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Managerial innovation incentives, management buyouts, and shareholders' intolerance of failure

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ABSTRACT

This study demonstrates that, apart from managerial agency problem, shareholders' intolerance of failure also deteriorates managerial innovation incentives in public firms. Furthermore, management buyouts improve the innovation intensity, even if managers gain no excess value from the buyouts in collaboration with private equity firms. The study provides insights into the interrelation between firms' innovation, corporate governance, and dividend policy. It presents a rationale behind empirical evidence of a positive relationship between management buyouts and innovation intensity. It provides empirical implications on firms' characteristics that facilitate management buyouts and the return and risk structure of private equity firms.

1. Introduction

Management buyouts (MBOs) of public firms have thrived as a method of corporate restructuring. The corporate finance theory demonstrates that MBOs can increase firm value by realigning managers' interests with those of shareholders, improving operating efficiency, increasing tax shields, and prompting close monitoring by large outside shareholders.[1] Existing studies on leveraged buyouts have accumulated empirical evidence that supports these theoretical predictions.[2] Furthermore, several studies on corporate finance and management present empirical evidence that post-MBO firms increase investments in innovation, such as new product developments, technological inventions, patenting activity, R&D size and capabilities, and new business creation.[3]

[1] Shleifer and Vishny (1987) discuss the potential factors of MBOs that create excess value. Bayar (2011) provides a comprehensive survey of theoretical and empirical studies on MBOs.

[2] Nikoskelainen and Wright (2007), Renneboog et al. (2007), and Wilson et al. (2012) examine the impact of going-private transactions on firms' equity returns and operating performance using data of UK public firms. Renneboog et al. (2007) also summarize previous studies by presenting empirical evidence on the US and UK firms' equity returns.

[3] See Wright et al. (1996), Zahra (1995) and Lerner et al. (2011).

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This study provides a rationale behind the empirical evidence of a positive relationship between MBOs and innovation intensity by examining managerial innovation incentives in public firms and the impact of MBOs in collaboration with private equity firms on managerial innovation incentives. A theoretical model is developed based on the studies of Fluck (1998) and Myers (2000).[4] In the model, a self-interested manager of a public firm can decide whether to stay public or go private before he chooses a level of innovation intensity. The expected values of a project and the probability of innovation failure increase with innovation intensity.

When the firm stays public, managerial choice of the innovation intensity is subject to shareholders' intolerance of innovation failure, which arises from the fact that two types of investors, sophisticated and unsophisticated investors, display their different perceptions of firm value when an innovation realizes its outcome. Their intolerance of failure poses excessive dismissal risk to the manager in the event of innovation failure. It dissuades him to reduce a dividend and share the loss of the failure with shareholders, particularly when the manager can gain large value of future appropriation from strong managerial entrenchment. The model demonstrates that the shareholders' intolerance of failure exhibits harmful effects when unsophisticated investors coexist with sophisticated investors and this causes further deterioration of managerial innovation incentives in public firms, apart from the agency problem between shareholders and managers. It also demonstrates that managerial choice of innovation intensity is interrelated with corporate governance stringency against managerial entrenchment and the dividend policy in the event of innovation failure.

When the firm goes private, the manager can choose the innovation intensity without being subject to the dismissal risk posed by the shareholders' intolerance of failure. The model demonstrates that MBOs improve the innovation intensity, even if the manager gains no excess value from the buyout in collaboration with a private equity firm. However, the manager fails to attain the optimal innovation intensity that maximizes the firm's expected present value, net of the managerial efforts, because the agency problem remains in the private firm.

This study contributes to four topics of corporate finance studies: managerial innovation incentives, corporate governance, dividend policy, and public-to-private ownership restructuring. A strand of the study examines the impact of corporate governance on innovation incentives in public firms and suggests that public firms' innovation incentives can be improved by nurturing managerial entrenchment that mitigates the investors' intolerance of failure.[5] This study presents a consistent result that as corporate governance becomes stringent, managerial innovation intensity diminishes for a given dividend policy, which is also supported by empirical evidence.[6] It also demonstrates the condition under which shareholders' intolerance of innovation failure poses potential risk to hinder managerial innovation incentives and how it poses this risk.

This study shows that a firm exhibits identical innovation intensity under corporate governance with different stringency against managerial entrenchment because it chooses a different dividend policy. This result provides an empirical implication on the interrelation between corporate governance stringency and the sensitivity of dividends to cash flow changes in the event of innovation failure.

Managerial motivation for undertaking MBOs of public firms and its impact on managerial innovation incentives to enhance firm value have not been explored. To the best of the author's knowledge, two outstanding studies have been conducted to examine the issues.[7] The present study extends this literature by highlighting different managerial motivations for going private to those emphasized in the previous studies. It suggests that the manager who has an opportunity to innovate a project is induced to undertake MBOs by circumventing excessive dismissal risk that arises from shareholders' intolerance of failure. It also provides empirical implications regarding firms' characteristics that facilitate MBOs of public firms and the return and risk structure of private equity firms.

This paper proceeds as follows. Section 2 describes the model and assumptions. Section 3 derives the managerial appropriation of operating cash flows in a public firm. It also examines managerial innovation intensity and the dividend policy. Section 4 considers a going-private transaction in collaboration with a private equity firm and examines managerial innovation intensity in a post-MBO firm. Section 5 concludes the paper.

[4] These studies examine the feasibility of equity financing by self-interested managers and dividend policy under the condition that the firm's cash flows are unverifiable.

[5] Holmstrom (1989) and Manso (2011) show that fostering managerial innovation incentives requires that managerial compensation contracts display substantial tolerance of innovation failure in their principal-agent models. Aghion et al. (2013) demonstrate that when a competent manager is exposed to the risk of being dismissed because of poor performance caused by a random shock, large shareholders' monitoring can insulate him from unfortunate dismissal and this improves his innovation incentives. Ferreira et al. (2014) examine managerial incentives to search for innovative projects under public and private ownership and show that public firms' intolerance of failure diminishes the innovation incentive. Sapra et al. (2014) demonstrate a U-shape relationship between managerial innovation intensity and takeover costs by examining a self-interested manager's investment decisions on innovation in the presence of a takeover threat.

[6] See Danielson and Karpoff (2006), Stráska and Waller (2010), and Becker-Blease (2011).

[7] Elitzur et al. (1998) demonstrate that managers with substantial equity shares are motivated to undertake an MBO by simultaneously diversifying unsystematic risk of the manager's shares and retaining ownership control. Boot et al. (2008) demonstrate that the manager is motivated to go private by the uncertainty on shareholders' interference in the managerial investment decision, which arises from the market liquidity of public firms. These studies also derive the conditions under which MBOs improve the managerial incentives to increase operating cash flows and to search for innovative projects.

2. The model

2.1. Model setting

A model is developed based on the studies by Fluck (1998) and Myers (2000). It is a discrete and infinite time model. The initial date is set as $t = 0$. It is assumed that all economic agents are risk-neutral and a risk-free interest rate r is constant over time.

There is a public firm with dispersed shareholders at $t = 0$. The firm has existing assets and an investment project. The existing assets perpetually generate constant cash flows a. The investment project is undertaken with investment costs I at $t = 0$ and generates perpetual cash flows from $t = 1$. The firm's operating decisions are delegated to an incumbent manager. The manager is a self-interested agent who acts to maximize his interest. He also finds an opportunity to innovate the project at $t = 1$ and undertakes the innovation. If the innovation succeeds, it increases the cash flows that the project generates from $t = 2$ onwards. However, if the innovation fails, it decreases the cash flows.[8]

The cash flows generated by the firm are assumed to be non-verifiable in the sense that it is impossible for shareholders to verify their existence to legal third parties. This non-verifiability creates the opportunity for the self-interested manager to appropriate the cash flows as private benefits. However, shareholders can exert their property right derived from equity ownership. They can decide to dismiss their manager by a costly collective action at any time. The dismissal threat limits managerial appropriation and induces the manager to pay dividends to the shareholders to retain his management position.

2.2. Investment project and innovation

The firm undertakes an investment project at $t = 0$. At $t = 0$, the firm's manager and the financial market expect that the project perpetually generates cash flows c from $t = 1$. The project requires investment costs I. It is assumed that the NPV of the project is non-negative, $\frac{c}{r} - I \geq 0$. The manager can issue new equity and debt in the financial market to finance the investment costs.

After the project generates cash flows c at $t = 1$, the manager finds an opportunity to innovate the project. The innovation increases the cash flows of the project from $t = 2$ if it succeeds, and decreases the cash flows otherwise. The amount of cash flows generated by the innovation and the probabilities of its success and failure depend on the innovation intensity $i \in (0, \infty)$ that the manager chooses.

The project perpetually generates cash flows $s(i)$ from $t = 2$ if the innovation succeeds, and cash flows $f(i)$ otherwise, where $f(i) < c < s(i)$ for any $i \in (0, \infty)$. The cash flow function $s(i)$ satisfies the conditions: $s'(i) > 0$, $s''(i) > 0$, and $s(0) = c$. The cash flow function $f(i)$ satisfies the conditions: $f'(i) < 0$ and $\lim_{i\to\infty} f(i) = 0$. The innovation succeeds with probability $p(i)$ and fails with probability $1 - p(i)$. The probability of success satisfies the conditions: $p'(i) < 0$, $p(0) = 1$, and $\lim_{i\to\infty} p(i) = 0$. The innovation requires the manager to bear costly efforts $e(i)$, which are non-pecuniary. The effort function satisfies the following conditions: $e'(i) > 0$, $e''(i) > 0$, and $e(0) = 0$. It is assumed that the net expected value of the innovative project $\frac{p(i)s(i)+(1-p(i))f(i)}{r} - e(i)$ is strictly concave in i.

The above assumptions regarding characteristics of the project mean that managerial innovation has the potential to increase future cash flows, but may decrease them if it fails. If the innovation succeeds, the amount of cash flows increases with the innovation intensity chosen by the manager. However, the probability that the innovation succeeds decreases when the innovation intensity increases. This project's characterization is consistent with that of Rajan (2012). It implies that managerial innovation further differentiates a project from the standard in terms of product quality, design, business management, and so on. When the manager differentiates a project from the standard by enhancing the innovation intensity, the project can generate large cash flows if the innovation succeeds. However, the probability of success decreases with the innovation intensity because highly differentiated projects tend to be exposed to higher risk of failure in terms of attracting consumers and generating sufficient demand.

2.3. Investors

There are two types of investors: sophisticated investors and unsophisticated investors. The difference between the two is the ability to recognize change in the cash flows that the firm generates. Sophisticated investors can detect a change and update their expectation of the value of the firm, whereas unsophisticated investors cannot do so.

At $t = 0$, both investors have identical expectations that existing assets generate cash flows a and that a new project generates c from $t = 1$ onwards. At $t = 1$, they cannot perceive the nature of the innovation undertaken by their manager or its impact on the project's cash flows. Therefore, their expectations of the firm value remain unchanged at $t = 1$. When the firm generates cash flows at $t = 2$, the sophisticated investors update their expectation because they detect the change in the cash flows. In contrast, the unsophisticated investors continue to perceive that the firm generates $a + c$.

[8] Unsuccessful innovation can be abandoned with restoration costs to recover the original level of cash flows. The assumption of the costly restoration of innovation failure does not change the qualitative characteristic of the results in this model. Therefore, the study excludes the assumption to simplify the derivations of the managerial dividend reduction policy and the innovation intensity.

The type of investors is private information. Therefore, the manager fails to identify whether each of the firm's shareholders is sophisticated or unsophisticated. It is assumed that the manager forms a belief regarding the ratio of the number of shares held by sophisticated investors to that held by sophisticated and unsophisticated investors. This ratio is denoted by $\sigma \in [0, 1]$. The manager's belief on σ is expressed as the distribution function: $\Phi(\sigma) = \int_0^{\sigma} \phi(y)dy$, where $\phi(y)$ represents a density function.

2.4. Agency conflicts between managers and shareholders and corporate governance in a public firm

The model assumes that a self-interested manager seeks to appropriate firm's cash flows as private benefits and maximizes the value of this appropriation. The opportunity for the appropriation derives from non-verifiability of the firm's cash flows and the costs shareholders must incur to dismiss their manager by collectively exerting the voting rights of equity ownership.

Shareholders fail to prevent their manager from appropriating firm's cash flows. However, they are able to dismiss their manager at any time, and decide to dismiss their manager if their received dividend falls short of their expectation. Although it costs them to collectively dismiss their manager, this dismissal threat induces their manager to pay sufficient dividends to retain his managerial position. The model assumes that the shareholders' costs to dismiss their manager is a fraction $1-g$ of future cash flows, where $g \in (0, \frac{1}{1+r})$. The model requires $g < \frac{1}{1+r}$ to prevent the manager from appropriating all cash flows and intentionally being dismissed at $t = 0$.

The parameter g represents the stringency of corporate governance in public firms. High values of g imply low costs of managerial dismissal and weak managerial entrenchment. When g increases, shareholders can salvage a large amount of firm value by dismissing the manager. Therefore, the manager is forced to decrease the appropriation of the firm's cash flows to retain his position.

3. Managerial decision on innovation in a public firm

This section begins by considering the managerial dividend payout and appropriation of the firm's cash flows at $t = 0$. Section 3.2 examines the investment and financing decisions of a new project. Section 3.3 derives the managerial optimal dividend payout and appropriation from $t = 1$ onwards. Section 3.4 formulates the expected present value of the managerial appropriation at $t = 1$ and examines the optimal innovation intensity for the manager to maximize the value of the managerial appropriation. Section 3.5 numerically illustrates the interrelation between managerial innovation intensity, corporate governance, and dividend policy.

3.1. Dividend payout and managerial appropriation at $t = 0$

After the existing assets have generated cash flows a at $t = 0$, the manager pays a dividend to the shareholders. The shareholders decide whether to dismiss their manager or to continue the delegation after receiving the dividend. The manager needs to set the dividend that induces the shareholders to continue the delegation. The sophisticated and unsophisticated shareholders expect that their equity value is $\frac{ga}{r}$ if they dismiss the manager at $t = 0$, because their perceptions of the future cash flows of the firm are identical. Therefore, they are induced to continue the delegation by the following condition:

$$\frac{1}{1+r}\left(E_0[div_1] + \frac{ga}{r}\right) \geq \frac{ga}{r}, \tag{1}$$

$$E_0[div_1] \geq ga, \tag{2}$$

where $E_0[div_1]$ represents the conditional expected total dividend at $t = 0$ that the shareholders receive at $t = 1$. The left-hand side of Eq. (1) represents the expected present value of the equity for the shareholders if they continue the delegation until $t = 1$. The right-hand side represents the present value of the equity for the shareholders if they dismiss the manager at $t = 0$. Eq. (2) indicates that the manager can retain his position at $t = 0$ if the shareholders expect to receive the dividend that exceeds ga at $t = 1$. Therefore, he needs to pay the dividend at $t = 0$ to induce the shareholders to believe that they will receive at least ga at $t = 1$.

The model follows the assumption of Myers (2000) on the connection between the current dividend and the expected future dividend in order to construct an equilibrium dividend payout. It is assumed that shareholders expect to receive the same dividend at the next future date $t + 1$ as that paid out at the current date t. Under this assumption, the manager pays dividend ga to shareholders at $t = 0$ to retain his position. The dividend ga represents the minimum dividend for the manager to avoid dismissal because it satisfies Eq. (2) with equality. As a result, it maximizes the appropriation of the firm's cash flows. The following lemma demonstrates the managerial optimal dividend payout and appropriation under the shareholders' strategy of managerial dismissal.

Lemma 1. *Assume that shareholders expect that the value of the equity is $\frac{ga}{r}$ if they dismiss the manager. There exists an equilibrium where the manager pays a dividend ga and the shareholders continue the delegation at $t = 0$. As a result, the manager appropriates the rest of the cash flows $(1 - g)a$.*

Proof. See Appendix.

3.2. Investment and financing of a new project

The manager can issue both equity and debt to finance the investment. All investors and the manger expect the investment to perpetually generate cash flows c from $t = 1$. The shareholders are entitled to claim a part of the net present value of the investment $g(\frac{c}{r} - I)$ because they can undertake the investment by themselves by dismissing the manager at $t = 0$. Therefore, the manager can raise $\frac{g(c-b)}{r} - g(\frac{c}{r} - I)$ with an equity issuance if he raises $\frac{b}{r}$ with a debt issuance, where $b \in [0, c]$ represents perpetual coupon payments of a console debt from $t = 1$. This implies that the manager is required to co-invest if $I - (\frac{g(c-b)}{r} - g(\frac{c}{r} - I)) - \frac{b}{r} > 0$.

The manager needs to co-invest $(1-g)I$ if $b = 0$. Therefore, the co-investment needs to be financed by a debt issuance under the assumption that the manager has no wealth. The debt financing forces the manager to reduce future appropriation of the cash flows by $(1-g)b$ from $t = 1$ onwards, because the debt payments must be fulfilled to avoid default. Thus, the manager can raise the co-investment with the debt financing by committing to reduce future appropriation. The manager also can co-invest his appropriation$(1-g)a$, the dividend of the firm's shares m_0ga, and the net present value of the investment for the shareholders $m_0g(\frac{c}{r} - I)$ at $t = 0$, where m_0 represents the ratio of the manager's equity stake. If $(1-g)a + m_0ga + m_0g(\frac{c}{r} - I) \geq (1-g)I$, the manager can finance his co-investment without debt financing. Otherwise, the manager needs to issue the debt. The following condition demonstrates the level of the debt coupon that the manager needs to pay to finance his co-investment.

$$I - \left(\frac{g(c-b)}{r} - g\left(\frac{c}{r} - I\right)\right) - \frac{b}{r} - \left((1-g)a + m_0ga + m_0g\left(\frac{c}{r} - I\right)\right) = 0, \tag{3}$$

$$b = \begin{cases} r(I-a) - \frac{m_0g}{1-g}(c - r(I-a)) & \text{if} \quad a < I - \frac{m_0g}{1-g+m_0g}\frac{c}{r}, \\ 0 & \text{otherwise}. \end{cases} \tag{4}$$

The manager increases his appropriation by $(1-g)(c-b)$ from $t = 1$ onwards if his co-investment is financed by a console debt that pays coupon payments b. Therefore, the net present value of the managerial appropriation for the investment is expressed as

$$\frac{(1-g)(c-b)}{r} - \left(I - \left(\frac{g(c-b)}{r} - g\left(\frac{c}{r} - I\right)\right) - \frac{b}{r}\right) = (1-g)\left(\frac{c}{r} - I\right). \tag{5}$$

Eq. (5) indicates that the managerial investment decision is consistent with the NPV rule.

When the investment is undertaken at $t = 0$, all investors expect that the firm's cash flows increase to $a + c$ from $t = 1$ onwards. Therefore, they perceive that the value of the equity becomes $\frac{g(a+c-b)}{r}$ if they dismiss the manager at $t = 1$. The following lemma demonstrates that the manager pays a total dividend $g(a + c - b)$ at $t = 1$ to induce shareholders to continue the delegation.

Lemma 2. *Assume that shareholders expect that the value of the equity is $\frac{g(a+c-b)}{r}$ if they dismiss the manager at $t = 1$. There exists an equilibrium where the manager pays a dividend $g(a + c - b)$ and the shareholders continue the delegation at $t = 1$. As a result, the manager appropriates the rest of the cash flows $(1-g)(a + c - b)$.*

Proof. See Appendix.

3.3. Dividend payout and managerial appropriation after innovation

The manager discovers an innovation opportunity after the shareholders decide to continue the delegation at $t = 1$. He chooses the innovation intensity i. The cash flows increase to $a + s(i)$ from $t = 2$ onwards if the innovation succeeds, and decreases to $a + f(i)$ otherwise. The sophisticated shareholders detect the cash flows' change and update their expectation of the value of the equity. On the other hand, the unsophisticated shareholders fail to do so, and keep the original expectation from $t = 0$.

If the innovation succeeds, the sophisticated shareholders detect that the cash flows increase from $a + c$ to $a + s(i)$, and update their expectation of the equity value to $\frac{g(a+s(i)-b)}{r}$ at $t = 2$. This means that the sophisticated shareholders continue the delegation at $t = 2$ if they expect to receive a dividend of $g(a + s(i) - b)$ at $t = 3$ as follows:

$$\frac{1}{1+r}\left(E_2[div_3] + \frac{g(a+s(i)-b)}{r}\right) \geq \frac{g(a+s(i)-b)}{r}, \tag{6}$$

$$E_2[div_3] \geq g(a + s(i) - b), \tag{7}$$

where $E_2[div_3]$ represents the conditional expected dividend at $t = 2$ that the shareholders receive at $t = 3$. The manager needs to pay a dividend of $g(a + s(i) - b)$ at $t = 2$ to induce the sophisticated shareholders to continue the delegation.

Even if sophisticated shareholders are the minority, the manager is forced to increase the dividend to $g(a + s(i) - b)$ to retain his position. If unsophisticated shareholders are the majority, the manager might be tempted to pay $g(a + c - b)$ as a dividend and appropriate the rest of the cash flows. However, the manager fails to retain his position by paying $g(a + c - b)$ as a dividend at $t = 2$, because the dividend induces the sophisticated investors to take over the firm with a share acquisition from the unsophisticated shareholders. The sophisticated investors detect that the equity value becomes $\frac{g(a+s(i)-b)}{r}$ with the managerial dismissal although the unsophisticated shareholders perceive that it becomes $\frac{g(a+c-b)}{r}$. Therefore, the sophisticated investors gain the excess value created by the arbitrage opportunity, as long as they can acquire the firm's shares at a discount. This implies that the sophisticated investors are induced to take over the firm if the manager pays a dividend below $g(a + s(i) - b)$ at $t = 2$. This takeover threat forces the manager to pay $g(a + s(i) - b)$ if the innovation succeeds, irrespective of whether or not the sophisticated shareholders are the majority. The following lemma demonstrates an equilibrium dividend policy and managerial appropriation in the event of innovation success.

Lemma 3. *Assume that if the manager is dismissed from $t = 2$ onwards, the sophisticated shareholders expect that the equity value of the firm is $\frac{g(a+s(i)-b)}{r}$ and the unsophisticated shareholders expect that it is $\frac{g(a+c-b)}{r}$. There exists an equilibrium where the shareholders continue the delegation as long as the manager pays a dividend $g(a + s(i) - b)$ from $t = 2$ onwards. As a result, the manager appropriates the rest of the cash flows $(1 - g)(a + s(i) - b)$ from $t = 2$ onwards.*

Proof. See Appendix.

If the innovation fails, the firm's cash flows decrease to $a + f(i)$ from $t = 2$ onwards. Given that debt payments are fulfilled, the sophisticated shareholders update their expectation of the equity value to $\frac{g(a+f(i)-b)}{r}$ if they dismiss the manager, detecting the decrease in the cash flows. Therefore, the sophisticated shareholders continue the delegation at $t = 2$ if they expect to receive a dividend of $g(a + f(i) - b)$ at $t = 3$ as follows:

$$\frac{1}{1+r}\left(E_2[div_3] + \frac{g(a+f(i)-b)}{r}\right) \geq \frac{g(a+f(i)-b)}{r}, \tag{8}$$

$$E_2[div_3] \geq g(a + f(i) - b). \tag{9}$$

On the other hand, the unsophisticated shareholders perceive that the equity value becomes $\frac{g(a+c-b)}{r}$ if they dismiss their manager. Therefore, the unsophisticated shareholders dismiss the manager if they expect to receive a dividend below $g(a+c-b)$ as follows:

$$\frac{1}{1+r}\left(E_2[div_3] + \frac{g(a+c-b)}{r}\right) \geq \frac{g(a+c-b)}{r}, \tag{10}$$

$$E_2[div_3] \geq g(a + c - b) > g(a + f(i) - b). \tag{11}$$

Eqs. (9) and (11) imply that the manager retains his position with all shareholders' unanimous agreement only if he pays a dividend of $g(a + c - b)$. Therefore, the manager appropriates the rest of the cash flows $(1 - g)(a + f(i) - b) - g(c - f(i))$ from $t = 2$ onwards.

The unsophisticated shareholders are induced to dismiss their manager by their misperception if the manager reduces the dividend below $g(a + c - b)$, while the sophisticated shareholders accept the dividend reduction until $g(a - f(i) - b)$. It means that the manager can retain his position with a dividend reduction if the shareholding ratio of the sophisticated shareholders and the manager accounts for more than 50% at $t = 2$. Thus, even if he decreases the dividend to $g(a + f(i) - b)$, the manager retains his position under the condition that $\frac{\sigma+m_1}{1+m_1} \geq 0.5$, where $m_1 = \frac{m_0 a}{a+c-b-m_0 a}$.

If the manager knew the actual value of σ at $t = 2$, he would reduce the dividend to $g(a + f(i) - b)$ when $\sigma \geq 0.5(1 - m_1)$. However, because the actual value of σ is unknown, the manager is always exposed to the dismissal risk by reducing the dividend to $g(a+f(i)-b)$. He is dismissed with the dividend reduction when the actual value of σ exists in $0 < \sigma < 0.5(1-m_1)$. The probability with which the manager is dismissed by reducing a dividend to $g(a + c - b - \delta)$ is expressed as

$$F(\delta) = \begin{cases} 0 & \text{if } \delta \leq 0, \\ \Phi(0.5(1 - m_1)) & \text{if } 0 < \delta \leq c - f(i), \\ 1 & \text{if } \delta > c - f(i). \end{cases} \tag{12}$$

The manager can increase his present appropriation by decreasing the dividend below $g(a + c - b)$ at $t = 2$, while he loses the value of his future appropriation with probability $F(\delta)$. Faced with this trade-off, the manager chooses the optimal level of the dividend reduction that maximizes the expected present value of the appropriation at $t = 2$. The maximization problem is expressed as

$$\max_{\delta} (1-g)(a+f(i)-b) - g(c-f(i)-\delta) + (1-F(\delta))\frac{(1-g)(a+f(i)-b) - g(c-f(i)-\delta)}{r} + \frac{m_1}{1+m_1}\left[g(a+c-b-\delta) + (1-F(\delta))\frac{g(a+c-b-\delta)}{r} + F(\delta)\frac{g(a+f(i)-b)}{r}\right]. \quad (13)$$

Three types of the optimal dividend reduction policy δ^* derive from this maximization problem, considering the functional form of $F(\delta)$. The following lemma demonstrates that δ^* depends on the innovation intensity and the model parameters.

Lemma 4. *Assume that the manager chooses innovation intensity i at $t = 1$. The optimal dividend reduction policy δ^* is characterized as follows.*

If $\Phi(0.5(1-m_1)) \leq 1 - \frac{r}{1+m_1}\frac{g}{1-g}$, δ^* is expressed as

$$\delta^* = \begin{cases} 0 & \text{if } i \leq i_0, \\ c - f(i) & \text{otherwise}, \end{cases} \quad (14)$$

where $i_0 = \left\{ i \middle| \frac{1+r}{1+m_1}\frac{g(c-f(i))}{(1-g)(a+f(i)-b)} = \Phi((0.5(1-m_1)) \right\}$.

If $\Phi(0.5(1-m_1)) > 1 - \frac{r}{1+m_1}\frac{g}{1-g}$, δ^* is expressed as

$$\delta^* = \begin{cases} 0 & \text{if } \quad i \leq i_1, \\ a + c - b & \text{otherwise}, \end{cases} \quad (15)$$

where $i_1 = \left\{ i \middle| \frac{1+r}{1+m_1}\frac{g(c-f(i))}{(1-g)(a+f(i)-b)} = 1 - \frac{r}{1+m_1}\frac{g}{1-g} \right\}$.

Proof. See Appendix.

The following proposition describes the sophisticated and unsophisticated shareholders' dismissal decisions and equilibrium outcomes under the optimal dividend reduction policy.

Proposition 1. *Assume that if the manager is dismissed from $t = 2$ onwards, the sophisticated shareholders expect that the equity value of the firm is $\frac{g(a+f(i)-b)}{r}$, and the unsophisticated shareholders expect that it is $\frac{g(a+c-b)}{r}$. Three kinds of equilibrium emerge if the innovation fails, depending on the innovation intensity i chosen by the manager at $t = 1$.*

(i) *The manager pays a dividend $g(a+c-b)$ from $t = 2$ onwards. The sophisticated and the unsophisticated shareholders continue the delegation. The manager appropriates the rest of the cash flows $(1-g)(a+f(i)-b) - g(c-f(i))$. These strategies emerge as an equilibrium outcome if $i \leq min[i_0, i_1]$.*
(ii) *The manager pays a dividend $g(a + f(i) - b)$ from $t = 2$ onwards and loses his position with $\Phi(0.5(1-m_1))$. The sophisticated shareholders decide to continue the delegation, whereas the unsophisticated shareholders decide to dismiss the manager. The manager is dismissed at $t = 2$ if $\sigma < 0.5(1-m_1)$. Otherwise, the manager retains his position as long as the dividend $g(a + f(i) - b)$ is paid from $t = 2$ onwards. In the latter case, the manager appropriates the rest of the cash flows $(1-g)(a+f(i)-b)$. These strategies emerge as an equilibrium outcome if $\Phi(0.5(1-m_1)) \leq 1 - \frac{r}{1+m_1}\frac{g}{1-g}$ and $i > i_0$.*
(iii) *The manager pays no dividend and appropriates all cash flows at $t = 2$. The sophisticated and the unsophisticated shareholders dismiss the manager at $t = 2$. These strategies emerge as an equilibrium outcome if $\Phi(0.5(1-m_1)) > 1 - \frac{r}{1+m_1}\frac{g}{1-g}$ and $i > i_1$.*

Proof. See Appendix.

3.4. Managerial choice of innovation intensity

This section examines the impact of sophisticated and unsophisticated investors on managerial innovation incentives. Managerial innovation intensity is separately derived under three assumptions: all investors are unsophisticated, all investors are sophisticated, and sophisticated and unsophisticated investors coexist.

If all investors are unsophisticated, the manager pays $g(a+c-b)$ as a dividend to the shareholders from $t=2$ onwards despite the innovation outcomes. As explained in the previous section, the manager can retain his position with this dividend policy because of the unsophisticated shareholders' misperception. As a result, the manager extracts the entire surplus of the innovation by appropriating $(1-g)(a+s(i)-b)-g(c-s(i))$ if the innovation succeeds, and compensates for the entire loss by decreasing his appropriation to $(1-g)(a+f(i)-b)-g(c-f(i))$ to retain his position if the innovation fails. Therefore, the manager chooses the innovation intensity at $t=1$ to maximize the sum of the expected present value of the managerial appropriation and the value of his equity stake, net of the managerial efforts as follows:

$$\max_i \frac{p(i)[(1-g)(a+s(i)-b)-g(c-s(i))]+(1-p(i))[(1-g)(a+f(i)-b)-g(c-f(i))]}{r}+\frac{m_1}{1+m_1}\frac{g(a+c-b)}{r}-e(i). \tag{16}$$

The managerial innovation intensity satisfies the following first-order condition:

$$\frac{p'(i^*)s(i^*)+p(i^*)s'(i^*)-p'(i^*)f(i^*)+(1-p(i^*))f'(i^*)}{r}-e'(i^*)=0. \tag{17}$$

This demonstrates that if all investors are unsophisticated, the manager chooses the optimal innovation intensity i^* that maximizes the expected present value of the innovation, net of managerial efforts. The result derives from the fact that the manager extracts the entire surplus of the innovation if it succeeds, but compensates for the entire loss by relinquishing some of his appropriation if it fails.

If all investors are sophisticated, the manager pays $g(a+s(i)-b)$ as a dividend to shareholders from $t=2$ onwards in the event of innovation success, and $g(a+f(i)-b)$ in the event of innovation failure. As explained in the previous section, the manager can retain his position with this dividend policy and maximize the appropriation. Therefore, the manager chooses the innovation intensity at $t=1$ as follows:

$$\max_i \frac{p(i)(1-g)(a+s(i)-b)+(1-p(i))(1-g)(a+f(i)-b)}{r}+\frac{m_1}{1+m_1}\frac{p(i)g(a+s(i)-b)+(1-p(i))g(a+f(i)-b)}{r}-e(i). \tag{18}$$

The managerial innovation intensity satisfies the following first-order condition:

$$\begin{aligned}&\frac{p'(i^{**})s(i^{**})+p(i^{**})s'(i^{**})-p'(i^{**})f(i^{**})+(1-p(i^{**}))f'(i^{**})}{r}-e'(i^{**})\\&-\frac{g}{1+m_1}\frac{p'(i^{**})s(i^{**})+p(i^{**})s'(i^{**})-p'(i^{**})f(i^{**})+(1-p(i^{**})f'(i^{**})}{r}=0.\end{aligned} \tag{19}$$

This demonstrates that if all investors are sophisticated, the managerial innovation intensity i^{**} is below the optimal intensity i^*. The result derives from the agency problem that the manager incurs all costs to undertake the innovation, but is forced to share the expected value with shareholders to retain his position.

Next, the managerial choice of the innovation intensity is considered under the assumption that both types of investor exist. The maximization problem for the manager to choose the innovation intensity is expressed as follows:

$$\max_i \quad p(i)\frac{M_2^s(i)}{1+r}+(1-p(i))\frac{M_2^f(i)}{1+r}-e(i), \tag{20}$$

$$M_2^s(i)=(1-g)(a+s(i)-b)+\frac{(1-g)(a+s(i)-b)}{r}+\frac{m_1}{1+m_1}(g(a+s(i)-b)+\frac{g(a+s(i)-b)}{r}), \tag{21}$$

$$\begin{aligned}M_2^f(i)=&(1-g)(a+f(i)-b)-g(c-f(i)-\delta^*)+(1-F(\delta^*))\frac{(1-g)(a+f(i)-b)-g(c-f(i)-\delta^*)}{r}\\&+\frac{m_1}{1+m_1}\left(g(a+c-b-\delta^*)+(1-F(\delta^*))\frac{g(a+c-b-\delta^*)}{r}+F(\delta^*)\frac{g(a+f(i)-b)}{r}\right),\end{aligned} \tag{22}$$

where $M_2^s(i)$ and $M_2^f(i)$ represent the combined values of the managerial appropriation and the equity stake at $t=2$ given the success or failure of the innovation. The combined value in the event of failure depends on the optimal dividend reduction policy δ^* and the probability of dismissal $F(\delta^*)$. The managerial innovation intensity satisfies the following first-order condition:

$$\begin{aligned}
&\frac{p'(i^{pub})s(i^{pub})+p(i^{pub})s'(i^{pub})-p'(i^{pub})f(i^{pub})+(1-p(i^{pub}))f'(i^{pub})}{r}-e'(i^{pub})\\
&-\frac{g}{1+m_1}\frac{p'(i^{pub})s(i^{pub})+p(i^{pub})s'(i^{pub})-p'(i^{pub})f(i^{pub})+(1-p(i^{pub})f'(i^{pub})}{r}\\
&-F(\delta^*)\frac{1-g}{1+r}\frac{(1-p(i^{pub}))f'(i^{pub})-p'(i^{pub})(a+f(i^{pub})-b)}{r}\\
&+1_{\delta^*\neq c-f(i^{pub})}\left[\frac{g}{1+m_1}\left(1-\frac{F(\delta^*)}{1+r}\right)\frac{(1-p(i^{pub}))f'(i^{pub})+p'(i^{pub})(c-f(i^{pub})-\delta^*)}{r}\right]=0,
\end{aligned}\tag{23}$$

where $1_{\delta^*\neq c-f(i^{pub})}$ represents an indicator function. It is equal to 0 if $\delta^*=c-f(i^{pub})$, and 1 otherwise.

The first-order condition has two additional terms when compared with Eq. (19). This indicates that the managerial choice of innovation intensity depends on the dismissal risk posed by the unsophisticated shareholders' intolerance and the dividend reduction in the event of innovation failure. These impacts of the innovation intensity are displayed in the third and fourth lines.

The following proposition 2summarizes the relationship between the optimal dividend reduction policy and the managerial choice of innovation intensity.

Proposition 2.

(i) *If* $\delta^*=0$, $i^{pub}<i^{**}<i^*$.
(ii) *If* $\delta^*=c-f(i^{pub})$ *and* $a+c-b$, $i^{pub}<i^{**}<i^*$ *under the condition that* $(1-p(i^{pub}))f'(i^{pub})-p'(i^{pub})(a+f(i^{pub})-b)\geq 0$.

Proof. See Appendix.

Proposition 2 (i) indicates that if the manager forgoes decreasing a dividend in order to eliminate the dismissal risk posed by the unsophisticated shareholders' intolerance of the innovation failure, the innovation intensity i^{pub} is below i^* and i^{**}. This is why the unsophisticated shareholders' coexistence with sophisticated investors dissuades the manager from sharing the loss with them if the innovation fails and forces him to compensate for the entire loss by relinquishing some of his appropriation, while still needing to share the surplus with them if it succeeds.

Proposition 2 (ii) also indicates that even if the manager decides to decrease a dividend in the event of failure, the innovation intensity i^{pub} can be below i^* and i^{**}. The condition $(1-p(i^{pub}))f'(i^{pub})-p'(i^{pub})(a+f(i^{pub})-b)\geq 0$ is sufficient for this outcome to emerge as the optimal managerial decision. The result derives from the fact that even if the manager shares the losses with the shareholders in the event of failure, the manager is exposed to the dismissal risk posed by the unsophisticated shareholders' intolerance and dismissed with the probability $F(\delta^*)$.

The model demonstrates that if all investors are sophisticated, the manager can reduce the dividend to $g(a+f(i)-b)$ with $\delta^*=c-f(i)$ with no concern about being dismissed. However, this dividend reduction poses a dismissal risk if unsophisticated shareholders coexist with sophisticated shareholders and their shareholding ratio is unknown to the manager. The probability of dismissal is expressed as $F(\delta^*)=\Phi(0.5(1-m_1))$ if $\delta^*=c-f(i)$. Therefore, the managerial innovation incentives are impaired by unsophisticated shareholders' intolerance of failure. If the manager reduces the dividend to 0 with $\delta^*=a+c-b$ in the event of innovation failure, both unsophisticated and sophisticated shareholders dismiss the manager. This means that $F(\delta^*)=1$ if $\delta^*=a+c-b$. Therefore, the dismissal threat impairs the managerial innovation incentives. This outcome also emerges as the optimal managerial decision if the value of managerial appropriation in the event of innovation failure is too small to induce the manager to retain his position.

Proposition 2 indicates that shareholders' intolerance of failure impairs managerial incentives of innovation. This is also consistent with the results of Aghion et al. (2013), Manso (2011), and Ferreira et al. (2014). In addition, the result implies that unsophisticated investors' coexistence with sophisticated investors impairs managerial innovation incentives in a public firm. This model demonstrates that the manager chooses the optimal innovation intensity i^* if all investors are unsophisticated. Thus, unsophisticated shareholders have no negative impact on managerial innovation incentives by their own presence. However, when they coexist with sophisticated shareholders, their intolerance of failure exerts a negative effect on managerial innovation incentives.

3.5. Numerical results of managerial innovation intensity in a public firm

This section demonstrates the interrelation between the managerial innovation intensity i^{pub}, corporate governance stringency g, and the optimal dividend reduction policy δ^* using a numerical illustration. For this purpose, the functions of innovation cash flows, probability of innovation success, managerial efforts, and the density function of the ratio of the number of shares held by sophisticated investors to that by sophisticated and unsophisticated investors are specified as follows: $s(i)=c(1+\gamma i)^2$,

$f(i) = \frac{c}{1+\eta i}$, $p(i) = exp(-\kappa i)$, $e(i) = \frac{i^2}{2}$, and $\phi(y) = \frac{y^{\alpha-1}(1-y)^{\beta-1}}{B(\alpha,\beta)}$, respectively, where $B(\alpha,\beta) = \int_0^1 y^{\alpha-1}(1-y)^{\beta-1}dy$. The basic values of the model parameters are as follows: $a = 3$, $c = 3$, $r = 0.02$, $m_0 = 0$, $I = 50$, $\alpha = 2$, $\beta = 2$, $\gamma = 0.2$, $\eta = 0.1$, and $\kappa = 0.2$.

Fig. 1 depicts the value of managerial appropriation and equity stake in Eq. (20) as a function of the innovation intensity i with respect to six different values of g, which are 0.72, 0.77, 0.82, 0.87, 0.92, and 0.97. These panels display the innovation intensity i^{pub} that maximizes the managerial value in Eq. (20), the optimal innovation intensity i^*, and the innovation intensity i^{**} that maximizes the managerial value under the assumption that all investors are sophisticated. The panels illustrate the result in Proposition 2.

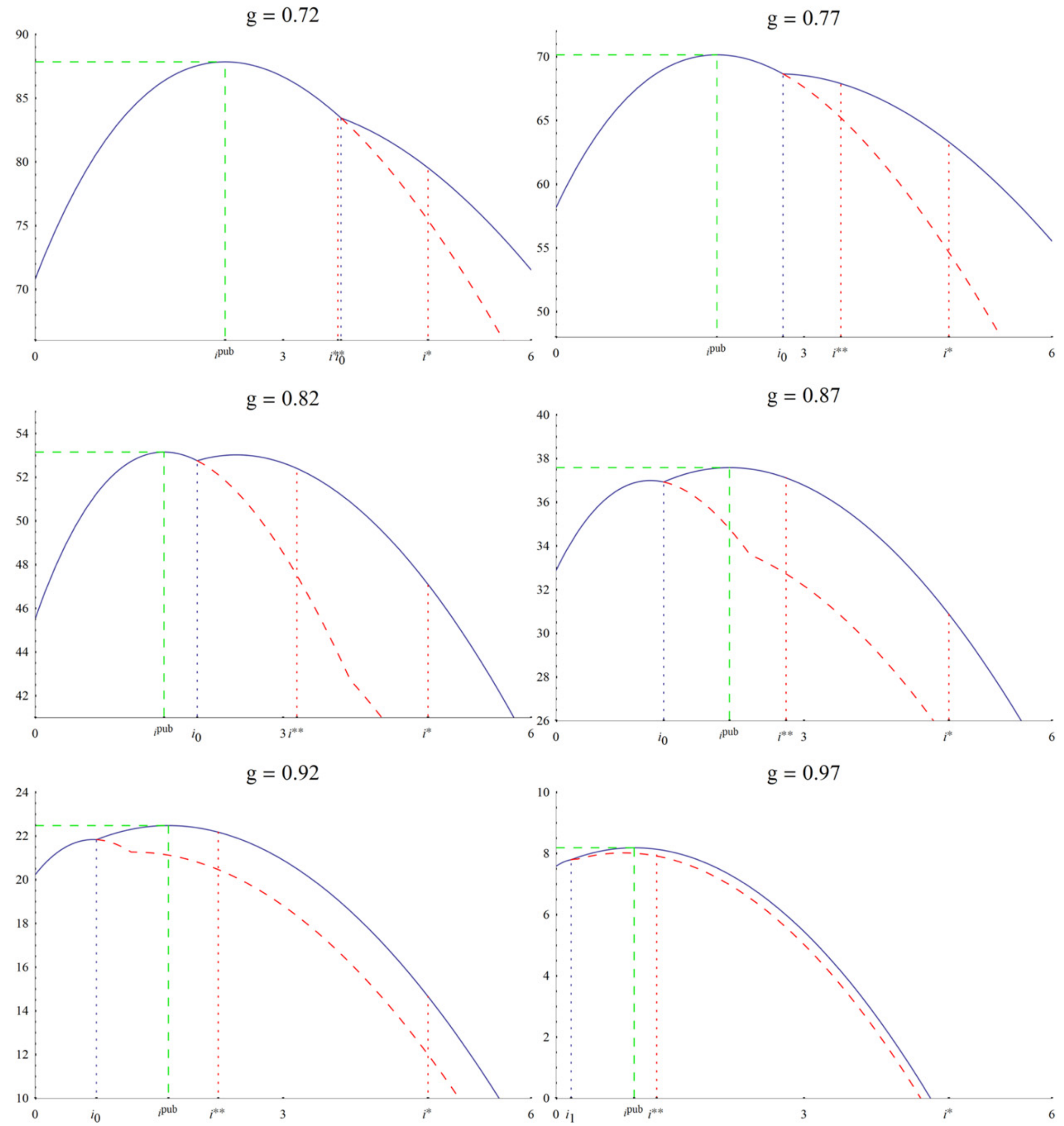

Fig. 1. The value of managerial appropriation and the managerial innovation intensity. The figure illustrates the value of managerial appropriation as a function of the innovation intensity i with respect to different values of the parameter of corporate governance stringency g. The figure also displays the managerial innovation intensity i^{pub} and the optimal innovation intensity i^*.

They also illustrate that the interrelation between i^{pub}, g, and δ^*. The optimal dividend reduction policy δ^* is 0 when $g = 0.72$, 0.77, and 0.82, $c - f(i^{pub})$ when $g = 0.87$ and 0.92, and $a + c - b$ when $g = 0.97$. It means that weak corporate governance induces the manager to forgo decreasing a dividend and to compensate for the loss if the innovation fails.

This occurs because high managerial appropriation enhances the incentive for the manager to retain his position when g decreases. The manager is induced to forgo decreasing a dividend to eliminate the dismissal risk. When g increases, the managerial appropriation decreases and the incentive to retain his position becomes weak. When g exceeds a threshold, the manager is induced to reduce the dividend to $g(a + f(i^{pub}) - b)$ with $\delta^* = c - f(i^{pub})$ and take the dismissal risk in the event of innovation failure. Furthermore, the manager is induced to appropriate all cash flows $a + f(i^{pub}) - b$ by extremely stringent governance if the innovation fails, because the value of managerial appropriation is insufficient to motivate him to retain his position.

The innovation intensity i^{pub} decreases when g increases from 0.72 to 0.82. However, the right panel in the middle displays an increase in i^{pub}. The increase reflects a change in δ^* from 0 to $c - f(i^{pub})$ when g increases from 0.82 to 0.87. After the change occurs, the innovation intensity begins to decrease again when g increases from 0.87 to 0.97. The manager can share the loss of the innovation failure with shareholders by reducing the dividend to $g(a + f(i^{pub}) - b)$ with $\delta^* = c - f(i^{pub})$. This enhances the managerial innovation incentives. However, the manager expects to be exposed to the dismissal risk with the probability $F(c - f(i^{pub}))$ if he reduces the dividend. Therefore, the innovation intensity in the panels are smaller than i^{**}.

Fig. 2 depicts the innovation intensity i^{pub} as a function of the parameter of corporate governance stringency g. The figure demonstrates the interrelation between managerial innovation intensity, corporate governance stringency, and the dividend reduction that occurs from the innovation failure. As demonstrated in Fig. 1, these panels show the negative impact of corporate

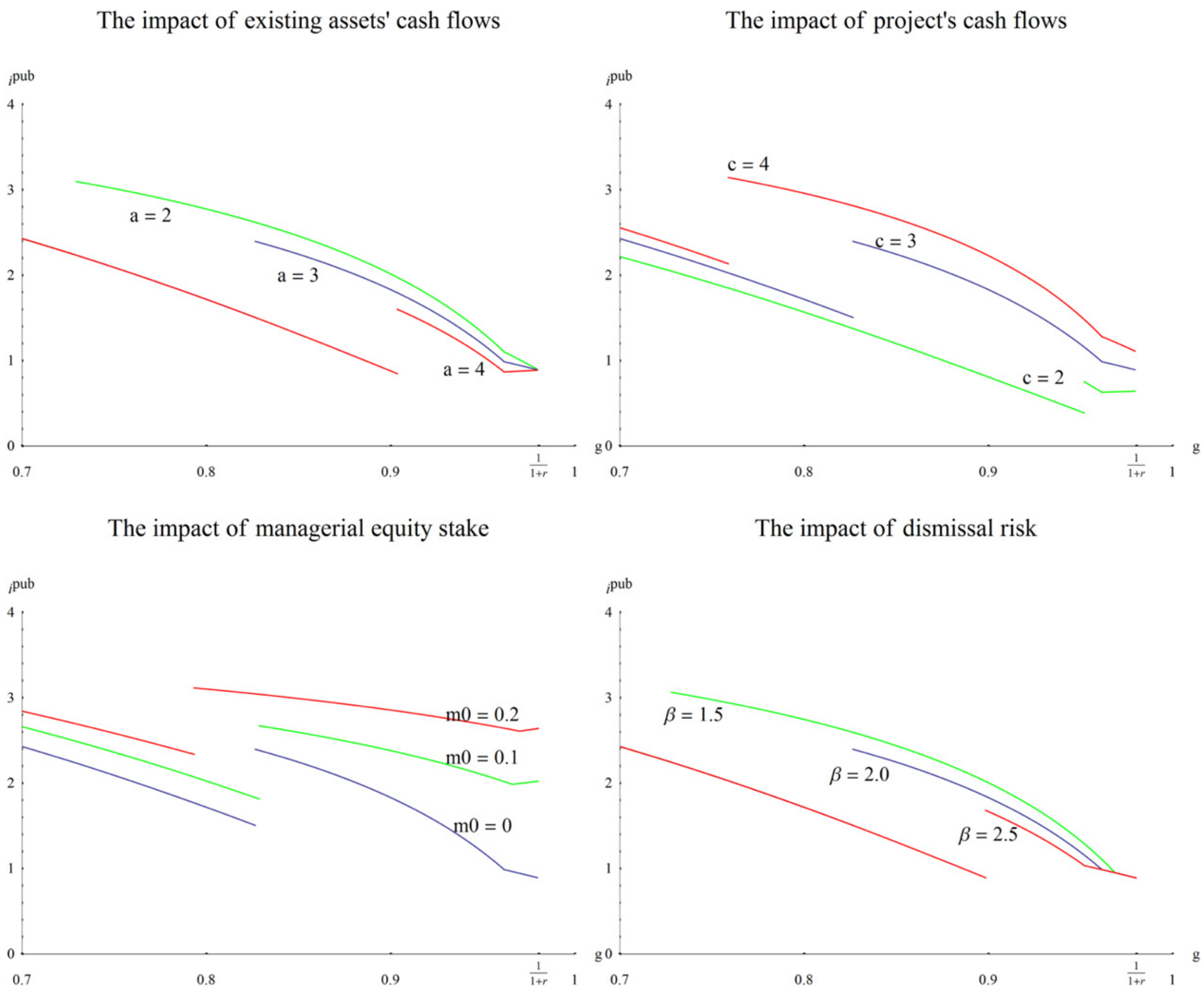

Fig. 2. The impact of model parameters on managerial innovation intensity. The figure illustrates the managerial innovation intensity i^{pub} as a function of the parameter of corporate governance stringency g with respect to three different values of existing assets' cash flows a, project's cash flows c, manager's initial shareholding m_0, and a parameter β of a beta distribution of the ratio of the number of shares held by sophisticated investors to that by sophisticated and unsophisticated investors.

governance stringency on the innovation incentives. The result is consistent with the empirical evidence of Danielson and Karpoff (2006), Stráska and Waller (2010) and Becker-Blease (2011) that adaptations of anti-takeover provisions have positive effects on firms' operating performance, firm value, and innovative activities.

These panels also display the upward shift of the innovation intensity. As shown in Fig. 1, the upward shift is triggered by the change in δ^* from 0 to $c - f(i^{pub})$. This creates the possibility that the firm exhibits identical innovation intensity under corporate governance with different stringency, because it chooses a different dividend policy. The result in Fig. 2 indicates that, for a given innovation intensity, firms with weak corporate governance display low sensitivity of a dividend to decreases in cash flows in the event of innovation failure because they forgo decreasing the dividend. This empirically predicts a negative relationship between the degree of managerial entrenchment and the sensitivity of a dividend to innovation failure. This is in part consistent with the empirical evidence of Leary and Michaely (2011) and Javakhadze et al. (2014) that firms with weak corporate governance tend to smooth their dividend payout.

The left panel at the top illustrates the impact of the existing assets' cash flows a on i^{pub}. It demonstrates that the upward shift of the innovation intensity occurs at large values of g when the existing assets' cash flows increase. The result reflects from the fact that the dividend reduction to $g(a + f(i^{pub}) - b)$ occurs at large values of g when the existing assets' cash flows increase. When the managerial appropriation increases with the existing assets' cash flows, the incentive for the manager to retain his position improves. It induces the manager to forgo decreasing the dividend to eliminate the dismissal risk in the event of innovation failure. However, the managerial incentive to eliminate the dismissal risk declines when g increases. Therefore, the manager is induced to reduce the dividend to $g(a + f(i^{pub}) - b)$ with $\delta^* = c - f(i^{pub})$ when g reaches a threshold.

It also demonstrates that i^{pub} is independent of the existing assets' cash flows a if $\delta^* = 0$, but is negatively related with a otherwise. The result implies that small firms exhibit high innovation intensity and undertake large dividend reductions if the innovation fails.

The right panel at the top illustrates the impact of the project's cash flows c on i^{pub}. The innovation intensity increases when the cash flows c increase, despite the dividend reduction, and the upward shift occurs at small values of g. Since the expected value of the innovation increases with c in the model, the marginal costs of the managerial efforts relatively decrease when c increases. This enhances the innovation intensity. Given that the manager forgoes decreasing the dividend, high innovation intensity creates the possibility of compensating for a large dividend shortfall in the event of innovation failure. This decreases the managerial appropriation and weakens the incentive for the manager to eliminate the dismissal risk. Therefore, the manager is induced to reduce the dividend to $g(a + f(i^{pub}) - b)$ at small values of g when c increases.

The left panel at the bottom illustrates the impact of managerial shareholding m_0 on i^{pub}. It demonstrates that the innovation intensity increases with m_0. This is because the value for the manager increases with m_0. It also demonstrates the upward shift of the intensity. High managerial shareholding lowers the dismissal risk in the event of innovation failure because a small percentage of sophisticated shareholders' shares is required to retain the managerial position. Therefore, high managerial shareholding induces the manager to reduce a dividend if the innovation fails. The panel shows that the upward shift occurs at the smallest value of g when $m_0 = 0.2$. However, the effect becomes ambiguous when m_0 is below 0.1. Managerial appropriation decreases when g increases. It also induces the manager to reduce a dividend and to take the dismissal risk if the innovation fails. The effect becomes strong when the managerial shareholding decreases.

The right panel at the bottom illustrates the impact of the parameter β of the density function of sophisticated investors' shareholding on i^{pub}. It demonstrates that the upward shift of the innovation intensity occurs at small values of g when β decreases. Small values of β mean that the probability for the manager to be dismissed is low even if he reduces a dividend to $g(a + f(i^{pub}) - b)$ in the event of innovation failure. Therefore, the manager is induced to reduce the dividend at small values of g when β decreases. It also demonstrates that i^{pub} is independent of the value of β if $\delta^* = 0$. This is because the manager secures his position by forgoing the dividend reduction.

4. Managerial decision on innovation in a private firm

This section begins by explaining the assumptions of MBO transactions and the role of a private equity firm. Section 4.2 demonstrates the value of equity after the completion of an MBO at $t = 1$ and that of newly issued debt. Sections 4.3 and 4.4 characterize the manager's decision on the innovation and the private equity firm's decision on the buyout transaction as a value maximization problem. Section 4.5 examines the optimal innovation intensity in the post-MBO firm using numerical illustration.

4.1. MBOs and private equity firms

The manager needs to acquire all outside shareholders' equity to undertake an MBO. He collaborates with a private equity firm to take the public firm private. Furthermore, the private equity firm is organized and operated by sophisticated investors. The private equity firm raises debt and equity capital to finance the acquisition of all outside shareholders' equity, and becomes the sole majority shareholder after the MBO is completed. Therefore, it can prevent the manager from appropriating the cash flows because it can dismiss the manager without any collective action costs.

The private equity firm can obtain knowledge about the innovation opportunity from the manager in the buyout transaction. However, it cannot force the manager to choose a specific level of innovation intensity because the choice is unverifiable.

Therefore, the private equity firm needs to provide x% of the equity stake for the manager as an incentive to undertake the innovation. The private equity firm holds more than 50% of the equity to maintain the majority position. In addition, it can provide equity capital to induce the manager to participate in the MBO transaction.

After the buyout is completed, the manager chooses a level of innovation intensity to maximize the value of his equity stake. The private equity firm maximizes the value of its equity stake by incorporating the innovation intensity chosen by the manager. This implies that the private equity firm has full bargaining power in the negotiation of the buyout transaction.[9]

4.2. Value of equity and debt of a buyout firm

The manager needs to offer shareholders at least $\frac{1}{1+m_1}\frac{g(a+c-b)}{r}$ to succeed in the MBO because the shareholders perceive that the value of the equity is $\frac{g(a+c-b)}{r}$ if they dismiss the manager. It is assumed that the shareholders accept the buyout offer of $\frac{1+\theta}{1+m_1}\frac{g(a+c-b)}{r}$, where θ represents a premium of the equity acquisition. The premium derives from the possibility that the buyout offer partially conveys new information about the innovation opportunity to the sophisticated shareholders.

It is worth noting that if the announcement of the MBO conveys the full information to the sophisticated shareholders, the premium θ^* is expressed as follows:

$$\begin{aligned}&\frac{1+\theta^*}{1+m_1}\frac{g(a+c-b)}{r}=\frac{1}{1+m_1}\frac{g(a+p(i)s(i)+(1-p(i))f(i)-b)}{r},\\&\theta^*=\frac{p(i)s(i)+(1-p(i))f(i)-c}{a+c-b}.\end{aligned}\tag{24}$$

Eq. (24) indicates that the premium θ^* is the expected return of the innovation.

The private equity firm arranges a new debt contract and provides equity capital K. It is assumed that the new debt contract is a console with coupon payments $b_1(i)$ from $t=2$ onwards, and the payments are subordinated by the outstanding debt contract. Therefore, after the completion of the buyout at $t=1$, the value of equity $E_1^{bo}(i)$, the value of debt D_1^{bo}, and the coupon payments $b_1(i)$ are expressed as follows:

$$\begin{aligned}E_1^{bo}(i)&=\begin{cases}p(i)\frac{a+s(i)-b-b_1}{r}+(1-p(i))\frac{a+f(i)-b-b_1}{r} & \textit{if}\ \ i\le i_d,\\ p(i)\frac{a+s(i)-b-b_1}{r} & \textit{otherwise},\end{cases}\\&=\frac{m_1-\theta}{1+m_1}\frac{g(a+c-b)}{r}+\frac{(1-g)(a+c-b)}{r}+\frac{p(i)s(i)+(1-p(i))f(i)-c}{r}+K,\end{aligned}\tag{25}$$

$$\begin{aligned}D_1^{bo}&=\begin{cases}\frac{b_1(i)}{r} & \textit{if}\ \ i\le i_d,\\ p(i)\frac{b_1(i)}{r}+(1-p(i))\frac{a+f(i)-b}{r} & \textit{otherwise},\end{cases}\\&=\frac{1+\theta}{1+m_1}\frac{g(a+c-b)}{r}-K,\end{aligned}\tag{26}$$

$$b_1(i)=\begin{cases}\frac{1+\theta}{1+m_1}(a+c-b)-rK & \textit{if}\ \ i\le i_d,\\ \left(1+\frac{1-p(i)}{p(i)}\right)\left(\frac{1+\theta}{1+m_1}(a+c-b)-rK\right)-\frac{1-p(i)}{p(i)}(a+f(i)-b) & \textit{otherwise},\end{cases}\tag{27}$$

where $i_d=\{i|a+f(i)-b=\frac{1+\theta}{1+m_1}(a+c-b)-rK\}$. The equity value in Eq. (25) consists of four terms. The first term represents the value of the managerial equity stake of the public firm, net of the premium of equity acquisition. The second represents the managerial appropriation in the public firm that the manager relinquishes after the buyout is completed. The third represents the expected net present value of the innovation. The fourth represents the equity capital provided by the private equity firm. The value of the new subordinate debt in Eq. (26) represents the acquisition costs of the public firm's equity. It is the value of the outside shareholders' equity stake in the public firm, net of the equity capital. These equations indicate that these values are not subject to the default risk that derives from the innovation failure if the innovation intensity exceeds i_d. This is why the model assumes that the firm bears no bankruptcy costs in the default.

[9] This assumption can be reversed. If the manager has full bargaining power, the private equity firm must provide as much equity stake x and equity capital K as possible and gain no excess value from the buyout transaction.

4.3. Managerial choice of innovation intensity

The manager chooses the innovation intensity to maximize the value of his equity stake, net of managerial efforts at $t = 1$. The maximization problem is expressed as follows:

$$\max_{i} \; xE_1^{bo}(i) - e(i). \tag{28}$$

Therefore, the optimal innovation intensity for the manager i^{bo} needs to satisfy the following first-order condition:

$$x\frac{p'(i^{bo})s(i^{bo}) + p(i^{bo})s'(i^{bo}) - p'(i^{bo})f(i^{bo}) + (1-p(i^{bo}))f'(i^{bo})}{r} - e'(i^{bo}) = 0. \tag{29}$$

The first-order condition indicates that the optimal innovation intensity for the manager depends on his equity stake x, but it is independent of the equity capital K. Therefore, the optimal innovation intensity for the manager is expressed as $i^{bo}(x)$ to explicitly indicate the dependence.

Eq. (29) is consistent with Eq. (17) if $x = 1$. The result implies that if the manager can undertake the MBO by himself, he chooses the optimal innovation intensity i^* that maximizes the expected present value of the innovation, net of managerial efforts. This is why the manager can capture the entire expected value created by the innovation.

However, there is a caveat. The above result is valid under the condition that the premium θ is an exogenous parameter. Therefore, it is worth considering the managerial choice of the innovation intensity under the assumption that the announcement of the MBO conveys the full information about the innovation to the sophisticated shareholders. If $\theta = \theta^*$, the first-order condition is expressed as follows:

$$\begin{aligned} &x\frac{p'(i^{bo})s(i^{bo}) + p(i^{bo})s'(i^{bo}) - p'(i^{bo})f(i^{bo}) + (1-p(i^{bo}))f'(i^{bo})}{r} - e'(i^{bo}) \\ &-x\frac{g}{1+m_1}\frac{p'(i^{bo})s(i^{bo}) + p(i^{bo})s'(i^{bo}) - p'(i^{bo})f(i^{bo}) + (1-p(i^{bo})f'(i^{bo})}{r} = 0. \end{aligned} \tag{30}$$

This is consistent with Eq. (19) if $x = 1$. Therefore, the manager chooses the innovation intensity i^{**} if he can undertake the MBO by himself. Thus, the minimum level of the innovation intensity is i^{**} if the manager can undertake the MBO by himself. The result derives from the fact that the MBO eliminates the dismissal risk posed by the unsophisticated shareholders' intolerance of the innovation failure. This result leads to the following proposition, considering Proposition 2.

Proposition 3. *Suppose the manager takes the public firm private by himself and becomes the sole owner of the private firm.*

(i) *If* $\delta^* = 0$, $i^{pub} < i^{bo}$.
(ii) *If* $\delta^* = c - f(i^{pub})$ *and* $a + c - b$, $i^{pub} < i^{bo}$ *under the condition that* $(1-p(i^{pub}))f'(i^{pub}) - p'(i^{pub})(a + f(i^{pub}) - b) \geq 0$.

The proposition demonstrates that MBOs enhance the managerial innovation intensity if the manager can take the public firm private by himself. This proposition is valid even if the manager needs to pay the maximum premium θ^* to acquire all shareholders' equity.

4.4. Private equity firm's decision

The private equity firm provides the equity stake for the manager in the MBO to enhance the managerial innovation incentive. It can also invest equity capital. It chooses the managerial equity stake and the amount of equity capital investment to maximize the value of its own equity stake, considering the impact of the equity stake provision on the optimal innovation intensity $i^{bo}(x)$.

Furthermore, since the manager and the private equity firm voluntarily participate in the buyout, they at least need to break even by going private instead of staying public. Therefore, the private equity firm needs to maximize the value of its equity stake with regard to x and K, subject to their participation constraints. The maximization problem for the equity firm is expressed as follows:

$$\max_{x,K} \quad (1-x)E_1^{bo}\left(i^{bo}(x)\right) - K \tag{31}$$

$$st. \quad xE_1^{bo}\left(i^{bo}(x)\right) - e\left(i^{bo}(x)\right) \geq p(i^{pub})\frac{M_2^s(i^{pub})}{1+r} + \left(1-p(i^{pub})\right)\frac{M_2^f(i^{pub})}{1+r} - e(i^{pub}), \tag{32}$$

$$(1-x)E_1^{bo}\left(i^{bo}(x)\right) \geq \frac{1+\mu(i^{pub})}{1+r}K, \tag{33}$$

$$\mu(i^{pub}) = \ r + (1+r)\frac{p(i^{pub})s(i^{pub}) + (1-p(i^{pub}))f(i^{pub}) - c}{a+c-b} + \frac{(1-p(i^{pub}))(1+r-F(\delta^*))(c-f(i^{pub})-\delta^*)}{a+c-b}. \tag{34}$$

Eqs. (32) and (33) represent the participation constraints for the manager and the private equity firm. These constraints indicate that the manager and the private equity firm voluntarily participate in the MBO because they at least realize the value of staying public. Therefore, as Eq. (32) indicates, the private equity firm must provide the manager with the value of equity stake that exceeds the value for the manager in the original public firm. The equity firm also needs to at least break even by participating in the MBO relative to investing in the original public firm at $t = 1$.

The rate of the expected return on the public firm is expressed as $\mu(i^{pub})$ in Eq. (33). Eq. (34) demonstrates that the expected return $\mu(i^{pub})$ exceeds the risk-free rate r. Thus, the private equity firm can, on average, earn excess returns by arranging the MBO. The excess returns derive from two facts. One is that the rate of the expected return on the innovation is higher than the risk-free rate under the condition that $i = i^{pub}$. This is indicated by the second term. The other is the possibility that if the innovation fails, the manager in the public firm forgoes decreasing a dividend to eliminate the dismissal risk posed by the unsophisticated shareholders' intolerance. This is indicated by the third term.

4.5. *Numerical results of managerial innovation intensity in a private firm*

Fig. 3 depicts the value of the managerial equity stake in a private firm and the value of managerial appropriation in a public firm as a function of the innovation intensity i with respect to different values of g, which are 0.72, 0.77, 0.82, 0.87, 0.92, and 0.97. These panels also display the managerial innovation intensity in a private firm $i^{bo}(x^*)$, the managerial innovation intensity in a public firm i^{pub}, and the optimal innovation intensity i^*. They demonstrate that the MBO improves managerial innovation intensity, even if the manager gains no excess value from the buyout. However, the innovation intensity $i^{bo}(x^*)$ fails to reach the optimal innovation intensity i^*. As indicated by Eq. (29), the result is maintained as long as managerial efforts are required by undertaking the innovation. This result is consistent with empirical evidence of Wright et al. (1996), Zahra (1995), and Lerner et al. (2011).

These panels also show that when corporate governance stringency g increases, the value of the managerial equity stake in a private firm and the value of the managerial appropriation in a public firm decrease. Furthermore, they indicate that a threshold of g exists, above which the manager gains excess values from the MBO. Therefore, the stringent corporate governance against managerial entrenchment induces the manager to undertake the MBO, and this is conducive to the buyout supported by private equity firms. This result provides an empirical prediction that when corporate governance facilitates managerial turnover, innovative managers are more likely to undertake MBOs, and resultantly the private equity backed buyouts increase.

Fig. 4 depicts the managerial innovation intensity $i^{bo}(x^*)$ as a function of the parameter of corporate governance stringency g. Each panel illustrates the impact of the existing assets' cash flows a, the project's cash flows c, the manager's initial shareholding m_0, and the premium of the equity acquisition θ on $i^{bo}(x^*)$, with three parametric values. These panels show that the innovation intensity $i^{bo}(x^*)$ decreases when g increases. They also show that $i^{bo}(x^*)$ increases with the existing assets' cash flows a, the project's cash flows c, the manager's initial shareholding m_0, and the premium of the equity acquisition θ.

These panels show that the innovation intensity $i^{bo}(x^*)$ becomes inelastic when the value of g decreases to a certain level. As Fig. 5 shows, the result derives from the fact that the managerial equity stake x^* reaches 50% at this level. The panels also show that these innovation intensities kink and increase when g reaches about 0.95. The trend arises because the private equity firm increases the managerial equity stake to improve the managerial innovation intensity in the range of g, where the marginal value of the equity provision by the private equity firm exceeds its marginal cost and the value of the managerial equity stake is larger than the value for the manager in a public firm.

The left panel at the top illustrates the impact of the existing assets' cash flows a on $i^{bo}(x^*)$. It demonstrates the tendency that managerial innovation incentives increase with the existing assets' cash flows. The result derives from the fact that the equity stake provision increases with the existing assets' cash flows. Because the managerial appropriation in a public firm increases with the existing assets' cash flows, the private equity firm needs to increase the equity stake provision to induce the manager to participate in the buyout. When g reaches a certain value, the curves kink and begin to increase. In this range, the value of the managerial equity stake in a private firm exceeds the value of the managerial appropriation in a public firm. Thus, the participation constraints in Eqs. (32) and (33) are satisfied with inequality, and the marginal cost of the equity stake provision increases with the existing assets' cash flows. Therefore, the managerial innovation intensity decreases when the existing assets' cash flows increase.

The right panel at the top illustrates the impact of the project's cash flows c on $i^{bo}(x^*)$. It demonstrates that the managerial innovation incentives increase with c. When c increases, the value of the managerial appropriation in a public firm increases. Thus, the private equity firm needs to increase the equity stake provision to induce the manager to participate in the buyout. In addition, the marginal cost of the managerial efforts for the innovation decreases relative to its marginal value, because the expected value of the innovation increases with c. Therefore, the managerial innovation intensity increases with the project's cash flows.

The left panel at the bottom illustrates the impact of the manager's initial shareholding m_0 on $i^{bo}(x^*)$. It demonstrates that managerial innovation incentives increase with m_0. The value for the manager in a public firm increases with his initial shareholding. Therefore, the private equity firm needs to increase the equity stake provision to induce the manager to participate in the buyout. This enhances the managerial innovation intensity.

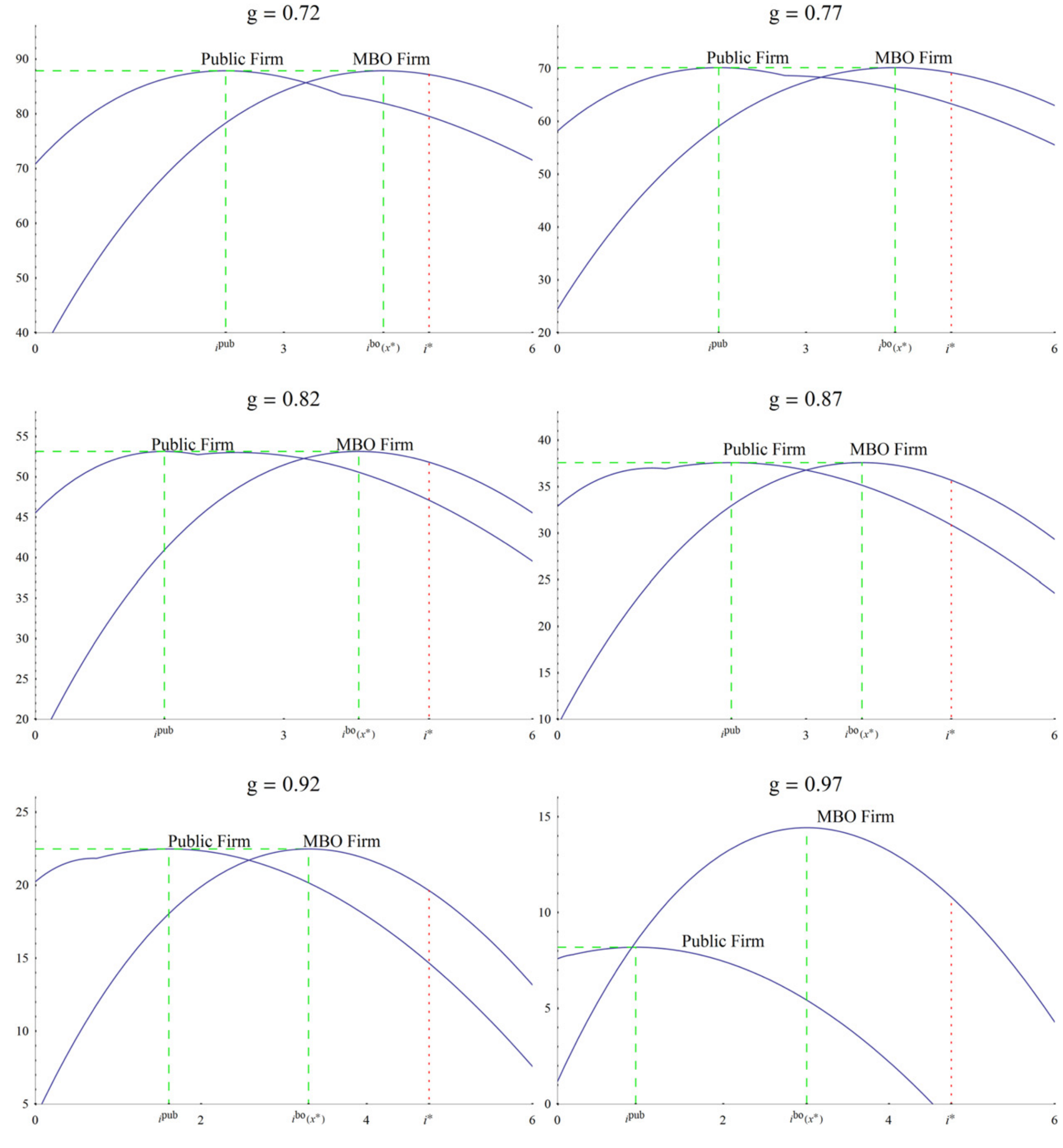

Fig. 3. Managerial innovation intensities in a private firm and a public firm The figure illustrates the value of the managerial equity stake in a private firm and that of managerial appropriation in a public firm as a function of the innovation intensity *i* with respect to different values of the parameter of corporate governance stringency *g*. The figure also displays the managerial innovation intensity $i^{bo}(x^*)$ in a private firm, the managerial innovation intensity i^{pub} in a public firm, and the optimal innovation intensity i^*.

The right panel at the bottom illustrates the impact of the premium of the firm's equity acquisition θ on $i^{bo}(x^*)$. It demonstrates that managerial innovation incentives increase with the premium of the acquisition. The equity value of the private firm decreases when the premium increases. This induces the private equity firm to increase the equity stake provision for the manager. Therefore, the managerial innovation intensity increases with the premium of the firm's equity acquisition.

Fig. 5 depicts the optimal equity stake provision to the manager x^* as a function of the parameter of corporate governance stringency *g*. Each panel illustrates the impact of the existing assets' cash flows *a*, the project's cash flows *c*, the manager's initial shareholding m_0, and the premium of the firm's equity acquisition θ on x^*, with three parametric values. These panels demonstrate the positive correlation between the equity stake provision x^* and the optimal innovation intensity $i^{bo}(x^*)$ in Fig. 4.

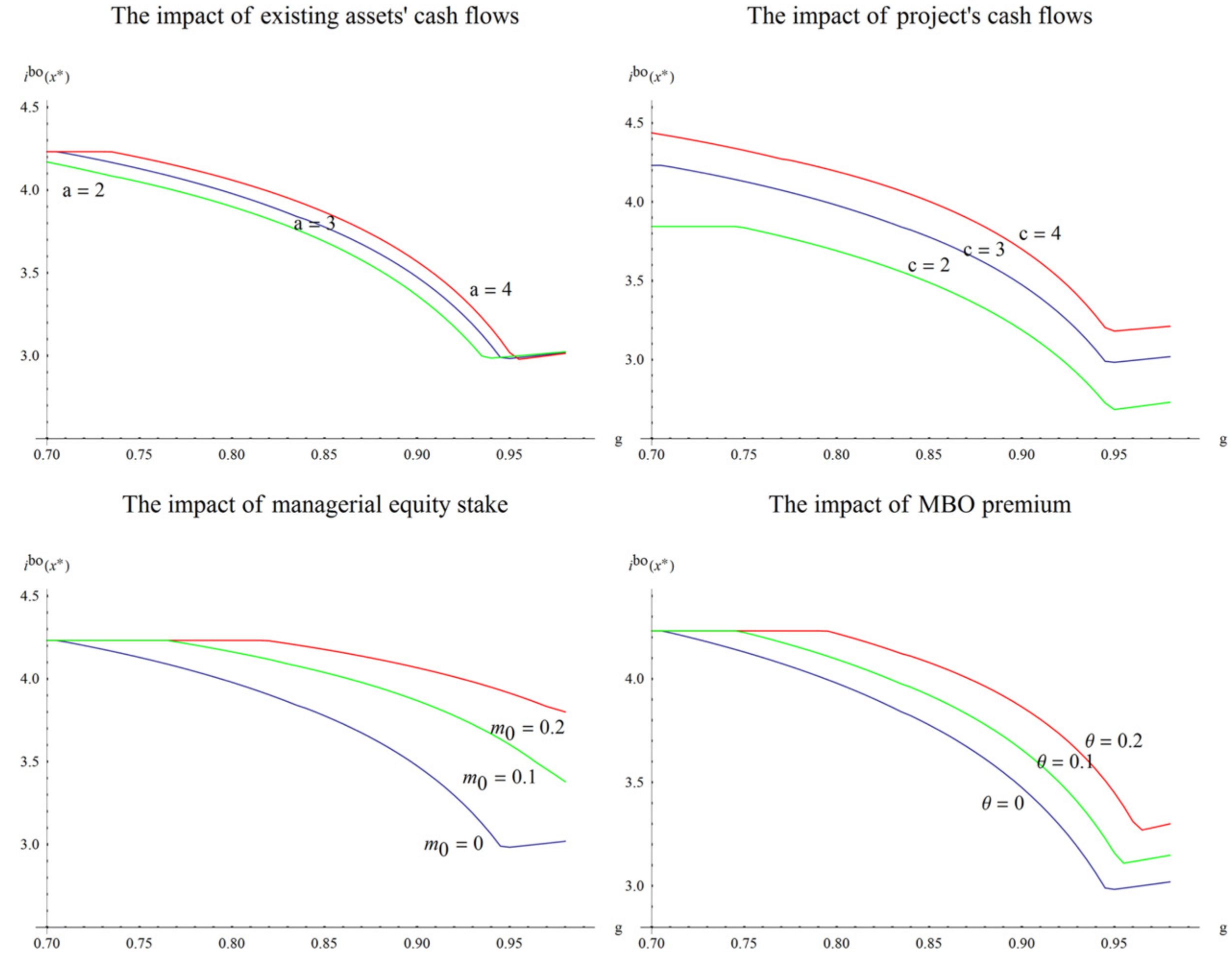

Fig. 4. The impact of model parameters on the managerial innovation intensity in a private firm The figure illustrates the managerial innovation intensity $i^{bo}(x^*)$ as a function of the parameter of corporate governance stringency g with respect to three different values of existing assets' cash flows a, project's cash flows c, manager's initial shareholding m_0, and a premium of the equity acquisition θ.

The left panel at the top illustrates the impact of the existing assets' cash flows a on x^*. The equity stake provision increases with the existing assets' cash flows until these curves kink. The equity stake provision negatively correlates with the existing assets' cash flows in the interval over which these curves kink and increase with g.

The right panel at the top illustrates the impact of the project's cash flows c on x^*. The equity stake provision increases when the project's cash flows decrease. Because the value of the firm's equity increases with c, the private equity firm can decrease the equity stake provision x^*.

The left panel at the bottom illustrates the impact of the manager's initial shareholding m_0 on x^*. The equity stake provision increases with m_0. The value for the manager in a public firm increases with his initial shareholding. Therefore, the private equity firm needs to increase the equity provision x^* to induce the manager to participate in the buyout.

This result implies that the private equity firm is discouraged to collaborate on undertaking an MBO with a manager whose shareholding is high. It seems counter-intuitive when it is considered that high managerial shareholding decreases the acquisition costs of existing shareholders' shares. If the manager is wealthy enough to undertake the MBO by himself, high managerial shareholding decreases the acquisition costs and facilitates going private. However, if the manager is wealth constrained and thus needs to seek private equity firm's support, high managerial shareholding hinders the MBO. This is why it becomes costly for the private equity firm to induce the manager to participate in the buyout when his shareholding increases. This finding is consistent with the empirical evidence of Fidrmuc et al. (2013) that the probability that managers undertake MBOs by themselves increases with their equity ownership and the probability that they undertake MBOs with private equity firms' support decreases with it.

The right panel at the bottom illustrates the impact of the premium of the firm's equity acquisition θ on x^*. The value of the firm's equity decreases when the premium increases. Therefore, the private equity firm needs to increase the equity stake provision x^* to induce the manager to participate in the buyout.

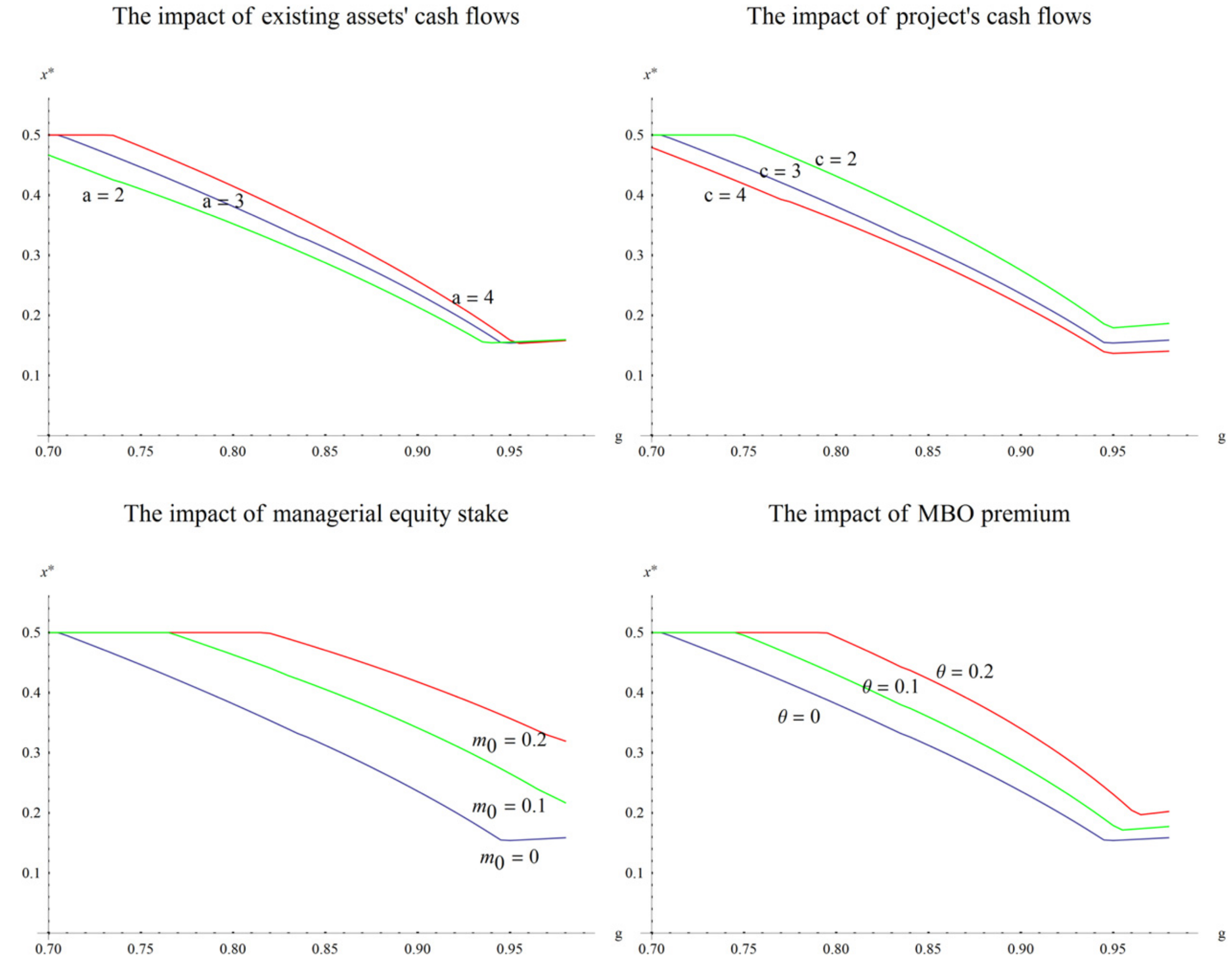

Fig. 5. The impact of model parameters on the managerial equity stake. The figure illustrates the managerial equity stake of a buyout firm x^* as a function of the parameter of corporate governance stringency g with respect to three different values of existing assets' cash flows a, project's cash flows c, manager's initial shareholding m_0, and a premium of the equity acquisition θ.

5. Conclusion

This ástud y examines managerial innovation incentives in public firms and the impact of MBOs in collaboration with a private equity firm on innovation incentives. The results indicate that in addition to corporate governance that restricts managerial appropriation of the firm's resources, the firm's ownership structures also matter to managerial innovation incentives because they impact the extent of the shareholders' intolerance of failure. The model demonstrates that, apart from managerial agency problem, shareholders' intolerance of failure also deteriorates managerial innovation incentives when unsophisticated investors coexist with sophisticated investors within a public firm. This result provides a policy implication for a public firm's ownership structure and corporate governance. It helps nurture the public firm's innovation incentives to induce institutional investors, who are more capable of monitoring and understanding the firm's operations, to increase their ownership, to hold it for a long term, and to become members of the board. This implication is consistent with the theoretical result and empirical evidence of Aghion et al. (2013) that institutional ownership of public firms has a positive impact on innovation.

By examining MBOs in collaboration with private equity firms, the study also provides insights into the return and risk structure of private equity firms. In the model, the probability of innovation failure increases with innovation intensity. This indicates that the private equity firm bears a high risk by investing in the MBO because the manager chooses higher innovation intensity in the post-MBO firm than in the public firm. This result is in part consistent with the empirical evidence of Tykvová and Borell (2012) that firms supported by private equity firms increase financial distress risk after their buyout transactions. In addition, as the results of the private equity firm's expected returns show, this study indicates that on average, private equity firms earn excess returns and bear high risks by arranging MBO transactions relative to investing in peer public firms. This is consistent with the empirical evidence of Buchner et al. (2016) that buyout investments continue to outperform investments in the public market and their consistent outperformance is attributed to the risk taken by buyout funds.

This study merely considers the intermediate role of private equity firms in arranging the MBO transactions. It does not consider the managerial roles of private equity firms that enhance a firm's value or the bargaining processes of MBOs.[10] In addition, the study ignores the impact of private equity firms' short-termism on managerial innovation incentives and MBO decisions. This will be a promising avenue for future research.

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Appendix A

A.1. Proofs of Lemma 1, Lemma 2, and Lemma 3

It is assumed that the shareholders expect a firm to perpetually generate constant cash flows *CF*. Suppose that they dismiss their manager if they receive a dividend below *gCF*, and continue the delegation otherwise. Given this dismissal strategy, the manager can retain his position as long as he pays a dividend above *gCF*. The manager can also depart from the firm by paying a dividend below *gCF*. If the manager intends to retain his position, he pays a dividend of *gCF* and appropriates the rest of the firm's cash flows $(1-g)CF$, which maximizes the value of the managerial appropriation. Otherwise, he pays nothing and appropriates all cash flows *CF*, resulting in being dismissed. It is demonstrated that it is optimal for the manager to pay *gCF* and retain his position if $g \le \frac{1}{1+r}$ as follows:

$$
\begin{aligned}
&(1-g)CF + \frac{(1-g)CF}{r} \ge CF, \\
&g \le \frac{1}{1+r}. \qquad (35)
\end{aligned}
$$

Given that the manager pays *gCF* now, shareholders cannot improve the value of the equity by dismissing him. Therefore, if their expectation of the firm's cash flows remains unchanged, the manager pays a dividend *gCF* and the shareholders continue the delegation from now onwards in equilibrium. **Q.E.D.**

A.2. Proof of Lemma 4

The sum of the value of the managerial appropriation and the value of the equity stake in the event of innovation failure is expressed as follows:

$$
M_2^f(i) = \begin{cases}
(1-g)(a+f(i)-b) + \frac{(1-g)(a+f(i)-b)}{r} - \left(g(c-f(i)) + \frac{g(c-f(i))}{r}\right) \\
+\frac{m_1}{1+m_1}\left(g(a+f(i)-b) + \frac{g(a+f(i)-b)}{r} + g(c-f(i)) + \frac{g(c-f(i))}{r}\right) + \frac{g(1+r)}{1+m_1}\frac{\delta}{r} & \text{if} \quad \delta \le 0, \\
(1-g)(a+f(i)-b) + \frac{(1-g)(a+f(i)-b)}{r} - \Phi(0.5(1-m_1))\frac{(1-g)(a+f(i)-b)}{r} \\
+\frac{m_1}{1+m_1}\left(g(a+f(i)-b) + \frac{g(a+f(i)-b)}{r}\right) & \text{if} \quad 0 < \delta \le c - f(i), \\
-\frac{g}{1+m_1}\left(1 + \frac{1-\Phi(0.5(1-m_1))}{r}\right)(c-f(i)-\delta) \\
(1-g)(a+f(i)-b) + \frac{m_1}{1+m_1}\left(g(a+f(i)-b) + \frac{g(a+f(i)-b)}{r}\right) \\
-\frac{g}{1+m_1}(c-f(i)-\delta) & \text{if} \quad \delta > c - f(i).
\end{cases}
$$

The above equation demonstrates that each value of $M_2^f(i)$ is maximized at $\delta = 0$, $\delta = c - f(i)$, and $\delta = a + c - b$. Therefore, three types of manager's optimal dividend reduction exist, depending on the managerial innovation intensity *i* and the model parameters. Lemma 4 is proved by a comparison with these three values of $M_2^f(i)$. **Q.E.D.**

A.3. Proof of Proposition 1

Proposition 1 is proved by Lemma 3 and Lemma 4.

[10] See Cunny and Talmor (2007) for the role of private equity firms in the turnaround of underperforming firms. They derive the condition that the turnaround strategy of private equity firms' buyouts is superior to the strategies initiated by insiders.

A.4. Proof of Proposition 2

If $\delta^* = 0$, the third term of Eq. (23) becomes 0 because $F(0) = 0$, and the fourth term becomes negative because $f'(i) < 0$ and $p'(i)) < 0$. This result proves Proposition 2 (i) with the first-order conditions in Eqs. (17), (19), and (23).

If $\delta^* = c - f(i^{pub})$, the third term of Eq. (23) becomes negative under the assumption that $(1 - p(i^{pub}))f'(i^{pub}) - p'(i^{pub})(a + f(i^{pub}) - b) \geq 0$, and the fourth term becomes 0. If $\delta^* = a + c - b$, the third and fourth terms are expressed as follows:

$$\frac{(1 - p(i^{pub}))f'(i^{pub}) - p'(i^{pub})f(i^{pub})(a + f(i^{pub}) - b)}{r}\left[g - \frac{1}{1+r} - \frac{gm_1}{1+m_1}\left(1 - \frac{1}{1+r}\right)\right]. \tag{36}$$

The above value becomes negative because of the assumption that $g \leq \frac{1}{1+r}$ and $(1 - p(i^{pub}))f'(i^{pub}) - p'(i^{pub})(a + f(i^{pub}) - b)) \geq 0$. This result proves Proposition 2 (ii) with the first-order conditions in Eqs. (17), (19), and (23) **Q.E.D.**

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