Double Moral Hazard in Teams

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Abstract

This paper addresses a central question in the theory of the ¯rm: separation of ownership and control rights. We approach the problem by studying the optimal incentive schemes in a two-sided moral hazard scenario where one party is the principal and the other is a small managerial team. The optimal incentive scheme implies that the purpose of monitoring is not only to discipline the agents but also to discipline the principal herself. However the reasons are di®erent from that of McAfee and McMillan (1991) where in our model, better monitoring technology disciplines the principal in the fashion that she has to exert more e®ort. Furthermore, given that entrepreneurial abilities, which are private information to the agents, also count in output, the separation of ownership and control is a trade-o® between better discipline in the ¯rm and acquiring more high ability managers. One advantage of a classic team managed ¯rm over a partnership is that it restores the information e±ciency between the agents, which is crucial in project selection. The separation of ownership and control also implies that grouping a senior manager and a junior manager in a team is bene¯cial.

Résumé

Ce papier adresse la question centrale dans la théorie de l'entreprise: séparation de propriété et droits du contrôle. Nous approchons le problème en étudiant la motivation optimale intrigue dans un scénario du hasard moral à deux aspects où une

réception est le directeur et l'autre est une petite équipe directoriale. Le plan de la motivation optimal implique que le but d'écoute est discipliner les agents pas seul mais aussi discipliner le directeur elle-même. Cependant les raisons sont différent de cela de McAfee et McMillan (1991) où mieux la technologie de l'écoute discipline le directeur dans la mode qu'elle doit exercer plus d'effort dans notre modèle. En outre, donné aussi ces capacités d'entrepreneur qui sont de l'information privée aux agents incluent la production, la séparation de propriété et contrôle est un échange entre meilleure discipline dans l'entreprise et acquérir de plus hauts directeurs de la capacité. Un avantage d'une équipe classique dirigé l'entreprise sur une association est qu'il restaure l'efficacité de l'information entre les agents qui sont crucial dans sélection du projet. La séparation de propriété et contrôle implique aussi ce groupement un directeur aîné et un directeur plus jeune dans une équipe est salutaire.

Do not impose others what yourself do not desire.

| | | Confucius

1 Introduction

The problem of double (or two-sided) moral hazard was not studied until lately. Cooper and Thomas (1985) is probably the ¯rst one who studied the double moral hazard problem through examining the optimal product warranty when the failure rate of a product is a®ected by both the ¯rm's and the consumer's privately observed actions taken on the product. Mann and Wissink (1988), Dybvig and Lutz (1993) also discussed the same issue. In this literature, the optimal warranty is based on the notion of Nash equilibrium of the noncooperative game. When arriving at a conclusion about the level of the warranty jointly, both parties anticipate their reciprocal pattern of unobserved behavior, they consequently maximize their joint surplus under the restriction of the Nash equilibrium. The conclusion of the double moral hazard warranty model is that, ¯rst, parties who feel that they are unobserved when carrying out their product investments normally agree for a partial warranty; second, this voluntary agreement resolves the double moral hazard problem in a suboptimal manner. Mann and Wissink (1988) discussed the case of a voluntary money-back warranty. In their model, the buyer is allowed to return the product within a period speci¯ed beforehand. The authors conclude that under extreme conditions the double moral hazard problem is solved by the ¯rst-best levels of care-taking.

For the form of the optimal compensation schemes, Romano (1994) and Bhattacharyya and Lafontaine (1995) show that a simple linear contract in which both principal and agent share the output with constant proportions after a certain amount of transfer is made between them when both the principal and the agent are risk neutral is optimal. When the principal is risk neutral and the agent is risk averse, Kim and Wang (1998) argue that the optimal contract is generally not linear if the ¯rst order approach is valid. Agrawal (1999) models the double moral hazard scenario between a landlord and a tenant with di®erent levels of farming e±ciency. The optimal contract maximizes the output net of the risk-taking and agency costs with risk averse landlord and tenant mutually monitoring each other. The primary ¯nding in Agrawal (1999) is that the farming e±ciency di®erence is the principal determinant of the contract.

In an example of Bhattacharyya and Lafontaine (1995) on franchising, it is shown that with some speci¯c assumptions[2], the optimal share proportion is independent of market size or competition, franchisees' disutility parameters and the size of the franchise chain. Lutz (1995) studies the dynamic double moral hazard problem in

[2]Cobb-Douglas production technology, constant marginal cost of private e®ort for the franchisor and CARA disutility functions for heterogeneous franchisees.

franchising in which she found that franchising may be a preferred organizational form when the local manager's effort has a relatively small effect on the unit's current profit, but a large effect on the unit's future profit.

Many have considered the remedies for double moral hazard. Feess and Nell (1998) consider a double moral hazard problem in a one-manager-one-auditor game. They show that an efficient liability rule without punitive penalties can be solved through contingent auditing fees and fair insurance contracts where deductibles above the damages are not required. Demski and Sappington (1991) show that the double moral hazard problem can be completely and costlessly resolved if both parties have the option for the risk-averse agent to purchase the firm at a prenegotiated price. Hence the agent will not be exploited under the buyout scheme, nor will he bear any unnecessary uncertainty. However, they noticed that in order to make the buyout scheme feasible, the agent will have to have sufficient wealth to buy out the firm, thus, the model is generally restricted to the literature on the vertical relations between manufacturer and retailer. Tsoulouhas (1999) proposed that a piece rate tournament can eliminate double moral hazard with multiple agents. However this holds only if two conditions hold: 1. the principal sufficiently saves transaction costs by employing a tournament; 2. the number of agents is sufficiently large.

Recently, Creightney (2000) tries to generalize some properties including optimal risk sharing in a comprehensive double moral hazard model in a repeated setting.

It is found that the optimal sensitivity is lower than that of a single moral hazard problem. Also, the marginal utility ratio is changing across periods, suggesting an history independent dynamic contract.

However the current literature on double moral hazard is problematic in the sense that double moral hazard is implicitly assumed as the cause of some inefficiencies. If, the conjecture is false or misunderstood, then the remedies offered will be naturally rejected whatsoever. Secondly, most models are static, therefore any interactions between the two sides of the relationship due to the repeated nature of the relationship is ignored, making the model less vigorous and convincing. Thirdly, an agent's output in the real world does not only depend on the agent's effort but also his ability, especially entrepreneurial abilities for a manager. In this sense, the tournament proposed in Tsoulouhas (1999) is too restrictive to us. Fourth, most models use very general functional forms on production technology, players' utility, and information structure etc. This makes the model somewhat general but less manipulable and gives no close form solutions therefore less convincing.

With the above points in mind, our model differs in at least four aspects: 1, the inefficiency of double moral hazard, if it ever exists, is not presumed before hand; 2, the timing in our model allows learning to nest; 3, the decision to participate the production or not by the principal is endogenous depending on his own ability, the information he has and risk bearing; 4, we seek the close form solutions with aggregate production technology, CARA utility functions and commonly adopted monitoring technologies.

Our major ¯ndings are: the optimal incentive sensitivity is higher for the principal if her e®ort a®ects the output positively and stochastically, implying that it is optimal for the principal to have more residual claims and optimal incentive sensitivity is lower for the agents in a double moral hazard scenario. Furthermore, we show that when the principal has better information about agents' abilities and e®orts than the agent's teammate has, she will have to exert a high e®ort level in equilibrium. Then the principal is trapped into a double moral hazard dilemma and this may be the cause of separation of ownership and control rights in which the owner quits from monitoring or management but turns to be a pure residual claimant. This result, together with a trivial sequel that an agent will exert more e®ort if monitoring technology is better, indicates that the purpose of improving monitoring technology by the risk averse principal is to convince her subordinates that she will not shirk if she ever decides to stay in partnership.

We also attempt to o®er an explanation on the separation of ownership and control when the remaining management is team oriented. In Marino and Matsusaka (2001), partial delegation allows the principal to reject the bad projects but causes the agent to distort the information transmitted to the principal. In our case, total delegation, i.e., separation of ownership and control rights, restores information e± ciency between the team members. In McAfee and McMillan (1991), the purpose of monitoring is to only discipline the principal, if the principal is subject to moral hazard. In the case of double moral hazard, if monitoring is effective, the principal would commit herself in monitoring to discipline the agents and eventually discipline herself. By the Revelation Principle, in our case, if a menu of contracts are offered, self-estimated abilities will be revealed and hence separation of ownership and control can be used as a substitute for monitoring if monitoring is too costly and/or the principal is too risk averse.

The structure of the rest of this paper follows: section 2 introduces the model, section 3 analyzes the optimal scheme for the second period, section 4 derives the optimal incentive scheme in the first period, section5 concludes the model.

2 The Model

The firm is constituted by two agents and one principal. Production is a function of both agents' and the principal's labour inputs plus a random shock,

$$\begin{aligned} y &= f(a; b; e) + \varepsilon \qquad (2.1) \\ &= a + b + e + \eta_a + \eta_b + \varsigma + \varepsilon; \end{aligned}$$

where $a; b; e$ are the effort exerted by agent 1, 2 and principal, respectively, and all of which have the support $[\underline{a}; \bar{a}]$; and η_a; η_b; ς are the abilities of agent 1, 2 and the principal, respectively, and all distributed as $N(m_0; \sigma^2)$ a priori with zero correlation and ε is a random transient shock, distributed as $N(0; \sigma_\varepsilon^2)$. There are two periods in the model, therefore learning about team mates' ability is involved. Only aggregate output in each period is observable and verifiable to all parties. We use backwards induction to analyze the two-sided moral hazard.

Consider first in the second period, output is

$$y_2 = a_2 + b_2 + e_2 + \eta_a + \eta_b + \varsigma + \varepsilon_2;$$

where the subscripts denote the period[3]. Following Holmstrom and Milgrom (1987), we assume a linear incentive contract in the following form,

$$S_2 = \alpha_2 + \beta_2 y_2. \qquad (2.2)$$

Therefore agent 1's[4] utility maximization problems is

$$\max_{a_2} E[U(\alpha_2 + \beta_2 y_2) - h(a_2)]; \qquad (2.3)$$

and principal's utility maximization problem is

$$\max_{e_2} E[V((1 - 2\beta_2) y_2 - 2\alpha_2) - g(e_2)]; \qquad (2.4)$$

where $U(\cdot); V(\cdot)$ are the utility functions of the agents and principal respectively. $h(\cdot); g(\cdot)$ are disutilities of effort.

[3] The intrinsic abilities do not change over time.

[4] Because of information symmetry, we take agent 1 as representative agent.

Formally, the principal's utility maximization problem is

$$\max_{e_2} E[V((1 - 2\beta_2)(a_2 + b_2 + e_2 + \eta_a + \eta_b + \varsigma + \varepsilon_2) - 2\alpha_2) - g(e_2)] \tag{2.5}$$

subject to

$$\max_{a_2} E[U(\alpha_2 + \beta_2 y_2) - h(a_2)]; \tag{2.6}$$

$$\max_{b_2} E[U(\alpha_2 + \beta_2 y_2) - h(b_2)]; \tag{2.7}$$

$$E[U(\alpha_2 + \beta_2 y_2) - h(a_2)] \geq \underline{U}; \tag{2.8}$$

$$E[U(\alpha_2 + \beta_2 y_2) - h(b_2)] \geq \underline{U}; \tag{2.9}$$

where $\underline{U}$ is the agent's reservation utility, $(2.6); (2.7)$ are agents 1 and 2's incentive compatibility constraints, and $(2.8); (2.9)$ are the agent's participation constraints.

We assume that both the principal and the agents have CARA utility functions as we do not impose ad hoc assumption on the asymmetry on the two parties risk aversion. In our point of view, the major difference between a principal and an agent is the authority within the firm. In particular, principal sets up the contract. Firms are different sorts of agencies, although the relationship between the owner and the managers of a firm can be depicted by principal-agent models, it is different from between a patient and a doctor, or a defendant and her attorney. The firm owner can supervise or monitor her sta® to get a less vague picture on her fellow employees' abilities and e®ort while the reverse is much harder. This is not because the ¯rm owner's activities are less relevant to the ¯rm's output, but because of three reasons: ¯rstly, the boss is a worker who works under the shadow in which his talent or work that has been done is hard to measure; secondly, it is too costly to the agents to measure the owner's e®ort while the owner could be using accounting information generated from each department of the ¯rm to measure and evaluate employees, these could be seen as some by-products from the production process and hence costless; ¯nally, the owner has the authority, or voting rights to implement his action, using resources within the ¯rm, this implies that even if monitoring is costly, she can still implement it.

We assume a costless monitoring technology to the principal where by the end of the ¯rst period she can ¯nd out the probability distribution[5] of the true level of total e®ort exerted by the agents and it is denoted by ¼; and with 1 ¡ ¼ she does not

[5] Assume that we can decompose the probability function for the agent' e®ort, ¼; into the following form,

$$¼(a_1) = a_1 ¼^H + (1 ¡ a_1)¼^L;$$

for a_1 2 [0; 1]: In the case of one agent, it implies that the principal can be only sure that the e®ort exerted by the agent was a_1 with con¯dence $¼^H$; thus the principal obtains information on agents' e®ort levels probablistically. According to Hart and Holmstrom (1987), we call the form the condition of linearity of the distribution function.

retrieve any information. The principal's conditional variance of estimated sum of the agents' abilities, σ_P^2, by DeGroot (1982), is

$$\sigma_P^2 \equiv Var(\eta_a + \eta_b + \varepsilon | y_1) = (1-\pi)\left(2\sigma_\eta^2 + \sigma_\varepsilon^2\right) + \pi\left(\frac{2\sigma_\varepsilon^2\sigma_\eta^2}{2\sigma_\eta^2 + \sigma_\varepsilon^2} + \sigma_\varepsilon^2\right)$$

$$= \frac{2\pi\sigma_\varepsilon^2\sigma_\eta^2}{2\sigma_\eta^2 + \sigma_\varepsilon^2} + 2(1-\pi)\sigma_\eta^2 + \sigma_\varepsilon^2.$$

Note that even the salary paid to the team members cannot be ex post dependent on the effort levels not only as what the principal observes is a distribution, but also because it is about an aggregate statistics. This argument holds even if the agents choose between two discrete effort levels.

3 Second Period Double Moral Hazard

We can now rewrite the principal's utility maximization problem in period 2 as

$$\max_{e_2;\beta_2} -\exp\left\{-R\left[(1-2\beta_2)E_P[y_2] - 2\alpha_2^*(\beta_2) - g(e_2) - \frac{1}{2}R(1-2\beta_2)^2\sigma_P^2\right]\right\}; \quad (3.1)$$

where R is the principal's coefficient of absolute risk aversion, and α_2^* can be derived from agent's participation constraint (2.8),

$$\alpha_2^* = \underline{u} - \beta_2^* E_A[y_2] + h(\hat{e}_2) + \frac{1}{2}r\beta_2^{*2}\sigma_A^2; \quad (3.2)$$

where $\underline{U} = -\exp(-r\underline{u})$; superscript * denotes equilibrium level, $\hat{e}_2$ is agent 1's second period equilibrium effort level, which is expected by the principal, and the agent's posterior belief on randomness, $\varepsilon_2 + \eta_b + \zeta$; is

$$\sigma_A^2 = 2\sigma_\eta^2 + \sigma_\varepsilon^2;$$

which is equal to the agent's *a priori* belief since neither of them has monitoring technology. Therefore (3:1) can be rewritten as

$$\max_{e_2;\beta_2} -\exp\left\{-R\left[E_P[y_2] - 2\underline{u} - (m_1 - 2m_0) - 2h(\tilde{a}_2) - g(e_2) - r\beta_2^2\sigma_A^2 - \frac{1}{2}R(1-2\beta_2)^2\sigma_P^2\right]\right\}; \tag{3.3}$$

where the principal's posterior belief on $\eta_a + \eta_b$; m_1; is

$$m_1 = 2\pi\frac{\sigma_\varepsilon^2 + 2\sigma_\eta^2(y_1 - \tilde{a}_1 - \tilde{b}_1 - \tilde{e}_1 - \zeta)}{2\sigma_\eta^2 + \sigma_\varepsilon^2} + 2(1-\pi)m_0; \tag{3.4}$$

where decoration ~ denotes the associated variable is the actual value that the principal perceives.

The first order condition to (3:3) with respect to β_2 implies

$$e_2' \equiv \frac{\partial e_2}{\partial \beta_2} = -\frac{2}{\frac{\partial g'(e_2)}{\partial \beta_2}} = -\frac{2}{g''(e_2)}; \tag{3.5}$$

and first order condition for the agent's second period utility maximization yields,

$$a_2' = \frac{1}{h''(a_2)}: \tag{3.6}$$

Therefore the first order condition to (3:3) with respect to β_2 yields

$$\beta_2^* = \frac{\frac{1}{h''(a_2^*)} - \frac{1}{g''(e_2^*)} + R\sigma_P^2}{\frac{1}{h''(a_2^*)} - \frac{1}{g''(e_2^*)} + (r\sigma_A^2 + 2R\sigma_P^2)}: \tag{3.7}$$

where r is the agents' coefficient of absolute risk aversion. One can easily verify that if the principal and the agents are equally risk averse and the principal can not retrieve any of the agents' private information, the optimal incentive parameter, β_2^*; for this one principal two agent team, is $\frac{1}{3}$: This is due to the symmetry of the relationship between the principal and the agents.

Proposition 1 In a double moral hazard scenario, the optimal incentive for the principal is (weakly) higher than that of an agent[6].

Proof. Suppose the agents and the principal have the same disutility function, and the same absolute risk aversion coefficient, and because $\sigma_A^2 \geq \sigma_P^2$; then (3:7) can be simplified as

$$\frac{1}{h''(a_2^*)} - \frac{1}{g''(e_2^*)} \leq r\sigma_A^2 - R\sigma_P^2: \tag{3.8}$$

Now suppose that $h'''(\cdot) \equiv g'''(\cdot) \geq 0$; we have $\beta \leq \frac{1}{3}$ and consequently $1 - 2\beta_2^* \geq \frac{1}{3}$: ■

Therefore, in our model, the purpose of monitoring is not only to discipline the subordinates, but also discipline the principal herself as undertaking more risks by the more informed party is optimal. The optimal incentive parameter with double moral hazard in teams is a trade-off between optimal trade-off between risk bearing

[6] Note that the piece rate here should not be confused with surplus sharing between the principal and the agents as the agents' expected utility is binding in our model.

and incentive effect for the agents, and that for the principal herself. However the discipline effect is different from which in McAfee and McMillan (1991) where in their model, monitoring is completely irrelevant *per se* but just to discipline the principal from moral hazard activities like escaping if upfront payments by the agents were pre-collected.

Corollary 2 *The optimal incentive for the principal is (weakly) higher if the principal's information on agents' abilities is more precise or she is less risk averse and/or if the agents are more risk averse.*

Proof. This is to say

$$\frac{\partial \beta_2^*}{\partial \sigma_P^2} \geq 0;$$

$$\frac{\partial \beta_2^*}{\partial R} \geq 0$$

and

$$\frac{\partial \beta_2^*}{\partial r} \leq 0$$

It can be easily checked by taking partial derivatives on (3.7) with respect to σ_P^2; R and r. ■

Consider now the principal has an option to quit from everyday production but just turn to be a residual claimant. Therefore the work is left to the two agents in second period. The principal will quit if and only if the utility from being a residual claimant is greater than that from directly participating in production. That is,

$$(1-\beta_2^B)(a_2+b_2+m_1) - 2\alpha_2^B - \frac{1}{2}R(1-2\beta_2^B)^2\sigma_P^2 \tag{3.9}$$
$$\geq (1-\beta_2^*)(a_2+b_2+e_2+m_1+\varsigma) - 2\alpha_2^* - g(e_2) - \frac{1}{2}R(1-2\beta_2^*)^2\sigma_P^2,$$

where superscript B represents the case of no principal participates in production.

To obtain conditions for inequality (3.9) to hold, we solve β_2^B and α_2^B. First order conditions of the maximization over the principal's certainty equivalent when she quits from production operation in period two yield,

$$\beta_2^B = \frac{\frac{1}{h''(a_2^B)} + R\sigma_P^2}{\frac{1}{h''(a_2^B)} + r\sigma_A^{B2} + 2R\sigma_P^2}. \tag{3.10}$$

where σ_A^{B2} is the similar to σ_A^2 in the double moral hazard case, and $\sigma_A^{B2} = var[\varepsilon_2+\eta_i]$, $i = a, b$.

Lemma 3 *The principal who does not participate production but is a residual claimant, will have positive claims on the residue.*

Proof. This is to say that $1-2\beta_2^B > 0$ or equivalently $\beta_2^B < \frac{1}{2}$. From rearranging (3.10), we have if and only if

$$r\sigma_A^{B2} > 0, \tag{3.11}$$

then

$$\beta_2^B < \frac{1}{2}. \tag{3.12}$$

■

Corollary 4 If there is no uncertainty on the agents ability and randomness in production and/or the agents are risk neutral, then the contract offered to the agents is a rental lease.

Proof. Because if

$$r\sigma_A^{B2} = 0;$$

then

$$\beta_2^B = \frac{1}{2};$$

which implies a contract in which the principal undertakes no risk but just charges the agents a fixed term. ■

Lemma 5 Optimal incentive sensitivity for the agent in a double moral hazard scenario is lower than that of a one-sided moral hazard case in teams.

Proof. Assuming that $h'''(\cdot) \equiv g'''(\cdot) \geq 0$; the relation $\beta_2^* \gtrless \beta_2^B$ is equivalent to

$$\left(r\sigma_A^2 + 2R\sigma_P^2\right)\frac{1}{g''(e_2)} - R\sigma_P^2\frac{1}{g''(e_2^*)} \gtrless 0: \qquad (3.13)$$

It is then apparent that

$$\beta_2^* < \beta_2^B: \qquad (3.14)$$

■

Assuming for the moment that $h(x) = g(x) = \frac{x^2}{2}$; then (3:9) can be rewritten as

$$2\beta_2^B - \left(\beta_2^B\right)^2 - r(\beta_2^B)^2\sigma_A^{B2} - \frac{1}{2}R(1 - 2\beta_2^B)^2\sigma_P^2 \quad (3.15)$$
$$\geq \frac{1}{2} + \varsigma - 3\beta_2^{*2} + \beta_2^* - r\beta_2^{*2}\sigma_A^2 - \frac{1}{2}R(1 - 2\beta_2^*)^2\sigma_P^2;$$

where $\sigma_A^{B2} = \sigma_\tau^2 + \sigma_\varepsilon^2 < \sigma_A^2$:

Lemma 6 If the principal's entrepreneurial ability is sufficiently low, i.e., (3:15) holds, she will quit from the production operation.

Remark 1 Note that $\sigma_A^{B2} < \sigma_A^2$ and $\beta_2^* < \beta_2^B$; the sufficient condition (3:15) can be simplified to a further sufficient condition,

$$\varsigma \leq \beta_2^B - \left(\beta_2^B\right)^2 + 3\beta_2^{*2} - r(\beta_2^B)^2\left(\sigma_A^B\right)^2 + r\beta_2^{*2}\sigma_A^2:$$

Because uncertainty is reduced, i.e., $\left(\sigma_A^B\right)^2 < \sigma_A^2$; the trade-off between insurance effect and incentive to the agents is improved and hence the optimal incentive sensitivity is higher. Recently, Mario Lemieux, the Pittsburgh Penguins' owner who ended a 3 1/2-year retirement in December 2000, helped to take his team to the conference finals for the first time since 1996. On the other hand, Lemieux's fellow superstar, Jaromir Jagr, who is one of the best players in the history of the National Hockey League, scored only twice during the entire playoffs in 2001. Jagr will also end his

11 years draft with the Pittsburgh Penguins this summer. Our theory may explain the above story[7].

4 First Period Incentive Problem

With the second period optimal incentive problem solved, we advance to the first period. In the first period, the utility maximization problem to agent 1 is,

$$\max_{a_1} -\exp\{-r[\alpha_1 + \beta_1^* E_A[y_1] - h(a_1) + \delta\alpha_2^* + \delta\beta_2^* E_A[y_2] - h(\hat{a}_2) + \frac{1}{2} r\sigma_A^2]\}; \quad (4.1)$$

where variance σ_A^2 captures all the uncertainties to agent 1 at the first period perspective. The principal's problem is then

$$\begin{aligned} \max_{e_1;\beta_1} -\exp\{-R[(1-2\beta_1) E_P[y_1] - 2\alpha_1^* - g(e_1) \quad (4.2) \\ +\delta(1-2\beta_2^*) E_P[y_2] - 2\delta\alpha_2^* - \delta g(\hat{e}_2) - \frac{1}{2} R\sigma_P^2]\}; \end{aligned}$$

[7] According to Proposition 1 and Lemma 5, if Jagr rationally predicts low incentive featured by the new contract with the owner's participation in production, he would not sign a new contract with Penguins, which is also what we have seen. However Jagr's individual rationality constraint can be satisfied if Lemieux pays him an α_2 high enough. Nevertheless, Lemieux was not able to commit to it in 2000-2001 season as the club was experiencing cash flow crisis.

where variance Σ_P^2 captures all the uncertainties to the principal at the first period perspective and

$$\Sigma_P^2 = \left(1 - 2\beta_1 - \frac{\delta\pi\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2} + \delta(1 - 2\beta_2)\right)^2 \left(2\sigma_\epsilon^2\right) + \left[\left(1 - 2\beta_1 - \frac{\delta\pi\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2}\right)^2 + \delta^2(1 - 2\beta_2)^2\right]\sigma_\eta^2. \tag{4.3}$$

The first order condition for (4.1) yields

$$h'(a_1) = \beta_1 + \delta\pi\frac{\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2}.$$

To obtain β_1^*, maximize (4.2) with respect to β_1, i.e.,

$$0 = -2\left(\beta_1^* + \frac{\delta\pi\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2}\right)a_1' - \left(1 - 2\beta_1^* - \frac{2\delta\pi\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2}\right)e_1' - 2r\beta_1^*\sigma_A^2 - \frac{1}{2}R\frac{\partial\Sigma_P^2}{\partial\beta_1}, \tag{4.4}$$

where

$$\frac{\partial\Sigma_P^2}{\partial\beta_1} = 8\beta_1(2\sigma_\epsilon^2 + \sigma_\eta^2) + 4\left(\frac{\delta\pi\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2} - 1\right)(2\sigma_\epsilon^2 + \sigma_\eta^2) - 8\sigma_\epsilon^2\delta(1 - 2\beta_2). \tag{4.5}$$

Therefore some algebra manipulations from (4.4) imply that

$$\beta_1^* = \frac{\frac{1}{g''(e_1)} + 2R\delta\sigma_\epsilon^2(1 - 2\beta_2^*) - \left(\frac{1}{h''(a_1)} + \frac{2}{g''(e_1)}\right)\frac{\delta\pi\sigma_\epsilon^2}{2\sigma_\epsilon^2 + \sigma_\eta^2} + R((2 - \delta\pi)\sigma_\epsilon^2 + \sigma_\eta^2)}{\frac{1}{h''(a_1)} + \frac{2}{g''(e_1)} + (r + 2R)(2\sigma_\epsilon^2 + \sigma_\eta^2)}. \tag{4.6}$$

The first term in the numerator of (4.6) is similar to that of (3.7); the second term is the effect of principal's estimation error on agents' first period effort; the third term is to balance out the career concerns of the agents and the last term in the numerator is similar to that of (3.7), an appropriate risk aversion adjuster. Once again, if there is no uncertainty or the players are risk neutral, $\beta_1^* = \frac{1}{3}$.

Lemma 7 An advanced monitoring technology induces the agents to exert higher effort levels, in particular, the representative agent will exert an effort level higher than that of the principal's if and only if

$$\pi \geq \frac{2r(1 - 2\beta_2^*)\sigma_A^2}{r\sigma_A^2 + 2},$$

where $\sigma_A^2 = 2\sigma_\varepsilon^2 + \sigma_\eta^2$.

Proof. First order conditions to (4.2) and (4.1) show that

$$h'(a_1^*) = \beta_1^* + \frac{\delta\pi\sigma_\varepsilon^2}{2\sigma_\varepsilon^2 + \sigma_\eta^2},$$

and

$$g'(e_1^*) = 1 - 2\beta_1^* - \frac{2\delta\pi\sigma_\varepsilon^2}{2\sigma_\varepsilon^2 + \sigma_\eta^2}.$$

Suppose $g(\cdot) = h(\cdot)$, then $h'(a_1^*) \geq g'(e_1^*) \iff a_1^* \geq e_1^*$, which is equivalent to

$$\beta_1^* \geq \frac{1}{3} - \frac{\delta\pi\sigma_\varepsilon^2}{2\sigma_\varepsilon^2 + \sigma_\eta^2}$$

which in turn is equivalent to

$$\pi \geq \frac{2r(1 - 2\beta_2^*)\sigma_A^2}{r\sigma_A^2 + 2}.$$

■

Lemma 6 seems to be a trivial result, however combined with Corollary 2, the implication is that a risk averse principal should have an advanced monitoring technology to convince her subordinates that she will not shirk if she ever participates in production operation, rather than monitoring the agents in Alchain-Demsetz sense.

Lemma 8 The cross period change of optimal explicit incentive for the subordinates in a firm with double moral hazard depends increases with better monitoring technology, and decreases with better precision on subordinates' abilities, i.e.,

$$\frac{\partial(\beta_2^* - \beta_1^*)}{\partial \pi} \geq 0;$$

and

$$\frac{\partial(\beta_2^* - \beta_1^*)}{\partial \sigma_\varepsilon^2} \geq 0.$$

Proof. Suppose that the principal and the agents have the same disutility function and they are equally risk averse, i.e., $h = g$; $R = r$; then some algebras yield that

$$\beta_2^* - \beta_1^* = \frac{\frac{R}{h''(a_1)}\left(3\delta\pi\sigma_\varepsilon^2 + 6\delta\pi\frac{\sigma_\varepsilon^2\sigma_P^2}{\sigma_A^2} + \sigma_P^2 - \sigma_A^2\right) + 3\delta\pi R^2\sigma_A^2\sigma_\varepsilon^2 - 2R^2\delta\sigma_\varepsilon^2(1 - 2\beta_2^*)(\sigma_A^2 + 2\sigma_P^2)}{R\left((\sigma_A^2 + 2\sigma_P^2)\right)\left(\frac{3}{h''(a_1)} + 3R\sigma_A^2\right)}. \tag{4.7}$$

Note the denominator of RHS in (4.7) is positive. It is then straightforward to show that $\frac{\partial(\beta_2^* - \beta_1^*)}{\partial\pi} \geq 0$ and $\frac{\partial(\beta_2^* - \beta_1^*)}{\partial\sigma_\varepsilon^2} \geq 0$. ■

The above lemma implies that the change of optimal incentive parameter over time is a trade-off between reduced incentives to the agents under better monitoring technology[8] and exaggerated incentives due to a large *a priori* variation on their abilities. This trade-off is shown by the first two terms of the numerator in (4:7) : In particular, with sufficiently large δ; π and σ^2_ε; one can obtain $\beta^*_2 > \beta^*_1$; which implies that a risk averse owner of the firm will work harder in later career if she ever decides to stay in production operation. This result is against the common sense as it seems an owner quits from business as time goes. Note the analysis here assumes ability does not change over time and there is no interaction between effort and ability. Many of the facts attribute to the ability, for instance, a chair of a department, commonly a productive senior faculty, usually does not always painstakingly stay in office or lab overtime to produce good research, instead, much of her late work is due to her superior academic ability that she gained from previous years. Same thing happens in a business world[9].

[8] In the sense that the true levels of effort is more likely to be found probabilistically and hence the increase in α_2 due to an increase on the mean of posterior belief of their abilities will not be enough to balance the over-exerted effort in the first period.

[9] Recently, Lee Iacocca, the legendary former chairman of Chrysler, is now on the board of San Diego-based Online Asset Exchange, a commodities-like exchange for used corporate assets. Though selling used machine tools might not sound as glamorous as launching the original Mustang or bringing the first minivan into market or saving one of America's Big Three automakers from bankruptcy, Iacocca is pretty successful especially given that fact that about 20 dot com companies

5 Multiplicative Technology, Grouping, Information Efficiency and the Separation of Ownership and Control

Another class of technology, contrary to linear additive technology and perhaps equally natural, is multiplicative technology. In this section, we give some results based on multiplicative technology. In order to obtain the illustrative results, we adopt a VNM utility function and restrict our analysis in a static environment. Consider now the output of the managerial team managed firm is

$$y = \varepsilon(abe\eta_a\eta_b\zeta)^{\gamma};$$

where ε is a random shock, γ is a constant, a, b and e are agent 1, 2 and the principal's effort, $\eta_a; \eta_b$ and ζ are agent 1 2 and the principal's ability, respectively. It is assumed that $E[\varepsilon] = 1; 0 < \gamma < 1:$

The learning of ability in this environment is difficult to depict and appears uninteresting, therefore we analyze in a static setting.

Each of the agents takes a proportion of β of the output[10] and agent 1's expected utility is

$$E[U(\beta\varepsilon(abe\eta_a\eta_b\zeta)^{\gamma}) - h(a)]$$

go bankruptcy every day in the Sillicon Valley alone. Jeffrey Bezos claims in a TV show that he works extremely hard to keep Amazon.com alive while Lee Iacocca is taking time in his part.

[10]Once again since the monitoring is based on aggregate indice, the two agents must be symmetric.

where $h(a)$ is agent's disutility of effort and $h'(\cdot) > 0$; $h''(\cdot) > 0$. By the first order condition of the manager 1's utility maximization, we have

$$\beta\gamma a^{\gamma-1}E[U'(\cdot)\varepsilon] = h'(a); \tag{5.1}$$

where the second order condition is satisfied, i.e.,

$$\frac{\gamma-1}{a} + \gamma\frac{E[U''(\cdot)\varepsilon^2\beta(be\eta_a\eta_b\zeta)^\gamma a^{\gamma-1}]}{E[U'(\cdot)\varepsilon]} - \frac{h''(a)}{h'(a)} < 0. \tag{5.2}$$

For simplicity, assume the principal is risk neutral so that the profit maximization can be written as

$$E[(1-2\beta)\varepsilon(abe\eta_a\eta_b\zeta)^\gamma - g(e)] = (1-2\beta)(abe\eta_a\eta_b\zeta)^\gamma - g(e). \tag{5.3}$$

First order condition of (5.3) with respect to β yields

$$\frac{2}{1-2\beta} = \frac{\gamma}{e}\frac{\partial e}{\partial\beta} + \frac{\gamma}{a}\frac{\partial a}{\partial\beta} + \frac{\gamma}{b}\frac{\partial b}{\partial\beta} - \frac{g'(e)}{g(e)}\frac{\partial e}{\partial\beta}. \tag{5.4}$$

Assuming that the principal's marginal incentive with respect to contract sensitivity is negatively twice of an agent's, i.e., $\frac{\partial e}{\partial\beta} = -2\frac{\partial a}{\partial\beta}$; we can rewrite (5.4) as

$$\frac{1}{1-2\beta} = \frac{\gamma}{a^*}\frac{\partial a}{\partial\beta} - \frac{\gamma}{e}\frac{\partial a}{\partial\beta} - \frac{g'(e)}{g(e)}\frac{\partial a}{\partial\beta}. \tag{5.5}$$

Now we focus on the optimal contract β. Differentiating the natural logarithm form of (5.1) with respect to β; we have

$$\begin{aligned}&\frac{1}{\beta} + \frac{E[U''(\cdot)\varepsilon^2(abe\eta_a\eta_b\zeta)^\gamma]}{E[U'(\cdot)\varepsilon]} \\ =\ &\frac{h''(a)}{h'(a)}\frac{\partial a}{\partial\beta} + \frac{1-\gamma}{a}\frac{\partial a}{\partial\beta} - \gamma\frac{E[U''(\cdot)\varepsilon^2\beta(be\eta_a\eta_b\zeta)^\gamma a^{\gamma-1}]}{E[U'(\cdot)\varepsilon]}\frac{\partial a}{\partial\beta}.\end{aligned} \tag{5.6}$$

Assume that the agents have constant relative risk aversion (CRRA), i.e.,

$$-\frac{U''\varepsilon\beta(abe\eta_a\eta_b\zeta)^{\gamma}}{U'} = R; \tag{5.7}$$

and the first order derivative of disutility function has constant elasticity in labour supply, i.e.,

$$\frac{h''a}{h'} = \phi. \tag{5.8}$$

Substituting (5.7) and (5.8) into (5.6) and rearranging terms; we have

$$\frac{\beta}{a}\frac{\partial a}{\partial \beta} = \frac{1-R}{\phi + (1-\gamma) + \gamma R}. \tag{5.9}$$

Rearranging (5.5) and substituting into (5.9) yields

$$\beta = \frac{(1-R)\left(\gamma - \frac{a\gamma}{e} - a\frac{g'}{g}\right)}{2(1-R)\left(\gamma - \frac{a\gamma}{e} - a\frac{g'}{g}\right) + \phi + (1-\gamma) + \gamma R}. \tag{5.10}$$

Corollary 9 Optimal share to the agents should be increasing in the principal's effort if the principal's effort is low and vice versa, i.e.,

$$\text{if } e < \frac{1}{2}; \text{ then } \frac{\partial\beta}{\partial e} > 0;$$

$$\text{if } e > 1; \text{ then } \frac{\partial\beta}{\partial e} < 0.$$

Proof. Straightforwardly by taking partial derivative on (5.10) with respect to e. ■

Proposition 10 The optimal sharing in double moral hazard is a trade-off between incentive effect to the agents and disciplining the principal herself.

Analytical hint. Proposition 10 is implied by Corollary 9. Corollary 9 simply says that if there is a major factor on output other than the agents' effort whatsoever, giving the agents a large share would be unwise, likewise, if this factor is too small, optimal contract should bring sufficient incentives to the agents to induce them to exert effort. In fact, this factor is the principal's effort which itself is assumed decreasing in β; therefore the optimal share to the principal, $1 - 2\beta$; is high in equilibrium, according to Corollary 9. □

Suppose now that the principal quits from production but turns to be a pure residual claimant, information efficiency might be restored. To illustrate this effect, consider the following numerical example.

Suppose that there are two projects, one good project and one bad project. The good project, project A, will yield a net present value of $100 where the bad one, project B, yields $79. The owner of the firm who does not have control rights, takes 45% of the output. To obtain a nontrivial result, we assume that the two managers are asymmetric on abilities, i.e., the high ability manager has a ability worth of $40 in project A and $20 in project B; the low ability one's ability contribution in project A is $10 and $19 in project B. In order to achieve the project NPV, the rest must be made up by effort. Furthermore, the projects have the property that if the effort made is less than the amount of NPV apart from ability contribution requires, the project NPV will be zero. The two managers are also different in disutilities, more speci¯cally, the high ability manager has a disutility that equals $\frac{a^2}{30}$ on the good project and $\frac{a^2}{20}$ on the bad project, where the low ability manager has a disutility that equals $\frac{b^2}{20}$ everywhere. To focus on information e± ciency, we treat the managers as risk neutral for the moment.

Under 50:50 sharing rule, in the bad project, each one of the manager will exert \$20 of e®ort and incurs a cost of \$20 and ¯nally remunerated with \$21.725. In the good project, each one of the manager should exert \$25 of e®ort as 50:50 sharing rule dictates, however, the high ability manager incurs a cost of only \$20.83 while the low ability one incurs a cost of \$31.25 where the 50:50 sharing rule compensates the low ability only \$27.5 which is not enough to recover the e®ort cost. Because project information is private for the agents, under the partnership scheme which implies a 50:50 sharing rule, the agents will promote the bad project to the principal.

However with the separation of ownership and control, the good project shall be selected. Given the two projects's NPVs are common knowledge to the managers, consider a 60%:40% scheme resulted from private negotiation between the two executive managers, then the high ability manager will exert an e®ort of \$30 with a cost of \$30 and the low ability manager will exert an e®ort of \$20 with a cost of \$20, consequently according to the sharing rule, the high ability manager and the low ability manager will be compensated with \$33 and \$22, respectively. The principal gains a net of \$9.45 from choosing the good project, essentially by the separation of ownership and control.

We summarize the data in the following two tables.

Partnership	Good Project (50:50)		Bad Project (50:50)	
NPV	\$100		\$79	
principal's share: 45%	\$45		\$35.55	
effort required	25	25	20	20
ability contribution	\$40	\$10	\$20	\$19
disutilities (high ability on the left)	$\frac{a^2}{30} = 20.83$	$\frac{b^2}{20} = 31.25$	$\frac{a^2}{20} = 20$	$\frac{b^2}{20} = 20$
renumeration	\$27.5	\$27.5	\$21.725	\$21.725
net gain	\$6.67	$-\$3.75$	\$1.725	\$1.725
project chosen	No		Yes	

Table 1. Information inefficiency in a partnership firm.

Classic firm (separation of ownership and control)	Good Project (60%:40%)	
NPV	\$100	
principal's share: 45%	\$45	
effort required	30	20
ability contribution	\$40	\$10
disutilities (high ability on the left)	$\frac{a^2}{30} = 30$	$\frac{b^2}{20} = 20$
renumeration	\$33	\$22
net gain	\$3	\$2
project chosen	Yes	

Table 2. Information efficiency in a classic firm.

Now we consider the optimal sharing when the two managers are symmetric over abilities. Profit maximization in the case of separation of ownership and control will yield

$$\frac{1}{1-2\beta} = \frac{\gamma}{a^*}\frac{\partial a}{\partial \beta}. \tag{5.11}$$

Consequently, the optimal share, β', is

$$\beta' = \frac{(1-R)\gamma}{1+\phi+\gamma+\gamma R}. \tag{5.12}$$

By (5.12), we obtain the following lemma on grouping.

Lemma 11 Suppose the common sense that junior manager's effort supply elasticity is higher relative to the seniors' and seniors' ability is relatively higher to juniors is true. Then, if a managerial team is composed by a senior manager and a junior manager, the high ability manager should have more control rights. Furthermore, if bargaining between the two agents on sharing scheme is not perfectly costless, grouping a senior with a junior manager will have an advantage as it would encompass a bigger feasible project set because the junior will exert an e®ort level higher relative to his control rights.

Analytical hint. Assuming that junior manager's e®ort supply elasticity is higher relative to the seniors', i.e., $Á_{senior} < Á_{junior}$; then from (5:12) ; $¯'_{senior} > ¯'_{junior}$: Reconsider the numerical example illustrated above, distribution of control rights between the two managers is irrelevant as project information and disutility functions are all public between the agents, however if some information is private, bargaining may not be always result an e± cient sharing rule. Nonetheless, with cross grouping[11], the junior is willing to \sacri¯ce" therefore keeps the good projects be chosen. This is the bene¯t to a senior manager in cross grouping. On the other hand, if grouping a junior with another junior, even though e®ort levels are higher, the good projects may not be chosen which will be socially ine± cient.

[11] Grouping a senior agent with a junior agent.

	Junior agent	Senior agent
entrepreneurial abilities (assumed)	low	high
e®ort supply elasticity (assumed)	high	low
Control rights	low	high
e®ort exerted in equilibrium	high	low

Table 3. Optimal Cross Grouping.

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Separation of ownership and control occurs when the bene¯t from the improvement on information e± ciency is greater than the net gain from management e®ort and/or the principal's disutility is too high relative to her e®ort contribution to the output. As shown in the numerical example, since adverse selection problem is also involved, inequalities of equilibrium e®orts and direct comparisons are di± cult to make. However, intuition about the conditions on the separation of ownership and control is not hard to obtain.

Remark 2 When the principal's entrepreneurial ability is low, and/or disutility is high, relative to the agents', separation of ownership and control will be bene¯cial. Furthermore, even if the principal's entrepreneurial ability is high, since separation of ownership and control improves the information e± ciency between the agents and consequently results welfare improving bargaining or trading between the agents is, separation of ownership and control is still Pareto e± cient if the information e± ciency e®ect dominates the owner's high ability.

6 Conclusion

In this paper, we study the double moral hazard problem in a ¯rm's optimal incentive scheme design. We ¯rstly suppose the relationship between the ¯rm owner and the salaried managers are repeated; and the owner's decision to stay in board or quit for retirement is endogenous; managerial team size is small. We do not adopt lump sum transfer or buyout as options to improve the risk sharing as the relationship considered in our model is between a ¯rm owner and professional managers where the managers' wealth is constrained.

Our model ¯nds that there is no ine± ciency in the sense of double moral hazard in a team managed ¯rm because any ine± ciencies in an organization caused by double moral hazard will be adjusted by the optimal incentive scheme and the principal's strategic decision on participation and hence any remedy to it is not necessary. With double moral hazard, monitoring by the principal does not discipline the agents, but also disciplines the principal herself. Some properties that the optimal incentive scheme exhibits are consistent with commonly observed facts. These properties include: a ¯rm owner's salary is more powered than a manager's in the contract; the sensitivity of the incentive is higher for a publicly held ¯rm than a privately held ones with block shareholders.

We also studied the two-sided moral hazard problem under multiplicative technology. It is shown that optimal output sharing is a trade-o® between incentive e®ect to the agents and disciplining the principal herself. Although double moral hazard may not be the source of ine± ciency from moral hazard perspective, we argue that it could be a primary source of ine± ciency from adverse selection perspective as it could distort the information that the agents transmitted to the principal, therefore through separation of ownership and control, information e± ciency can be improved. It is suggested for future research that this scenario can be depicted in a bargaining model with di®erent threat points which would yield di®erent pro¯t sharing or information e± ciency, for example, with Nash bargaining and Kalai-Somosky bargaining.

Finally, we considered grouping problem and we found from optimal sharing rule, that cross grouping which is commonly observed, may be e± cient.

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