Professor Huihua NIE, PhD
School of Economics, Renmin University of China
E-mail: niehuihua@gmail.com

HOLD-UP, PROPERTY RIGHTS AND REPUTATION

Abstract: *By introducing asymmetric information of investors' abilities and finitely repeated games into the classic hold-up model, this paper revisits the relationship between property rights and reputation under incomplete contracting environment and obtains some different insights. First, even facing holdup agents can make efficient investments due to the reputation effect in some periods of relationship, which is sharply contrary to existing research. Second, although reputation is an incentive tool for agents, property rights are complementary or even necessary for reputation, and reputation itself is not enough to motivate agents to make first-best investments without ownership. Third, this paper explains underinvestment, efficient investment, and overinvestment in a unified dynamic model of property rights.*

Keywords*: hold-up; property rights; asymmetric information; reputation; incomplete contracts*

JEL classifications: **L14, L22, D23**

1. Introduction

In the real world, people usually sign simple trading contracts. These simple contracts do not specify all of the rules for every conceivable eventuality, so they are incomplete contracts. In the presence of relationship-specific investments, incomplete contracts will lead to hold-up problems and ex ante inefficient investments, but vertical integration can alleviate hold-up because of ex post adaption within hierarchy (Williamson, 1985). Based on this idea, a formal property rights theory of the firm has been provided to show that appropriately allocating ownership can motivate agents to make second-best investments (Grossman and Hart, 1986; Hart and Moore, 1990; hereafter GHM), which significantly influenced the direction of research on the boundary of firms, corporate finance, government scope, law and economics, and institutional design in the last twenty years.

In contrast to the role of ownership as a solution to reduce the investment inefficiency proposed by the property rights theory of the firm, there are three strands of literature arguing that efficient investment can be achieved by other solutions in an incomplete contracting environment. First, mechanism literature emphasizes the roles of message game (Aghion *et al.*, 1994), option contracts (Lyon and Rasmusen, 2004), and contractual time design (Guriev and Kvasov, 2005). Second, reputation literature argues that market reputation can eliminate hold-up and assure investment efficiency (Coase, 1988). The third strand of literature discusses the interaction between ownership and reputation (Baker, *et al.*, 2002; Halonen, 2002) in infinitely repeated games. While Halonen (2002) considers joint ownership to be optimal, all three literatures assert that efficient investment can be achieved irrespective of ownership. Interestingly, Hart (2001) does not think that reputation will add new insight to static property-rights models, so it is worth revisiting the role of property rights, and the interaction of property rights and reputation in a dynamic environment.

By introducing asymmetric information of investors' ability in a finitely repeated game, this paper discusses the relationship between property rights and reputation and provides some different insights. First, I find that even facing holdup agents can make efficient investments due to the reputation effect in some periods of relationship, which is sharply contrary to existing research. Second, although reputation is an incentive tool for agents, property rights are complementary or even necessary for reputation, and reputation itself is not enough to motivate agents to make first-best investments without ownership. Third, this paper explains underinvestment, efficient investment, and overinvestment in a unified dynamic model of property rights. Compared to existing literature on reputation and ownership (e.g., Baker *et al*., 2002), the assumption of finite game is weaker in this paper, and ownership has a positive effect for agents' incentive in investment. In Baker *et al*. (2002) and Halonen (2002), more asset ownership increases the involved parties' temptations to renege on the relationship, so relational outsourcing or joint ownership can be an efficient organizational structure. However, in this paper, integration ("relational employment" in terms of Baker *et al*.) is still the optimal ownership model when there is one-side investment, which is consistent with the static model in GHM.[1]

To elicit some results from the model in this paper, let us consider a slightly modified story of Hart and Moore (1990). On an island, there are many skippers and tycoons, who stay for two days. A typical skipper can provide cruise services for a typical tycoon with a yacht. The cruise can bring the tycoon utility with a probability that depends on the skipper's private type. A skipper can be an experienced hand or an inexperienced hand, which is unknown to the tycoon. With the same sunk learning costs, an experienced skipper can provide a successful service for a tycoon with a higher probability than an inexperienced skipper can. Of course, the tycoon wants to search for an experienced skipper and prefers to fire an inexperienced one if, the next day, he recognizes that the skipper lacks experience. The value of a successful service provided by a particular skipper to a tycoon is unverifiable by a third party, so the skipper faces holdup by the tycoon. Even so, to get a good reputation on the first day, under certain conditions, the skipper would like to make specific investments according to the first-best standard to signal the behavior of an experienced hand and then make second-best specific investments on the second (last) day. Facing loss on the first day, the more physical assets there are, the more willing the skipper is to make a first-best

[1] This paper also discusses the case without assets and two-asset case, while Baker *et al*. (2002) is silent on this.

specific investment. Formally, in a two-period game model with asymmetric information, this paper argues that contractual incompleteness can lead to hold-up but that, due to the reputation effect, hold-up does not necessarily lead to inefficient investment.

This paper contributes to the existing reputation literature by combining the reputation effect with property rights. On one hand, since the 1980s, there have been a large number of studies on reputation mechanisms pioneered by Kreps and Wilson (1982) and Milgrom and Roberts (1982) (hereafter KMRW). Holmstrom (1999) shows that market reputation provides incentives for managers to make efforts, but first-best investment levels cannot be achieved. Unlike this paper, previous literature takes reputation as a vehicle to maintain trade that has nothing to do with hold-up and property rights. This paper takes reputation as an incentive tool complementary to property rights in dynamic environments.

This paper responds to Tirole's criticism (1999) that incomplete contract theory neglects the role of asymmetric information by combining the symmetric information of investment level and the asymmetric information of investors' ability. For a long time, complete contract theory and incomplete contract theory have diverged on the assumption of informational symmetry. This is not the first paper that introduces asymmetric information in hold-up models. Other papers either assume that there is asymmetric information in investors' costs or benefits (e.g., Bac, 1993), or they use static hold-up models (e.g., Matouschek, 2004). Recently, Aghion *et al.* (2012) revisited the truth-telling mechanism and discovered that hold-up still exists in incomplete contracting environments. Given that hold-up exists, this paper analyzes investment efficiency and is complementary to Aghion *et al.* (2012).

The rest of this paper proceeds as follows: section 2 builds on a hold-up model with asymmetric information and describes a separating perfect Bayesian equilibrium and a pooling perfect Bayesian equilibrium in a case with one asset and a one side investment; section 3 further analyzes the incentive effect of all kinds of ownership structures in a case with two assets and one side investment; and section 4 summarizes conclusions and lays out implications for future research.

2. The Model

2.1 Setup

Suppose that there are Agents 1 (e.g., skippers) and Agents 2 (e.g., tycoons), and there is one physical asset a_1 (e.g., a yacht). All agents are risk neutral and possess boundless wealth. A pair consisting of Agent 1 and Agent 2 meets randomly and signs a contract, which specifies that Agent 1 uses asset a_1 and her specific human capital to supply a certain widget (W) to Agent 2, who in turn uses W and his physical assets (if possible) to supply a final product to the market. There are two kinds of Agent 1: high-type (H) with high productivity and low-type (L) with low productivity. With the same cost, high-type and low-type Agent 1 can enhance the value of W to σ with probability γ or ζ ($0 < \zeta < \gamma < 1$), respectively, while they may fail and obtain zero value with probability $1-\gamma$ and $1-\zeta$, respectively. σ stands for Agent 1's investment level or value. Agent 1's type θ is private information, and the probability for each type of Agent 1 is $p_L = p_H = 0.5$.[2] Agent 2 can observe only successful investment by Agent 1. Agent 2 does not invest, and his contribution to the final product is a fixed value (V), so the joint surplus is $V+\sigma$ with a probability. Agent 1's investment costs are $C(\sigma)$, which are strictly convex. Let $\sigma \geq 0$, $C(0)=0$, $C'(\cdot)>0$, and $C''(\cdot)>0$. Because investment σ is too complicated to be specified in an initial contract, the contract is incomplete. After the nature of the situation is clear, the costs and values of both parties' investments are symmetrical, so ex post bargaining can be efficient according to Coase theorem, though Agent 1's type of information is asymmetric.[3] There is no side payment, and two parties share the surplus according to a symmetric Nash bargaining solution.[4] When the relationship breaks, if Agent 1 owns physical asset a_1 and a specific investment succeeds, her outside option is $\mu\sigma$. If Agent 1 has no asset or the specific investment fails, her outside option is 0. $\mu \in [0,1]$ indicates the economic relationship between two agents. When another agent is indispensable, μ=0; otherwise, μ=1.

The game lasts for two periods with a discount factor of $\delta \in (0,1]$. In period 2, according to Bayes' rule, Agent 2 can update his belief based on Agent 1's investment in period 1, which affects his decision to cooperate with Agent 1. If Agent 2 quits working for Agent 1, he can find employment with another Agent 1 with probability $1-\kappa$ in the market. Here $0<\kappa\leq 1$, which represents the search costs for agent 2. Meanwhile, we suppose that after breaking up with Agent 2, the probability that Agent 1 can find another agent 2 to cooperate with is κ; otherwise, Agent 1 can sell her physical asset at a fixed price of $\underline{A}$. For simplicity, we normalize $\underline{A}$ as 0.[5]

To summarize, the timing is as follows.

In period 1:

(1) Agent 1's type and corresponding proportions are selected by nature.

(2) Agent 1 and Agent 2 meet randomly and sign a contract.

(3) Agent 1 makes an ex ante investment in human capital.

(4) The state of nature is clear, and the two parties renegotiate.

In period 2:

(5) Agent 2 updates his belief in Agent 1's type and decides whether to keep the relationship or not, which determines whether Agent 1 searches for another

---

[2] It is just for convenience, but it will not qualitatively change our main conclusions.

[3] It is noted that there is no contradiction between ex post bargaining and asymmetric information about Agent 1's type.

[4] There is no sharing rule because the costs, benefits, and investment are observable to both parties but not verifiable to a third party.

[5] It is not a strong assumption. Even we suppose at that time agent 1's "outside option" is $\mu\sigma$, our main conclusion still holds.

Agent 2.

(6) Agent 1 makes an ex ante investment in human capital if she cooperates with Agent 2 or sells her physical assets at a fixed price.

(7) Renegotiation happens if Agent 1 works with an agent 2.

(8) Game over.

2.2 One period

Let us start with a simple case in which there are two agents, Agent 1 and Agent 2, one physical asset, a_1, and one period. As a benchmark, at first we consider the first-best standard to maximize total social surplus. Because high-type Agent 1 can generate more social surplus than low-type Agent 1, to make things interesting, we suppose that the market prefers high-type Agent 1.[6] The objective function of social welfare is

$$\underset{\sigma}{Max}\,\gamma\sigma+(1-\gamma)*0+V-C(\sigma)\,. \tag{1}$$

The first-order condition (FOC) is

$$C'(\sigma^*)=\gamma \tag{2}$$

Because of the convexity of the cost function, the solution to equation (1) exists and is unique. Equation (2) characterizes the standard of first-best specific investment in human capital, i.e., σ^*, and it is efficient.

Next, we discuss investment efficiency under different allocations of property rights and game structures. There are two subclasses: Agent 1 owns a_1, or Agent 2 owns a_1. In incomplete contracting environments, Agent 1 and Agent 2 independently choose the optimal strategy and obtain Nash equilibrium. Because Agent 1 is the only one who makes an ex ante specific investment in human capital, we will focus on Agent 1's investment efficiency. If Agent 1 owns a_1, her outside option is $\mu\sigma$ or 0, but high-type and low-type Agent 1 have different expected outputs. Specifically, Agent 1's objective functions of expected revenue and corresponding FOCs are the following.

For high-type Agent 1:

$$\underset{\sigma}{Max}\,\gamma[\mu\sigma+\frac{1}{2}(\sigma+V-\mu\sigma)]+(1-\gamma)\frac{V}{2}-C(\sigma) \tag{3}$$

$$C'(\sigma_H)=\frac{(1+\mu)\gamma}{2}\,. \tag{4}$$

For low-type Agent 1:

---

[6] I will justify the assumption below.

$$\underset{\sigma}{Max}\, \zeta[\mu\sigma + \frac{1}{2}(\sigma + V - \mu\sigma)] + (1-\zeta)\frac{V}{2} - C(\sigma) \tag{5}$$

$$C'(\sigma_L) = \frac{(1+\mu)\zeta}{2}. \tag{6}$$

Agent 2 does not make a specific investment, so his expected revenue depends on Agent 1's type with an equal probability, i.e.,

$$\frac{1}{2}[\gamma\frac{(\sigma + V - \mu\sigma)}{2} + (1-\gamma)\frac{V}{2}] + \frac{1}{2}[\zeta\frac{(\sigma + V - \mu\sigma)}{2} + (1-\zeta)\frac{V}{2}]. \tag{7}$$

Because $\gamma > \zeta$, the expected revenue brought by a high-type Agent 1 (the first square bracket in the above expression) is more than that brought by a low-type Agent 1 (the second square bracket). Agent 2 is preferred to a high-type agent 1, which is the reason we take high-type Agent 1's efficient investment level (expression (2)) as the first-best standard.

If Agent 2 owns a_1, Agent 1's outside option is 0. Similar to expression (3) or (5), we can get Agent 1's FOC,

$$C'(\sigma_H) = \frac{\gamma}{2} \text{ for high-type} \tag{8}$$

$$C'(\sigma_L) = \frac{\zeta}{2} \text{ for low-type.} \tag{9}$$

FOC conditions (4), (6), and (8), (9) characterize Agent 1's optimal investment level with and without physical assets, respectively. Notice that $\gamma \geq \frac{(1+\mu)\gamma}{2} \geq \frac{\gamma}{2}$ and $\zeta > \frac{(1+\mu)\zeta}{2} \geq \frac{\zeta}{2}$. Compared to the first-best standard, two kinds of Agent 1 underinvest, i.e., Agent 1's specific investment is second-best in a one-period game, because Agent 1 can only get half the marginal revenue of a specific investment facing holdup by Agent 2, so Agent 1 does not have sufficient incentive to invest ex ante. In addition, two kinds of agent 1 with physical assets invest more than in a situation without physical assets. In fact, Agent 1's investment incentive is increasing with her outside option which depends on the value of the physical asset she owns and her importance in the relationship.

Proposition 1: *If only Agent 1 invests and there is only one asset, both high-type and low-type agents 1 make second-best specific investment in the one-period game. Agent 1's incentive to invest in specific human capital is increasing the value of the physical asset.*

Proposition 1 suggests that Agent 1 will underinvest under hold-up and that the physical asset will increase Agent 1's bargaining power and her incentive to invest ex ante. These points are in the spirit of the GHM model. Due to adverse selection from asymmetric information of an agent's productivity, allocating bargaining power to an investing party does not assure first-best specific investment in a one-period game because Agent 1 always has the incentive to claim that she is high-type, regardless of her real type. Even in a finite-period game, first-best investment cannot always be achieved, which is what we will show in the next section.

2.3 Two Periods

Suppose that the games last for finite periods[7], say $T \geq 2$. For a finitely repeated game, the solution to a two-period game is similar to that of an N-period game. Without generality, we assume $T = 2$, and we will discuss the case of $T > 2$ in detail soon. Because a high-type (H) agent 1 will bring higher expected revenue than a low-type (L) agent 1, Agent 2 would like to cooperate with a high-type agent 1. Because the game is repeated and Agent 1's productivity is asymmetric information, at the beginning of period 2, Agent 2 can update his information based on Agent 1's investment level in period 1. Agent 1 anticipates that situation, and in period 1, she has an incentive to signal her investment level to Agent 2. Naturally, the reputation effect works. The logic behind this model is similar to the signaling model; however, here an agent's signal (investment) itself is useful for production, and property rights have a role. In a repeated game, there are a lot of equilibria. What concerns us is whether Agent 1 makes an efficient specific investment when facing holdup by Agent 2 in equilibrium.

A. Separating PBE

Because high-type Agent 1 has higher expected revenue in a specific investment with the same cost than low-type Agent 1, a single-crossing condition is satisfied. By construction, naturally, there would be a separating equilibrium. Notice that when $\mu = 0$, the value of the physical asset is 0. First, we concentrate on the case in which Agent 1 owns physical asset a_1, and then we compare it to the case without a physical asset.

We can construct a separating perfect Bayesian equilibrium (PBE) where both

[7] Almost all of the dynamic hold-up models adopt the infinitely repeated game approach (e.g., Che and Sakovics, 2004). However, as Hart (2001) points out, that reputation effect can lead to any possible result, regardless of any organizational forms. Of course, it will be not interesting.

types of Agent 1 choose different signals in period 1, $\sigma^* \neq \sigma_L$, such that Agent 2's posterior beliefs are $\Pr ob(\theta = H \mid \sigma_s = \sigma^*) = 1$, $\Pr ob(\theta = L \mid \sigma_s = \sigma_L) = 1$ on the equilibrium path, and $\Pr ob(\theta = H \mid \sigma_s \neq \sigma^*) = 0$ on the off-equilibrium path (s stands for "separating"). Agent 2 fires any low-type Agent 1 and hires another Agent 1 in the market with a probability of $1-\kappa$. Because period 2 is the last period, both types of Agent 1 definitely make second-best specific investments σ_j ($j = H, L$) in period 2. If Agent 1 does not want to keep the relationship with Agent 2, her optimal strategy is to invest σ_j, which obviously dominates any other strategy.

For high-type Agent 1, if she makes her first-best specific investment in human capital in period 1, she will be regarded as high-type and can keep cooperating with Agent 2 in period 2.[8] If she makes any other investment, with probability κ, she can find another Agent 2 to cooperate with, or with probability $1-\kappa$, she will fail to find another Agent 2 and receive zero (or a fixed payment for her physical asset). Her incentive compatibility constraint is

$$\begin{aligned}&[\frac{(1+\mu)\gamma}{2}\sigma^* + \frac{V}{2} - C(\sigma^*)] + \delta[\frac{(1+\mu)\gamma}{2}\sigma_H + \frac{V}{2} - C(\sigma_H)] \\ &\geq (1+\kappa\delta)[\frac{(1+\mu)\gamma}{2}\sigma_H + \frac{V}{2} - C(\sigma_H)]\end{aligned} . \qquad (10)$$

For low-type Agent 1, it is too costly for her to pretend to be high-type, so she would rather make a second-best investment in period 1. Once she discloses her real type, she has to quit working for Agent 2 and search for another Agent 2 to cooperate with at probability κ in period 2. If she cannot find an Agent 2 to cooperate with, she will get zero with probability $1-\kappa$. As a result, her incentive compatibility constraint is:

[8] In this case, Agent 1 and Agent 2 build a kind of relational employment in terms of Baker *et al*. (2002).

$$(1+\kappa\delta)[\frac{(1+\mu)\zeta}{2}\sigma_L+\frac{V}{2}-C(\sigma_L)]$$
$$\geq[\frac{(1+\mu)\zeta}{2}\sigma^*+\frac{V}{2}-C(\sigma^*)]+\delta[\frac{(1+\mu)\zeta}{2}\sigma_L+\frac{V}{2}-C(\sigma_L)] \quad (11)$$

For Agent 2, on the one hand, he must have no incentive to deviate once he meets a high-type Agent 1, even if high-type Agent 1 makes a second-best investment in the second period. On the other hand, he must have an incentive to search for another Agent 1 in period 2 once he finds Agent 1 is low-type in period 1. In that case, he meets a high-type or a low-type Agent 1 with equal probabilities. His incentive compatibility constraints are

$$[\frac{\gamma(\sigma^*+V-\mu\sigma^*)}{2}+\frac{(1-\gamma)V}{2}]+\delta[\frac{\gamma(\sigma_H+V-\mu\sigma_H)}{2}+\frac{(1-\gamma)V}{2}]$$
$$\geq(1+\delta)[\frac{\gamma(\sigma_H+V-\mu\sigma_H)}{2}+\frac{(1-\gamma)V}{2}] \quad (12)$$

$$[\frac{\zeta(\sigma_L+V-\mu\sigma_L)}{2}+\frac{(1-\zeta)V}{2}]+(1-\kappa)\delta\{\frac{1}{2}[\frac{\gamma(\sigma_H+V-\mu\sigma_H)}{2}+\frac{(1-\gamma)V}{2}]$$
$$+\frac{1}{2}[\frac{\zeta(\sigma_L+V-\mu\sigma_L)}{2}+\frac{(1-\zeta)V}{2}]\}\geq(1+\delta)[\frac{\zeta(\sigma_L+V-\mu\sigma_L)}{2}+\frac{(1-\zeta)V}{2}] \quad (13)$$

where σ^*, σ_H, and σ_L are determined by conditions (2), (4), and (6), respectively. It is noted that Agent 2 ends cooperation with Agent 1, who did not, given Agent 1's beliefs, make an equilibrium investment level in period 1. For high-type Agent 1, if she deviates from the equilibrium investment level (say, σ^*) and even makes investment σ_H, Agent 2 has an incentive to quit because he expects that Agent 1 is low-type. Actually, in this case, a high-type Agent 1 has no incentive to deviate, unless we employ a more strict refinement approach below.

Now, we will discuss these incentive constraints. In condition (10), by making a first-best investment, high-type Agent 1 burdens some loss in period 1 because σ_H is her optimal investment decision under static environments, but she will be compensated in period 2. Given the costs function, if the loss is sufficiently small (i.e., $\mu\to 1$) in period 1, or the repayment is sufficiently large (i.e., $\delta\to 1$ and κ is sufficiently small) in period 2, then condition (10) holds.

Condition (11) requires the mimicking cost to be sufficiently high (i.e., $\zeta \to 0$ or $\mu \to 0$) or the repayment to be sufficiently low (i.e., $\delta \to 0$ or $\kappa \to 1$) to induce low-type Agent 1 to indicate her real type. Notice that there is a tradeoff: the larger the benefit in period 2, the more motivated a high-type Agent 1 has to be to make a first-best investment, and the more motivated a low-type Agent 1 has to mimic a high-type one. As for Agent 2, because his expected revenue is increasing in Agent 1's investment, condition (12) is loose for $\sigma^* > \sigma_H$. Condition (13) holds if the search cost is sufficiently small (i.e., $\kappa \to 0$) or the difference in productivity between the high-type and low-type Agent 1 is sufficiently large (i.e., $\gamma \gg \zeta$). Considering the continuity of σ, in some certain parameters, i.e., ζ is sufficiently small or μ, δ, or κ is appropriately moderate, constraints (10), (11), and (13) can be satisfied simultaneously. Given Agent 2's belief, the strategies of both high-type and low-type Agents 1 are optimal. Meanwhile, Agent 2's strategy is optimal, and his belief is consistent on the equilibrium path, so we have a separating PBE.

Proposition 2: *If only Agent 1 invests and there is only one asset, a separating PBE exists. In this equilibrium, high-type Agent 1 makes a first-best specific investment in period 1, and low-type Agent 1 makes a second-best specific investment in period 1. High-type Agent 1 and low-type Agent 1 make second-best specific investments in period 2.*

The reasoning behind proposition 2 is very straightforward. Facing a loss resulting from deviating from a second-best investment in period 1, high-type Agent 1 will be subsidized in period 2 because of her good reputation. Conversely, low-type agent 1 has less expected production than high-type in period 2, even if she can imitate the high-type in period 1, which will not offset her loss in period 1. Although it could be a PBE at $\sigma_s = \sigma^*$, we can consider other cases. According to the "intuitive criterion" of refinement (Cho and Kreps, 1987), under certain parameters, a high-type Agent 1 can reduce her investment by an infinitesimally small amount below the efficient level σ^*, if the low-type agent 1 would never find it beneficial to make the same investment no matter the inference of Agent 2. So, there could be a case where $\sigma^* > \sigma_s \geq \sigma_H$ exists. In this case, the situation is a little better than the one-period game, where high-type Agent 1 makes more, but not efficient, specific investments. There could also be another case with $\sigma_s > \sigma^*$. In that case, high-type agent 1 overinvests, which is not efficient. It is very difficult to partition parameter spaces for all of the cases exactly, but there is a tendency, other things being equal, that the further the distance σ_s over σ^*, the more high-type Agents 1 experience loss in period 1 and the smaller the probability that a separating PBE exists. The point is that there exists an equilibrium in which Agent 1 will make a first-best investment under some conditions, which is what we want to emphasize in this article. When the mimicking benefit is large enough for low-type Agent 1 to make a specific investment, there can be a pooling PBE.

B. Pooling PBE

In a pooling PBE, both high-type and low-type Agents 1 make the same specific investment in period 1: $\sigma_p = \sigma^*$ is such that Agent 2's posterior beliefs are $\Pr ob(\theta = H \mid \sigma_p = \sigma^*) = \Pr ob(\theta = L \mid \sigma_p = \sigma^*) = 0.5$ on the equilibrium path and $\Pr ob(\theta = H \mid \sigma_p \neq \sigma^*) = 0$ on the off-equilibrium path (p stands for "pooling"). Both kinds of agent 2 make a second-best specific investment of σ_j ($j = H, L$) in period 2. Agent 2 keeps cooperating with Agent 1, who makes specific investment $\sigma_p = \sigma^*$, and Agent 2 fires the Agent 1 who makes other investments and then finds another Agent 1 with a probability of $1-\kappa$ in period 2.

To construct a pooling PBE, high-type Agent 1's incentive compatibility constraint is the following, which is the same as (10):

$$\begin{aligned}&[\frac{(1+\mu)\gamma}{2}\sigma^* + \frac{V}{2} - C(\sigma^*)] + \delta[\frac{(1+\mu)\gamma}{2}\sigma_H + \frac{V}{2} - C(\sigma_H)] \\ &\geq (1+\delta\kappa)[\frac{(1+\mu)\gamma}{2}\sigma_H + \frac{V}{2} - C(\sigma_H)]\end{aligned} \quad . \tag{14}$$

Low-type Agent 1's incentive compatibility constraint is

$$\begin{aligned}&[\frac{(1+\mu)\zeta}{2}\sigma^* + \frac{V}{2} - C(\sigma^*)] + \delta[\frac{(1+\mu)\zeta}{2}\sigma_L + \frac{V}{2} - C(\sigma_L)] \\ &\geq (1+\kappa\delta)[\frac{(1+\mu)\zeta}{2}\sigma_L + \frac{V}{2} - C(\sigma_L)]\end{aligned} \quad . \tag{15}$$

On the equilibrium path, both high-type Agent 1 and low-type Agent 1 have no incentive to deviate. Because Agent 1 makes a first-best investment that will bring more expected revenue for Agent 2 than making a second-best investment, Agent 2's incentive compatibility constraint is automatically satisfied. Specifically, it is

$$[\frac{\gamma(\sigma^* + V - \mu\sigma^*)}{2} + \frac{(1-\gamma)V}{2}] + \delta\{\frac{1}{2}[\frac{\gamma(\sigma_H + V - \mu\sigma_H)}{2} + \frac{(1-\gamma)V}{2}] + \frac{1}{2}[\frac{\zeta(\sigma_L + V - \mu\sigma_L)}{2} + \frac{(1-\zeta)V}{2}]\} \geq (1+\delta)\{\frac{1}{2}[\frac{\gamma(\sigma_H + V - \mu\sigma_H)}{2} + \frac{(1-\gamma)V}{2}] + \frac{1}{2}[\frac{\zeta(\sigma_L + V - \mu\sigma_L)}{2} + \frac{(1-\zeta)V}{2}]\} \tag{16}$$

When the future benefit is sufficiently large (i.e., $\delta \to 1$, or $\kappa \to 0$) or the difference in productivity between high-type and low-type Agent 1 is sufficiently small (i.e., $\zeta \to \gamma$), constraints (14) and (15) can be satisfied simultaneously, and we have a pooling PBE.

Proposition 3: *If only Agent 1 invests and there is only one asset, a pooling PBE exists. In equilibrium, both high-type and low-type Agent 1 make a first-best specific investment in period 1, and they make second-best specific investment in period 2.*

Similarly, a pooling PBE can exist in other cases except for $\sigma_p = \sigma^*$. If $\sigma^* > \sigma_p \geq \sigma_H$ exists, the specific investment is still inefficient, though it is better than the one-period game. In this case, according to "intuitive criterion," the high-type Agent 1 must have an incentive to deviate until $\sigma_p \to \sigma^*$ or even $\sigma_p = \sigma^*$ in the space of a certain parameter, which is the separating PBE. If $\sigma_H > \sigma_p > \sigma_L$ exists, this situation will not happen because high-type Agent 1 must have an incentive to deviate until at least $\sigma_p = \sigma_H$. If $\sigma_p > \sigma^*$ exists, both kinds of Agent 1 overinvest, which, again, is not efficient. In sum, there could be an equilibrium where both kinds of Agent 1 invest efficiently, which is not achieved in the static holdup model.

3. The Optimal Ownership Structure

3.1 No Physical Asset For Agent 1

Now let us discuss the role of physical assets for Agent 1 to achieve first-best investment. Physical assets are important because they affect agents' investment incentives via outside options. Remember that Agent 1's expected revenue is increasing with her outside option, which implies that given the first-best standard of specific investment (i.e., condition (2)), an Agent 1 with more physical assets has looser incentive constraints than an Agent without physical assets, regardless of being a high-type or low-type Agent 1. There is no doubt that physical assets will highly affect Agent 1's incentive to make a first-best investment. To make the point clearer, we take the separating PBE as an example. Now we suppose that Agent 1 has no asset, but Agent 2 has the only asset and his outside option is μV.

Without physical assets, high-type Agent 1's incentive compatibility constraint is

$$\begin{aligned}&[\frac{\gamma}{2}\sigma^* + \frac{(1-\mu)V}{2} - C(\sigma^*)] + \delta[\frac{\gamma}{2}\sigma_H + \frac{(1-\mu)V}{2} - C(\sigma_H)] \\ &\geq (1+\delta\kappa)[\frac{\gamma}{2}\sigma_H + \frac{(1-\mu)V}{2} - C(\sigma_H)]\end{aligned}. \qquad (17)$$

Compared to the case with one physical asset (condition (10)), given the same cost of first-best investment, high-type Agent 1 must bear more loss in period 1 but gets less expected revenue. In particular, when the cost of searching for another Agent 2 is sufficiently small (i.e., $\kappa \to 1$), condition (17) cannot hold. Because of $\gamma > \zeta$, it is more impossible that low-type Agent 1's incentive constraint holds under the same situation. So, we have proposition 4.

Proposition 4: *If Agent 1 has no physical asset and the search cost for Agent 2 is sufficiently small (*$\kappa \to 1$*), the first-best investment cannot be achieved.*

Proposition 4 indicates that property rights provide a basis for the reputation effect. That is to say, when agents face hold-up under incomplete contracting environments, the reputation effect does not provide sufficient incentive for agents to make first-best investments, while property rights can alleviate the tension between hold-up and investment efficiency. However, reputation has nothing to do with property rights in a traditional reputation model (e.g., KMRW model). In sum, property rights have a first-order effect on an agent's investment level, and reputation has second-order effect on investment level. We will further discuss the role of property rights below.

3.2 Two Physical Assets

To build a theory of firm scope, we suppose that there are two physical assets, a_1 and a_2. These two physical assets initially belong to and are essential to Agent 1 and Agent 2, respectively. Only Agent 1 invests. With his own physical asset, the outside option for Agent 1 and Agent 2 is $\mu\sigma$ and μV, respectively. With two physical assets, the outside options for Agent 1 and Agent 2 are $\lambda_2(\sigma + A_2)$ and $\lambda_1(V + A_1)$, respectively. λ_j ($j = 1, 2$) indicates the importance of Agent j as a trade partner. If Agent j is indispensable, then $\lambda_j = \mu$; if not, then $\lambda_j = 1$. A_j indicates the value of asset a_j departing from Agent j. Let $0 < \mu \le \lambda_j \le 1$ for $j = 1, 2$, $0 \le A_1 \le \bar{A}$, and $0 \le A_2 \le V$.

Following the GHM model, we define firm boundaries for the ownership structure of physical assets. We discuss five kinds of ownership structures: (a) non-integration (NI), i.e., Agent 1 and Agent 2 own asset a_1 and a_2, respectively; (b) integration I ($I1$), i.e., Agent 1 owns both assets, and Agent 2 has no asset; (c) integration II ($I2$), i.e., Agent 2 owns both assets, and Agent 1 has no asset; (d) joint ownership (JO), i.e., both agents jointly own both assets, and neither agent can use any asset without consensus from the other; and (e) cross ownership (CO), i.e., Agent 1 owns asset a_2, and Agent 2 owns asset a_1.

In the forgoing discussion, we know that Agent 1's incentive to make a first-best investment is increasing with her outside option, which is determined by the physical assets she owns. The best ownership structure is the one that provides the most outside options for Agent 1. It is evident that Agent 1 has the most outside options under integration I ($\lambda_2(\sigma + A_2)$), which is followed by non-integration ($\mu\sigma$), and then followed by integration II or a joint or cross ownership structure. Under the last three ownership structures, Agent 1 has no outside option, which is similar to the case without physical assets.

Proposition 5: *If only Agent 1 invests and there are two assets, integration I is the optimal ownership structure that can motivate Agent 1 to make a first-best specific investment in period 1.*

We have shown that property rights still matter in dynamic environments. It turns out that integration I is still superior to other ownership structures, which is different from Halonen (2002) but consistent with Hart (1995). It also indicates that relational outsourcing (in terms of Baker *et al*. (2002)) cannot be the optimal ownership structure when only one side invests.

3.2 Extensions

Theoretically the conclusion of a two-period game can be naturally extended to a finite-period game with $T > 2$. When T is small, it is only easy to prove that both types of Agent 1 make first-best specific investment in pooling PBE if the marginal return to investment under ownership structures is sufficiently large or the probability of repetition is sufficiently large. The high-type Agent 1 makes first-best specific investments in separating PBE from period 1 to period $T-1$, and both types of Agent make second-best specific investments in the last period T. However, if T is very large, things may change. Making a first-best specific investment means a loss compared to making a second-best specific investment. On one hand, it tends to separate PBE, while on the other hand, it imposes too much loss for high-type Agent 1, so that even a high-type Agent 1 has no incentive to make a first-best investment as a signal.[9]

We have only considered one-side investments, but the main conclusions can be naturally extended to the situation in which both Agent 1 and Agent 2 invest and have private information regarding types. Similar to the case with one-side investment, we can characterize a separating PBE or a pooling PBE in which both Agent 1 and Agent 2 make a first-best investment.

4. Conclusion

Introducing agents' asymmetric information of investors' ability in a dynamic hold-up model, this paper revisits the role of property rights in relation to the reputation effect and sheds lights on several theoretical points. First, this paper shows that hold-up does not necessarily lead to inefficient investment due to the reputation effect under some conditions, providing a stronger argument compared to existing models. Second, this paper demonstrates that property rights still matter even in dynamic environments and that property rights provide a basis for the reputation effect. Third, integration has a positive effect on agents' incentives in relational contracts, which is contrary to the literature on ownership and reputation (e.g., Baker, *et al*., 2002). In addition to introducing asymmetric information of agent types into a hold-up model, this paper provides a possible way to model ex post inefficiency, which will be helpful to explain authority, hierarchy, and delegation from a new perspective.

Drawing on these theoretical contributions, we still have some questions to solve. First, if we relax the assumption that Agent 1 and Agent 2 meet randomly, we can consider the matching problem between different types of agents. In a broader environment, property rights, search costs, and reputation will interact, which raises more complex questions and requires more sophisticated models. Second, we need more empirical tests or experiments on hold-up to help us understand investment efficiency in the real world.

Acknowledgements

I am greatly indebted to Professor Oliver Hart for many invaluable discussions and continuous encouragement when I visited Harvard University as a post-doc. I also thank Nicola Gennaioli, Enying Zheng, Jie Zheng, and participants in the Organizational Economics Brownbag seminar at Harvard University for helpful comments. The financial support from China National Excellent Doctoral Dissertation Grant (No.200903) is gratefully acknowledged.

---

[9] We do not consider the case $T \to \infty$ because in this case, property rights do not matter when the discount factor is sufficiently large, and the conclusion converges to the case of finite period when the discount factor is sufficient small.

REFERENCES

[1] **Aghion, P., M. Dewatripont and P. Rey (1994),** ***Renegotiation Design with Unverifiable Information****; Econometrica, 62(2): 257-282;*

[2] **Aghion, P., D. Fudenberg, R. Holden, T. Kunimoto and O. Tercieux (2012)**, ***Subgame Perfect Implementation under Information Perturbations****; Quarterly Journal of Economics, forthcoming;*

[3] **Bac, M. (1993)**, ***Opportunism and the Dynamics of Incomplete Contracts****; International Economic Review, 34(3): 663-683;*

[4] **Baker, G., R. Gibbons and K. Murphy (2002)**, ***Relational Contract and the Theory of the Firm****; Quarterly Journal of Economics, 117(1): 39-83;*

[5] **Che, Y.-K., and J. Sakovics (2004)**, ***A Dynamic Theory of Holdup****; Econometrica, 72(4): 1063-1103;*

[6] **Cho, I. and D. M. Kreps (1987)** ***Signaling Games and Stable Equilibria****; Quarterly Journal of Economics, 102(2): 179-221;*

[7] **Coase, R. (1988)**, ***The Nature of the Firm: Influence****; Journal of Law, Economics and Organization, 4: 33-47;*

[8] **Grossman, S. and O. Hart (1986)**, ***The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration****; Journal of Political Economy, 94(4): 691-719;*

[9] **Guriev, S., D. Kvasov (2005)**, ***Contracting on Time****; American Economic Review, 95(5): 1369-1385;*

[10] **Halonen, M. (2002)**, ***Reputation and Allocation of Ownership****; Economic Journal, 112: 539-558;*

[11] **Hart, O. (1995)**, ***Firm, Contract and Financial Structure****, Oxford University Press;*

[12] **Hart, O. (2001)**, ***Norm and the Theory of the Firm***; *University of Pennsylvania Law Review*, 149(6):1701-15;

[13] **Hart, O. and J. Moore (1990)**, ***Property Rights and Nature of the Firm****; Journal of Political Economy, 98(6): 1119-1158;*

[14] **Holmstrom, B. (1999)**, ***Managerial Incentive Problems: A Dynamic Perspective****; Review of Economic Studies, 66(1): 169-182;*

[15] **Kreps, D. and Wilson, R. (1982)**, ***Reputation and Imperfect Information****; Journal of Economic Theory, 27(2): 253-279;*

[16] **Lyon, T. and E. Rasmusen (2004)**, ***Buyer-Option Contracts Restored: Renegotiation, Inefficient Threats, and the Hold-Up Problem****; Journal of Law, Economics, and Organization, 20(1): 148-169;*

[17] **Matouschek, N. (2004)**, ***Ex Post Inefficiencies in a Property Rights Theory of the Firm****; Journal of Law, Economics, and Organization, 20(1): 125-147;*

[18] **Milgrom, P. and J. Roberts (1982)**, ***Predation, Reputation and Entry Deterrence****; Journal of Economic Theory, 27(2): 280-312;*

[19] **Tirole, J. (1999)**, ***Incomplete Contracts: Where Do We Stand****; Econometrica, 67(4): 741-781;*

[20] **Williamson, O. (1985)**, ***The Economic Institution of Capitalism****, New York: Free Press.*