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Team Production, Sequential Investments and Stochastic Payoffs

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Summary

We investigate a team production problem where two parties invest sequentially to generate a joint surplus. In this framework, it is possible to attain the first best even if the investment return is highly uncertain. The optimal contract entails a basic dichotomy: it is a simple option contract if investments of both parties are substitutive, and a linear incentive contract if they are complementary. These schemes can be interpreted in terms of asset ownership: for the case of substitutive investments, a conditional ownership structure is optimal while for complementary investments shared equity in combination with a bonus component renders efficiency feasible. In either case, the parties renegotiate the initial arrangement after the first party invested.

Keywords: Team Production, Sequential Investments.

JEL-Classification: D23, K12, L23.

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1 Introduction

This paper studies a team production problem where two parties sequentially invest into an asset whose value is realized subsequently. We allow for a stochastic environment where uncertainty is resolved at any arbitrary date in the game, and show that efficient investments can generically be implemented. The optimal type of contract crucially depends on whether investments are substitutive or complementary on the margin. If they are substitutive, a simple option-to-buy contract leads both parties to invest efficiently. Under this contract, the second agent is assigned the right to buy the asset at a prespecified option price after the first agent invested, and a first best is attained even if the final payoff (the asset value) is not verifiable.

Conversely, if the investments of both parties have a complementary effect on the return, a verifiable asset value is required to facilitate an efficient outcome of the relationship.[1] Assuming verifiability, we demonstrate that a simple linear incentive contract in form of a bonus scheme that is based on the asset value uniquely implements an efficient outcome. In equilibrium, the initial incentive structure is modified after the first party invested. Since the second agent refrains from any investment when the initial bonus contract remains in force, the parties successfully rescind their initial agreement in order to make the latter party residual claimant for the return on its own investments. In line with results by Hermalin and Katz (1991) and Edlin and Hermalin (1999), our findings stress the important role that equilibrium renegotiation can play in moral hazard situations with verifiable outcome.[2]

The model draws on distinct strands of the literature. First, it is related to the literature on moral hazard in teams that starts with Holmström (1982), and shows that team production in general yields inefficient results when team members simul-

[1] Edlin and Hermalin (2000) prove that even a general mechanism cannot attain the first best when parties are risk neutral, investments are complementary, and the asset value is non-contractible.

[2] While the reason for renegotiation in these papers is to free the risk-averse agent from an uncertain payoff, renegotiation in the present framework ensures (conditionally) efficient investments of the party which invests subsequently.

taneously expend effort and a budget-balancedness requirement is imposed. Strausz (1999) has shown that efficient investments can be attained when the parties invest sequentially, and when output is deterministic. He develops a mechanism where a deviating party faces a punishment that serves to deter shirking, and under which the initially contracted sharing rule is not renegotiated in equilibrium. In line with the present approach, the functioning of the mechanism (at least out-of-equilibrium) requires the agents to make monetary side payments which, however, do never exceed a finite level.[3] The present paper is less general in the sense that the team size is confined to two individuals. On the other hand, however, the mechanism we develop guarantees efficiency even if output (the asset value) is subject to any degree of uncertainty.

We also bear on asset ownership models with sequential investments where the asset value is assumed to be nonverifiable. Demski and Sappington (1991), Nöldeke and Schmidt (1998) and Edlin and Hermalin (2000) have shown that the first best is attainable if the investments of both parties are either substitutive [Edlin and Hermalin (2000)], or if renegotiation is either infeasible or can be prevented [Demski and Sappington (1991), Nöldeke and Schmidt (1998)].[4] In all these papers, the optimal mechanism is an option contract which is never renegotiated and grants the second party the right to sell the asset to (or to acquire the asset from) the first agent at a predetermined fixed price. While Edlin and Hermalin allow for the resolution of uncertainty after both parties invested, the efficiency results of Demski and Sappington and Nöldeke and Schmidt require the absence of significant uncertainty.[5] The present paper extends these findings by showing that verifiability

[3] In our model, it is sufficient that the second agent has some initial wealth, while the first agent may have no monetary endowment.

[4] In contrast to Edlin and Hermalin (2000) whose approach is taken up in the present model, Demski and Sappington and Nöldeke and Schmidt consider option contracts with an exercise date after both parties invested. Under the optimal contract, the second party is then (after having observed efficient investments of the first party) just indifferent between investing efficiently and exercising her option, and not to invest and let her option expire. Edlin and Hermalin (2000) notice that the effectiveness of a date-2 option contract is sensitive with respect to the timing of investments. For a detailed discussion, see their paper.

[5] Nöldeke and Schmidt (1998) show that the first best can be attained if uncertainty is not "too

of the asset return is not needed to implement an efficient outcome if investments are substitutive and the asset return is highly uncertain.[6] However, in our stochastic scenario, the option is not always exercised in equilibrium and the parties renegotiate the initial contract with positive (but less than full) probability after the first agent invested.

Finally, the paper is related to the literature on renegotiation in complete contracting principal-agent problems, notably Hermalin and Katz (1991) and Edlin and Hermalin (1999). There, it is shown under mild conditions that renegotiation facilitates an efficient outcome of the principal-agent relationship in a setup where the agent (the first party in our framework) is risk averse. While the principal (the second agent in our setting) does not expend own effort in these models, Edlin and Hermalin (1999, fn.4) note that their results carry over to bilateral sequential investments as long as the principal's effort does not affect the verifiable signal (the asset value in our model). The present paper shows that, at least if both parties are risk-neutral, optimal investments can be implemented even if the principal's subsequent investment affects the verifiable asset return on which the agent's compensation is based.

The remainder is organized as follows. Section 2 introduces the model, which is solved in Section 3 for the case of substitutive investments, and in Section 4 for complementary investments. Section 5 concludes.

2 The Model

Consider two risk-neutral parties, A and B who can invest in an asset, e.g. a joint venture. At *date 0*, both agents sign an initial contract. Thereafter, A expends at *date 1/2* value-enhancing effort $a \in \boldsymbol{R}_0^+$ into the asset. At *date 1*, the parties observe a stochastic signal $s \in [\underline{s}, \bar{s}]$ which provides some information on the asset return and is drawn from a continuous cumulative distribution $F(s)$. After observing s, A

large", but not otherwise. For details, see their paper.

[6] Edlin and Hermalin (2000) consider a more general setting with a risk-averse agent, but do not allow for the resolution of uncertainty after the first party (and before the second party) invested.

and B can renegotiate their initial contract. Subsequently, B invests at *date 3/2* an amount $b \in \boldsymbol{R}_0^+$, and an additional signal $\theta \in [\underline{\theta}, \bar{\theta}]$ is drawn from a continuous distribution function $F(\theta)$ at *date 2*. At that date, the final asset value $v(a, b, s, \theta)$ materializes and the game ends at *date 5/2* where final payoffs are realized.

We suppose that both parties have complete information throughout the game. Moreover, the asset value $v(a, b, s, \theta)$ as realized at date 2 is verifiable and therefore contractible, while investments (a, b) and the stochastic signals (s, θ) are so complex that they are not.

Notice that renegotiations will (although technologically feasible) never occur after date 3/2. Since the expected asset value is already fixed at those points in time, the continuation after date 3/2 is a constant-sum game and further bargaining cannot facilitate a pareto improvement. The sequence of events is illustrated in the following figure.

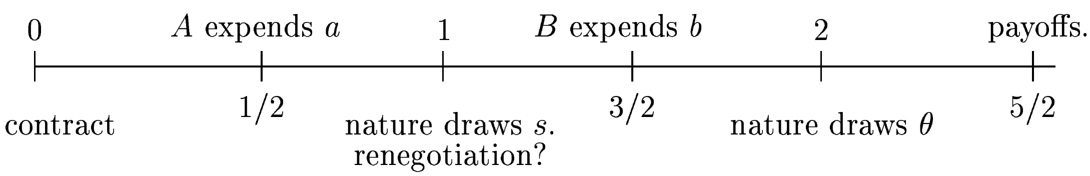

FIGURE 1

We denote the cost functions for the parties' idiosyncratic investments (i.e., their efforts) as $\psi(a)$ and $\phi(b)$, respectively. Also, we define $V(a, b, s) \equiv E_\theta v(a, b, s, \theta)$ as the date-1 expected asset value conditional on B's subsequent investment b.

Assumption 1. The functions $v(\cdot)$, $\psi(\cdot)$ and $\phi(\cdot)$ are non-negative, twice continously differentiable, strictly increasing in their arguments, and satisfy for all a, b and s (subscripts denote derivatives)

(a) $V(a, b, s) \geq 0$ for all (a, b, s).

b) $v_{ii}(\cdot) < 0$, $\lim_{i\to 0} v_i(\cdot) = \infty$ and $\lim_{i\to\infty} v_i(\cdot) = 0$ for $i = \{a, b\}$,

c) $\psi_{aa}(\cdot) \geq 0$, $\psi(0) = \lim_{a\to 0} \psi_a(a) = 0$ and $\lim_{a\to\infty} \psi_a(a) = \infty$,

d) $\phi_{bb}(\cdot) \geq 0$, $\phi(0) = \lim_{b\to 0} \phi_b(b) = 0$ and $\lim_{b\to\infty} \phi_b(b) = \infty$,

These assumptions ensure that the asset has a non-negative expected value in every state of the world s and for any investment tuple, and that a finite pair of positive investment levels maximizes joint surplus.

We suppose that the outcome of renegotiations is described by the generalized Nash-bargaining solution. Hence, when renegotiations occur at date 1, the parties share the efficiency gain above their respective threat point payoffs in fixed proportions determined by bargaining parameters γ for A and $(1-\gamma)$ for B, respectively.[7]

Benchmark Cases

I. First Best

For later comparison, we compute the first-best effort levels $(a^{FB}, b^{FB}(s))$. Define $S(a,b) = E_s V(a,b,s) - \psi(a) - \phi(b)$ as the ex ante expected joint surplus for any investment tuple (a,b). Also, let $b^*(a,s)$ be the conditionally efficient investment level of agent B in state s for given a. Then, the first-best investment of agent A is

$$a^{FB} = \arg\max_a S(a, b^*(a,s), s) = E_s V(a, b^*(a,s), s) - \psi(a) - \phi(b^*(a,s)), \qquad (1)$$

while the efficient investment level of B in state s maximizes the date-1 joint continuation surplus indicated as $\tilde{S}(a,b,s) \equiv V(a,b,s) - \phi(b)$, i.e.,

$$b^{FB}(s) = \arg\max_b \tilde{S}(a^{FB}, b, s) = V(a^{FB}, b, s) - \phi(b). \qquad (2)$$

Under Assumption 1 and using the envelope theorem, these first-best investment levels are uniquely determined by the first-order conditions

$$E_s V_a(a^{FB}, b^{FB}, s) = \psi_a(a^{FB}) \quad \text{and} \quad V_b(a^{FB}, b^{FB}, s) = \phi_b(b^{FB}), \qquad (3)$$

[7]This efficiency gain is the difference between the maximal joint continuation surplus after A invested and s has been realized, and the sum of the parties' threat point payoffs at that date.

respectively. The efficient investments of both parties equate the marginal return and the marginal costs from effort.

II. No Initial Contract

Let us now assume that the parties do not sign an initial contract, and that party A is asset owner at date 0.[8] If A remains owner after he invested, B will expend no own effort at date 3/2 because she appropriates none of the returns. Hence, joint surplus can be raised when the parties renegotiate the ownership structure at date 1.[9] Let $\hat{U}^A(a,0,s) = V(a,0,s)$ be the corresponding default payoff of A at date 1, and notice that the renegotiation surplus at that date is given by $\Delta \equiv \tilde{S}(a, b^*(a,s), s) - \tilde{S}(a,0,s)$ which is strictly positive. Taking equilibrium renegotiation into account, A thus chooses at date 1/2 an investment level $\hat{a}$ which maximizes her utility

$$\begin{aligned} U^S(a) &= E_s[\hat{U}^S(a,0,s) + \gamma\Delta] - \psi(a) \\ &= E_s\{(1-\gamma)V(a,0,s) + \gamma[V(a,b^*(a,s),s) - b^*(a,s)]\} - \psi(a). \end{aligned} \tag{4}$$

Under Assumption 1, the equilibrium investment $\hat{a}$ is uniquely determined by the corresponding first-order condition

$$E_s\{(1-\gamma)V_a(\hat{a},0,s) + \gamma V_a(\hat{a}, b^*(\hat{a},s),s)\} - \psi_a(\hat{a}) = 0. \tag{5}$$

To interpret this condition, notice that $\hat{a} = a^{FB}$ if and only $\gamma = 1$ or if investments are independent on the margin, $V_{ab}(\cdot) = 0$. If they are substitutive, i.e., $V_{ab}(\cdot) < 0$, we have $\hat{a} > a^{FB}$ and A overinvests. Conversely, A chooses $\hat{a} < a^{FB}$ and underinvests if investments are complementary, $V_{ab}(\cdot) > 0$. The next sections show that there exist simple date-0 contracts which can restore an efficient outcome for the cases of substitutive as well as complementary investments.

[8] One can easily verify that A will expend no investments if B is owner from the beginning.

[9] Of course, A could also retain ownership but agree on an incentive contract with B. Since B will expend the conditionally efficient investment $b^*(a,s)$ in either case, we can concentrate w.l.o.g. on the - informationally less demanding - transfer of ownership.

3 Substitutive Investments

In a model where no uncertainty s is resolved at date 1, Edlin and Hermalin (2000) have shown that a simple option-to-own contract uniquely implements efficient investments if those investments are substitutive. Under the optimal contract, B is in equilibrium just indifferent between exercising her option or not at date 1 provided A invested a^{FB}, while she will not exercise (and insist on renegotiation) after observing any $a < a^{FB}$. In the former case, she pays the option price and accrues ownership, and therefore exerts b^{FB} at date 3/2. For a strike price $p = V(a^{FB}, b^{FB}) - \phi(b^{FB})$, A thus appropriates the entire social surplus from the relationship when expending a^{FB}, and is prompted to invest efficiently. In our model where some uncertainty is already resolved at date 1, this logic does not immediately apply for the following reasons: first, if the option price is chosen sufficiently small so that B exercises in *every* state s after A invested efficiently, A may now choose an effort smaller than a^{FB} because she does not reap the entire expected social surplus from the relationship. Second, for a larger strike price, B does *not* exercise in every state s and subsequent renegotiation deteriorates A's investment incentives. Still, the following proposition shows that the efficiency properties of option contracts can be generalized to the case where the asset value is subject to uncertainty s.

Proposition 1. *Suppose the asset value is stochastic, and consider substitutive investments. Then, there exists an option contract with positive strike price p^* which implements efficient investments $(a^{FB}, b^{FB}(s))$. Moreover, B exercises her option-to-buy with positive but less than full probability. Even in states s where B lets the option expire, renegotiation ensures that ownership is transferred at date 1.*

Proof: Consider an option contract with strike price p. At date 1, B finds it optimal to exercise her option iff

$$V(a, b^*(a,s), s) - b^*(a,s) - p \geq (1-\gamma)[V(a, b^*(a,s), s) - b^*(a,s) - V(a,0,s)], \tag{6}$$

i.e., iff

$$p \leq \gamma[V(a, b^*(a,s), s) - b^*(a,s)] + (1-\gamma)V(a,0,s). \tag{7}$$

If (7) is not satisfied, B lets her option expire and renegotiations ensure that she becomes owner at date 1. Define $\hat{s}(a,p)$ as the (unique) boundary state where B is just indifferent between her two actions for given (a,p) provided that indifference indeed prevails for some $s \in [\underline{s}, \bar{s}]$. Otherwise, let $\hat{s}(\cdot)$ be the boundary state $\underline{s}$ if (7) is satisfied, and $\bar{s}$ if (7) is not satisfied. Notice that any interior $\hat{s}(a,p)$ is decreasing in a and increasing in p. Anticipating B's decision to exercise and the outcome of renegotiation, A therefore maximizes at date 1/2

$$U^A(a,p) = \int_{s<\hat{s}(a,p)} \{(1-\gamma)V(a,0,s) + \gamma[V(a,b^*(\cdot),s) - b^*(\cdot)]\} dF(s) + \int_{s \geq \hat{s}(a,p)} p \, dF(s) - \psi(a). \tag{8}$$

Verifying that this payoff function is strictly concave in a for any p (because $d\hat{s}(a,p)/da \leq 0$), the equilibrium investment a^* is uniquely determined by the first-order condition

$$\int_{s<\hat{s}(a,p)} \{(1-\gamma)V_a(a^*,0,s) + \gamma V_a(a^*, b^*(a^*,s), s)]\} dF(s) = \psi_a(a^*). \tag{9}$$

Suppose first $p = 0$. By Assumption 1, B then exercises her option for any (a,s) so that $\hat{s}(a,p) = \underline{s}$ and A finds it optimal not to invest. Conversely, consider an option price $p = \bar{p}$ so large that B never exercises for any s and any $a \leq \hat{a}$ as defined in (5). Then, program (8) coincides with (4) and A overinvests because investments are substitutive, $V_a(a,0,s) > V_a(a, b^*(a,s), s)$. Accordingly, and recalling that $a^*(p)$ is unique for any p, the theorem of the maximum and an intermediate value argument imply the existence of some $p^* \in (0, \bar{p})$ which implements $a^*(p^*) = a^{FB}$. $\square$

The result of Proposition 1 has a simple intuition.[10] When investments are substitutive on the margin, the optimal contract must prevent an overshooting of A's

[10] While an option contract implements efficient investments, it is not the only solution to the parties' contracting problem: another way to achieve the same outcome is stochastic ownership where a date-1 random draw determines whether B accrues ownership of the firm. However, stochastic ownership schemes are rarely seen in practice which may be due to legal obstacles to the use of lotteries.

investments. Granting an option to B serves this purpose: in a given state s and for a given strike price p, B exercises her option whenever A's effort exceeds some threshold level. If p is very large, B will never exercise and the parties rely on bargaining to realize their maximal joint continuation surplus. Accordingly, A will overinvest and choose $\hat{a} > a^{FB}$. On the other end of the price spectrum, for p very small, B always exercises her option, which means that A's return on investments is zero and she expends no effort. By continuity, there thus exists an intermediary strike price p^* under which A expends first best investments and B exercises her option in a subset of (favorable) states of the world. Also, A's optimization program is well behaved for any precontracted p so that the investment solution is unique.[11]

Thus, and as has been already emphasized by Edlin and Hermalin (2000) for the deterministic case, option contracts are an efficient tool to *reduce* A's investments below the level $\hat{a}$ that prevails when A holds unconditional ownership. For this reason, an option contract implements an efficient outcome when the parties' investments are substitutive, while it cannot improve upon unconditional A-ownership otherwise. In fact, Edlin and Hermalin show that, when the asset value is unverifiable, even a general mechanism is unable to raise A's investments above the level $\hat{a}$. As a consequence, the first best is unfeasible when investments are complementary. The next section demonstrates that efficiency is restored when the asset value is verifiable and the parties agree on a contract that directly conditions on $v(\cdot)$.

4 Complementary Investments

Suppose now that investments are complementary, and consider the following simple arrangement. At date 0, the parties sign a contract $(T(v(\cdot)), \delta)$ which grants B an equity fraction δ of the asset (possibly in return for some lump sum payment). In addition, A becomes eligible for an incentive payment $T(v(\cdot))$ as a function of the asset's verifiable value that is realized at date 2. When designing an incentive

[11] Intuitively, A's payoff function is concave because a marginal increase in a augments the set of states where the option is exercised and A obtains no return on effort.

scheme that leads A to expend proper investments, the parties face the following problem: since the asset value is verifiably observed only after *both* parties invested, B's subsequent effort affects the signal $v(a, b, s, \theta)$ on which A's incentive payment is based, and she may have an incentive to disturb this signal for strategic reasons.

Nevertheless, the following Proposition shows that a simple linear bonus plan overcomes the hold-up problem.

Proposition 2. *Suppose the asset value $v(a, b, s, \theta)$ is verifiable, and that investments are complementary on the margin. Then, an initial contract that (a) assigns B an arbitrary fraction $\delta \in [0, 1]$ of the firm's equity, and (b) makes A eligible for a linear bonus payment $t^*v(\cdot)$ with a constant and strictly positive incentive factor*

$$t^*(\delta) = (1-\gamma)\frac{\psi_a(a^{FB})}{E_s V_a(a^{FB}, 0, s)} - [1 - \gamma - \delta]$$

implements the first best. In equilibrium, renegotiation ensures that the initial incentive scheme is rescinded at date 1 after A invested, and B accrues full asset ownership at that date.

The optimal ex-ante contract combines an arbitrary equity structure with a linear bonus plan.[12] This bonus scheme (whose specification depends on the initially chosen ownership structure δ) serves to increase A's investment incentives above those prevailing under unconditional A-ownership. Under the optimal plan, t^* is chosen in a way that B does not provide own effort into the asset when renegotiations at date 1 fail. To see this, imagine bargaining is unsuccessful and B now has to decide on b at date 3/2. Her (default) payoff function $\hat{U}^B(a, \delta, s)$ is then given by

$$\hat{U}^B(a, \delta, s) = V(a, b, s)(\delta - t^*) - \phi(b) = (1-\gamma)\Big[1 - \frac{\psi_a(a^{FB})}{E_s V_a(a^{FB}, 0, s)}\Big]V(a, b, s) - \phi(b). \tag{10}$$

Notice that, for any s, this function is strictly decreasing in b since $\psi_a(a^{FB}) > E_s V_a(a^{FB}, 0, s)$ when investments are complementary. Hence, B will not invest at

[12]Note that, for δ set equal to unity, the result of Proposition 1 carries over to a 'trade' model where the asset is viable at date 5/2 only if it is owned by B.

date 3/2 when the initial contract $(t^*(\delta), \delta)$ is still in force and, as a consequence, A's threat point payoff in date-1 bargaining becomes $\hat{U}^A(\cdot) = (1 - \delta + t^*)V(a, 0, s)$. In equilibrium, the parties have a joint interest to assign (conditionally) efficient investment incentives to B. Therefore, A is bought out at date 1 and the bonus plan is rescinded. Anticipating this outcome, A chooses at date 1/2 his equilibrium investment a^* in order to maximize the (strictly concave) function

$$\begin{aligned} U^A(a, \delta, t^*) &= E_s\{(1 - \delta - \gamma + t^*)V(a, 0, s) + \gamma[V(a, b^*(a, s), s) - b^*(a, s)]\} - \psi(a) \qquad (11) \\ &= E_s\{(1 - \gamma)\frac{\psi_a(a^{FB})}{E_s V_a(a^{FB}, 0, s)} V(a, 0, s) + \gamma[V(a, b^*(a, s), s) - b^*(a, s)]\} - \psi(a). \end{aligned}$$

Using the envelope theorem, the corresponding first-order condition reads

$$(1 - \gamma)\psi_a(a^{FB}) + \gamma E_s V_a(a^*, b^*(a, s), s) = \psi_a(a^*), \qquad (12)$$

which yields the unique solution $a^*(t^*(\delta), \delta) = a^{FB}$. Accordingly, an appropriately chosen linear bonus contract implements a first-best outcome. In a related model, Strausz (1999) uses a punishment scheme to deter agents from expending suboptimal investments. Under his scheme, the agent "next in line" refuses to expend any further investment and insists on a penalty payment after observing a deviation by his immediate predecessor. This scheme prevents all agents from shirking if the verifiable outcome is deterministic. However, in general it cannot implement the efficient solution if output is a stochastic function of investments.[13] Our results are thus complementary to those of his work: while our findings apply only to team production with two agents, our mechanism can also cope with the possibly more realistic scenario where the outcome of team production is subject to significant uncertainty.[14]

[13] While the bonus scheme we explore uses no punishments, it requires that agent B (though not agent A) is not severely wealth constrained: she must be able to pay agent A an amount of maximal size $t^* v(a^{FB}, 0, \bar{s})$ if the bonus contract remains in force. While this payment is never provided in the equilibrium of the game where bargaining is successful, a lack of a monetary endowment on B's side would alter the parties' threatpoint payoffs and hamper the efficient outcome of the mechanism.

[14] In principle, a bonus contract can facilitate an efficient outcome in team production problems with more than two agents. However, since the mechanism we explore relies on equilibrium renego-

5 Conclusion

This note explores a team production problem where two parties sequentially invest to enhance the value of a joint project (an asset). We show that an efficient outcome is generically feasible even if the output, i.e., the final asset value, is subject to any degree of uncertainty. Hence, we complement a recent efficiency result by Strausz (1999) who considers deterministic environments but allows for more than two agents. In our framework, efficient contracting is characterized by a basic dichotomy. If the parties' inputs are complementary on the margin, it is optimal to combine some arbitrary equity structure with a properly chosen bonus scheme that is linear in the ex-post verifiable asset value. In equilibrium, this initial incentive scheme is always renegotiated after the first agent invested, and the second party becomes residual claimant for the returns from her own investments. Conversely, if investments are substitutive, efficient investments are feasible even if the asset value is non-verifiable. In this case, the optimal contract is an option-to-buy arrangement under which the the second party has the right (but not the obligation) to acquire the asset at a fixed price after the first agent expended his effort. We thus extend a recent result by Edlin and Hermalin (2000) to a setting where the asset value is stochastic rather than deterministic. In contrast to their findings, however, the option is not always exercised in equilibrium, and renegotiation arises with positive probability.

All in all, the results of our paper reinforce previous insights that the moral hazard in teams problem can often be resolved if the parties invest sequentially rather than simultaneouly. This scenario also bears empirical relevance, for example with regard to research joint ventures where a small high-tech firm exerts the basic research

tiation, the bargaining solution with more than two agents is sensitive to the underlying bargaining process. For example, in a setting with three agents the date-1 bargaining outcome between parties A and B has to take the continuation of the game into account, i.e., the subsequent bargaining between B and the last agent, say C. Also, it might be reasonable to assume that C already enters negotiations between A and B, which would further complicate the analysis. At this point, we have to leave a thorough analyisis for future research.

for a large enterprise that is responsible for subsequent later-stage development and marketing. While our paper confines attention to the important case of team production with only two agents, an analysis of optimal contracting with sequential investments and stochastic payoffs is a fruitful direction for future reseach.

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