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Moral hazard in investment and endogenous risk taking

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HIGHLIGHTS

- I study a dynamic moral hazard model with endogenous risk taking.
- High-risk taking may enforce incentive provisions and raises the firm value.
- A firm switches to high-risk taking after bad performances.

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ABSTRACT

I study a dynamic moral hazard model with endogenous risk taking, in which exposing the firm to greater risks could align the manager's private benefit with that of the owner and thus enhance the incentive provision.

1. Introduction

A prominent aspect of the 2007 financial crisis is that many financial companies and investment banks took excessive risks by selling billions of dollars' worth of credit default swaps on montage-backed securities. This kind of aggressive risk-taking behavior makes the entire financial system unstable and has triggered several recessions in history. Therefore, a large literature has been devoted to understanding the motivations behind it. Most of the existing papers attribute this risk-taking behavior to the conflict between managers' incentives to improve firm performance and their incentives to take excessive risks. For example, Jensen and Meckling (1976) pointed out that a convex incentive scheme implemented in practices such as levered equity and options would lead to aggressive risk taking. More recently, De Marzo et al. (2014) and Li and Williams (2016) show that the pay-performance sensitivity under the optimal contract induces the manager to improve short-run performance by putting the firm at risk.

Different from the existing papers, this paper proposes a firm dynamic model with moral hazard in investment to show that excessive risk taking could enhance the incentive provision even if it is publicly observable and controlled by the firm owner. Intuitively, by making firm growth more volatile, the owner imposes on the manager greater uncertainty about the future. Such uncertainty lowers the manager's expected utility and creates a precautionary saving effect if the manager's preference exhibits a small intertemporal elasticity of substitution. Thus, the intertemporal income effect induces the manager to abstain from hidden diversions and make appropriate investments. As a result, a higher level of risk taking aligns the manager's future private benefit more closely with the owner's and thus raises the firm's value if the owner is well diversified.

2. The model

A risk-neutral firm owner, the principal, delegates her firm to a risk-averse manager, the agent, over the time horizon $[0, \infty)$. At time t, the firm's operating profit is AK_t, with K_t being its capital stock and $A > 0$ being its marginal product. The capital accumulates according to

$$dK_t = K_t \left[(i_t - \delta)\, dt + \sigma_u dB_{u,t} + \sigma_{o,t} dB_{o,t} \right] \quad \text{with } K_0 = 1. \tag{1}$$

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Here, i_t is the investment-to-capital ratio chosen by the agent privately and $\delta > 0$ is the capital depreciation rate. Capital accumulation is subject to the random shocks represented by two independent Brownian motions, $\{B_{u,t}\}$ and $\{B_{o,t}\}$, where $B_{o,t}$ is publicly observable but $B_{u,t}$ is not observable to the principal. The volatility of the unobservable shocks, $\sigma_u > 0$, is exogenous, and that of the observable shocks, $\sigma_{o,t}$, is chosen by the principal from a binary set $\{\underline{\sigma}, \bar{\sigma}\}$ with $0 \leq \underline{\sigma} < \bar{\sigma}$. The choice of $\sigma_{o,t}$ is the *risk-taking* behavior in the model.[1]

The principal delegates the firm by offering the agent a contract under which the operating profit is divided among the dividend payment to the principal, D_t, the compensation to the manager, C_t, and the investment $i_t K_t$ so that $D_t + C_t + i_t K_t = AK_t$. Moral hazard arises because the principal cannot distinguish the unobservable shocks from the actual investment made by the agent,[2] so that the agent has the freedom to divide the payment received from the principal, $P_t = C_t + i_t K_t$, between consumption and investment. The contract, denoted by $(\{P_t\}, \{\sigma_{o,t}\})$, specifies the payment to the agent and the risk-taking policies according to the performance history to induce the agent to make appropriate investments. Under the contract, the agent chooses investment to maximize

$$E_0\left[\beta \int_0^\infty e^{-\beta t} \frac{C_t^{1-\gamma}}{1-\gamma} dt\right] = E_0\left[\beta \int_0^\infty e^{-\beta t} \frac{(P_t - i_t K_t)^{1-\gamma}}{1-\gamma} dt\right]$$

subject to (1). Here $\beta > 0$ is the discount rate, $\gamma > 0$ is the relative risk aversion coefficient, and E_0 is the time zero expectation operator.[3] On the other hand, the principal's expected payoff is

$$E_0\left[\int_0^\infty e^{-\beta t} D_t dt\right] = E_0\left[\int_0^\infty e^{-\beta t} (AK - P_t)\, dt\right].$$

I assume that D_t and P_t must be nonnegative.[4] I focus on the optimal contract that maximizes the principal's expected payoff and delivers to the agent an initial expected utility, W_0. I also assume that the principal has full bargaining power so that W_0 is optimally chosen.

3. The contract delivering a fixed share

The key intuition of this paper can be seen clearly through a special kind of contract under which the principal pays a fixed fraction of the income to the agent, namely, $P_t = pAK_t$ for some $p \in [0, 1]$, and $\sigma_{o,t} = \sigma_o \in \{\underline{\sigma}, \bar{\sigma}\}$ is time invariant and chosen at $t = 0$. The agent chooses the optimal investment-to-capital ratio to maximize his expected utility. Let $W(K)$ be the value function of the maximization problem which satisfies

$$0 = \max_i \beta \frac{[(pA - i)K]^{1-\gamma}}{1-\gamma} - \beta W(K) + W'(K)K(i-\delta) + \frac{1}{2} W''(K) K^2 \left(\sigma_u^2 + \sigma_o^2\right). \quad (2)$$

Given the homogeneity of his maximization problem, it is easy to show that

$$W(K) = \underline{w} K^{1-\gamma} \quad (3)$$

for some scalar, $\underline{w}$, and thus (2) is simplified to

$$0 = \max_i \frac{\beta (pA - i)^{1-\gamma}}{1-\gamma} \frac{1}{\underline{w}} - \beta + (1-\gamma)(i-\delta) - \frac{1}{2}\gamma(1-\gamma)\left(\sigma_u^2 + \sigma_o^2\right),$$

which implies the optimal investment-to-capital ratio

$$\hat{\imath} = \frac{1}{\gamma}\left(pA - \beta - (1-\gamma)\delta - \frac{1}{2}\gamma(1-\gamma)\left(\sigma_u^2 + \sigma_o^2\right)\right), \quad (4)$$

and $\underline{w} = \frac{\beta}{1-\gamma}(pA - \hat{\imath})^{-\gamma}$.[5] Given the capital stock K and the agent's investment policy, the principal's expected payoff is $\underline{v}K$ with

$$\underline{v} = \frac{(1-p)A}{\beta + \delta - \hat{\imath}}.$$

Therefore, fixing p, the firm value for the principal increases with $\hat{\imath}$.[6] Thus, according to (4), if $\gamma > 1$, it is optimal to choose $\sigma_o = \bar{\sigma}$ at $t = 0$. Intuitively, the agent is subject to greater uncertainty in his income if the owner chooses a higher level of risk taking, which lowers his future utility. In this model, the inverse of the constant relative risk aversion coefficient, $\frac{1}{\gamma}$, is the intertemporal elasticity of substitution of the agent's preference. If it is smaller than one, the intertemporal income effect dominates the substitution effect so that the agent becomes more cautious and chooses to consume less and invest more when his future is more risky.[7] Clearly, the principal is made better off from the higher level of investment induced by more risk taking because she is well diversified.

Although under the optimal contract the fraction p is time variant and determined by the incentive provision and risk sharing, it is bounded in [0, 1]. Therefore, to some extent, higher levels of risk taking are desired for the same reason. To characterize the optimal contract, it is convenient to write the two scalars just mentioned, $\underline{w}$ and $\underline{v}$, as functions of p and σ_o, $\underline{w}(p, \sigma_o)$ and $\underline{v}(p, \sigma_o)$.

4. The optimal contract

We define the agent's continuation utility as

$$W_t = E_t\left[\beta \int_0^\infty e^{-\beta(s-t)} \frac{(P_s - i_s K_s)^{1-\gamma}}{1-\gamma} ds\right],$$

and then the Martingale representation theorem implies

$$dW_t = \beta\left(W_t - \frac{(P_t - i_t K_t)^{1-\gamma}}{1-\gamma}\right) dt + g_{u,t}(1-\gamma) W_t \sigma_u dB_{u,t} + g_{o,t}(1-\gamma) W_t \sigma_{o,t} dB_{o,t}, \quad (5)$$

with processes $\{g_{u,t}\}$ and $\{g_{o,t}\}$ indicating the sensitivities of W_t with respect to the unobservable and observable shocks, respectively. Let $V(K_t, W_t)$ be the value function of the principal's contract design problem. Given the homogeneity of the problem, we can show that $V(K_t, W_t) = K_t v\left(\frac{W_t}{K_t^{1-\gamma}}\right)$ with some normalized value function $v(w_t)$. Here, $w_t = \frac{W_t}{K_t^{1-\gamma}}$ is the normalized continuation utility that can be interpreted as the manager's *stake* in the firm, the ratio of his future utility to the size of the firm. According to (3), this stake is constant across time under the contract discussed in Section 3. However, (5) implies that, in general, it evolves according to (6) (in Box I)

[1] One could write an alternative model by replacing $\{B_{o,t}\}$ with a compensated Poisson jump process with negative jumps, as in Li and Williams (2016), which better matches the motivating story at the beginning of the introduction. However, the alternative model is mathematically equivalent to the current model if we only care about the choice of risk taking.

[2] Namely, the principal only observes the noised investment.

[3] The probability basis of the expectation operator depends on the agent's investment behavior and the firm's level of risk taking.

[4] Thus, the principal cannot issue equity, and the agent is protected by limited liability.

[5] To guarantee that the agent's utility is well defined, we assume that $pA > \hat{\imath}$ for all p. Notice that, here, $\hat{\imath}$ depends on the value of p and σ_o

[6] We assume $\hat{\imath}$ is smaller than $\beta + \delta$ because otherwise the firm value is infinite.

[7] This phenomenon has been documented in the literature of macroeconomics and international economics. See, for example, Obstfeld (1994).