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December 2012

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Abstract

An inventor can invest research effort to come up with an innovation. Once an innovation is made, a contract is negotiated and unobservable effort must be exerted to develop a product. In the absence of liability constraints, the inventor's investment incentives are increasing in his bargaining power. Yet, given limited liability, overinvestments may occur and the inventor's investment incentives may be decreasing in his bargaining power.

Keywords: hold-up problem, incomplete contracts, research and development, limited liability

JEL Classification: D86; L23; O31

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1 Introduction

The hold-up problem plays a key role in the incomplete contracting literature (see Grossman and Hart, 1986; Hart and Moore, 1990; Hart, 1995).[1] In a standard hold-up problem, there are two parties who tomorrow can generate a surplus. One of the two parties can today make an investment in order to increase the surplus that can be generated tomorrow. Suppose the investment is completely relationship-specific; i.e., it does not yield a return outside of the relationship between the two parties under consideration. Moreover, suppose that today no contracts can be written, so that the two parties can negotiate a contract only tomorrow, after the investment is sunk. If the investing party has all the bargaining power tomorrow, it will extract the total surplus generated in the relationship, so today it has first-best investment incentives. However, if the investing party has no bargaining power tomorrow, then the other party will extract the total surplus, so that today the investment incentives are zero. This is the hold-up problem in its most severe form. In general, the investment incentives today are the larger the more bargaining power the investing party tomorrow will have.

In the present paper, we show that these simple insights need no longer hold if the creation of the surplus tomorrow involves a moral hazard problem and the investing party is protected by limited liability. In this case, if the non-investing party has all the bargaining power, the investment incentives today may be too strong compared to the first-best benchmark. In particular, the investment incentives may then be decreasing in the investing party's bargaining power.

We consider the relationship between an inventor and a costumer (in the spirit of Aghion and Tirole, 1994a, 1994b). In a first stage, the inventor can invest basic research effort to come up with an innovation. There are two possibilities. Either a high-quality innovation or only a low-quality innovation is made. After the innovation has been observed by both parties, the devel-

[1] See also Schmitz (2001) for a literature review. For experimental evidence, see Hoppe and Schmitz (2011).

opment of a final product based on the innovation becomes contractible. At this point in time, a contract is negotiated, and we are interested in the effects of the inventor's bargaining power on his incentives to invest. What distinguishes our set-up from a standard hold-up problem is that once the innovation is made, further development effort must be spent, which is unobservable. In line with Hart, Shleifer, and Vishny (1997), a high-quality innovation leads to larger potential benefits, but also to larger effort costs compared to a low-quality innovation. Only the outcome of the development stage (i.e., whether or not a marketable final product is developed) is verifiable, so that there is a moral hazard problem.

We show that if there are no liability constraints, then the moral hazard stage does not cause any frictions and the solution has the usual characteristics of a standard hold-up problem. In particular, the inventor's investment incentives are increasing in his bargaining power. Yet, if the inventor has no wealth and is protected by limited liability, then overinvestments compared to the first-best solution may occur, and the inventor's investment incentives can be decreasing in his bargaining power.

2 The model

There are two risk-neutral parties, party A and party B. In line with Aghion and Tirole (1994a, 1994b), party A might be an inventor (say, a biotechnology start-up firm), while party B might be a customer (say, a pharmaceutical company). The reservation utilities of both parties are zero. At some initial date 1, party A can invest effort $i \in [0, 1]$ in basic research activities, where party A's effort costs are given by $\psi(i)$, with $\psi(0) = \psi'(0) = 0$, $\psi'(i) > 0$ and $\psi''(i) > 0$ for $i > 0$, and $\lim_{i \to 1} \psi'(i) = \infty$. At date 2, party A comes up with a high-quality innovation with probability i, while only a low-quality innovation is made with probability $1 - i$. Following the incomplete contracting approach, we assume that at date 1 no contract can be written, while contracting becomes possible at date 2.[2] At date 3, based on the innovation observed by both parties at date 2, party A can exert unobservable effort $e \in \{e_l, e_h\}$ to develop a marketable final product, where $0 < e_l < e_h < 1$. Party A's effort costs at date 3 are c if $e = e_h$, and zero otherwise. Finally, at date 4 with probability e the development is successful, so that party B's benefit is b, while with probability $1 - e$ there is no success and party B's benefit is zero.

The effort costs c which are incurred by party A if it exerts high effort at date 3 as well as the benefit b that party B obtains in case of a successful development at date 4 depend on whether at date 2 a low-quality or a high-quality innovation was made. Specifically, in line with Hart, Shleifer, and Vishny (1997), we assume that a high-quality innovation at date 2 improves the potential benefit b (which is desirable), but it also increases the associated effort costs c (which is an undesirable side-effect). In particular, $b = b_h$ and $c = c_h$ in case of a high-quality innovation, while $b = b_l$ and $c = c_l$ in case of a low-quality innovation, where $b_h > b_l > 0$ and $c_h > c_l > 0$. To focus the analysis on the most interesting case, we make the following assumptions.

Assumption 1. $e_h b_h - c_h > e_h b_l - c_l$.

Assumption 1 ensures that if high effort is exerted at date 3, then the expected total surplus is larger in case of a high-quality innovation; i.e., the fact that a high-quality innovation comes along with larger effort costs is overcompensated by the larger benefit.

Assumption 2. $(e_h - e_l)b_h > c_h + c_h e_l/(e_h - e_l)$ and $(e_h - e_l)b_l > c_l + c_l e_l/(e_h - e_l)$.

In particular, Assumption 2 guarantees that at date 3 it is always desirable to exert high instead of low effort, because the corresponding increase of the expected benefit $(e_h - e_l)b$ is larger than the effort costs c, regardless of whether there is a high-quality or a low-quality innovation.[3]

[2] See Hart and Moore (1999), Maskin and Tirole (1999), and Tirole (1999) for discussions of the incomplete contracting paradigm that was developed by Grossman and Hart (1986).

[3] Moreover, Assumption 2 also ensures that high effort will always be implemented even

In a first-best world in which effort was verifiable, Assumption 2 thus implies that at date 3 high effort would always be exerted, $e^{FB} = e_h$. Moreover, at date 1 the first-best investment level is characterized by

$$i^{FB} = \arg\max i(e_h b_h - c_h) + (1-i)(e_h b_l - c_l) - \psi(i). \tag{1}$$

Thus,

$$\psi'(i^{FB}) = e_h(b_h - b_l) - (c_h - c_l). \tag{2}$$

In the remainder of the paper, we consider a second-best world in which the parties agree on a contract after the innovation at date 2 is made. Specifically, we assume that with probability $\alpha \in [0,1]$ party A can make a take-it-or-leave-it contract offer to party B, while with probability $1-\alpha$ party B makes a take-it-or-leave-it offer to party A. Thus, party A's bargaining power in the contract negotiations at date 2 is given by the parameter α.[4]

3 No liability constraints

As a benchmark, we first consider the case in which there are no (binding) wealth constraints. At date 2, both parties have observed whether a high-quality innovation ($b = b_h$, $c = c_h$) or only a low-quality innovation ($b = b_l$, $c = c_l$) was made. Now the parties negotiate a contract. Let the contractually specified transfer payment from party B to party A be given by t_1 if at date 4 there is a success and by t_0 if there is a failure.

At date 3, party A exerts high effort whenever the incentive compatibility constraint

$$e_h t_1 + (1-e_h)t_0 - c \geq e_l t_1 + (1-e_l)t_0 \tag{3}$$

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when party A is protected by limited liability. In the latter case, party A can only be motivated to exert high effort if in addition to a reimbursement of its effort costs c it also gets a "limited liability rent" $ce_l/(e_h - e_l)$; see footnote 7 and condition (8) below.

[4] This simple bargaining game has also been used by Ma (1994) in a moral hazard framework. See Hart and Moore (1999), Bajari and Tadelis (2001), and Schmitz (2006) for further applications in incomplete contracting settings.

is satisfied, which can be rewritten as $(e_h - e_l)(t_1 - t_0) \geq c$. Moreover, the participation constraints are given by

$$e_h t_1 + (1 - e_h)t_0 - c \geq 0 \tag{4}$$

for party A and

$$e_h(b - t_1) - (1 - e_h)t_0 \geq 0 \tag{5}$$

for party B, respectively.

Note that if party A can make the contract offer at date 2, then it can extract the expected total surplus $e_h b - c$ by setting $t_0 = e_h b - e_h c/(e_h - e_l)$ and $t_1 = t_0 + c/(e_h - e_l)$. If party B makes the offer, then at date 2 it can extract the expected total surplus by setting $t_0 = -e_l c/(e_h - e_l)$ and $t_1 = t_0 + c/(e_h - e_l)$.

Hence, at date 1, party A's expected payoff is[5]

$$i\alpha(e_h b_h - c_h) + (1 - i)\alpha(e_h b_l - c_l) - \psi(i). \tag{6}$$

The investment level $i^{SB}(\alpha)$ is thus implicitly characterized by

$$\psi'(i^{SB}(\alpha)) = \alpha[e_h(b_h - b_l) - (c_h - c_l)]. \tag{7}$$

Note that Assumption 1 ensures that the right-hand side is non-negative. Given convexity of $\psi(i)$, it follows immediately that $i^{SB}(\alpha)$ is an increasing function.

Proposition 1 *Suppose that there are no wealth constraints. Then party A's investment incentives are always increasing in its bargaining power α.*

Observe that $i^{SB}(1) = i^{FB}$ and $i^{SB}(0) = 0$. Thus, the first-best solution is achieved if party A has all the bargaining power ($\alpha = 1$). In contrast, the hold-up problem is most severe if party B has all the bargaining power ($\alpha = 0$). In the latter case, at date 1 party A anticipates that the total returns of its investments will go to party B, so that it has no incentives to invest. These simple insights are well in line with the standard properties of hold-up problems discussed in the incomplete contracting literature.

[5] Observe that our simple non-cooperative bargaining game implies that at date 2 the expected surplus is split according to the generalized Nash bargaining solution, where α is party A's bargaining power (see e.g. Muthoo, 1999).

4 Limited liability

Now suppose that party A has no wealth, so that the limited liability constraints $t_0 \geq 0$ and $t_1 \geq 0$ must be satisfied in addition to the incentive compatibility and participation constraints.[6]

If at date 2 party A can make the contract offer, it can still extract the expected total surplus by setting $t_0 = e_h b - e_h c/(e_h - e_l)$ and $t_1 = t_0 + c/(e_h - e_l)$. Note that $t_0 \geq 0$, since $(e_h - e_l)b > c$ must hold by Assumption 2. Now suppose that at date 2 party B can make the contract offer. If it wants to implement $e = e_h$, party B will set $t_0 = 0$ and $t_1 = c/(e_h - e_l)$, so that its expected profit is $e_h(b - c/(e_h - e_l))$.[7] Alternatively, it can implement $e = e_l$ by setting $t_0 = t_1 = 0$, yielding an expected profit of $e_l b$. It is thus more profitable to implement high effort whenever the condition

$$(e_h - e_l)b \geq e_h c/(e_h - e_l) \tag{8}$$

is satisfied, which is ensured by Assumption 2 for both types of innovation.

Hence, party A's expected payoff at date 1 is

$$\begin{aligned} &i[\alpha(e_h b_h - c_h) + (1-\alpha)(e_h c_h/(e_h - e_l) - c_h)] \\ &+(1-i)[\alpha(e_h b_l - c_l) + (1-\alpha)(e_h c_l/(e_h - e_l) - c_l)] - \psi(i). \end{aligned} \tag{9}$$

The investment level $i^{LL}(\alpha)$ chosen by party A at date 1 is implicitly characterized by

$$\psi'(i^{LL}(\alpha)) = \alpha[e_h(b_h - b_l) - (c_h - c_l)] + (1-\alpha)(c_h - c_l)e_l/(e_h - e_l). \tag{10}$$

Note that again $i^{LL}(1) = i^{FB}$, but now $i^{LL}(0)$ is strictly positive.

[6] On moral hazard models with limited liability constraints, see also Innes (1990) and Pitchford (1994). See also Laffont and Martimort (2002) for an excellent textbook exposition.

[7] Observe that if it wants to implement high effort, party B cannot extract the total surplus. Instead, it must leave an expected rent $e_h c/(e_h - e_l) - c = ce_l/(e_h - e_l) > 0$ to party A. Laffont and Martimort (2002) call such a rent an agent's "limited liability rent."

Observe that $(c_h - c_l)e_l/(e_h - e_l) > e_h(b_h - b_l) - (c_h - c_l)$, and hence $i^{LL}(0) > i^{FB}$, whenever the condition $[e_h b_h - c_h] - [e_h b_l - c_l] < e_l(b_h - b_l)$ is satisfied. We can thus state our main result.

Proposition 2 *Suppose that party A is protected by limited liability. If $[e_h b_h - c_h] - [e_h b_l - c_l] < e_l(b_h - b_l)$, then party A's investment incentives are decreasing in its bargaining power α. Otherwise, party A's investment incentives are increasing in α.*

Hence, if the net social gain $e_h b - c$ of the high-quality innovation compared to the low-quality innovation is sufficiently small, then party A's investment is larger when it has less bargaining power, which is in stark contrast to the standard finding in the literature on hold-up problems.[8]

The reason for the counter-intuitive result is as follows. In the presence of limited liability, even when party B has all the bargaining power, it cannot extract the total surplus at date 2, since it must leave a rent to party A in order to induce high effort. The higher the effort costs of party A, the larger must be the rent that induces party A to exert high effort. Hence, at date 1 party A can have too strong incentives to invest compared to the first-best solution, because party A is only interested in increasing the costs c, regardless of the effect than an innovation has on the benefit b. In contrast, if party A has all the bargaining power, then at date 2 it will extract the total surplus, so that overinvestment at date 1 can never occur.[9]

[8]Note that the condition in Proposition 2 may well be satisfied given the assumptions made. For example, let $e_h = 0.8$, $e_l = 0.1$, $b_h = 50$, $b_l = 10$, $c_h = 30$, and $c_l = 1$.

[9]To avoid tedious case distinctions, we have focused the analysis on the most interesting case in which high effort will always be implemented. The cases in which Assumption 2 is not satisfied can be analyzed analogously. For instance, suppose that $c_l < (e_h - e_l)b_l < c_l + c_l e_l/(e_h - e_l)$, so that in case of a low-quality innovation party B would implement low effort only, which is a reasonable possibility. Then $i^{LL}(0) > i^{FB}$ holds if $[e_h b_h - c_h] - [e_h b_l - c_l] < e_l(b_h - b_l) + c_l e_l/e_h$. Thus, party A's investment incentives can again be decreasing in its bargaining power.

5 Conclusion

In a standard hold-up problem, the investing party typically has insufficient incentives to invest compared to the first-best solution. Moreover, the investments are increasing in the investing party's bargaining power. These basic insights are also true when after the investment stage unobservable effort must be exerted to generate a surplus, provided there are no liability constraints. Yet, in the presence of limited liability, there may be overinvestments and the investments may decrease in the investing party's bargaining power.[10]

[10] For related results, see also Kräkel and Schöttner (2010), who show that excessive effort may be induced in sequential moral hazard settings with minimum wages. Moreover, Schmitz (2008) shows that in a hold-up setting investment incentives may decrease in the investing party's bargaining power if there is two-sided asymmetric information (i.e., there is an adverse selection problem) when the surplus is created.

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