit spreads are affected by the fact that the capital structure is suboptimal, and this suboptimal decision is due to the agency problems between shareholders and manager as well as between shareholders and bondholders.[11] On the other hand, the right panel demonstrates that credit spreads are sharply decreasing as m_2 increases and are not defined when m_2 is greater than 1.2%. The pattern of decreasing credit spreads is in accordance with the empirical findings of Duru et al. (2005), asserting that earnings-based bonus compensation plays a role in reducing the credit spreads of debt.

3.4. Numerical results when the manager's expected wealth of compensation is fixed

The manager's wealth is composed of cash salary, ownership shares, and earnings-based bonus compensation after the project is initiated. To robustly address our results, we fix the expected managerial wealth, $M^L(P)$, to be \$1.2 and a cash salary, m_0, to be \$0.04 in order to investigate the effects from the combination of ownership shares and earnings-based bonuses on the manager's optimal investment triggers, optimal coupon payments, optimal debt ratios and credit spreads in Fig. 9.

When the expected managerial wealth is fixed, the higher the earnings-based bonus is, the lower the ownership share will be if the cash salary is unchanged. In the following, we would explain the results in Fig. 9 by directly using the numerical results in the last two subsections. Panel A of Fig. 9 shows that as we increase earnings-based bonus compensation, the manager's investment trigger is affected by two similar effects. Increased earnings-based bonus compensation induces the manager to defer an investment with a positive coupon payment, while decreased ownership shares also provide the manager with a similar incentive for investment, thereby leading to the upward-sloping curve as the earnings-based bonus increases and ownership share decreases. Panel B shows that optimal coupon payments are downward-sloping as the earnings-based bonus increases and ownership share decreases. This is because the effect of earnings-based bonus compensation dominates that of ownership shares. Finally, Panels C and D illustrate that optimal debt ratios and credit spreads are also downward-sloping as the earnings-based bonus increases and ownership share decreases. In these two cases, the increased earnings-based bonuses and decreased ownership shares both have negative impacts on optimal debt ratios and credit spreads, thereby leading to decreasing optimal debt ratios and credit spreads.

4. Conclusions

An earnings-based bonus and ownership shares are both performance-based compensation and are usually used to align a manager's incentive with the shareholders. However, there are few studies clarify whether these two types of compensation essentially offer the same incentives to managers. This paper employs a real-options framework developed by Mauer and Sarkar (2005) and Andrikopoulos (2009) to investigate the manager's optimal investment and financing decisions where the manager is compensated with a cash salary, ownership shares and an earnings-based bonus.

We first examine the individual effects of ownership shares and earnings-based bonus compensation and have the following findings: (1) the manager's investment triggers are reduced by an increase in either ownership shares or earnings-based bonus compensation, showing that ownership shares and earnings-based bonus compensation both provide incentives for managers to accelerate investment; (2) the manager has no incentive to use debt financing when she is compensated with only cash and earnings-based bonus compensation, but has an opposite incentive when she is compensated with only cash and ownership shares; and (3) the agency costs in both cases display a U-shaped curve as ownership shares or earnings-based bonus compensation increases.

When the manager is compensated with cash salary, ownership shares and earnings-based bonus compensation, the manager's investment and financing incentives interact with each other, thereby leading to some interesting results as follows. First, the manager tends to defer investment and then accelerate investment as the earnings-based bonus increases, whereas the manager only tends to accelerate investment when she holds more ownership shares. Second, the optimal coupon payments decrease to zero as earnings-based bonus compensation increases, but increase and then decrease when the manager holds more ownership shares. Third, the relationship between agency costs and earnings-based bonus compensation is increasing, then decreasing, and increasing again, whereas the relationship between agency costs and ownership shares display a U-shaped curve (Duru et al., 2005). Finally, firm leverages and credit spreads of debt both decrease when the manager is compensated with a greater earnings-based bonus (Duru et al., 2005), but they both increase when the manager is compensated with more ownership shares (Chemmanur et al., 2010; Ortiz-Molina, 2006). Stock-based ownership shares and earnings-based bonuses indeed have some different and even opposite impacts on a manager's optimal investment and financing decisions when she is compensated with cash salary, ownership shares and an earnings-based bonus.

In addition, our paper contributes to the literature by providing some implications. First, we extend the discussion on the relation between managerial compensation and capital structure by incorporating the firm's investment timing decision and earnings-based bonus compensation. Second, our numerical results clearly show that ownership shares and earnings-based bonus have different impacts on agency conflicts and capital structure, thereby demonstrating that the composition of managerial compensation does play a prominent role in a firm's optimal capital structure. Finally,

[11] We thank the referee for pointing out this fact.

we particularly demonstrate that the use of earnings-based bonus compensation is a disincentive to issuing debt, which may be an explanation why debt ratios are often lower in practice. Moreover, these implications should yield some new insights into the ongoing debate on optimal CEO (managerial) compensation, and the regulation development of labor (employment) market.

This research only considers a cash salary, ownership shares, and earnings-based bonus compensation, while ignoring executive stock-options compensation. The natural step to extend the paper is to include executive stock-options and re-examine the relevant issues (e.g., Duan and Wei, 2005; Tang, 2012). In addition, we analyze a firm's investment decision to enter a new market, and it is interesting to investigate the effect of earnings-based bonus compensation on a firm's growth or expansion decision (e.g., Mauer and Ott, 2000; Kanagaretnam and Sarkar, 2011).

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