The Property Rights, Multitask Crossover Effects, and Incentive Contracts

Wu-Chun Chi
Department of Accounting
National Chengchi University
Taipei, TAIWAN, ROC
(02)2939-3091 ext. 81031
wchi@nccu.edu.tw

Hung-Chao Yu[*]
Department of Accounting
National Chengchi University
Taipei, TAIWAN, ROC
(02)2939-3091 ext. 81010
hjyu@nccu.edu.tw

Preliminary draft – Comments welcome

August 1, 2002

[*]The corresponding author.

The Property Rights, Multitask Crossover Effects, and Incentive Contracts

Abstract

Prior agency models examining the design of incentive contracts generally suffer two major deficiencies. First, they implicitly assume that performance measures are available for contracting between the principal and agent. In many situations, however, certain important variables are unobservable (or unverifiable) and, therefore, uncontractible. The assignment of property rights of uncontractible output can provide one efficient solution to this problem. Second, under a multitask environment, it is common that doing one task may not only affect its "major" output, but also positively or negatively influences the outputs of other tasks. However, these positive and negative *crossover effects* have been overlooked in prior agency studies. The main purpose of this study is to use a multitask principal-agent model to investigate the joint impacts of property rights and crossover effects on incentive design and the agent's relative effort allocation decisions. We also provide a rule for determining the assignment of property rights.

JEL classification: D82, J33, L22, M41

Keywords: Agency model, Crossover effects, Incentive contract, Multitask, Property rights

1. INTRODUCTION

In his seminal paper of summarizing the contracting theory and accounting, Lambert (2001) indicates that much of the motivation for current accounting and auditing research relates to the control of incentive problems. In addition, Bushman and Smith (2001) also identifies that creating incentives to take actions is one of the three fundamental contracting roles for accounting information.[1] In fact, during the past two decades, the design of incentive contract to motivate agent's effort contributing to the success of a company has received much attention in managerial accounting.[2] Many early incentive models have addressed various factors determining optimal compensation contract from a single task perspective (e.g., Arya, Fellingham, and Glover 1997; Balakrishman and DeJong 1993; Cohen and Loeb 1989; Datar and Rajan 1995; Kirby, Reichelstein, Sen, and Paik 1991; Kwon 1989; Magee 1988; Villadsen 1995). As indicated by Holmström and Milgrom (1991), however, if there are multiple tasks facing the agent, incentive pay not only serves the dual function of allocating risks and motivating work effort, but also serves to direct agent's allocating his attention among various duties. Since multitask is common in the business world, an examination of incentive design under a multitask environment should provide more valuable insights into our understanding of incentive problems.[3] Based on Holmström and Milgrom's (1991) multitask setting, Feltham and Xie (1994) explores the role of multiple performance measures in influencing the direction and intensity of an agent's effort allocation among different tasks. Feltham and Wu (2000) provides a general characterization of the relative weights assigned to two performance measures (i.e., accounting earnings and market price) in an optimal linear contract in a two-task setting. In contrast, Indjejikian and Nanda (1999) presents a

---

[1]The other two contracting roles are the filtering of common noise from other performance measures and the rebalancing of managerial effort across multiple activities.

[2]See Gibbon (1998), Lambert (2001), Murphy (1999) and Prendergast (1999) for prior reviews of aspects of empirical and theoretical incentive contract literature.

[3]Hemmer (1995) analyzes incentives and job design using a two-stage production process. Under a similar multistage setting, Hemmer (1998) examines the interactions among responsibility assignment, performance measures, and incentive schemes. Different from multistage, which involves agent's efforts toward *sequential* tasks (i.e., the second operation is conditioned on the output generated from the first operation), multitask involves agent's doing several tasks *simultaneously*.

two-period multitask dynamic model to show that the use of more aggregate performance measures and greater consolidation of responsibility helps mitigate the ratchet effect. Since empirical evidence has shown that incentive contracts do affect agent's behavior (Prendergast 1999) and an understanding of how incentive scheme should be designed constitutes a cornerstone of the theory of the firm (Baker, Jensen, and Murphy 1988), additional research should continue to shed light on unsolved issues related to principal's design of optimal incentive contracts.

In general, most of prior agency studies in the area of incentive design have two distinct features. First, these studies focus on the role of performance measures in an optimal contracting framework under conditions of information asymmetry.[4] The key characteristic is the *informativeness* of the performance measure about the agent's action.[5] In particular, Banker and Datar (1989), Lambert and Larcker (1987), and Lambert (2001) emphasize that the informativeness of a performance measure should be a function of its sensitivity to the agent's actions and its noisiness. Second, these studies implicitly assume that performance measures are available for contracting between the principal and agent (e.g., Feltham and Xie 1994; Feltham and Wu 2000). This later feature is problematic in capturing the salient features of the real world because in many situations some certain important variables are either unobservable (Prendergast 1999) or unverifiable by a third party (Hart and Moore 1988). For example, the condition of a productive asset is unobservable to the principal and, therefore,

[4]Prior empirical studies have documented that profitability measures are extensively used in annual bonus plans and in long-term performance plans for corporate executives (e.g., Benston 1985; Murphy 1985). The literature also finds an important trend of using accounting numbers in contracts between pre-IPO entrepreneurs and venture capital firms in the U.S. (e.g., Kaplan and Stromberg 1999). However, over the past three decades, accounting profitability measures have become relatively less important in determining cash compensation of top executives (Bushman et al. 1998). Finally, there is a growing use of alternative performance measures (for example, the residual income performance measures) for executive compensation contracts (Wallace 1997). See Bushman and Smith (2001) for a comprehensive review of executive compensation research.

[5]The "informativeness" criterion is attributed to Holmström (1979). This criterion states that any performance measure that is marginally informative about an agent's actions, given other available performance measures, should be included in the incentive contract. However, field and empirical studies such as Merchant (1987) and Maher (1987) do not find empirical evidence to support this informativeness criterion. Yim (2001) reconciles the inconsistency between the theory and practice by abandoning the conventional full-commitment assumption. With the possibility of renegotiation, a performance measure's usefulness in incentive contracting depends on its information quality, not simply on whether the performance measure is informative. In particular, Yim (2001) finds that a performance measure is useful when its information quality is either sufficiently poor or sufficiently rich.

is not contractible. Also, the reputation of a company may be observable to its shareholders but is unverifiable by the court. Hence, shareholders can not use firm's reputation as a performance measure to sign incentive contract with the manager because this contract is not enforceable. Unfortunately, prior agency-based incentive studies are silent in this problem. In essence, the restriction of contracts to observable variables constrains the principal to an inefficient set of choices (Magee 2001).

Different from prior agency studies, the main purpose of this study is to investigate the joint impacts of property rights and crossover effects[6] on incentive design. This issue is important for two reasons. First, while the property rights theory of the firm has received much attention in economics over the past few decades (e.g., Che and Qian 1998; Chiu 1998; Coase 1960; Grossman and Hart 1986; Hart and Moore 1990; Joskow 1988; Meza and Lockwood 1998),[7] it has not been formally examined in the managerial accounting research. More important, property rights provide one efficient solution to the principal when certain important variables are unobservable or unverifiable (Hart and Moore 1988). In economic terms, property rights are different from other forms of incentive contract only where contracts determining specific decision rights over an asset and assigning its returns are imperfect and incomplete. Then, property rights may be identified with the right to exercise *residual control* where the contract is silent about decision rights, or with the right to receive any *residual returns* that remain after contractual obligations are fulfilled.[8] As Milgrom and Roberts (1992) points out, property ownership is "clearly the most common and effective means to motivate people to create, maintain, and improve assets, and its importance in practical business life would be hard to overstate (p.

[6]The term "crossover effects" was first introduced by Holmström and Milgrom (1991, p. 982) to describe the situation in which a good job coordinating the response to a customer complaint would save costs for the manufacturer but typically also enhance future sales. However, they sidestepped this possibility and did not formally incorporate crossover effects into their multitask model setting. We will explain the basic notion of crossover effects in more details later in this section and section 2.

[7]See Barzel (1989) and Milgrom and Roberts (1992, chapter 9) for comprehensive discussions about the property rights theory in economics.

[8]According to Milgrom and Roberts (1992), *residual control* represents the right to make any decisions concerning the asset's use that are not explicitly controlled by law or assigned to another by contract. On the other hand, *residual returns* denote the net income produced by an asset that is left over after everyone else has been paid. Prior economic analyses of property rights have concentrated on these two issues. Tying together residual control and residual returns is the key to the incentive effects of property rights.

321)”. Since economic literature has demonstrated that the distribution of property rights over productive assets (which are not contractible) determines agent’s motivation and incentive of doing tasks, an incorporation of the concept of property rights should provide significant contribution to the managerial accounting literature in the analysis of incentive design.

Second, under a multitask environment, it is ubiquitous that in many situations doing one task may not only affect its own output directly, but also influences the outputs of other tasks indirectly. For example, a medical school professor’s clinical experience should be *positively* helpful to his teaching performance. On the contrary, an overly high production volume may *negatively* harm the value of the productive asset. Theoretically speaking, these positive and negative *crossover effects* generate externality problem that may affect the determination of optimal incentive contract and agent’s effort allocation decision. However, few attempts, if any, have ever been made to examine the impacts of crossover effects on principal’s incentive design. Therefore, a rigorous consideration of multitask crossover effects together with property rights provides a good opportunity to investigate the overall incentive design in a more realistic and rich setting, which in turn improves the relevance of managerial accounting research to the decision makers. This study intends to provide an initial step in addressing this issue.

To illustrate how property rights and crossover effects may jointly influence the incentive design, we present an agency model in which a risk-neutral principal contracts with a risk-averse agent to perform two tasks in a single period. Our focus is limited to two aspect of incentive design, namely the determination of optimal incentive intensity and agent’s relative effort allocation. To illustrate the impacts of crossover effects on agent’s relative effort allocation, we consider a firm’s problem of motivating a single agent to perform two types of activities (e.g., production and maintenance) that may generate one *positive* crossover effect and one *negative* crossover effect to two outputs. To illustrate how the assignment of property rights may affect the principal’s design of optimal incentive contract, we assume that one output is contractible but the other one is uncontractible. This setting allows the property rights to play a significant role to the determination of optimal compensation contract. Without formally considering crossover effects and implicitly assuming that the principal owns the property rights of the uncontractible output, Holmström and Milgrom (1991) concludes that, since there are many tasks facing the agent, a higher incentive to a contractible output may provide the agent with *disincentives* to other important tasks whose outputs are uncontractible. Different from their paper, we incorporate property rights and crossover effects into the model and show that Holmström and Milgrom's (1991) conclusion is valid only under certain conditions. In addition, we also examine the agent's relative effort allocation decision under different property rights scenarios and provide a rule for determining the assignment of property rights. Overall, our analysis extends the managerial accounting literature to a wider class of incentive design issues such as property rights and crossover effects.

The remainder of this paper is organized as follows. A basic two-task principal-agent model is presented in section 2 to illustrate the role of property rights and crossover effects in incentive compensation and agent's relative effort allocation. In section 3 we describe a special case in which only a short-term contract is feasible and the crossover effects are trivial. A rule of determining the property rights between the principal and agent is also discussed. A final summary and conclusion is followed in section 4.

2. THE MODEL AND ANALYSES

2.1 Basic Incentive Model:

Following Holmström and Milgrom's (1991, 1994) multitask agency models, suppose an agent has two different tasks which require effort levels e_1 and e_2,[9] where $\{e_1, e_2\} \in R_+^2$, and produce two

[9]The Holmström and Milgrom models are more general with respect to the number of tasks. We limit the number of tasks to two so as to focus on the joint impacts of crossover effects and property rights on incentive design. We can assume that the measurement units of e_1 and e_2 are different (e.g., hour vs. minute) to reflect the fact that the agent's per-unit-cost of doing e_1 and e_2 may be unequal.

output values ϖ_1 and ϖ_2. Suppose we have the following two production functions *f* and *g*:

$$\varpi_1 = f(e_1, e_2) + \varepsilon_1 \text{ and } \varepsilon_1 \sim N(0, \sigma_1^2), \tag{1}$$

$$\varpi_2 = g(e_1, e_2) + \varepsilon_2 \text{ and } \varepsilon_2 \sim N(0, \sigma_2^2), \tag{2}$$

where $\text{cov}(e_1, e_2) = 0$. As depicted in equations (1) and (2), a given task effort level will affect more than one output value. In particular, task effort level e_i has a *direct* effect to ϖ_i and a *crossover* effect to ϖ_j, for $i \neq j$. In a typical manufacturing setting, for example, we can regard ϖ_1 as the production output and regard ϖ_2 as the value of the productive asset, given the *same* production task effort e_1 and maintenance task effort e_2. In this example, production effort e_1 is beneficial to ϖ_1 (the direct contribution), but is harmful to ϖ_2 (the negative crossover effect). In contrast, maintenance effort e_2 may contribute to both ϖ_1 (the positive crossover effect) and ϖ_2 (the direct contribution). In mathematical terms, these direct and crossover effects can be denoted by $\partial E(\varpi_i)/\partial e_i > 0$ and $\partial E(\varpi_i)/\partial e_j \neq 0$ (for $i \neq j$), respectively, and $\partial E(\varpi_i)/\partial e_i > \partial E(\varpi_i)/\partial e_j$.[10] For notation presentation, let $f_i = \partial f/\partial e_i$ and $g_i = \partial g/\partial e_i$, for i = 1 or 2. Suppose the agent has the following increasing and convex quadratic cost function:[11]

$$C(e_1, e_2) = \frac{1}{2}(e_1^2 + e_2^2). \tag{3}$$

This form of cost function reflects the fact that agent is effort-averse and agent's effort in two tasks is substitutable.[12] In our model, the principal is assumed to be risk-neutral and the agent is

[10]Our crossover effects are different from the substitution (or complementary) effect, which involves the change in input factor due to the relative price change in another input factor.

[11]Similar to Feltham and Xie (1994), Feltham and Wu (2000), and Lambert (2001), we restrict agent's cost function to this simple form to ensure that (a) closed form interior solutions exist, and (b) the level of effort equals its marginal cost. Including a fixed component or an interaction term to $C(e_1,e_2)$ shall not change our analysis.

[12]This assumption is different from Holmström and Milgrom (1991), which assumes that working is pleasant to the agent up to some limit (in their terms, the agent's cost function satisfies two criteria: $C'(t) \leq 0$ for $t \leq \bar{t}$ and $C(\bar{t}) = 0$, where $\bar{t}$ denotes the limit beyond which incentives are required to encourage agent's work), and finds that agent's optimal incentive under the single task setting is higher than that under a multitask setting. We do not appeal to this assumption because, if $\bar{t}$ is large enough, there is no agency problem at all. If $\bar{t}$ is small, on the other hand, Holmström and Milgrom (1991) does not provide guideline for determining the optimal incentive beyond $\bar{t}$. Furthermore, Holmström

risk-averse with a negative exponential utility function $U(W) = -\exp(-rw)$, where $r > 0$ denotes agent's risk aversion coefficient and W denotes his payoff (net of possible effort cost). The important feature of this utility function is that it exhibits constant absolute risk aversion. This means that the agent's wealth doe not affect his risk aversion and therefore does not affect the agent's incentive. The principal offers the following linear contract:[13]

$$S(\varpi_1, \varpi_2) = \alpha + \beta_1 \varpi_1 + \beta_2 \varpi_2 \quad (\beta_1 \text{ and } \beta_2 \geq 0), \tag{4}$$

where α is a fixed salary, and β_1 and β_2 are the commission rates (which are measures of wage incentive intensity) on output values ϖ_1 and ϖ_2, respectively. We restrict *β's* to be nonnegative to avoid encouraging agent to conceal his performance.

If the principal and agent can sign an incentive contract based on both ϖ_1 and ϖ_2, the principal's incentive design problem can be formulated by the following Program I:

Program I:

$$\max_{\alpha,\beta_1,\beta_2,e_1,e_2} \{f + g - \alpha - \beta_1 \cdot f - \beta_2 \cdot g\}$$

$$\text{s.t.} \quad (e_1, e_2) \in \arg\max \left\{ \alpha + \beta_1 f + \beta_2 g - \frac{1}{2}(e_1^2 + e_2^2) - \frac{1}{2} r\beta_1^2 \sigma_1^2 - \frac{1}{2} r\beta_2^2 \sigma_2^2 \right\},$$

$$\left\{ \alpha + \beta_1 f + \beta_2 g - \frac{1}{2}(e_1^2 + e_2^2) - \frac{1}{2} r\beta_1^2 \sigma_1^2 - \frac{1}{2} r\beta_2^2 \sigma_2^2 \right\} \geq \overline{U},$$

where the first and second constraints are the agent's incentive constraint (IC) and individual rationality constraint (IR), respectively, and $\overline{U}$ is the agent's reservation utility. Note that the IC

---

and Milgrom (1991) supports their assumption using instructor's teaching higher-think skills as an example (see footnote 9 on page 32). We believe this example is restrictive to the description of agent's behavior because instructors generally enjoy more rewards from education effort than pure monetary incentive. This may not be the case for other professions such as auditors and manufacturing workers. Therefore, we restore the classical effort-averse assumption and see how an optimal incentive scheme can be designed. Baron and Kreps (1999) and Lambert (2001) also adopts this effort-averse assumption in their introduction of agency models.

[13]To simplify the following analyses, we assume a linear contract. Prior studies such as Holmström and Milgrom (1991, 1994) and Feltham and Xie (1994) also restrict their analyses to linear contracts. Holmström and Milgrom (1987) and Banker and Dartar (1989) analyze conditions under which linear contracts are optimal. See Lambert (2001, 29-30) for discussions of justifications for the common use of linear contract in principal-agent models.

constraint implies that the agent's reaction functions with respect to principal's incentive strategy are $e_1 = \beta_1 f_1 + \beta_2 g_1$ and $e_2 = \beta_1 f_2 + \beta_2 g_2$. Similar to Holmström and Milgrom (1991, 1994), we use the first-order conditions of agent's IC constraint and the total certainty equivalent (TCE) approach to rewrite Program I as follows:

Program II:

$$\max_{\beta_1,\beta_2}\left\{ f + g - \frac{1}{2}(e_1^2 + e_2^2) - \frac{1}{2} r(\beta_1^2\sigma_1^2 + \beta_2^2\sigma_2^2) \right\}$$

$$\text{s.t.} \quad e_1 = \beta_1 f_1 + \beta_2 g_1,$$

$$e_2 = \beta_1 f_2 + \beta_2 g_2.$$

Differentiating the objective function with respect to β_1 and β_2 gives the following two first-order conditions:

$$f_1 \cdot \frac{\partial e_1}{\partial \beta_1} + f_2 \cdot \frac{\partial e_2}{\partial \beta_1} + g_1 \cdot \frac{\partial e_1}{\partial \beta_1} + g_2 \cdot \frac{\partial e_2}{\partial \beta_1} - e_1 \cdot \frac{\partial e_1}{\partial \beta_1} - e_2 \cdot \frac{\partial e_2}{\partial \beta_1} - r\beta_1\sigma_1^2 = 0, \tag{5}$$

$$f_1 \cdot \frac{\partial e_1}{\partial \beta_2} + f_2 \cdot \frac{\partial e_2}{\partial \beta_2} + g_1 \cdot \frac{\partial e_1}{\partial \beta_2} + g_2 \cdot \frac{\partial e_2}{\partial \beta_2} - e_1 \cdot \frac{\partial e_1}{\partial \beta_2} - e_2 \cdot \frac{\partial e_2}{\partial \beta_2} - r\beta_2\sigma_2^2 = 0. \tag{6}$$

Plugging equations (5), (6), and constraints $e_1 = \beta_1 f_1 + \beta_2 g_1$ and $e_2 = \beta_1 f_2 + \beta_2 g_2$ into the objective function gives:

$$\beta_1 = \frac{D \cdot C - B \cdot E}{A \cdot C - B^2}, \tag{7}$$

$$\beta_2 = \frac{A \cdot E - B \cdot D}{A \cdot C - B^2}, \tag{8}$$

where $A = (f_1^2 + f_2^2 + r\sigma_1^2)$, $B = (f_1 g_1 + f_2 g_2)$, $C = (g_1^2 + g_2^2 + r\sigma_2^2)$, $D = f_1^2 + f_2^2 + f_1 g_1 + f_2 g_2$, and $E = g_1^2 + g_2^2 + f_1 g_1 + f_2 g_2$. Therefore, if ϖ_1 and ϖ_2 are both contractible, the principal will design the incentive intensities at the levels specified by equations (7) and (8).

In many practical situations, however, ϖ_2 may not be economically observable or its noise component σ_2^2 may approach infinity. In other words, output value ϖ_2 becomes uncontractible to both parties. In this situation, equations (7) and (8) can be reduced to the following (9) and (10):

$$\lim_{\sigma_2^2 \to \infty} \beta_1 = \frac{D}{A}, \tag{9}$$

$$\lim_{\sigma_2^2 \to \infty} \beta_2 = 0. \tag{10}$$[14]

Equations (9) and (10) indicate that, if the value of the productive asset (i.e., ϖ_2) cannot be contracted upon and the principal owns the property rights of the productive asset, she will design the optimal incentive scheme with respect to ϖ_1 using equation (9). By comparing equations (7) and (9), we can explore how ϖ_2's *contractability* may affect the magnitude of optimal β_1:

$$\text{Equation (7) – Equation (9)} = \frac{-B\cdot(AE+BD)}{A\cdot(AC-B^2)}.$$

Obviously, the sign of the difference between equations (7) and (9) is indeterminable, depending on the specifications of the production functions f and g. We focus on the case where $f_1 > 0$ and $g_1 \leq 0$ (which means the manufacturing effort is beneficial to ϖ_1 but is harmful to ϖ_2) and $f_2 \geq 0$ and $g_2 > 0$ (which means the maintenance effort is beneficial to both ϖ_1 and ϖ_2) because it captures the salient features of a real manufacturing environment. Based on this assumption, we formulate the production functions using the following separable and linear form:

$$\varpi_1 = \pi_1 e_1 + \kappa e_2 + \varepsilon_1, \ (\pi_1, \kappa \geq 0), \tag{11}$$

$$\varpi_2 = -q e_1 + \pi_2 e_2 + \varepsilon_2, \ (0 \leq q \leq \pi_1, \pi_2 \geq 0), \tag{12}$$

where π_i measures the per-effort-unit contribution of e_i to output values ϖ_1 and ϖ_2 (hereafter called the *contribution coefficient of* e_i), κ measures the per-effort-unit benefit of maintenance to manufacturing (hereafter called the *positive crossover effect*), and q measures the per-effort-unit harm

[14]If ϖ_2 is not available for signing incentive contract, equation (4) will reduce to $S(\varpi) = \alpha + \beta_1\varpi_1$, implying that equations (6) and (8) will also vanish. Therefore, β_2 becomes trivial and we should only focus on β_1 specified in equation (9). On the other hand, if σ_2^2 approaches infinity, equations (6) and (8) give (10) while equation (9) is still valid.

of manufacturing to the value of productive asset (hereafter called the *negative crossover effect*). It should be noted that the negative crossover effect q (a) is greater than zero because we want to capture the harm feature of e_1 on ϖ_2, and (b) is less than π_1 because, if $q > \pi_1$, task e_1 should not be undertaken as it is undesirable to both the principal and agent, no matter who owns the property rights of ϖ_2. Also, we assume $\pi_1 > \kappa$ because, for output ϖ_1, e_1's direct effect is usually larger than e_2's crossover effect. Similarly, we assume $\pi_2 > q$. In the following analyses, we assume that ϖ_1 is contractible but ϖ_2 is uncontractible.

2.2 The Joint Impacts of Crossover Effects and Property Rights on Incentive Intensity:

Using equations (11) and (12), we can compare β_1's under two different settings: (a) only ϖ_1 can be contracted upon and the property rights of ϖ_2 belongs to the principal (denoted by β_1^P) and (b) similar to setting (a) except that the property rights of ϖ_2 belongs to the agent (denoted by β_1^A). These lead to the following Proposition 1:

PROPOSITION 1: *The principal's optimal β_1 to the contractible output ϖ_1 is determined as follows:*

(1) *If the principal owns the property rights of ϖ_2, then* $\beta_1^P = \dfrac{\pi_1^2 + \kappa^2 - \pi_1 q + \pi_2 \kappa}{\pi_1^2 + \kappa^2 + r\sigma_1^2}$. *In addition, the comparative statics show that* $\dfrac{\partial \beta_1^P}{\partial q} < 0$, $\dfrac{\partial \beta_1^P}{\partial \kappa} > 0$, *and* $\dfrac{\partial^2 \beta_1^P}{\partial \kappa \partial q} > 0$.

(2) If the agent owns the property rights of ϖ_2, then $\beta_1^A = \dfrac{\pi_1^2 + \kappa^2}{\pi_1^2 + \kappa^2 + r\sigma_1^2}$. *In addition, the comparative statics show that* $\dfrac{\partial \beta_1^A}{\partial q} = 0$, $\dfrac{\partial \beta_1^A}{\partial \kappa} > 0$, *and* $\dfrac{\partial^2 \beta_1^A}{\partial \kappa \partial q} = 0$.

(3) $\dfrac{\partial(\beta_1^P - \beta_1^A)}{\partial q} < 0$, $\dfrac{\partial(\beta_1^P - \beta_1^A)}{\partial \kappa} > 0$, *and* $\dfrac{\partial^2(\beta_1^P - \beta_1^A)}{\partial q \partial \kappa} > 0$.

Proof: See Appendix.

Proposition 1 indicates that the property rights of one task output plays an important role to principal's optimal incentive design of another task. Several important implications of this result deserve further discussions. First, part (1) of Proposition 1 shows the comparative statics that $\partial\beta_1^P/\partial\kappa > 0$, $\partial\beta_1^P/\partial q < 0$, and $\partial^2\beta_1^P/\partial\kappa\partial q > 0$. Because q and κ denote the *indirect* effects of e_1 and e_2 on ϖ_1 and ϖ_2, respectively, an increase in κ implies that effort e_2 is more valuable in a sense that it not only provides an *indirect* contribution to ϖ_1, but also provides a *direct* contribution to ϖ_2. Since the principal owns the residual claims of ϖ_1 and the property rights of ϖ_2, she has high incentive to set β_1^P at a higher level to motivate the agent to exert more effort on e_2 (i.e., $\partial\beta_1^P/\partial\kappa > 0$). On the other hand, an increase in q implies that effort e_1 becomes less favorable to the principal because it impairs the value of ϖ_2, which is owned by the principal. Therefore, she will provide a weaker β_1^P to discourage the agent to put more effort on e_1 (i.e., $\partial\beta_1^P/\partial q < 0$). When both q and κ increase simultaneously, however, the principal will tend to increase β_1^P because, even though a higher β_1^P will motivate the agent to exert more effort on e_1, which in turn incurs an extra cost q to ϖ_2 and an incremental contribution π_1 to ϖ_1, a higher β_1^P will also induce the agent to put more effort on e_2, which in turn generates incremental contributions of π_2 to ϖ_2 and κ to ϖ_1. Since the *net* benefit is still positive to the principal, she has strong incentive to set β_1^P at a higher level (i.e., $\partial^2\beta_1^P/\partial q\partial\kappa > 0$). These results are valuable to the managerial accounting literature because it suggests that, if the value of the productive asset is important to the principal, she can (a) *ex ante*, employ independent verifier to examine the asset's physical condition or lower down the incentive for the manufacturing output, and (b) *ex post*, use non-financial performance measures such as machine breakdown frequency to alleviate the agency problem. This result provides a theoretical foundation to support Sears, Roebuck, and Co.'s dropping the by-the-job rate system and paying mechanics hourly salary to balance both quantity and quality (Horngren, Datar, and Foster 2002, 803).

Second, part (2) of Proposition 1 shows the comparative statics of β_1^A with respect to q and κ when the agent owns the property rights of ϖ_2. Although an increase in κ only provides an *indirect* contribution to ϖ_1, the principal still prefers to set β_1^A at a satisfactory level to induce a higher effort on e_2. Therefore, we have $\partial\beta_1^A/\partial\kappa > 0$. In contrast, since the agent owns the property rights, the principal will never take q into consideration in designing her incentive scheme. Thus, we have $\partial\beta_1^A/\partial q = 0$ and $\partial^2\beta_1^A/\partial q\partial\kappa = 0$. The managerial implication of these results is that, even though the principal can ignore q because the property rights of ϖ_2 belongs to the agent, she may need to give the agent some kind of premium to compensate the agent's losses due to q so that he will exert more effort on e_1. For example, let e_1 and e_2 denote working and leisure activity, respectively, and define ϖ_1 and ϖ_2 as the production output value and the agent's family life, respectively. In this example, the agent will share β_1^A portion of the production output ϖ_1 but will possess his own family life ϖ_2 (which is not contractible). Obviously, the more the e_1 the agent exert, the higher the harm to the agent's family life. Therefore, part (2) of Proposition 1 implies that the principal may motivate the agent to put more effort on e_1 not by providing a higher incentive intensity β_1^A, but by giving extra premium or subsidy. This example can explain why many Taiwanese hi-tech companies afford "oversea" compensations, cars, and local lodging services (rather than an increase in β) to management staffs and workers who are dispatched to their subsidiaries in Mainland China.

Third, we can further explore the effects of property rights on principal's optimal incentive design by calculating the difference between β_1^P and β_1^A:

$$\beta_1^P - \beta_1^A = \frac{\pi_2\kappa - \pi_1 q}{\pi_1^2 + \kappa^2 + r\sigma_1^2}. \tag{13}$$

Equation (13) indicates that q and κ not only affect the sign of $\beta_1^P - \beta_1^A$, but also affect the magnitude of the difference between β_1^P and β_1^A. We first discuss the negative crossover effect q. Since (a) $\beta_1^P - \beta_1^A$ is positive when q equals zero, (b) $\partial\beta_1^P/\partial q < 0$, and (c) $\partial\beta_1^A/\partial q = 0$, part (3) of Proposition 1 implies that the line $\beta_1^P - \beta_1^A$ has a positive intercept and a negative slope (i.e., $\partial(\beta_1^P - \beta_1^A)/\partial q < 0$). As depicted by the dot line in panel A of Figure 1, when the negative crossover effect q approaches a certain $q^* = (\pi_2/\pi_1)\kappa$, for any given κ, from either direction, the property rights of ϖ_2 become less relevant to the principal's determination of ϖ_1's incentive intensity. We define this situation as *property rights irrelevance* (PRIR). Under this situation, the principal may tend to ignore the property rights effect in designing her optimal incentive intensity on ϖ_1. On the other hand, if q moves away from q* in both directions, the *distance* between β_1^P and β_1^A increases. Therefore, the property rights of ϖ_2 will become more relevant to the principal's incentive design (see the dot line in panel B of Figure 1). We call this situation *property rights relevance* (PRR). Under this situation, the principal will emphasize more on the property rights' effect in designing her optimal incentive intensity on ϖ_1.

[Insert Figure 1 here]

Different from the comparative statics analysis of q, parts (1) and (2) of Proposition 1 indicate that the principal's optimal incentive intensity β_1 is increasing in κ (i.e., $\partial\beta_1^P/\partial\kappa > 0$ and $\partial\beta_1^A/\partial\kappa > 0$), *no matter who owns the property rights*. However, since an increase in κ will generate both *direct* and *indirect* contributions to the principal when she owns the property rights of ϖ_2, but will only provide *indirect* contribution to the principal when the agent owns ϖ_2, the effect of an increase in κ on principal's determination of optimal incentive intensity on ϖ_1 is stronger when the principal owns the property rights of ϖ_2. Due to this reason, we have $\partial(\beta_1^P - \beta_1^A)/\partial\kappa > 0$ in part (3) of proposition 1. Based on the facts that $\beta_1^P - \beta_1^A$ is negative when κ equals zero and $\partial(\beta_1^P - \beta_1^A)/\partial\kappa > 0$, we know that the line $\beta_1^P - \beta_1^A$ has a negative intercept and a positive slope. As depicted by the dot line in panel A of Figure 2, when the positive crossover effect κ approaches a certain $\kappa^* = (\pi_1/\pi_2)q$, for any given q, from either direction, the property rights of ϖ_2 become less relevant to the principal's determination of incentive intensity on ϖ_1. On the contrary, the property rights of ϖ_2 will become more relevant when κ moves away from κ^* in both directions (see the dot line in panel B of Figure 2).

[Insert Figure 2 here]

Finally, the marginal effects of increasing both q and κ on the *difference* between β_1^P and β_1^A should be examined through two PRR scenarios (i.e., the original β_1^P is either strictly smaller or strictly larger than β_1^A) and one PRIR scenario (i.e., the original β_1^P is equal to β_1^A). Under the first PRR case, in which the original β_1^P is strictly smaller than β_1^A, a simultaneous increase in q and κ will *decrease* the relevance of the property rights of ϖ_2 to principal's incentive design on β_1. In contrast, under the second PRR case (in which the original β_1^P is strictly larger than β_1^A) and the PRIR case (in which the original β_1^P is equal to β_1^A), a simultaneous increase in q and κ will *increase* the relevance of the property rights to principal's incentive design. Therefore, we have $\partial^2(\beta_1^P - \beta_1^A)/\partial q \partial \kappa > 0$.

2.3 The Joint Impacts of Crossover Effects and Property Rights on Relative Effort Allocation:

Proposition 1 has demonstrated the combined consequences of property rights and crossover effects on principal's determination of optimal incentive design and how these consequences may change when individual crossover effect changes. As indicated by Lambert (2001), however, in a multitask setting, the emphasis shifts from motivating the intensity of the agent's effort to the allocation of his effort among tasks. Accordingly, in this section, we will take a further step to explore the joint impacts of property rights and crossover effects on agent's effort allocation between e_1 and e_2.

We first look at the case in which the agent owns the property rights of ϖ_2. From equations (A1) and (A2) in the Appendix, we have:

$$e_1^A = \beta_1^A \pi_1 - q = \frac{\pi_1 \cdot (\pi_1{}^2 + \kappa^2) - q \cdot (\pi_1{}^2 + \kappa^2 + r\sigma_1{}^2)}{\pi_1{}^2 + \kappa^2 + r\sigma_1{}^2}, \tag{14}$$

$$e_2^A = \pi_2 + \beta_1^A \kappa = \frac{\pi_2 \cdot (\pi_1{}^2 + \kappa^2 + r\sigma_1{}^2) + \kappa \cdot (\pi_1{}^2 + \kappa^2)}{\pi_1{}^2 + \kappa^2 + r\sigma_1{}^2}. \tag{15}$$

Therefore, the agent's effort allocation can be represented by the effort ratio $ER^A \equiv e_2^A / e_1^A$:

$$ER^A \equiv \frac{\pi_2(\pi_1{}^2 + \kappa^2 + r\sigma_1{}^2) + \kappa(\pi_1{}^2 + \kappa^2)}{\pi_1(\pi_1{}^2 + \kappa^2) - q(\pi_1{}^2 + \kappa^2 + r\sigma_1{}^2)}. \tag{16}$$

In contrast, if the principal owns the property rights, then from the constraints of Program II and equations (11) and (12), we have:

$$e_1^P = \pi_1\beta_1^P - q\beta_2^P = \frac{\pi_1 \cdot (\pi_1^{\,2} + \kappa^2 - q\pi_1 + \kappa\pi_2)}{\pi_1^{\,2} + \kappa^2 + r\sigma_1^{\,2}}, \tag{17}$$

$$e_2^P = \kappa\beta_1^P + \pi_2 \cdot \beta_2^P = \frac{\kappa(\pi_1^{\,2} + \kappa^2 - q\pi_1 + \kappa\pi_2)}{\pi_1^{\,2} + \kappa^2 + r\sigma_1^{\,2}} \tag{18}$$

Therefore, the agent's effort allocation can be represented by the effort ratio $ER^P \equiv e_2^P / e_1^P$:

$$ER^P \equiv \frac{\kappa}{\pi_1}. \tag{19}$$

Equation (19) indicates that, when the principal owns the property rights, the agent will ignore the production coefficients of ϖ_2 (i.e., q and π_2) but solely focus on the production coefficients of ϖ_1 (i.e., π_1 and κ). Since equation (11) has shown that the production function of ϖ_1 involves two linearly substitutable input factors e_1 and e_2, the agent's optimal effort ratio will be the ratio of π_1 and κ.[15] On the other hand, when the agent owns the property rights, the agent will also take the production coefficients of ϖ_2 into his effort allocation decision. Therefore, equation (16) shows that the agent's optimal effort ratio is a function of all four production coefficients.

To further examine the effects of property rights on agent's relative effort allocation, we can take the difference between ER^P and ER^A:

$$ER^P - ER^A = \frac{(\pi_1\pi_2 + \kappa q)(\pi_1^{\,2} + \kappa^2 + r\sigma_1^{\,2})}{\pi_1 \cdot [qr\sigma_1^{\,2} - (\pi_1 - q)(\pi_1^{\,2} + \kappa^2)]}. \tag{20}$$

Since the nominator in equation (20) is always positive, the sign of $ER^P - ER^A$ depends on the sign of the denominator, which is determined by the bracket term $[qr\sigma_1^2 - (\pi_1 - q)(\pi_1^2 + \kappa^2)]$.

[15]In fact, equation (19) is exactly the effort ratio obtained in Feltham and Wu (2000) when there is only one performance measure available.

Obviously, the bracket term is positive only when the following condition holds:

$$q > \pi_1 \cdot \left[\frac{\pi_1^2 + \kappa^2}{\pi_1^2 + \kappa^2 + r\sigma_1^2} \right]. \tag{21}$$

From part (2) of Proposition 1, we can see that the term inside the bracket of equation (21) is right the β_1^A. Therefore, equation (21) can be reduced to $q > \pi_1 \cdot \beta_1^A$. Since π_1 measures the per-effort-unit contribution of e_1 to ϖ_1 and β_1^A denotes the portion of ϖ_1 the agent can share when the agent owns the property rights of ϖ_2, $\pi_1 \cdot \beta_1^A$ represents the *marginal* benefit the agent can earn from exerting one more unit of effort e_1. Recall that q measures the per-effort-unit harm of e_1 to ϖ_2. Hence, the agent's relative effort allocation decision under different property rights situations is determined by comparing the marginal benefit (from ϖ_1) and marginal cost (from ϖ_2) of employing an extra unit of e_1, given the agent owns the property rights of ϖ_2. In particular, if marginal cost is larger than marginal benefit, ER^P tends to be greater than ER^A. That is, *if the negative crossover effect q is high enough (i.e.,* $q > \pi_1 \cdot \beta_1^A$*), the agent will put "relatively" more (less) effort on* e_2 *rather than* e_1 *when the principal (agent) owns the property rights.*[16] Note that β_1^P plays no role to agent's relative effort allocation decision because equation (19) has indicated that the agent's effort ratio ER^P is not a function of q.

3. SHORT-TERM CROSSOVER EFFECTS – A SPECIAL CASE

In our manufacturing case, a more difficult task facing the principal is how to design an incentive contract within a "relatively short" period in which the harm of production effort e_1 to ϖ_2 is severe (i.e., *q is large*, which implies that the productive asset tends to be "overused," given a certain effort level e_1), but the benefit of maintenance effort e_2 to ϖ_1 is negligible (i.e., κ *is small*). This situation is of particular interest to the principal because, when q is large but κ is small, the adverse

[16]In fact, this conclusion is also implied in the comparative statics $\partial ER^P / \partial q = 0$, $\partial ER^A / \partial q < 0$, and equation (21).

consequences of an improper incentive contract on TCE-maximization will be even stronger. The reasons are as follows. First, since the harm of e_1 on ϖ_2 is unobservable during a short time period, the principal cannot write an enforceable short-term contract based on ϖ_2. This "externality" becomes a real problem to the principal when q is large. Second, the principal may mitigate the "externality" problem if she can induce the agent to exert a higher level of e_2. However, because the principal can only design a contract based on ϖ_1 and the agent's cost function is convex in e_1 and e_2, if κ is too small, the principal cannot induce a satisfactory level of e_2 through a high incentive intensity on ϖ_1.[17] Clearly, these problems will become trivial when a *long-term* contract is feasible between the principal and agent (e.g., the length of the enforceable contract is longer than the useful life of the machine). In this section, we examine this *short-term effect* using an extreme situation in which κ equals zero.

3.1 Short-term Effects of Property Rights on Incentive Intensity:

Plugging $\kappa = 0$ into parts (1) and (2) of Proposition 1 gives $\beta_1^{P,\kappa=0} = (\pi_1^2 - \pi_1 q)/(\pi_1^2 + r\sigma_1^2)$ and $\beta_1^{A,\kappa=0} = \pi_1^2/(\pi_1^2 + r\sigma_1^2)$, which implies $\beta_1^{P,\kappa=0} - \beta_1^{A,\kappa=0} < 0$. In other words, under the situation in which the benefit of maintenance activity e_2 to ϖ_1 is negligible (i.e., $\kappa = 0$) and only a short-term contract is feasible, the incentive intensity to ϖ_1 will always be weaker when the principal possesses the ownership of ϖ_2 than when the agent owns ϖ_2. This conclusion is consistent with Holmström and Milgrom's (1991) two-task example, which shows that, since there are two tasks facing the agent, a relatively higher incentive to one task may provides disincentive to another important task which can not be contracted by output performance measure. Note that Holmström and Milgrom's (1991) two-task setting is equivalent to our model in which κ equals zero and the principal owns the property rights of ϖ_2. In fact, Proposition 1 has indicated that, when κ is large enough (i.e., κ is bigger than κ^* in Figure 2), the incentive intensity on ϖ_1 can be stronger when the principal owns

[17]Theoretically speaking, a high incentive intensity on ϖ_1 will induce the agent to put more effort on either e_1 or e_2. For a relatively small κ and the convexity of the cost function, however, the agent will tend to exert more effort on e_1 rather

the property rights of ϖ_2. This reflects the fact that crossover effect κ plays an important role to principal's determining the relative magnitude of β_1^P and β_1^A.

If we differentiate the difference between β_1^P and β_1^A with respect to *q*, we have $\partial(\beta_1^{P,\kappa=0} - \beta_1^{A,\kappa=0})/\partial\, q < 0$. This result implies that, if there is no other alternatives available to the principal's incentive design (e.g., non-financial performance measurement or the agent's long-term reputation), then when $\kappa = 0$ and the principal owns the property rights of ϖ_2, the incentive intensity β_1^P will be *far more* weaker than β_1^A as *q* increases. However, if κ is large enough, Proposition 1 indicates that this result shall be reversed.

3.2 The Determination of Property Rights:

So far, we have explored the effects of property rights on principal's incentive design and agents relative task allocation. We now turn our attention to the determination of property rights. In particular, we intend to identify conditions under which the property rights of ϖ_2 should be assigned to the principal or the agent. We first formulate the following Lemma:

LEMMA: *If we define TCE^P (or TCE^A) as the total TCE when the principal (or agent) owns the property rights of ϖ_2, then based on β_1^P and β_1^A specified in Proposition 1 and equations (9) and (10), we have:*

(1) $TCE^P = \dfrac{\pi_1^2(\pi_1 - q)^2}{2(\pi_1^2 + r\sigma_1^2)}$ *and* $TCE^A = \dfrac{1}{2}\left[\pi_2^2 + q^2 - 2\pi_1 q - r\sigma_2^2\right] + TCE^P \cdot \left[\dfrac{\pi_1^2}{(\pi_1 - q)^2}\right]$.

(2) Define $\Omega = TCE^A - TCE^P$, *then the sign of* Ω *is equivalent to the sign of* $(\pi_1 - q)^2 - Z$, *where* $Z = \dfrac{r\sigma_1^2(\pi_1^2 - \pi_2^2) + r\sigma_2^2(\pi_1^2 + r\sigma_1^2) - \pi_1^2\pi_2^2}{r\sigma_1^2}$.

(3) $\partial\Omega/\partial r < 0$, $\partial\Omega/\partial\sigma_2^2 < 0$, $\partial\Omega/\partial q < 0$, $(\partial\Omega/\partial\pi_1)\cdot[-qr\sigma_1^2 - \pi_1(r\sigma_2^2 - \pi_2^2)] \geq 0$, *and* $\partial\Omega/\partial\pi_2 > 0$.

Proof: See Appendix.

---

than e_2 to achieve a high performance on ϖ_1.

Part (2) of the Lemma indicates that, since the sign of Ω determines the property rights assignment of of ϖ_2, the term $(\pi_1 - q)^2 - Z$ can be regarded as the *asset ownership rule* for determining who should own ϖ_2. More important, the first part of the rule $(\pi_1 - q)^2$ denotes the *square of direct net contribution* (SDNC) of e_1 on both ϖ_1 and ϖ_2, while the second part Z constitutes an *adjustment metric* to the net contribution. Note that Z is not a function of the negative crossover effect q (recall that κ equals zero in our short-term analysis). Apparently, if Z is negative, it becomes an addition to the SDNC, resulting in a positive Ω. This implies that the agent should own the ϖ_2. As shown in part (2) of the Lemma, a negative Z requires a small σ_2^2, a small r, and a large π_2. That is, when the agent is not very risk sensitive, the uncertainty of the uncontractible output ϖ_2 is low, and the per-effort-unit contribution of e_2 to ϖ_2 is high, the property rights of ϖ_2 should be assigned to the agent.[18] These results are further supported by part (3) of the Lemma, which shows that $\partial\Omega/\partial r < 0$, $\partial\Omega/\partial\sigma_2^2 < 0$, and $\partial\Omega/\partial\pi_2 > 0$. Note that, when Z is negative, the negative crossover effect q plays no role to the determination of optimal ownership right because π_2 may be large enough to cover q and the uncertainty threat to the risk-averse agent is negligible. The economic rule is: *As long as the adjustment Z is negative, then under the conditions that e_1 adversely affects the uncontractible output ϖ_2, the social optimal property rights should belong to the agent, no matter how harmful e_1 may be to ϖ_2.*

If Z is positive, on the other hand, the sign of Ω depends on the relative magnitudes of SDNC and adjustment Z. Since a positive Z requires a high uncertainty of ϖ_2, a more risk-averse agent, and a low per-effort-unit contribution of e_2 to ϖ_2, the opportunity cost for agent to own ϖ_2's property rights increases. If this opportunity cost is larger than SDNC, the property rights should be assigned to the risk-neutral principal. Note that the Lemma implies a rule: *Given Z is positive, the higher the negative crossover effect q, the higher the probability that the principal should own the property rights.* This

[18] Since ϖ_2 becomes more valuable when π_2 increases, assigning the property rights to the agent can better mitigate the agency problem.

conclusion is further supported by the comparative static $\partial\Omega/\partial q < 0$. The reason underlying this conclusion is that, if the agent owns the property rights when the harm of e_1 on ϖ_2 is high, the principal will offer an overly high β_1^A to satisfy equation (18). This high β_1^A together with the property rights ownership provide three additional costs to the agent: (a) the ($\beta_1^A - \beta_1^P$) portion of production activity's uncertainty σ_1^2, (b) maintenance activity's total uncertainty σ_2^2, and (c) a higher harm q. If the principal owns the property rights, however, the agent will not suffer these three additional costs. Our analytical result enriches the managerial accounting and property rights literatures by explicitly emphasizing the importance of the negative crossover effect to the determination of asset ownership.

Using the above Lemma, we provide the following guideline for assigning the ownership of uncontractible output ϖ_2:

PROPOSITION 3: *Under the short-term situation (i.e., $\kappa = 0$), the assignment of the property rights of the uncontractible output ϖ_2 can be determined by the following rule:*

(1) The property rights of ϖ_2 should be assigned to the agent when: (a) the agent is not very risk sensitive, (b) the uncertainty of ϖ_2 is low, or (c) the per-effort-unit contribution of e_2 to ϖ_2 is high. Since these conditions lead to a negative adjustment metric Z, the negative crossover effect q plays no role to the determination of optimal ownership right.

(2) The property rights of ϖ_2 should be assigned to the principal when: (a) the agent is very risk sensitive, (b) the uncertainty of ϖ_2 is high, or (c) the per-effort-unit contribution of e_2 to ϖ_2 is low. Since these conditions lead to a positive adjustment metric Z, the probability that the principal should own the property rights is increasing in the magnitude of the negative crossover effect q.

Together, Proposition 3 suggests that, when only a short-term contract is feasible, the principal should take the negative crossover effect into consideration in determining the optimal property rights ownership. The importance of the negative crossover effect depends on three variables: the uncertainty of ϖ_2, the agent's risk-averse attitude r, and the direct contribution of e_2 to ϖ_2. In particular, if these three variables lead to a negative adjustment Z value, the negative crossover effect plays no role to the property rights attribution. However, this negative crossover effect does matter when the above three variables give rise to a positive adjustment Z.

4. SUMMARY AND CONCLUSION

The main purpose of this paper is to adopt the property rights theory of the firm to examine, under a multitask setting, the impacts of crossover effects on the design of optimal incentive contract. While ignoring the crossover effects and implicitly assuming that the principal owns the uncontractible output, Holmström and Milgrom (1991) concludes that a higher incentive to a contractible output may discourage the agent to exert more effort on other important tasks whose outputs are uncontractible. Different from their model setting, we incorporate both property rights and crossover effects into the model and show that Holmström and Milgrom's (1991) conclusion is no longer valid. In particular, the analytical results from our model reveal that, *ceteris paribus*, when a *positive* crossover effect κ exists, the principal should provide a higher incentive intensity on the contractible output, no matter who owns the uncontractible output. In contrast, when a *negative* crossover effect q exists, the principal should provides a weaker incentive intensity on the contractible output when she owns the property rights of the uncontractible output; however, the principal will ignore q in determining the incentive intensity when the agent owns the property rights of the uncontractible output. Second, when both the positive and negative crossover effects approach their corresponding cutoff points, the property rights of the uncontractible output become less relevant to the principal's determination of incentive intensity on the contractible output. On the other hand, if any one of the two crossover effects moves away from its corresponding cutoff point, the property rights of the uncontractible output will become more relevant to principal's incentive design. In addition, the difference between the incentive intensities under two property rights scenarios (measured by $\beta_1^P - \beta_1^A$) is increasing in the positive crossover effect κ and is decreasing in the negative crossover effect q. Third, if the negative crossover effect q is high enough, the agent will put relatively more effort on the task which generates a direct effect on the uncontractible output (i.e., e_2) when the principal owns the property rights of this uncontractible output. Finally, the agent should own the property rights of the uncontractible output if (a) the uncertainty of the uncontractible output is small, (b) the agent is less risk-averse, and (c) the direct contribution on uncontractible output is large.

Several limitations of our model and future research directions should be recognized. First, Milgrom and Roberts (1992) indicates that the most important attribute of transactions for examining property rights is the *asset specificity* attribute. According to their definition, assets are specific to a certain use "if the services they provide are exceptionally valuable only in that use (p. 307)." Asset specificity is important because it leads to the *hold-up* problem.[19] Especially, if an asset is specific to a particular use, the owner of the specific asset can be held up, leading to value-destroying consequences such as discouraging the owner to invest in highly specific assets. In our model, we rule out the possibility of asset specificity and assume that the uncontractible output is for general purpose so that the agent's effort decision will not be affected by the hold-up problem. Second, the model is designed and analyzed in a one-period, two-task setting with linear incentive contract. Therefore, the effects of agent's reputation and nonlinear contract on the principal's design of optimal incentive scheme cannot be examined. As Demski and Dye (1999) points out, linear contracts may not independently direct the agent to act in the best interest of the principal. This raises the question about whether the analytical results found in our paper can be applied to situations with nonlinear contracts. A direct extension of our study would be to incorporate these other features into the model. Third, managerial accounting literature has indicated that communication is valuable to principal's production, marketing, and capital budgeting decisions because agent's reporting of his private information to the principal can reduce the costs of information asymmetry (Berg, Daley, Gigler, and Kanodia 1990; Christensen 1981, 1982; Lambert 2001; Melumad and Reichelstein 1987, 1989). This result suggests that future agency-based

[19]The hold-up problem describes a general business situation in which either the principal or the agent worries about being forced to accept disadvantageous contract terms later, after it has sunk an investment, or worry that's its investment may be devalued by the actions of others. See Baron and Kreps (1999) and Milgrom and Roberts (1992) for more detailed discussions about this hold-up problem and its influences on property rights.

contracting research should take the value of communication into consideration in determining the optimal incentive intensity. Finally, our model can also be extended to incorporate the role of multiple performance measures in influencing the direction and intensity of agent's effort allocation decision and the determination of relative weights assigned to various performance measures.

REFERENCES

Arya, A., J. Fellingham, and J. Glover. 1997. Teams, repeated tasks, and implicit incentives. *Journal of Accounting and Eeconomics* (May). Vol. 23, Iss: 1. 7-30.

Baker, G., M. Jensen, and K. Murphy. 1988. Competition and incentives: practice vs theory. *The Journal of Finance* 43 (July): 593-616.

Balakrishnan, R. and D. V. DeJong. 1993. The role of cost allocations in the acquisition and use of common resources. *Contemporary Accounting Research*. (Spring). Vol. 9, Iss: 2. 395-414.

Banker, R. D., and S. M. Datar. 1989. Sensitivity, precision, and linear aggregation of signals for performance evaluation. *Journal of Accounting Research* 27 (Spring): 21-39.

Baron, J.N. and D.M. Kreps. 1999. *Strategic Human Resources*. NY: John Wiley & Sons.

Barzel, Y. 1989. *Economic Analysis of Property Rights*. Cambridge: Cambridge University press.

Benston, G. 1985. The self-serving management hypothesis: Some evidence. *Journal of Accounting and Economics* 7 (April): 67-83.

Berg, J., L. Daley, F. Gigler, and C. Kanodia. 1990. The value of communication in agency contracts: Theory and experimental evidence. *Research Monograph No. 16*. The Canadian Certified General Accountants' Research Foundation.

Bushman, R.M., E. Engle, J. Milliron, and A. Smith. 1998. An empirical investigation of trends in the absolute and relative use of earnings in determining CEO cash compensation. Working paper, University of Chicago.

Bushman, R.M. and A.J. Smith. 2001. Financial accounting information and corporate governance. *Journal of Accounting and Economics* 32 (December): 237-333.

Che, J. and Y.Y. Qian. 1998. Insecure property rights and government ownership of firms. *Quarterly Journal of Economics* (May). Vol. 113, Issue 2. 467-496.

Chiu, Y. S. 1998. Noncooperative bargaining, hostages, and optimal asset ownership. *American Economic Review* (September). Vol. 88, Issue 4. 882-901.

Christensen, J. 1981. Communication in agencies. *The Bell Journal of Economics.* Vol. 12: 661-674.

Christensen, J. 1982. The determination of performance standards and participation. *Journal of Accounting Research* 20 (Autumn): 589-603.

Coase, R. 1960. The Problem of Social Cost, *Journal of Law and Economics*. Vol. 1. 1-44.

Cohen, S. and M. P. Loeb. 1989. The demand for cost allocations: the case of incentive contracts versus fixed-price contracts. *Journal of Accounting and Public Policy* (Fall). 165-180.

Datar, S. M. and M. V. Rajan. 1995. Optimal incentive schemes in bottleneck-constrained production environments. *Journal of Accounting Research* (Spring). Vol, 33. Iss: 1. 33-57.

Demski, J.S. and R.A. Dye. 1999. Risk, return, and moral hazard. *Journal of Accounting Research* 37 (Spring): 27-55.

Feltham, G. A. and J. Xie. 1994. Performance measure congruity and diversity in multi-task principal/agent Relations. *The Accounting Review* 69(3) (July): 429-453.

Feltham, G. A. and M. G.H. Wu. 2000. Public reports, information acquisition by investors, and management incentives. *Review of Accounting Studies* 5 (June): 155-190.

Gibbons, R. 1998. Incentives in organizations. *Journal of Economic Perspectives* 12: 115-132.

Grossman, S. J. and O. D. Hart. 1986. The cost and benefits of ownership: A theory of vertical and lateral integration. *Journal of Political Economy* 94(4) (August): 691-719.

Hart, O. D. and J. Moore. 1988. Incomplete contracts and renegotiation. *Econometrica* 56 (July): 755-785.

Hart, O. D. and J. Moore. 1990. Property rights and the nature of the firm. *Journal of Political Economy* 98(6) (December): 1119-1158.

Hemmer, T.. 1995. On the interrelation between production technology, job design, and incentives. *Journal of Accounting and Economics* (19): 209-245.

Hemmer, T. 1998. Performance measurement systems, incentives, and the optimal allocation of responsibilities. *Journal of Accounting and Economics* (June). Vol. 25, Iss: 3. 321-347.

Holmström, B.. 1979. Moral hazard and observability. *Bell Journal of Economics* 10 (Spring): 74-91.

Holmström, B. and P. Milgrom. 1987. Aggregation and linearity in the provision of intertemporal incentives. *Econometrica* 55(2) (March): 303-328.

Holmström, B. and P. Milgrom. 1991. Multitask principal-agent analysis: Incentive contracts, Asset ownership, and job design. *Journal of Law, Economics and Organizations* 7:24-52.

Holmström, B. and P. Milgrom. 1994. The firm as an incentive system. *America Economic Review* 84 (September): 972-991.

Horngren T. C., G. Foster and S. Datar. 2002. *Cost accounting: A managerial emphasis, 10th edition.* Prentice Hall.

Indjejikian, R. and D. Nanda. 1999. Dynamic incentives and responsibility accounting. *Journal of Accounting and Economics* 27 (April): 177-201.

Joskow, P. L.. 1988. Asset specificity and the structure of vertical relationship: Empirical evidence, *Journal of Law, Economics and Organization* (4) (Spring): 95-117.

Kaplan, S. and P. Stromberg. 1999. Financial contracting theory meets the real world: An empirical analysis of venture capital contracts. Working paper, University of Chicago.

Kirby, A. J., S. Reichelstein, P. K. Sen, and T. Y. Paik. 1991. Participation, slack,and budget-based perfomance evaluation. *Journal of Accounting Research* (Spring). 109-128.

Kwon, Y. K. 1989. Accrual versus cash-basis accounting methods: an agency-theoretic comparison. *Journal of Accounting and Public Policy* (Winter). 267-281.

Lambert, R.A. and D. Larcker. 1987. An analysis of the use of accounting and market measures of performance in executive compensation contracts. *Journal of Accounting Research* 25 (supplement): 85-125.

Lambert, R.A. 2001. Contracting theory and accounting. *Journal of Accounting and Economics* 32 (December): 3-87.

Magee, R. P. 1988. Variable cost allocation in a principal/agent setting. *The Accounting Review* (January). 42-54.

Magee, R. P. 2001. Discussion of "Contracting theory and accounting." *Journal of Accounting and Economics* 32 (December): 89-96.

Meher, M.W. 1987. The use of relative performance evaluation in organizations. In W.J. Burns and R.S. Kaplan (Eds.), *Accounting & Management: Field Study Perspectives*. Boston, MA: Harvard Business School Press.

Merchant, K.A. 1987. How and why firms disregard the controllability principle. In W.J. Burns and R.S. Kaplan (Eds.), *Accounting & Management: Field Study Perspectives*. Boston, MA: Harvard Business School Press.

Meza, D. and B. Lockwiid. 1998. Does asset ownership always motivate managers? Outside options and property rights theory of the firm. *Quarterly Journal of Economics* (May). 361-386.

Milgrom, P. and J. Roberts. 1992. *Economics, organization and management*. *Prentice-hall.*

Melumad, N. and S. Reicheletein. 1987. Centralization versus delegation and the value of communication. *Journal of Accounting Research* 25 (supplement): 1-18.

Melumad, N. and S. Reicheletein. 1989. Value of communication in agencies. *Journal of Economic Theory.* Vol. 47: 334-368.

Murphy, K.J. 1985. Corporate performance and managerial remuneration: An empirical analysis. *Journal of Accounting and Economics* 7 (April): 11-42.

Murphy, K.J. 1999. Executive compensation. In: A. Orley and C. David (Eds.), *Handbook of Labor Economics*. Vol. 3. North-Holland, Amsterdam.

Prendergast, C. 1999. The provision of incentives in firms. *Journal of Economic Literature* 37 (March): 7-63.

Rogerson, W. 1985. The first-order approach to principal-agent problems. *Econometrica* 53: 1357-68.

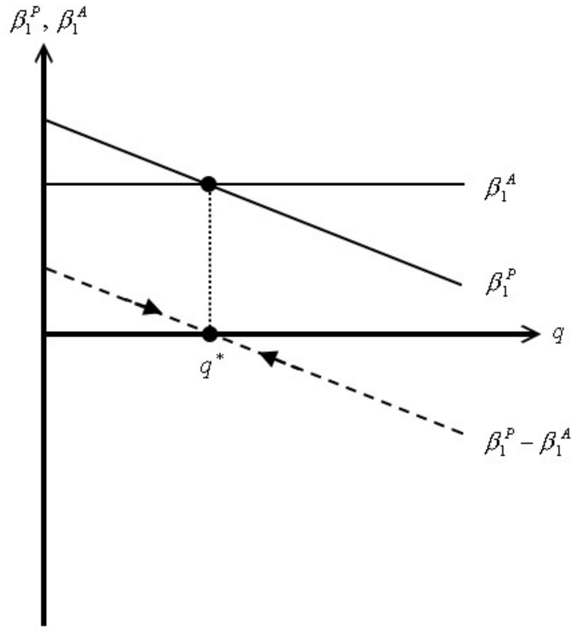
Villadsen, B. 1995. Communication and delegation in collusive agencies. *Journal of Accounting and Economics* (March-May). Vol. 19, Issue 2,3. 315-344.

Wallace, J. 1997. Adopting residual income-based compensation plans: Do you get what you pay for? *Journal of Accounting and Economics* 24 (December): 275-300.

Yim, A. 2001. Renegotiation and relative performance evaluation: Why an informative signal may be useless. *Review of Accounting Studies* 6 (March): 77-108.

Figure 1
The Impacts of Negative Crossover Effect *q* on Property Rights Relevance

Panel A: Property Rights Irrelevance (PRIR)



Panel B: Property Rights Relevance (PRR)

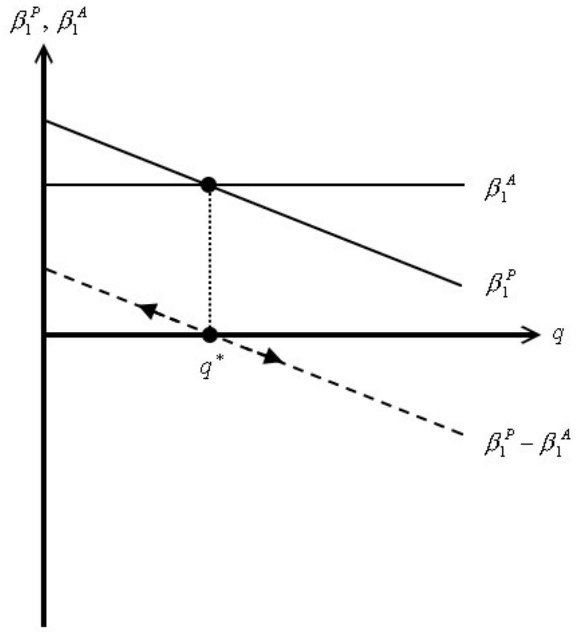
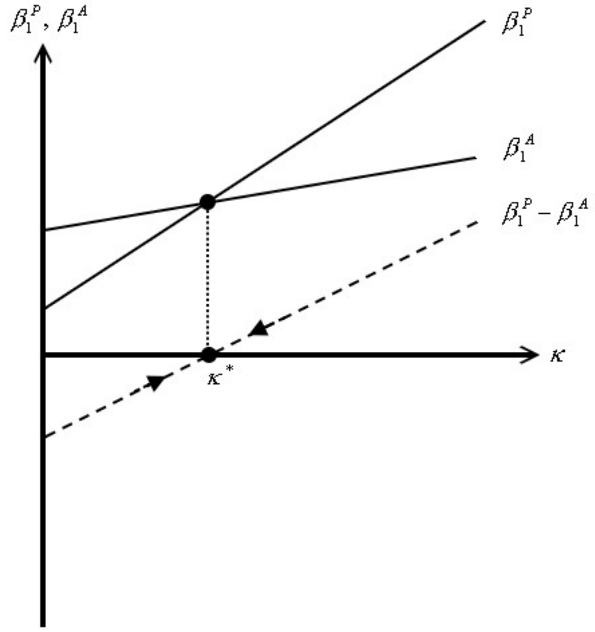
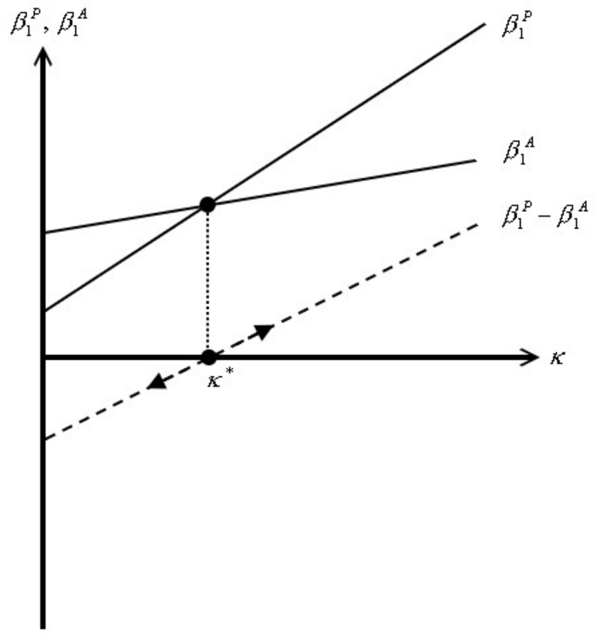


Figure 2
The Impacts of Positive Crossover Effect κ on Property Rights Relevance

Panel A: Property Rights Irrelevance (PRIR)



Panel B: Property Rights Relevance (PRR)



APPENDIX

Proposition 1:

β_1^P can be found through equations (9), (11), and (12). For β_1^A, if the agent owns the property rights of ϖ_2 and ϖ_1 can be contracted by both parties, the optimal TCE will be:

$$\max_{\beta_1^A}\left\{\pi_1 e_1+\kappa e_2-qe_1+\pi_2 e_2-\frac{1}{2}(e_1^2+e_2^2)-\frac{1}{2}r(\beta_1^A)^2\sigma_1^2-\frac{1}{2}r^2\sigma_2^2\right\},$$

$$\text{s.t.}\quad e_1=\beta\pi_1-q,$$

$$e_2=\pi_2+\beta\kappa. \qquad \text{(A1)}$$

Plugging constraints into the objective function and differentiating it with respect to β_1^A gives:

$$\pi_1\frac{\partial e_1}{\partial\beta_1^A}+\kappa\frac{\partial e_2}{\partial\beta_1^A}-q\frac{\partial e_1}{\partial\beta_1^A}+\pi_2\frac{\partial e_2}{\partial\beta_1^A}-e_1\frac{\partial e_1}{\partial\beta_1^A}-e_2\frac{\partial e_2}{\partial\beta_1^A}-r\beta_1^A\sigma_1^2=0.$$

Therefore, we have $\beta_1^A=\dfrac{\pi_1^2+\kappa^2}{\pi_1^2+\kappa^2+r\sigma_1^2}$. (A2)

Q.E.D.

Lemma:

First, we calculate TCE^P as follows:

By Proposition 1, $\kappa = 0$, and equation (8), we have: $\beta_1^P=\dfrac{\pi_1^2-\pi_1 q}{\pi_1^2+r\sigma_1^2}$ and $\beta_2^P=0$.

Using the constraints of **Program I**, we obtain the equations for e_1 and e_2:

$$e_1=\frac{\pi_1^2(\pi_1-q)}{\pi_1^2+r\sigma_1^2}\ \text{and}\ e_2=0. \qquad \text{(A3)}$$

Plugging (A1) into $TCE^P=(\pi_1-q)e_1+\pi_2 e_2-\frac{1}{2}(e_1^2+e_2^2)-\frac{1}{2}r(\beta_1^P)^2\sigma_1^2$ gives:

$$TCE^P=\frac{\pi_1^2(\pi_1-q)^2}{2(\pi_1^2+r\sigma_1^2)}. \qquad \text{(A4)}$$

Second, we calculate TCE^A as follows:

By (A1), (A2), and $\kappa = 0$, we have:

$$\beta_1^A=\frac{\pi_1^2}{\pi_1^2+r\sigma_1^2},\quad e_1=\pi_1\beta_1^A-q,\ \text{and}\ e_2=\pi_2. \qquad \text{(A5)}$$

Plugging (A5) into $TCE^A=(\pi_1-q)e_1+\pi_2 e_2-\frac{1}{2}(e_1^2+e_2^2)-\frac{1}{2}r(\beta_1^A)^2\sigma_1^2-\frac{1}{2}r\sigma_2^2$ gives:

$$TCE^A=\frac{1}{2}\left[\pi_2^2+q^2-2\pi_1 q-r\sigma_2^2\right]+TCE^P\cdot\left[\frac{\pi_1^2}{(\pi_1-q)^2}\right]. \qquad \text{(A6)}$$

Tedious calculations show that

$$\Omega = TCE^{A} - TCE^{P} = \frac{\left[\pi_1^2\pi_2^2 + r\sigma_1^2(\pi_2^2 + q^2 - 2\pi_1 q) - r\sigma_2^2(\pi_1^2 + r\sigma_1^2)\right]}{2(\pi_1^2 + r\sigma_1^2)}. \quad \text{(A7)}$$

Since in (A7) the denominator is positive, the sign of Ω is the same as that of the numerator. In other words,

$$\begin{aligned}
&\Omega < 0 \\
&\Leftrightarrow [\pi_1^2\pi_2^2 + r\sigma_1^2(\pi_2^2 + q^2 - 2\pi_1 q) - r\sigma_2^2(\pi_1^2 + r\sigma_1^2)] < 0 \\
&\Leftrightarrow \pi_1^2\pi_2^2 + r\sigma_1^2(\pi_2^2 + q^2 - 2\pi_1 q) < r\sigma_2^2(\pi_1^2 + r\sigma_1^2) \\
&\Leftrightarrow (\pi_1 - q)^2 r\sigma_1^2 < \pi_1^2 r\sigma_1^2 + (\pi_1^2 + r\sigma_1^2)r\sigma_2^2 - \pi_1^2\pi_2^2 - \pi_2^2 r\sigma_1^2 \\
&\Leftrightarrow (\pi_1 - q)^2 < \frac{\pi_1^2 r\sigma_1^2 + (\pi_1^2 + r\sigma_1^2)r\sigma_2^2 - \pi_1^2\pi_2^2 - \pi_2^2 r\sigma_1^2}{r\sigma_1^2} \\
&\Leftrightarrow (\pi_1 - q)^2 < \frac{r\sigma_1^2(\pi_1^2 - \pi_2^2) + r\sigma_2^2(\pi_1^2 + r\sigma_1^2) - \pi_1^2\pi_2^2}{r\sigma_1^2} = Z \\
&\Leftrightarrow (\pi_1 - q)^2 - Z < 0.
\end{aligned}$$

Finally, It is straightforward that $\partial\Omega/\partial r < 0$, $\partial\Omega/\partial\sigma_2^2 < 0$, $\partial\Omega/\partial q < 0$, *and* $\partial\Omega/\partial\pi_2 > 0$.

Q.E.D.