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Appropriability, Investment Incentives and the Property Rights Theory of the Firm

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Abstract
This paper examines the property rights theory of the firm when a manager's relationship-specific investment can be partially appropriated by the owner of an asset when cooperation breaks down. For example ownership typically confers the right to continue with a project even should the production team dissolve. The investments of non-owners may then be devalued, but are seldom wholly loss to the owner. With such spillovers, the outside-option principle can be incorporated into the Grossman-Hart-Moore framework without implying that ownership demotivates. Enriched predictions on the determinants of integration emerge.

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1 Introduction

Whether for good or ill, managers often have influence well beyond their tenure in a job. Examples are so numerous as to be commonplace. According to Chandler (1977), the American railroad network took its modern form by the 1880s and "...salaried career executives played a critical role in the system building of the 1880s" (p167). Irreversible investment decisions aside, a theme of Peters and Waterman (1982) is that effective managers inculcate an enduring culture. Typical is the quote of Richard Deupree, former CEO of Procter and Gamble, "William Procter and James Gamble realized that the interests of the organization and its employees were inseparable. That has never been forgotten." (p76).

The common element here and much more generally is that since employees at all levels have limited ownership of their own output, a firm may continue to benefit from an employee's past efforts even if they quit. This feature evidently affects employees' bargaining position with employers and hence the incentives of both parties to make non-contractible investments in the relationship. The underlying perspective is the property rights theory of the firm (PRT). This bold attempt to explain patterns of industrial organization by the incentive effects of asset ownership can be applied to all sorts of on make-or-buy decisions. The seminal papers are Grossman and Hart (1986) and Hart and Moore (1990), henceforth GHM. They argue that costly verification of relationship-specific investment means that contracts are necessarily incomplete and can always be renegotiated. Eventual payoffs, and consequently the *ex ante* incentive to invest, are therefore determined by *ex post* bargaining. As ownership of non-human assets affects bargaining power, ownership ultimately influences the *ex ante* incentive to invest. The boundary of the firm (that is, the extent to which assets are under common ownership) is thus determined by the ownership structure that provides the best bundle of investment incentives.

The concern of this paper is with the neglected but pervasive feature that one party's investment often creates benefits for the other even if the relationship breaks down. This is particularly likely to apply when the asset is work in progress or reputational capital, but can also easily arise with other assets. The remainder of the paper shows that such spillovers have major implications for PRT.

Perhaps the central result of GHMs formulation is that a party acquiring additional assets does not suffer a decrease in its investment incentives[1]. To see this, suppose that there are two parties, A and B, and one asset. All that can be contracted over is ownership of the asset.[2] GHM assume that the final surplus is shared *ex post* according to the Nash bargaining solution, i.e. each party gets its disagreement utility[3] plus half of the difference between total surplus and the sum of the disagreement utilities. Thus, 50% of the marginal return of

[1] This result is formally stated and proved as Proposition 1 below.

[2] The more general case with n managers is dealt with by Hart and Moore(1990).

[3] Disagreement utilities are the payoffs available to the two parties while negotiations over the division of the surplus take place.

the investment stems from the effect of the investment on total surplus, while another 50% stems from its effect on the disagreement utility. Now, if A owns the asset, the marginal return of her investment outside the relationship will be higher as compared to the situation where B controls the asset. Therefore, her investment incentives will be higher. This is GHM.

The qualitative predictions of PRT do not appear to be especially robust. Two recent papers, Chiu (1998) and de Meza and Lockwood (1998), note that the Nash bargaining solution obtains in a non-cooperative Rubinstein alternating-offer game only if the disagreement utilities are interpreted as '*inside options*', that is they can only be consumed during negotiations. For example, the parties may be in paid employment which they will quit once agreement is reached. In practice, the disagreement utilities relevant for PRT may be "*outside options".* That is, they are payoffs achievable by taking up some alternative offer which scuppers the relationship under negotiation.

As emphasized by de Meza and Lockwood, under these circumstances extra asset ownership may *demotivate* managers. When parties can irrevocably break off bargaining and take up some new opportunity (and under an additional assumption on the sequential order of moves) the subgame-perfect equilibrium of the Rubinstein game satisfies the outside-option principle. In its simplest form, this principle says that if the outside-option utility of one party is larger than 50% of the total surplus from cooperation, then this party will only get its outside option-utility, while the other party will get all of the additional social surplus. It is easy to see that with the outside -option principle, GHM's conclusion fails. Suppose that the outside-option utility of whoever owns the asset does exceed half of the surplus. Then, if A owns, she will get only her disagreement utility, so 100% of her investment incentives stem from the effect of the investment on the outside option. Given GHM's additional assumption that the marginal impact of the investment on the total relationship surplus is higher than on the outside option, it is clear that A's investment incentives are lower if she owns the asset than if she does not own it.

This paper presents a result below (Proposition 2) which shows that the foregoing argument applies quite generally[4]; under some weak assumptions - which together imply that a manager's outside option binds when he owns both assets i.e. that outside options are sufficiently valuable - a manager's incentive to invest is maximized when owning *no* assets.

Although there may be occasions where ownership demotivates, it is im-

[4] De Meza and Lockwood(1998) show that with outside options, increased ownership motivates only under rather special conditions namely ; (i) if the manager's outside option is already binding before he is given the asset; or, (ii) if the outside option is initially not binding on either manager, but becomes binding on the recipient following transfer of the asset, *and* the recipient's outside option is relatively sensitive to investment (i.e. the return on investment in the outside option is more than half the return to investment in team production). See also Chiu(1998) for similar results. Both (i) and (ii) require some asymmetry in the model. In particular, although both these cases involve the manager gaining the asset investing more, the manager losing the asset does not invest less (and in the second case invests strictly more). So even here the investment incentives of one of the managers is at a maximum when they own no assets.

plausible that this is the norm. Since in many contexts the relevant alternatives appear to be outside options and alternating offers a natural baragaining protocol, there is a puzzle. This paper offers a solution. It is shown that if managers' investments augment the value of the *physical asset(s)* as well as their own human capital, the conclusion of the earlier property rights literature (namely, that asset ownership motivates) can be restored *even when the outside option principle applies.*[5] This is because the value of investments in physical assets can be appropriated by the owner of the asset whether or not he works together with the agent who made the investment.

The mechanism at work is the following. If the team breaks up, the subsequent revenue generated by the owner of the asset depends on the investment made by the *non-owner, insofar as that investment is embodied in the physical asset.* In this paper, we call the (marginal) impact of an agent's investment on the individual revenue of the other agent a *cross-effect.* To illustrate the qualitative significance of cross effects for the property-rights theory suppose the outside option of an asset owner is binding at the bargaining stage so the non-owner is the residual claimant. With cross-effects, the non-owner's marginal return to investment is now the increase in team revenue *less* the boost in the owner's outside option due to the cross-effect. The cross effect thus weakens the non-owner's investment incentive since, to the extent investment augments asset value, it merely serves to strengthen the owner's bargaining power. Consequently, if the cross-effect is large enough, ownership may once more motivate (see Proposition 4 below).

The key ingredient of our approach, that the value of the owner's outside option depends on the investment of the other agent(s), is natural and realistic in many settings. For example, consider a vertical production relationship such as that between a car-maker and component supplier.[6] Suppose that one of the assets is a press for making parts of the car body, and that the manager of the component firm has invested some time making improvements to that machine. Then, if the manager of the car-maker owns this asset, in the event of individual production, (i.e. the managers do not agree to produce the car together), the manager of the car-making firm obtains some benefit from the other manager's time investment[7]. The situation is similar when an employee

[5] Noldeke and Schmidt (1998) allow investments to augment physical assets but work in a Nash bargaining framework and are concerned with different results.There are also cross effects in the contracting problems of Che and Hausch (1999) and Segal and Whinston (2000) but implications for asset ownership are not examined..

[6] The classic example is Fisher Car Body and General Motors. Klein, Crawford, and.Alchain, (1978) Williamson (1985) and Hart (1995) argue that the takeover of Fisher by GM, completed by 1926, was to mitigate hold-up problems. This is disputed by Casadesus-Masanell and Spulber (2000), Coase (2000) and Freeland (2000) who cite transaction cost savings and coordination benefits. The picture is mixed though. Coase reports that prior to 1926 many plants were owned by GM and leased to Fisher. This suggests that hold-up may have been an issue. In addition, the merger was prompted by the concern of GM that Fisher Brothers "...paid less attention to the needs of General Motors than General Motors would have liked" (Coase, p.23). This indicates that the ownership change was designed to change incentives.

[7] This variant of Hart's model is discussed in detail in Section 4.

makes organizational improvements, or when a scientist makes a discovery but the company owns the patent[8]. The ownership issue could also involve who has the right to work in progress, the value of which generally depends on the contribution of all team members. In all these cases, even in the presence of outside options, ownership may enhance incentives.

2 An Example

To illustrate these ideas, consider Hart and Moore's (1990) now standard example of a chef and skipper combining forces to offer a luxury cruise. They first decide which of them should own the yacht. Next the skipper can make an unverifiable investment which raises total cruise revenue. We suppose that this involves researching charts to provide a particularly suitable itinerary. At this stage, with prospective team revenue determined, the chef and skipper negotiate how it should be divided between the two of them. The protocol is alternate offer bargaining but the outcome of the negotiation depends on the opportunities the two parties face. One possibility is that both parties are currently employed in other jobs. Once they reach agreement they will quit these jobs and the income flows they generate. Instead each obtains the agreed share of cruise income. In this case, income from the current jobs represent inside options. Bargaining then results in the excess of cruise revenue over the sum of the inside options being equally split between the parties.

Another possibility is that neither chef nor skipper is presently employed, but each has alternative opportunities they could take up. Perhaps the chef could sign up for a different voyage whilst a yacht owning skipper could just set sail and combine both jobs. If either of these options is taken the original cruise is off for good. Now the bargaining involves outside options. The limiting equilibrium is that the cruise revenue is either equally split or, if one party has an outside option worth more than half cruise revenue, this is its payoff and the other party receives the remainder of cruise revenue.[9]

Resuming the detail of the example, let the skipper's unverifiable investment serve to raise total cruise revenue from 80 to 100 but involve a personal cost of 11. If the the skipper owns the vessel but works independently he earns 60 if the investment has been made and 50 otherwise. Without the yacht, the skipper's investment is wasted and he earns 20. If the chef owns the yacht but she works independently she earns 50, but only 20 if she does not own. So, for now, the

[8] All these examples assume that the investment of the non-owner augments the physical capital of the owner of the asset. However, a similar effect might arise if the investment is in human capital. For example, suppose an engineer trains an assistant to repair the machine before he leaves.

[9] Though our preferred interpretation is that the difference between the cases is the nature of the opportunities open to the agents, it could be the bargaining protocol that determines which equilibrium prevails. Suppose that there is a genuine outside option available to each agent. The bargaining is take-it-or-leave-it but each agent has an equal chance of being the proposer. Now expected payoffs equal the inside option interpretation of the text, or the Nash axiomatic outcome. So outside options could be consistent with the GHM results but the bargaining protocol required does not though seem particularly easy to justify.

individual revenue of the chef is independent of the skipper's investment (i.e. there are no spillovers).

Now consider investment incentives if the independent payoffs are inside options in the post-investment bargaining or the Nash axiomatic solution applies. First, suppose the skipper owns the yacht. If he invests, his payoff is 60+0.5(100-60-20)=70 whereas without investment the payoff is 50+0.5(80-50-20)=55. So, as 70-55 >11, the investment is undertaken. When the chef owns, the skipper gets 20+0.5(100-20-50)=35 if he invests, and if he does not, he gets only 20 +0.5(80-20-50)=25. In this case, his gain from investment is less than 11 and he does not invest. So the efficient investment only takes place if the skipper, the sole party with an investment choice, is the owner. As income transfers can be made *ex ante*, this ownership structure is the one that will be agreed at the outset. This first case illustrates the original GHM theory of the firm.

Now consider how matters turn out if the outside option principle applies, as in de Meza and Lockwood(1998). When the skipper owns the yacht, his outside option is binding at the bargaining stage, as it is worth more than 50% of team revenue whether or not he invests. Hence, the skipper gets 60 with investment and 50 without, and consequently does not invest. When the chef owns, her outside option binds, and so the skipper gets 80-50=30 without investment and 100-50=50 with, implying that the skipper now wishes to invest. It is now efficient for the *chef* to own, because only if the skipper does *not* own is he sufficiently motivated to invest.

Finally, retain the outside option principle, but suppose that when the skipper invests, in addition to researching charts (which augments only the skipper's human capital), he also supervises modifications to the keel of the yacht to allow easy access to more ports on the itinerary (which augments the value of the *physical* asset). This additional work raises the skipper's investment cost by 5 taking it to 16[10]. In the event negotiations breakdown irretrievably, the gain from easier port access is worth 10 whoever owns the yacht. There are now cross-effects i.e. the skipper's investment augments the value of the yacht to the chef if the chef owns it.

So, if the chef owns and the skipper invests, the chef's outside option increases from 50 to 60. Therefore, when the chef owns, the skipper's gain from investing is now only (100-60)-(80-50)=10, less than the cost of investment of 11+5=16. On the other hand, when the skipper himself owns, investment raises his now raises his outside option from 50 to 70, more than the investment cost of 16. So, we are back to the original GHM conclusion, i.e. the skipper can only be sufficiently motivated to invest if he owns.

3 The Model

Our model can be thought of as an extension of Hart's (1995, ch2) widget model, to accommodate cross-effects. There are two managers $i = 1, 2$ engaged in a

[10] We suppose for simplicity that investment is still binary i.e. either the skipper undertakes both the keel adjustment and the chart research, or neither.

vertical production relationship using two indivisible assets a_1, a_2. Specifically, 2 works with an asset a_2 to produce a widget which is then passed to 1 who works with a_1 to produce a final output (interpret a_1, a_2 as machines (or factories) that make the final product and the widget respectively). Investments at levels e_1, e_2 , $0 \leq e_i < \infty$, are made by managers 1,2 at date 0 and the widget is supplied at date 1.

Following Hart, we interpret investments e_1, e_2 as being money or time spent improving the efficiency of the relevant manager's operation. There is uncertainty about the type of the widget manager 1 requires, which is resolved at date 1; consequently, an effective long-term contract is impossible. Rather, at date 1, the parties negotiate about the widget price and type from scratch. Finally, both parties are risk-neutral and have unlimited wealth so that it is feasible for each party to own any asset that is it efficient for him to own.

The first possibility is that the managers trade a "specialized" widget, an event we refer to as *team production.* In this case, manager 1 gets payoff $R(e_1) - p^*$, where p^* is the price - negotiated at date 1- at which they trade, and R is the revenue from the sale of the widget. Similarly, manager 2 gets a payoff $p^* - C(e_2)$, where C is the cost of producing the widget. So, the total profit (ignoring investment costs) from team production is $\Pi = R - C$. We assume that R is strictly concave and differentiable in e_1 and C is strictly convex and differentiable in e_2.

The second possibility is that the two managers do not agree to trade, an event we call *individual production.* Let the payoffs to individual production be π^1, π^2. It is central to the property rights theory that π^1 (resp. π^2) depend also on the set of assets that manager 1 (resp. manager 2) owns[11]. Following Hart(1995), we consider two possible allocations of assets between the managers; *non-integration*, where manager 1 owns a_1, and manager 2 owns a_2, and *integration*, where one manager owns both assets (there are obviously two possibilities here). Formally, an *asset allocation* is a pair (α_1, α_2) where $\alpha_i \in \{\emptyset, \{a_i\}, \{a_1, a_2\}\}$ is the set of assets owned by $i = 1, 2$. Let the set of all possible asset allocations be A. So, we write $\pi^i(e_1, e_2, \alpha_i)$ to denote the value of individual production to i under different asset allocations.

In modelling individual production, we wish to capture cross-effects. In Hart(1995), there are no cross-effects i.e. π^1 is independent of e_2, and π^2 is independent of e_1. One way of interpreting this is the following. Hart assumes that the two managers have an additional input to production other than the non-contractible investments, which he calls "human capital" (Hart(1995), p36). It is an implicit assumption in Hart that in the absence of 2's human capital, 1 simply cannot produce a widget, and similarly, in the absence of 1's human capital, 2 simply cannot produce the final product. So, with individual production, there is no way for manager 1 to benefit from the investment e_2 that manager 2 has made in improving the efficiency of the asset a_2 which is used to make the widget (and vice-versa).

[11] Recall that in the example discussed in the previous section, the individual revenue of either the skipper or the chef depended on whether that agent owned the yacht.

Here, we relax this assumption. Specifically, we will assume that if manager 1 owns a_2 as well as a_1, he *can* make a widget, and thus benefit from 2's investment e_2 in asset a_2 (and symmetrically, if manager 2 owns both assets, he *can* make the final product, and thus benefit from 1's investment in the first asset). This implies that with integrated asset ownership, there will be cross-effects, but not otherwise. A more general formulation is that spillovers occur even under non integration. For example, the team members may work in close proximity so that an innovation introduced by one may be observed and applicable by the other. So manager 1's investment e_1 improves the efficiency of asset a_2 as well as that of asset a_1, and similarly for manager 2.As we note after Proposition 3, this extension does not upset our main results, but to avoid clutter we work with the simpler case.

The details are as follows. We will suppose that the investments e_1, e_2 consist in part of modifications to the assets (machines) a_1, a_2, and we denote by $0 \leq \lambda_2 < 1$ the fraction of 2's investment that is embodied in the widget-making machine (perhaps 2 has made some improvement to the speed or reliability of the machine) and similarly denote by $0 \leq \lambda_1 < 1$ the fraction of 1's investment that is embodied in the machine that produces the final product. So, in the event that team production does not take place, manager 1 has "access" to investment $\lambda_2 e_2$ of manager 2, and similarly for manager 2. Parameters λ_1, λ_2 are crucial in what follows.

Now suppose that team production does not take place. If 1 owns both machines, he has three options. First, he can buy a standard widget at price p and produce final output. Second, he can produce a standard widget with machine a_2, and use it in conjunction with a_1 to produce final output. Third, he can produce his own specialized widget with machine a_1, and use it in conjunction with a_2 to produce final output.

Denote the revenues from the second stage of individual production using specialized and standard widgets by $r(e_1)$, $\tilde{r}(e_1)$ respectively. Also, from the definition of λ_2 above, the costs to 1 of producing a specialized and standard widget with asset a_2 are $c(\lambda_2 e_2)$, $\tilde{c}(\lambda_2 e_2)$. It is natural to assume that revenue is higher if a specialized widget is used, and that such a widget is more costly to produce (i.e. $r > \tilde{r}$, $c > \tilde{c}$), but neither of these assumptions is necessary in what follows. All we assume[12] is that if 1 owns both assets, he prefers to produce the specialized rather than the standard widget, no matter what the investment levels.

Second, if 1 has only asset a_1, he can only buy a standard widget and produce the final good using this widget, or remain inactive. Finally, we suppose that without either machine, agent 1 can produce nothing[13]. A convenient simplifying assumption is that $\tilde{r}(0) > p > \tilde{c}(0)$ i.e. it is always better for manager 1 to buy a standard widget and produce the final output if he owns a_1, rather than remain inactive, and for manager 2 to produce and sell the standard

[12] Formally, we assume $r(e_1) - c(\lambda_2 e_2) > \tilde{r}(e_1) - \tilde{c}(\lambda_2 e_2)$, all e_1, e_2.

[13] This assumption seems very weak; the discussion in Hart(1995) makes it clear that in the model, assets are to be thought of as necessary for team production, so we simply assume the same of individual production.

widget if he owns a_2, rather than stay inactive. So, using above assumptions, the net revenue to manager 1 in these three cases is;

$$\begin{aligned} \pi^1(e_1, e_2 &: \{a_1, a_2\}) = r(e_1) - c(\lambda_2 e_2) \\ \pi^1(e_1, e_2 &: \{a_1\}) = \tilde{r}(e_1) - p \\ \pi^1(e_1, e_2 &: \emptyset) = 0 \end{aligned} \tag{1}$$

By similar arguments, we can write down the net revenue for manager 2 in the event that no team production takes place. If he has no assets, he cannot produce anything. If he only has the second asset, it is both feasible and optimal for him to produce a standard widget for sale to the spot market. If he has both assets, he has the same three options as manager 1 did in the same case, the only difference being that 2 only benefits from fraction λ_1 of 1's investment. Also, we assume[14] that if 2 owns both assets, he prefers to produce a specialized rather than a standard widget. So, we have;

$$\begin{aligned} \pi^2(e_1, e_2 &: \{a_1, a_2\}) = r(\lambda_1 e_1) - c(e_2) \\ \pi^2(e_1, e_2 &: \{a_2\}) = p - \tilde{c}(e_2) \\ \pi^2(e_1, e_2 &: \emptyset) = 0 \end{aligned} \tag{2}$$

We assume that $r, \tilde{r}$ are increasing and strictly concave, and $c, \tilde{c}$ are decreasing and strictly convex, in their arguments.

We now turn to the key issue of cross-effects. As remarked above, with integrated ownership, there *are* cross-effects as long as $\lambda_1, \lambda_2 > 0$ i.e.

$$\frac{\partial \pi^1(e_1, e_2 : a_1, a_2)}{\partial e_2} = -\lambda_2 c'(\lambda_2 e_2) > 0, \ \frac{\partial \pi^2(e_1, e_2 : a_1, a_2)}{\partial e_1} = \lambda_1 r'(\lambda_1 e_1) > 0 \tag{3}$$

On the other hand, with non-integration, there are no cross-effects[15]. When agent 1 owns only asset a_1, he must buy a widget from the spot market at price p, (and similarly for 2) and so the payoff to manager i from individual production is independent of $j's$ investment. So, we have the important observation that in a fully specified model, cross-effects are determined *endogenously* by the structure of asset ownership.

Finally, note that when $\lambda_1, \lambda_2 = 0$, our model is almost the same[16] as that of Hart(1995). Any differences are superficial, in the sense that the key assump-

[14] Formally, we assume that $r(\lambda_1 e_1) - c(e_2) > \tilde{r}(\lambda_1 e_1) - \tilde{c}(e_2)$, all e_1, e_2.

[15] Of course, it is possible to envisage situations where there are cross-effects even with non-integration. In our setting, this would occur when the investment of either agent augmented the productivity of *both* assets. The main results of the paper extend to this case, because the main mechanism at work would not change i.e. an increase in investment by the redisual claimant would still increase the outside option of the other agent by more, the greater the number of assets owned by the other agent.

[16] There are only two inessential differences. In Hart, agents engaged in individual production are assumed transact on the spot widget market, *whatever* assets they own. By contrast, in our model, (i) when an agent owns both assets, he finds it both feasible and profitable to make the specialized widget and use it as an input, and (ii) an agent with no assets cannot produce at all.

tions in Hart's model are also satisfied in our model, as we now show. The assumptions[17] on Π, π^1, π^2 made in Hart-Moore(1990) and Hart(1995) are:

Assumption 1. $\Pi > \pi^1 + \pi^2$, *all* e_1, e_2, *all* $(\alpha_1, \alpha_2) \in A$.

This assumption implies that team production will always take place. For Assumption 1, it is sufficient that $R(e) - C(e') > r(e) - c(e')$, all e, e'. The justification for this is the same as in Hart(1995), namely that with individual production, manager i no longer has access to j's human capital.

Assumption 2. $\frac{\partial \Pi(e_i)}{\partial e_i} > \frac{\partial \pi^i(e_i;a_1,a_2)}{\partial e_i} \geq \frac{\partial \pi^i(e_i;a_i)}{\partial e_i} \geq \frac{\partial \pi^i(e_i;\emptyset)}{\partial e_i} \geq 0$, *all* e_1, e_2.

This says that the marginal return to investment in individual production is (weakly) increasing in the number of assets owned, and is always strictly less than the marginal return to investment in the relationship. Also, at least one of the weak inequalities in Assumption 2 should hold strictly for the PRT to be non-trivial. For Assumption 2 to be satisfied, we require that $r'(e) \geq \tilde{r}'(e) \geq 0$, $c'(e) \leq \tilde{c}'(e) \leq 0$ i.e. investment by manager 1 has a higher marginal return if the final product is made using a specialized widget, and similarly investment by manager 2 has a higher marginal return if the specialized widget is produced.

The assumptions made so far imply the following useful intermediate result.

Lemma 1. *The payoff to individual production* π^i *is non-decreasing in the number of assets owned by* i.

This result follows directly from (1)-(2) and the assumption that $\tilde{r}(0) > p > \tilde{c}(0)$.

The order of events is as follows. First, the non-contractible investments e_1, e_2 are made. Then, once investments are made, agents bargain over the revenue from team production. Finally, production and consumption take place. We solve the model backwards in the usual way to locate the subgame-perfect equilibrium.

4 Bargaining

The way in which the revenue from team production is divided up depends on the assumed bargaining protocol i.e. the rules of the bargaining game. One way to think of the two alternatives studied in this paper is to think of both as bargaining games whose basic structure is alternating-offers. In GHM, a protocol is assumed which effectively treats π^1, π^2 as *inside options.* That is, each agent gets π^i per period while bargaining over the division of Π. The interpretation of this is that the two agents can engage in individual production whilst bargaining; this may be an appropriate assumption in some cases.

[17] Our Assumption 1 corresponds to part of Assumption 2 of Hart-Moore(1990), and Assumption 2.1 of Hart(1995). Our Assumption 2 corresponds to Assumption 6 of Hart-Moore(1990), and Assumptions 2.2, 2.3 of Hart(1995).

In this case, in the limit as the discounting goes to zero, it is well-known (e.g. Sutton(1986)) that the equilibrium payoff for each party is the inside option payoff plus half the net gain from trade;

$$v^1(e_1, e_2) = \pi^1 + \frac{1}{2}\left[\Pi - \pi^1 - \pi^2\right] \quad (4)$$

$$v^2(e_1, e_2) = \pi^2 + \frac{1}{2}\left[\Pi - \pi^1 - \pi^2\right] \quad (5)$$

where we have suppressed the dependence of v^1, v^2 on (α_1, α_2) for convenience.

By contrast, more recent work by De Meza and Lockwood(1998) and Chiu(1998) assume a bargaining protocol where π^1, π^2 are *outside options.* Here, it is assumed that agents *cannot* engage in individual production while bargaining. Rather, in any bargaining round, the responder may irrevocably leave the bargaining process and commence individual production. In this case, it is well-known (Binmore, Shaked and Sutton(1989), Sutton(1986)), that in the limit as the common rate of discounting goes to zero, the equilibrium payoffs at the bargaining stage may be characterized as follows.

Given some arbitrary investment levels (e_1, e_2), and asset ownership structure (α_1, α_2), say $i's$ outside option is *binding*, if

$$\frac{\Pi(e_1, e_2)}{2} < \pi^i(e_1, e_2, \alpha_i)$$

Then, if neither outside option is binding, each manager gets $\Pi/2$. If 1's outside option is binding, then he gets π^1, and manager 2 gets $\Pi - \pi^1$ i.e. 2 is "residual claimant". If 2's outside option is binding, then he gets π^2, and manager 1 gets $\Pi - \pi^2$ i.e. 1 is "residual claimant". By Assumption 1, these are the only possibilities. Let these payoffs as functions of e_1, e_2 be $w^1(e_1, e_2)$, $w^2(e_1, e_2)$.

5 Results on Investment and Asset Ownership

We begin with the inside option case. At date 0, managers 1 and 2 choose e_1 and e_2 respectively to maximize their payoffs net of investment costs, $v^1(e_1, e_2) - e_1$, $v^2(e_1, e_2) - e_2$ (we have set the unit cost of each type of investment to unity for convenience). Note from inspection of (4),(5) and the properties of Π, π^1, π^2 that the optimal e_1 is independent of e_2 and vice versa. So, for each asset allocation, by the strict concavity of $r, \tilde{r}, R$, and the strict convexity of $c, \tilde{c}, C$, there will be a unique pair of optimal investments e_1^*, e_2^*. Note also that - crucially - e_1^*, e_2^* depend on the asset allocation. As remarked above, Hart's(1995) widget model is effectively a special case of our model *without* cross-effects (i.e. $\lambda_1, \lambda_2 = 0$). In that case, we know that when the payoffs from individual production are inside options, investment is increasing in asset ownership (se e.g. De Meza and Lockwood(1998)) This first result extends straightforwardly when cross-effects are introduced.

Proposition 1 *With inside options, manager 1's (resp. $2's$) investment e_1^* (resp. e_2^*) is (weakly) increasing in the number of assets he owns, even when* *cross-effects are present. Moreover, the larger the cross-effects λ_1,λ_2 the lower is investment by the non-owner under integrated ownership.*

Proof. Consider first manager 1. The general formula for his payoff gross of investment cost is given by (4) i.e. $v^1(e_1, e_2) = \pi^1 + \frac{1}{2}\left[\Pi - \pi^1 - \pi^2\right]$. Substituting in our formulae for π^1, π^2, we get

$$\begin{aligned} v^1(e_1, e_2; a_1, a_2) &= r(e_1) - c(\lambda_2 e_2) + 0.5\,(R(e_1) - C(e_2) - r(e_1) + c(\lambda_2 e_2)) & (6)\\ v^1(e_1, e_2; a_1) &= \widetilde{r}(e_1) - p + 0.5\,(R(e_1) - C(e_2) - \widetilde{r}(e_1) + \widetilde{c}(e_2)) & (7)\\ v^1(e_1, e_2; \emptyset) &= 0.5\,(R(e_1) - C(e_2) - r(\lambda e_1) + c(e_2)) & (8)\end{aligned}$$

in obvious notation. So, if manager 1 owns both assets, from (6), his optimal choice of e_1 is given by

$$\frac{1}{2}R'(e_1) + \frac{1}{2}r'(e_1) = 1 \tag{9}$$

If he owns one asset, from (7), his optimal choice of e_1 is given by

$$\frac{1}{2}R'(e_1) + \frac{1}{2}\tilde{r}'(e_1) = 1 \tag{10}$$

and if he owns none, from (8), his optimal choice of e_1 is given by

$$\frac{1}{2}R'(e_1) - \frac{\lambda_1}{2}r'(\lambda_1 e_1) = 1 \tag{11}$$

The first result then follows from (9)-(11), the concavity properties of $R, r, \tilde{r}$, and Assumption 2 in the context of the cross-effects model i.e. $r' \geq \tilde{r}' \geq 0$. Also, the solution to (11) is clearly decreasing in λ_1. A similar argument applies for manager 2. □

This result shows that the most basic implication of the inside option bargaining protocol is that *asset ownership motivates,* and moreover, this conclusion is robust to the introduction of cross-effects. Note that the higher is λ_1 or λ_2, the lower is the investment by the non-owner. Intuitively, with a cross-effect, more investment by the non-owner simply increases the owner's inside option, and therefore his bargaining power, and the stronger the cross-effect, the stronger this loss of bargaining power for the non-owner is.

We now turn to the case of outside options. In this case, the payoffs in the investment stage are $w^1(e_1, e_2) - e_1$, $w^2(e_1, e_2) - e_1$. Contrary to the inside option case, there is strategic interaction at the investment stage in that optimal investment for 1 depends on 2's investment and vice-versa (De Meza and Lockwood (1998)). We will assume throughout that there is a unique pure strategy Nash equilibrium e_1^*, e_2^* to this investment game, conditional on a given asset allocation. Building on results of De Meza and Lockwood (1998), we show in Appendix A that a sufficient condition for the existence of a unique pure strategy Nash equilibrium is that r' be sufficiently close to $R'/2$, and that c' be sufficiently close to $C'/2$. That is, the return to the investment in the outside option for either manager must not be too high or too low relative to the return to the investment in the productive relationship.

Say $i's$ outside option is *binding in equilibrium* if in the equilibrium of the investment game,

$$\frac{\Pi(e_1^*, e_2^*)}{2} < \pi^i(e_1^*, e_2^*, \alpha_i)$$

Of course, which, if either, outside option is binding in equilibrium depends on the asset allocation. We now make one more, quite weak assumption:

Assumption 3. *For either manager, there exists an asset allocation such that his outside option is binding in equilibrium.*

This is quite a weak assumption. It rules out (i) a trivial case, where neither manager's outside option ever binds, in which case asset ownership can never affect investment, or (ii) the case where the model is highly asymmetric. Under these assumptions, we can now get the following general result about the effect of asset ownership on investment:

Proposition 2 *Suppose Assumptions 1-3 hold and there are no cross-effects ($\lambda_1, \lambda_2 = 0$). With outside options, the investment of either manager is strictly higher when he has no assets than two assets, and weakly higher when he owns no assets rather than one.*

Proof. (i) We first show that if a manager owning a single asset has a binding outside option in equilibrium, the option also binds when the manager owns both assets.

Let the equilibrium investments when manager 2 owns one asset be (e_1^*, e_2^*) .If the acquisition of the extra asset leads to an equilibrium in which 2's outside option still binds, 1's investment must be unchanged at e_1^*. With two assets, 2 invests more given 1's investment. Let the new investment level be $e_2' > e_2^*$. The question is whether e_2' could be so great that 2's outside option no longer binds. To show that it could not, suppose the contrary. Compare 2's payoff at (e_1^*, e_2') with one asset and with two. In either case, neither parties outside option binds (when 1 owns one asset its outside option does not bind at (e_1^*, e_2^*) so it cannot do so at (e_1^*, e_2')). Thus at (e_1^*, e_2') , 2 gets the same payoff with one or two assets. However, at e_2^* the payoff to 2 is greater when owning two assets. Thus with two assets it cannot be profitable to invest e_2'.

(ii) It follows that if manager i owns two assets, his outside option must be binding in equilibrium. For suppose not. Then from (i), his outside option cannot be binding when he has one asset either. Also, by assumption, his outside option is zero when he has no assets, and so cannot bind either. But then Assumption 3 is violated.

(iii) Now consider manager 1. If he has no assets, manager 2 must have both, and so from (ii), manager 2's outside option is binding. Therefore, manager 1's payoff is $\Pi - \pi^2 - e_1$. The first-order condition for his optimal investment is therefore

$$R'(e_1) = 1 \tag{12}$$

so by Assumption 2, his investment can be no higher under any other allocation of assets. If manager 1 has both assets, his payoff is $\pi^1 - e_1$, as his outside option is binding, so the first-order condition for his optimal investment is

$$r'(e_1) = 1 \tag{13}$$

and so from (12),(13), by Assumption 2, and strict concavity of R, r, his investment must be strictly lower than when he owns neither asset. The proof for manager 2 is symmetric. □

This is the most general possible formulation of the idea that with outside options, asset ownership may demotivate. This result consolidates Propositions 4 and 5 of de Meza and Lockwood(1998), and extends them to the case of relatively productive outside options[18]. It also relates to Proposition 3 of Chiu (1998), which says that if asset transfer causes the manager receiving the asset to invest strictly more, then the donor invests (weakly) more. So, under the stated condition, losing an asset motivates, and consequently, under the reverse asset transfer, the additional asset will demotivate the recipient.

The key focus of this paper is whether, with spillovers, asset ownership motivates when π^1, π^2 are outside options. On this question, we have the following result;

Proposition 3 *Suppose Assumptions 1-3 hold and that the return to investment in individual production is relatively high* ($r'(e) > 0.5R'(e)$, $-c'(e) > -0.5C'(e)$, *all* e). *Then, with outside options, when spillovers are sufficiently strong* ($1 > \lambda_1, \lambda_2 > \lambda_0$), *the investment of either manager is strictly increasing in the number of assets owned, except in the special case where manager i already owns* a_i *and is given* a_j *and initially,* $j's$ *outside option is binding. In this case, manager* $i's$ *investment falls.*[19]

Proof.

(i) Assumption 3 implies that if a manager owns both assets, his outside option must be binding (see the proof of Proposition 2 above). So, there are three possible cases.

Case A: non-integration implies neither manager's outside option binding.
Case B1: non-integration has 1's outside option binding.
Case B2: non-integration has 2's outside option binding.

Case A. By definition, if the return to investment in individual production is relatively high, then

$$r'(e) > 0.5R'(e) > R'(e) - r'(e)$$

[18] These occur when the marginal product of investment in individual production is at least half the marginal product of investment in team production. For a more formal definition, see Section 4 below.

[19] If spillovers arise even under non integration (the benefits accrue even to the unowned machine) the exception may not apply. The spillover lowers manager $i's$ incentive when owning only a_i and does not reduce incentives when also owning a_j.None of the other cases are qualitatively affected by the more general treatment of spillovers.

So, for $\lambda_1 \simeq 1$,

$$r'(e) > 0.5R'(e) > R'(e) - \lambda_1 r'(\lambda_1 e) \tag{14}$$

But the three terms in (14), reading from left to right, are simply the marginal returns to investment by manager 1 when he owns two, one or no assets respectively. It follows directly from this fact and strict concavity of r, R, that investment is monotonically increasing the number of assets owned. A similar argument applies to manager 2.

Case B1. In this case, when 1 owns no assets, 2's outside option is binding: otherwise, 1's outside option is binding. So, as manager 1 goes from owning one to two assets, his return to investment rises from $\tilde{r}'(e_1)$ to $r'(e_1)$. By assumption 2, the second return is greater than the first, so he will invest more with two assets rather than one. When manager 1 goes from owning one asset to no assets, his return to investment goes from $r'(e_1)$ to $R'(e_1) - \lambda_1 r'(\lambda_1 e)$, as manager 2's outside option is binding. If λ_1 is close to one, then $r'(e_1) - (R'(e_1) - \lambda_1 r'(\lambda_1 e :)) \simeq 2r'(e_1) - R(e_1) > 0$, where the last inequality follows from the fact that outside options are assumed productive. So, the incentive to invest is higher for manager 1 when he has one asset than when he has none.

Case B2. When manager 1 goes from owning one asset to no assets, then as 2's outside option in either case is still binding, manager 1's return to investment goes from $R'(e_1)$ to $R'(e_1) - \lambda_1 r'(\lambda_1 e)$, as only in the second case is there a cross-effect. So, he will invest more when he owns one asset. When manager 1 goes from owning one asset to two assets, his return to investment goes from $R'(e_1)$ to $r'(e_1)$. So, again he will invest more when he owns one asset. □

So, with cross-effects, the rather general result that in the presence of outside options asset ownership demotivates is partially reversed; when cross-effects are sufficiently strong, giving additional assets to a manager will strictly increase that manager's investment, except in the special case[20] identified in the Proposition. Taking Propositions 1 and 3 together, it follows that if the hypotheses of Proposition 3 hold, therefore, the effect of transferring ownership of additional asset(s) to a manager is to induce him to invest more, *irrespective* of the precise bargaining protocol.

Can the hypotheses of Proposition 3 all be satisfied, and are they also consistent with the conditions for existence and uniqueness of pure strategy Nash equilibrium in the investment game, as discussed above? In Appendix B, an example is presented which shows the mutual consistency of all these assumptions.[21]

Finally, note another novel implication of cross-effects. Introducing cross effects also creates the possibility that diversified ownership may be optimal

[20] In this special case, with non-integration, one manager's outside option is binding (say 2's) and thus manager 1 is residual claimant. As there are no cross-effects with non-integration, the marginal return to 1's investment in that case is $R'(e_1)$ and is thus as high as it can be. When 1 gets an additional asset (integrated ownership by 1), then 1's marginal incentive to invest must fall.

[21] If spillovers occur even under non integration.This does not upset Proposition 3. Spillovers have no effect if outside options are not binding under non integration whilst under integration all that matters is the total spillovers and not the decomposition across machines.

even with a binding outside option.[22] Suppose that agent 1 works with asset a_1 and agent 2 with asset a_2. Let each agent's investment increase the value of the asset they work with but have no effect on the other asset. Suppose initially that 1 owns both assets and her outside option binds. Now asset a_2 is transferred to manager 2, but this still leaves 1's outside option binding. Since the cross effect is eliminated, 2's investment increases whereas 1's is unaffected. Diversified ownership therefore dominates both assets being owned by manager 1. Were ownership concentrated in 2's hands it might be that 2's outside option binds, in which case his investment falls relative to the diversified solution. Whether 1 invests less depends on the effect on team productivity relative to the impact on his outside option, but whatever happens to 1's investment, diversified ownership may be best even though there is a binding outside option.

6 Conclusions

GHM explain the pattern of asset ownership by means of an incomplete contracting framework. Ownership matters for *ex-ante* investment decisions because of its influence on *ex-post* bargaining. Their detailed analysis is most naturally interpreted in terms of the effect of ownership on *inside* options. Yet in many instances it is the threat of *outside* options being exercised that drives *ex-post* bargaining. That is the consequences of team members committing to alternative employment arrangements is the key factor in negotiations. As ownership enhances a manager's opportunities, it may make the threat to break up the team credible, in which case the owner's payoff is determined by the outside option. The owner's incentive to raise the value of their own firm is therefore dulled. The striking implication is that, for at least one manager, and usually both, investment incentives are maximized when no assets are owned.[23]

This paper shows that the demotivating effect of ownership relies on the assumption that a manager's outside option only depends on her own investments. In many cases this is unrealistic. An owner typically has the right to continue with a project even if the team dissolves. The investment that the non owner made to enhance productivity may then be devalued, but is not normally wholly lost to the project. Indeed, the leading example in the property rights literature, the widget model, naturally exhibits the cross-effect property under integrated ownership. This matters, for if at least some of the worker's investment is available to the owner even without cooperation, the bargaining power of the non owner is weakened, diminishing her incentive to invest. Moreover, if the owner's investment is complementary with the non-human assets, the investments she makes may be largely preserved if the team breaks up. So, in the

[22] In de Meza and Lockwood (1998) it is noted that without cross effects, the agent with a binding outside option should own all the assets. Notice also that cross effects augment the case for joint ownership which may now boost the non-owners incentives as well as the owners. Halonen 2002 has an alternative explanation for joint ownership as the regime which in a repeated game framework, maximises the punishment for deviation from efficient investment..

[23] The circumstances where this applies to only one manager are given in footnote 3.

realistic case that cross effects are present, the GHM property that ownership motivates may extend to the case of outside options.

In the paper we have investigated the case in which investment enhances nonhuman asset value and shown how this implies that, even with outside options, it may be appropriate to give ownership to the party whose investment most influences team surplus. This allocation can also arise if, as is possible, investment *decreases* asset value. For example, in the skipper-chef story, investment could involve work on the keel of the boat which makes it faster but at the same time more likely to keel over without the expertise of the skipper. That is, the value of the asset is lowered by the investment. Making the chef the boat's owner then gives the skipper an excessive incentive to invest. The reason for giving ownership to the party with the investment decision is to prevent over investment.

The most basic claim of PRT is that ownership influences incentives and is distributed so as to maximise aggregate value added. Empirical work should therefore examine whether, when the importance of incentivising particular agents alters, so too does the ownership structure. Beyond this is the question of the direction of the effect. Some interesting evidence is provided by Baker and Hubbard (2002). They find that the advent of on-board computers diminishes the problem of incentivising truck drivers with the result that there are fewer owner drivers. This though begs the question of what benefit integration offers. The answer involves outside options. Truck ownership gives the driver an incentive to seek out opportunities to transport consignments for a variety of shippers. Indeed, it is privately profitable to divert resources into the establishment and enhancement of such outside options rather than improving the service to the eventual shipper. Integration, by eliminating this possibility, improves the efficiency of the drivers investment.[24] This benefit comes at a cost. The non-owning driver has less incentive to maintain the vehicle since such investments spillover almost entirely to the owner. So, even in the presence of outside options, ownership may, on balance be helpful for incentives. Trucking thus fits into our framework where ownership appears to be driven by the extent of the spillovers and on the presence of outside options. Ownership is least motivating in the absence of spillover effects and in the presence of outside options. As for the latter effect, experimental evidence that ownership is better for investment incentives when options are inside rather than outside is offered by Sonnemans, Oosterbeek, and Sloof (2001).

Which is the appropriate combination of assumptions requires case by case study. To illustrate, we sketch more generally how the ideas developed here may apply to whether an activity is undertaken in-house by employees rather than out-house by self-employed contractors.[25] The property-rights literature directs attention to the incentive effects of asset ownership. As often noted, in "people" businesses there may be few important capital inputs to own yet firms

[24] This mechanism whereby ownership induces inneficient investment in developing outside options, possible diverting relationship specific investment is discussed in de Meza and Lockwood (1998) and involves a minor reformulation of the present model.

[25] Serious discussion of these issues in began with Coase (1937)

still arise. We propose that the key asset to focus on is work in progress. What demarcates employees from the self employed is that they do not own their output. At first sight this implies that an employee is less protected against hold-up so has inferior investment incentives than does a self employed contractor. By threatening to sell output elsewere (a natural outside option) unless a satisfactory price is negotiated, the self-employed contractor seems able to capture a greater share of the value created. Nevertheless, it does not always follow that self employment sharpens the worker's incentives. The right to seize output may create a binding outside option for the employer, making the employee the residual income claimant. This potentially boosts worker incentives relative to self employment. What creates the ambiguity is that cross effects are intrinsic in this situation. Employee investment raises the employer's outside option, which depresses the employee's incentives. In contrast, the self-employed worker gains from investment to the extent that her outside option is raised. Application of our principal result shows that the marginal return to effort may then be greater for a self-employed contractor with a binding outside option. This occurs if the value of the outside option is relatively sensitive to investment and is high in comparison to team surplus, as is likely if the final product is sold in competitive markets.

That subcontracting is more likely to prevail in "thick" markets than in "thin" is not straightforward though. The specification of the contractors product may be a choice variable. Rather than tailoring the item to the needs of a particular user, in order to maximise her bargaining power, a subcontractor has an incentive to produce a generic product which can be sold to a range of customers. In thick markets with many alternative buyers there could therefore be more of a problem with subcontractors engaging in costly rent-seeking activities. It is precisely because employees have less bargaining power that they have more incentive to make relationship-specific investments.[26]

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[26] The most plausible avenue for employee rent seeking is to establish idiosyncratic production methods which a replacement worker cannot easily continue with.as in our overinvestment story. Such possibilities are not obviously related to the extent of product market competition.

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8 Appendix

Appendix A

In this Appendix, we present some sufficient conditions for a existence and uniqueness of a pure-strategy equilibrium in the investment game with outside options. Following De Meza and Lockwood, we classify outside options as *unproductive* if

$$\frac{\partial \pi^1}{\partial e_1} < \frac{R'(e_1)}{2},\ \frac{\partial \pi^2}{\partial e_2} < -\frac{C'(e_2)}{2},\ \text{all } e_1, e_2$$

and *productive* if the reverse conditions hold.

Note that in De Meza and Lockwood(1998), it is argued that a pure-strategy equilibrium, *if it exists*, in unique, but a proof is presented only for the case of unproductive outside options. So, this Appendix complements De Meza and Lockwood(1998) in two ways. First, it provides sufficient conditions for the *existence* of a pure-strategy equilibrium, and provides an explicit proof that these conditions are also sufficient for *uniqueness* of a pure strategy equilibrium in the case of productive outside options. The results are established for the model of this paper, which includes the model without cross-effects when $\lambda_1, \lambda_2 = 0$.

1. Productive outside options.

We provide an explicit proof only for the case of non-integration: the two cases of integrated ownership are both similar.[27] Throughout, we hold the asset ownership structure are fixed, and so suppress the assets as arguments of the various revenue and cost functions. Define

$$\frac{1}{2}R'(\underline{e}_1) = 1,\ -\frac{1}{2}C'(\underline{e}_2) = 1,\ r'(\overline{e}_1) = 1,\ -c'(\overline{e}_2) = 1$$

these are optimal investment levels for agents 1,2 when their outside options are not binding and when they are. Also, we can partition the space of feasible investment levels (e_1, e_2) i.e. $\Re^2_+$ into three sets: a set B_0 where neither outside option is binding, and sets B_1, B_2 where manager 1 or 2's outside option is binding. By A1, B_0 is always non-empty: either or both of B_1, B_2 may be empty. The most general case is where all three are non-empty, and it is this case that we deal with. Let the boundary of B_1 and B_0 be given[28] by the

[27] Under integration spillovers occur which potentially changes the slope of the regime boundary. Suppose manager one owns both machines. Consider the boundary between one's outside option binding and no binding outside option. An increase in $e_1$results in her outside option strictly binding. Were the boundary downward sloping the implication is that to offset the effect of one's extra investment e_2 must fall. This works if the marginal effect of e_2 is to boost one's outside option by more than double the boost in relationshipsurplus. Then, in the productive case, the double change in investment levels has raised outside options by more than the relationship surplus. The standard assumption is that investments are more productive in the relationship so if this is maintained, spillovers do not change the upward boundary slope. The argument then goes forward as in the non-integration case with the troublesome discontinuity in the response function being eliminated as there.

[28] These two functions are defined implicitly by the relations:

$$r(e_1) - c(\lambda_2 e_2) = \frac{R(e_1) - C(e_2)}{2},\ r(\lambda_1 e_1) - c(e_2) = \frac{R(e_1) - C(e_2)}{2}$$

function $b_1(e_2)$, and the boundary of B_2 and B_0 be given by the function $b_2(e_1)$. So, for any e_2, $(b_1(e_2), e_2)$ is a pair of investment levels for which 1's outside option just binds, and for any e_1, $(e_1, b_2(e_1))$ is a pair of investment levels for which 2's outside option just binds. A simple adaptation of the argument in de Meza and Lockwood(1998) indicates that $b_1(e) < b(e_2)$.

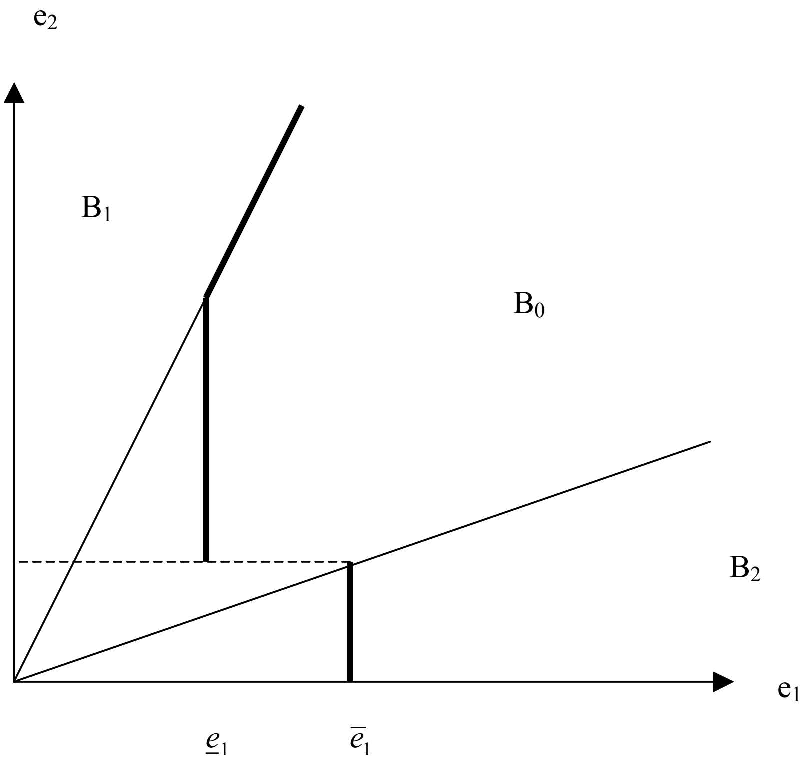
Then, it is possible to show that 1's reaction function is of the following form:

$$e_1 = g_1(e_2) = \begin{cases} b_2(e_2) & if \quad b_2(\underline{e}_1) \leq e_2 \\ \underline{e}_1 & if \quad b_1(\overline{e}_1) \leq e_2 < b_2(\underline{e}_1) \\ \overline{e}_1 & if \quad e_2 < b_1(\overline{e}_1) \end{cases}$$

That is, when $e_1 = \overline{e}_1$, 1's outside option is binding, and 1 is choosing optimal investment given that he gets his outside option payoff $r(e_1)$. When $e_1 = \underline{e}_1$, neither outside option is binding, and 1 is choosing optimal investment given that he gets half the surplus from joint production. Finally, when $b_1(\underline{e}_1) \leq e_2$, 1 would like to choose the level of investment given that he is residual claimant, i.e. which solves $1 = R'(e_1)$, but this larger level of investment would move the reaction function into region B_0 (or possibly B_1) where this reaction would no longer be optimal, and so 1's reaction function lies along the boundary between B_0 and B_2- for more discussion on this point, see De Meza and Lockwood(1998).

The following diagram shows g_1 where the bold line indicates the function:

Figure A1



Note the discontinuity at the point where $e_2 = b_2(\overline{e}_1)$. Agent 2's reaction function has an identical characterization, with the indices 1 and 2 permuted.

Note also that $b_1(.), b_2(.)$ are drawn upward-sloping, although with cross-effects, this is not necessarily the case.

Assume first the limit case where $r' = R'/2$ and $c' = C'/2$. Then $\overline{e}_1 = \underline{e}_1 = \hat{e}_1$, $\overline{e}_2 = \underline{e}_2 = \hat{e}_2$. It is then clear that neither reaction function g_1, g_2 has a discontinuity. So, it is easy to see that there exists a unique equilibrium. The following three cases shown below in Figure A2 are exhaustive, and in each case the equilibrium E is unique. Now perturb the revenue and cost functions slightly so that $r' > R'/2$ and $c' > C'/2$. Then, as long as $\overline{e}_i - \underline{e}_i$ is not too large, the discontinuities in the reaction functions do not generate additional equilibria.

Figure A2(i)

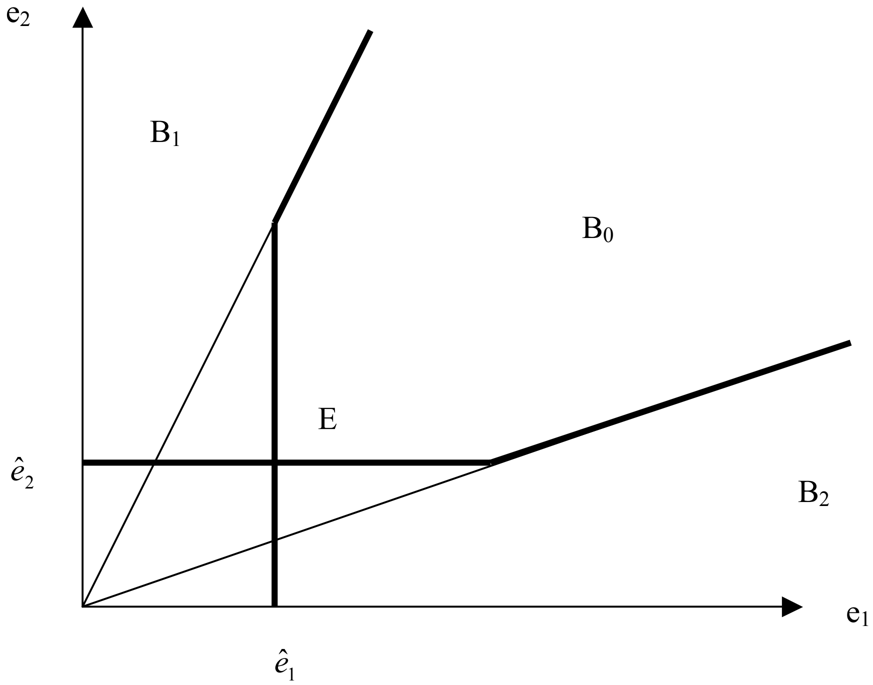


Figure A2(ii)

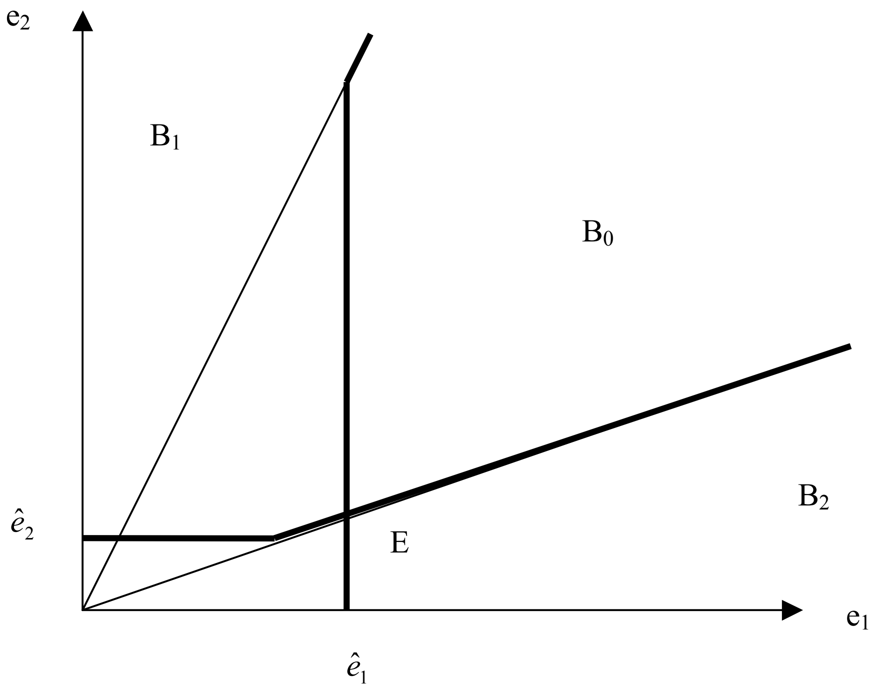
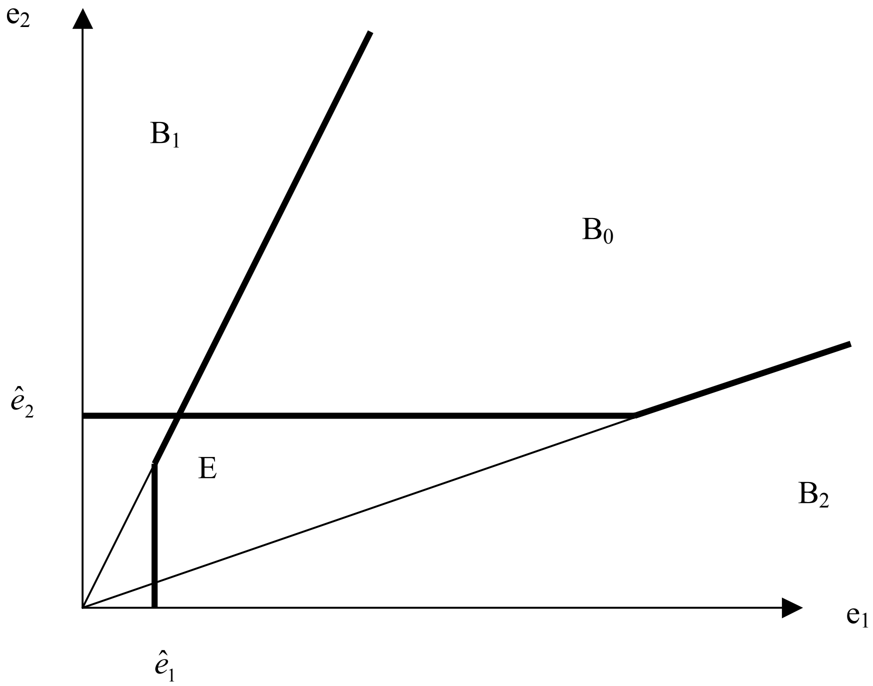


Figure A2(iii)



2. Unproductive outside options.

This case is dealt with extensively in De Meza and Lockwood(1998). As noted there (p.373), the investment space can be partitioned into at most two zones. If there are configurations in which one manager's outside option binds then it is impossible to find investment levels at which the other manager's outside option binds. There will though be investment levels at which neither option binds Once again, the assumptions of this paper means spillovers do not apply under non integration. By the argument of De Meza and Lockwood(1998), the equilibrium is always unique, and is a pure-strategy equilibrium except in the case where the reaction functions have the characteristics shown in Figure IIIc of the paper. So it suffices to state a condition that rules out that configuration. This configuration relies on the fact that (in the notation of the paper) $e_1 > \hat{e} > e_0$ Proceeding as before, assume first the limit case where $r' = R'/2$ eliminating the discontinuity in the response function thereby creating a unique equilibrium. Now perturb the revenue functions slightly so that $r' > R'/2$. Then, as long as $e_1 - e_0$ is not too large, the discontinuities in the reaction functions do not generate additional equilibria.

Turning to integration, the only new ingredient is whether, as a result of the spillover, the regime boundary is now upward sloping. This requires that to offset the effect of higher investment by manager one, which would otherwise render her outside option non binding, manager 2's investment must increase to offset this effect. Were this to be so, a higher investment by 2 boosts the outside option by more than relationship surplus. This though is contrary to the assumption of unproductive outside options.

Appendix B - An Example.

In this example, $R(e) = R_0 + \sqrt{e_1}$, $C(e) = C_0 - \sqrt{e_2}$, $r(e) = R_0 - \delta + \theta\sqrt{e_1}$, $\tilde{r}(e) = R_0 - \delta + \gamma\sqrt{e_1}$, $c(e) = C_0 + \delta - \theta\sqrt{e_2}$, $\tilde{c}(e) = C_0 + \delta - \gamma\sqrt{e_2}$, $\delta, \theta, \gamma > 0$, $1 > \theta > \gamma$ and finally, $\lambda_1 = \lambda_2 = \lambda$. Note that Assumptions 1-3 are certainly satisfied. Also, investment is relatively productive in the outside option if $\theta > 0.5$. Also, by the argument of Appendix A, pure-strategy equilibrium at the investment stage of the game exists and is unique if $\theta \simeq 0.5$. Finally, (**??**) and (**??**) are satisfied as $\theta > \gamma$.

Next, we show that if $\theta > 0.5$, and δ is small, Assumption 4 is satisfied i.e. with integrated ownership, the owner's outside option is binding for λ sufficiently close to 1. Suppose w.l.o.g. that 2 owns both assets. Then his outside option is binding for some *fixed* e_1, e_2 if

$$r(\lambda e_1) - c(e_2) > \frac{R(e_1) - C(e_2)}{2}$$

But this reduces to

$$R_0 - C_0 - 2\delta + \theta(\sqrt{\lambda e_1} + \sqrt{e_2}) > 0.5(R_0 - C_0) + 0.5(\sqrt{e_1} + \sqrt{e_2}) \qquad (15)$$

Now, assuming that it is binding, it is easy to check that the optimal investment levels are given by

$$e_1 = \frac{1}{4}(1 - \sqrt{\lambda}\theta)^2, \ e_2 = \frac{1}{4}\theta^2 \qquad (16)$$

So, substituting (16) back in (15), 2's outside option is binding in equilibrium if

$$R_0 - C_0 - 2\delta + 0.5\theta(\sqrt{\lambda}(1 - \sqrt{\lambda}\theta) + \theta) > 0.5(R_0 - C_0) + 0.25((1 - \sqrt{\lambda}\theta) + \theta)$$

which surely holds if $\delta \simeq 0$, and $\lambda \simeq 1$, as $\theta > 0.5$.

Finally, we show that for a range of spot prices, the outside options are not binding in equilibrium with non-integration, as required by Proposition 4. For some fixed e_1, e_2, outside options are not binding if

$$0.5(R_0 - C_0) + 0.5(\sqrt{e_1} + \sqrt{e_2}) \geq R_0 - \delta + \gamma\sqrt{e_1} - p, \ p - C_0 - \delta + \gamma\sqrt{e_2} \qquad (17)$$

If outside options are not binding in this case, it is easy to check that investment levels are $e_1 = e_2 = 1/16$. So, substituting these values back in (17), and rearranging, gives

$$0.5(R_0 + C_0) + \delta + \frac{(1 - \gamma)}{4} \geq p \geq 0.5(R_0 + C_0) - \delta - \frac{(1 - \gamma)}{4} \qquad (18)$$

So, if p is in the interval (18), then neither outside option is binding, as required. So, we conclude that all the hypotheses of Propositions 3 are satisfied for this example. □