WHY AREN'T THERE MORE R&D JOINT VENTURES?

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ABSTRACT. Why are there are not more R&D joint ventures? We provide an answer to this question based on two key ideas. The principal idea is that such ventures may diminish the power of a some firms in the product market. The second is that certain kinds of transaction costs are present, which do not allow for this deteriorating market power to be compensated for. We show that the larger the shift in the firms' *relative* market power following an R&D joint venture, the more likely it is that such (efficiency-enhancing) R&D joint ventures will not take be undertaken.
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1. INTRODUCTION

Research and Development (R&D) is a key engine of economic growth and development. Understanding the determinants of R&D is thus important for economic well-being. In many circumstances R&D joint ventures amongst two or more firms would comprise the best mechanism for undertaking R&D. Yet there is a paucity of such ventures. Why? In this paper we provide an answer to this question, an answer which uncovers a close connection between, on the one hand, the players' ex-ante product market powers and shifts in relative market power following an R&D joint venture, and, on the other hand, the absence of R&D joint ventures.

According to Milgrom and Roberts (1992), there are four basic approaches to explaining institutional organization: Marx explains organization as a reflection of underlying power relationships and class interest; the Harvard Industrial Organization approach can be summarized as explaining organization as an attempt to manipulate prices; the transactions cost approach associated with the work of Coase and Williamson sees organization as minimizing transactions costs; finally, the modern efficiency approach sees organization as the efficient choice for parties

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that can bargain effectively. The latter is based on an application of the Coase Theorem, which — for appropriate environments — applies value maximization. Milgrom and Roberts point out explicitly that it would be wrong to apply the Coase Theorem to many issues, since too many (all?) of its assumptions are violated in these cases.

The Coase Theorem, the reader may recall, states that if parties bargain to an efficient agreement (which requires effective bargaining, implementation, and enforcement) and if their preferences display no wealth effects (that is, are quasi-linear in money) then the value creating activities are allocated according to efficiency criteria only, and other factors such as bargaining power or asset ownership affect only how benefits and costs are shared. In other words, under frictionless conditions the parties choose efficient institutional arrangements (such as R&D joint ventures). Why then is there a paucity of such mutually beneficial collaborations? One of the many restrictive conditions of the Coase theorem must be violated. Most often the culprit is identified in some form of transactions cost, chiefly asymmetric information.

The explanation that we develop in this paper is also based upon the presence of certain kinds of frictions. Specifically, we consider situations in which firms are unable to make binding commitments, or, to put it differently, are unable to write enforceable (long-term) contracts. In addition, firms that gain relatively more from a R&D joint venture are wealth-constrained and unable to borrow the potentially large amounts of money required to compensate the firms who lose out from such a venture upfront. Our explanation builds on two key ideas. The principal idea is that a R&D joint venture may diminish the product market power of a key firm. The second is the one just described, namely the presence of the frictions stated above, which do not allow for this deteriorating market power to be compensated for.

The remainder of this paper is organized as follows. In the next section we develop our main point in the context of a simple set-up with two firms who are discussing whether or not to form a R&D joint venture. Then, in section 3, we develop our argument in an abstract setting which can be applied to the subject of R&D joint ventures in more general set-ups, but also to other areas. We conclude in section 4 by discussing some of those other areas and extensions of our argument.

2. THE ABSENCE OF R&D JOINT VENTURES: A NUMERICAL EXAMPLE

Consider the situation with two firms who compete in a product market. The firms may engage in R&D in order to improve their production technology (lower their unit costs.) R&D is lumpy (i.e., comes in discrete units) and there are dis-economies of R&D in the industry. Hence it would be efficient if there were joint R&D; yet, as we establish in this section, under standard assumptions the market leader may not wish to engage in a joint R&D venture.

The two firms face two separate issues: the R&D stage followed by the product market stage, and for legal reasons it may not be possible for them to agree on a product market sharing rule when they agree on the terms of the R&D joint venture. Also, the agreement on the R&D stage (in particular, if there is any agreement at all) will influence the situation in the subsequent product market, since joint R&D may imply that any initial technological advantages of one firm must be shared between the joint venture partners. Hence the initial leader may suffer a potential loss which cannot be compensated for, given the limitations on contracting (in particular, that no explicit market sharing rules may be contracted on, or, equivalently, no profit sharing agreements may be engaged in.)

Two firms are involved in a two stage game, in which they first invest in R&D effort and then compete in a product market (see, for example, Tirole (1989)). In the status quo, the firms conduct R&D independently and non-cooperatively, which is inefficient since there are dis-economies to R&D.

The second (product market competition) stage is modelled as follows. The two firms have constant marginal cost and are Bertrand (price) competitors in a homogeneous goods market. This assumption serves to allocate bargaining power to the low cost firm. Profit sharing agreements are illegal, but the firms may share the market. In order to convexify the payoff frontier it is assumed that the firms may share the market probabilistically, that is, each may be the monopolist with some probability.[1] The surplus from collusion is shared according to the Nash Bargaining Solution with the Betrand Nash Equilibrium payoffs as threat points.[2]

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[1] In many markets it is legal for a firm to withdraw from the market "voluntarily".

[2] The NBS is used for convenience only, similar results can be obtained using an alternating offers type bargaining game. We make the usual assumption that the Nash equilibrium of the Bertrand game for two firms with constant marginal costs involves the firms sharing the market at a price equal to their marginal costs, if marginal costs are equal. If marginal costs are unequal, the low cost firm will serve all of the market at the lower of its monopoly price or the high cost firm's marginal cost.

Suppose that market demand is linear, and that inverse demand is given by $P = 1 - Q$. The firms' marginal costs are $c_1, c_2 \in [0, 1)$. The monopoly prices for the firms are thus $p_i^m = (1 + c_i)/2$, with monopoly profits of $\pi_i^m = (1 - c_i)^2/4$. There are two cases to consider: equal marginal costs, and unequal marginal costs. In the first case the Nash equilibrium of the Bertrand price competition game will have each firm sell at the common marginal cost, and thus both firms have zero profits. The NBS for the collusion game then allocates the monopoly profits equally, and each firm will obtain a profit of $(1 - c_i)^2/8$.

In the second case, the low cost firm will serve all the market. Call the low cost firm Firm 1. Firm 2's cost are either above Firm 1's monopoly price, in which case Firm 1 simply is a monopolist, or below, in which case Firm 1 sells $1 - c_2$ units at a price of c_2. Since there is no surplus from product market collusion if firm 1 sells at its monopoly price we will focus on the second case. The Nash equilibrium for the Bertrand game therefore has payoffs for Firm 1 of $(c_2 - c_1)(1 - c_2)$. Firm 2 obtains zero in either case. The payoff frontier from collusion (allowing for randomization) is

$$\pi_2(\pi_1) = \frac{(1 - c_2)^2}{4} - \frac{(1 - c_2)^2}{(1 - c_1)^2}\pi_1.$$

In the Nash Bargaining Solution each player receives half of the surplus in excess of his disagreement payoff (inside option). It follows that the NBS for the collusion game has payoffs of:

$$(\pi_1, \pi_2) = \left(\frac{(1 - c_1)^2}{8} + \frac{(c_2 - c_1)(1 - c_2)}{2}, \frac{(1 - c_2)^2}{8} - \frac{(c_2 - c_1)(1 - c_2)^3}{2(1 - c_1)^2}\right)$$

In the first stage of the game the firms may invest in R&D which can lead to an innovation that reduces the marginal cost of production below the current lowest marginal cost. The probability of achieving such a breakthrough is independent of the initial marginal cost of the firm. Research comes in discrete lumps, each at a fixed cost of k. One may think of these as research laboratories. The success of any given laboratory is independent of the success of any other laboratory. Furthermore, the technology exhibits dis-economies, so that the probability of a successful innovation by any given laboratory is declining in the total number of laboratories in operation.[3]

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[3] We are thinking here of an unmodelled limited supply of suitable scientists.

In this first stage of the game the firms can either operate independently or cooperate on R&D. Cooperation on R&D is efficiency enhancing since it saves on the duplication of effort (investment cost) as well as internalizing the externality. We will focus on an equilibrium in which both firms operate one lab. Let p_2 denote the probability of success for a lab if two labs are in operation, and let c denote the new marginal cost from the drastic innovation, where $c < c_1 < c_2$. In order for the Bertrand equilibrium not to occur at the monopoly price we require that $2c_2 > 1 - c$, i.e., $c > 1 - 2c_2$. By computing the payoffs for both firms if they do invest, and comparing them to the payoff if they do not, we can find restrictions on the investment cost k for which it is an equilibrium for both firms to invest in one lab in the absence of collusion. For example, if $c = 0.25$, $c_1 = 0.3$, $c_2 = 0.4$, $k = 0.002$, and $p_2 = 0.2$ we get expected firm profits of 0.0850234 for the low cost firm and 0.0321484 for the high cost firm. Total expected industry profits in this equilibrium are therefore 0.117172.

Now suppose the firms were to cooperate on investment. Under the above parameters the equilibrium for the collusive R&D game will involve investment in one laboratory if $p_1 = 0.3$.[4]

The expected payoffs *before* investment costs are then 0.0849688 for the low cost firm and 0.0371652 for the high cost firm, for industry profits of 0.120134, net of the investment cost of $k = 0.002$. Cooperation thus is indeed joint profit maximizing.

However, no matter how the R&D expenditures are allocated, the firm with the initial low costs (Firm 1) will not find it in its interest to engage in joint R&D since its maximal expected profit of 0.0849688, obtained by not bearing any of the R&D costs, is less than the 0.0850234 it can achieve by refusing to cooperate.[5]

3. A SIMPLE MODEL

We now extend and generalize the main point made above. It is convenient to do so in an abstract setting. There are two players, 1 and 2, and two issues, X and Y. There is a status quo on both issues. The flow (per-period) payoff to player i

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[4] Of course, p_3 must be suitably chosen to make it optimal for there not to be three labs.

[5] Note that we need to assume that no side payments are possible at this stage. This is implied by our "transaction cost" assumption — discussed in the Introduction — that players are wealth-constrained and unable to borrow the required funds. Indeed, if, for example, firm 1 could charge firm 2 a licensing fee or some other device to transfer cash in the initial stage, an equilibrium in which both firms agree to cooperate will exist.

($i = 1, 2$) in the status quo from issue k ($k = X, Y$) is z_i^k. Thus, the total (flow) payoff to player i in the status quo is $d_i = z_i^X + z_i^Y$.

There exists a productivity-enhancing institutional arrangement (eg., a R&D joint venture) relating to issue X. If implemented, then the players' joint (flow) payoff would be m^X, where $m^X > z_1^X + z_2^X$. Therefore, at *date 0*, they decide whether or not to initiate negotiations aimed at implementing this arrangement. If one player refuses to negotiate, then the inefficient status quo remains in place, and the game ends. But if both agree to negotiate, then bargaining takes place at *date 1*.

During the negotiations at date 1, the status quo is in the place, and hence until agreement is reached the players receive their respective status quo payoffs, d_1 and d_2. The players are negotiating over the partition of the aggregate surplus m^X. If agreement is reached with player 1 obtaining a share x and player 2 a share $m^X - x$, then negotiations are completed, and the productivity-enhancing institutional arrangement is implemented.

We now come to the key aspect of our model: As a result of this institutional arrangement, the players' relative bargaining power on the other issue, Y, may alter. This is formalized by changes to the players' respective flow payoffs from issue Y: player i's flow payoff from issue Y is no longer z_i^Y, but it is instead $f_i(x)$.[6] Hence the total flow payoffs to players 1 and 2 after the date 1 negotiations are completed are respectively

$$V_1 = x + f_1(x) \quad \text{and} \quad V_2 = m^X - x + f_2(x).$$

We now come to the final element of our model. At this juncture, after the implementation of the institutional arrangement on issue X and the subsequent change in relative bargaining power on issue Y, the players now have an opportunity to conduct an arrangement (eg., product market collusive arrangement) in connection with issue Y that will create a larger joint (flow) payoff, m^Y, where $m^Y > f_1(x) + f_2(x)$ (for all x). It is also assumed that $m^Y > z_1^Y + z_2^Y$.

Hence, at *date 2*, the players negotiate over the partition of a surplus of size m^Y. If agreement is reached with player 1 obtaining a share y and player 2 a share $m^Y - y$, then the total flow payoffs from then onwards to players 1 and 2 are respectively

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[6] Notice that we allow for this change in i's flow payoff from issue Y to be sensitive to the outcome of the date 1 negotiations. However, we make no assumptions, for the time being, on this function f_i.

$x + y$ and $m^X - x + m^Y - y$. Until such an agreement, however, they receive their respective (newly established status quo) flow payoffs, V_1 and V_2, respectively.

We adopt the Nash bargaining solution to describe the outcome of each set of negotiations, where the manner in which we apply this bargaining solution is informed by non-cooperative bargaining theory (as discussed, for example, in Muthoo, 1999). This completes the description of our model. The model is a three-stage game. It is assumed that the game is one with complete information, which means in particular that all the parameters of the game are common knowledge between the players.

Using "backward induction" to characterize the (subgame perfect) equilibria of the three stage game, we begin by characterizing the outcome of the second set of negotiations conditional on an arbitrary outcome in the first. Thus, suppose that at date 0 the players agree to negotiate, and that at date 1 an agreement is struck over issue X on an arbitrary partition $(x, m^X - x)$. Now consider the second set of negotiations, over issue Y, at date 2. Applying the Nash bargaining solution, it follows that the players will reach agreement over issue Y, and the total flow payoffs to players 1 and 2 can be written as follows:

$$P_1(x) = x + \left[f_1(x) + \frac{1}{2}\left[m^Y - f_1(x) - f_2(x) \right] \right] \tag{1}$$

$$P_2(x) = [m^X - x] + \left[f_2(x) + \frac{1}{2}\left[m^Y - f_1(x) - f_2(x) \right] \right], \tag{2}$$

where, in each of these expressions, the first term is a player's (currently arbitrary) flow payoff from issue X, and the term inside the big brackets is his Nash-bargained flow payoff from issue Y.[7]

It follows that during the negotiations conducted over issue X, at date 1, the flow equilibrium payoffs to players 1 and 2 from reaching agreement on an arbitrary partition $(x, m^X - x)$ are respectively $P_1(x)$ and $P_2(x)$. Clearly, an agreement x on issue X not only determines a player's payoff from issue X, but also has a strategic effect on the player's Nash bargained payoff from issue Y.

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[7] The latter is the sum of the player's newly established status quo payoff from issue Y (following the implementation of the agreement on issue X) and one-half of the net surplus from issue Y.

4. EQUILIBRIUM INEFFICIENT INSTITUTIONAL ARRANGEMENTS

We begin by deriving the conditions under which in equilibrium at least one player refuses to negotiate at date 0 if and only if the parameters satisfy these conditions. Thus, when these conditions hold, the inefficient status quo remains in place; but not otherwise. We then analyze these conditions in order to derive our main results about the persistence (or otherwise) of inefficient institutional arrangements.

4.1. **The Inefficiency Conditions.**

Notice that for issue X, in isolation, player preferences are monotonic in x: more x means more of the surplus for player 1 and less for player 2. What about the equilibrium payoffs $P_1(x)$ and $P_2(x)$? Assuming, for expositional simplicity, that f_i $(i = 1, 2)$ is differentiable, it follows that monotonicity of $P_1(x)$ in x requires that

$$1 + f_1'(x) - \frac{1}{2}[f_1'(x) + f_2'(x)] > 0.$$

The interpretation of this inequality is that the utility gains from an increase in x (the 1) cannot be dominated by a potential loss in equilibrium payoff on issue Y that is caused by the change in the status quo payoffs. Similarly for player 2, monotonicity of $P_2(x)$ in x requires that

$$-1 + f_2'(x) - \frac{1}{2}[f_1'(x) + f_2'(x)] < 0.$$

Hence, both players' equilibrium payoffs are *monotonic* if and only if

$$1 > \frac{1}{2}[f_2'(x) - f_1'(x)] \quad \text{for any} \quad x \in [0, m^X]. \tag{3}$$

Under the monotonicity assumption (i.e., when inequality 3 holds), negotiations over the surplus-enhancing institutional change relating to issue X will not commence in equilibrium if and only if at least one player's total flow payoff from the status quo exceeds the maximal possible payoff he could get from the bargain; that is, either $P_1(m^X) < z_1^X + z_1^Y$ or $P_2(0) < z_2^X + z_2^Y$. Using (1) and (2), and re-arranging terms, we obtain

$$m^X + \frac{1}{2}\left[m^Y + f_1(m^X) - f_2(m^X)\right] < z_1^X + z_1^Y \tag{4}$$

$$m^X + \frac{1}{2}\left[m^Y - f_1(0) + f_2(0)\right] < z_2^X + z_2^Y. \tag{5}$$

Define for each $x \in [0, m^X]$,

$$\Delta(x) = [f_2(x) - f_1(x)]/2.$$

The value of $\Delta(x)$ is a measure of the degree of inequality in the players' ex-post bargaining powers: i.e., the advantage of player 2 over player 1 in the bargain on issue Y after the implementation of the productivity-enhancing institutional arrangement relating to issue X.[8] We can thus rewrite the above as

$$m^X + \frac{1}{2}m^Y - d_1 \quad < \quad \Delta(m^X) \tag{6}$$

$$m^X + \frac{1}{2}m^Y - d_2 \quad < \quad -\Delta(0), \tag{7}$$

where $d_i = z_i^X + z_i^Y$. Inequalities 6 and 7 have an easy interpretation. The right-hand side is a player's loss in bargaining power over the subsequent issue, evaluated at that player's maximally possible payoff. The left-hand sides are the maximal payoff gains possible if there were no second stage status quo payoffs. If, then, a player's loss in second stage bargaining power exceeds his maximal gain in a game without such bargaining power differences, the player will refuse to negotiate. To summarize, we have established the following result:

Lemma 1 (Inefficiency Conditions under Monotonicity)**.** *Assume that the functions f_1 and f_2 satisfy inequality 3. Then, in equilibrium, at least one of the players will refuse to negotiate at date 0 (and the inefficient status quo remains in place) if and only if either inequality 6 or inequality 7 is satisfied.*

Thus, under the monotonicity assumption, if neither inequality 6 nor inequality 7 holds then the players will agree to negotiate at date 0 and the surplus-enhancing institutional change takes place. But if either one of these two inequalities holds, then at least one player will refuse to negotiate, and the inefficient status quo remains in place.

Notice that we don't really need monotonicity — all it does is to ensure that player 1's equilibrium payoff $P_1(x)$ is maximized at $x = m^X$ and player 2's equilibrium payoff $P_1(x)$ is maximized at $x = 0$. So, in the absence of monotonicity, define $\overline{x}$ and $\underline{x}$ respectively to be the supremum and infimum of $\{x \in [0, m^X]$:

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[8] Recall from above that the Nash bargaining solution on Y allocates $\left[m^Y + f_1(x) - f_2(x)\right]/2 = m^Y/2 - \Delta(x)$ to player 1, and $\left[m^Y - f_1(x) + f_2(x)\right]/2 = m^Y/2 + \Delta(x)$ to player 2.

$P_1(x)\}$ and $\{x \in [0, m^X] : P_2(x)\}$ — which exist since the functions P_1 and P_2 are bounded. At least one player will refuse to negotiate at date 0 if and only if either $P_1(\overline{x}) < z_1^X + z_1^Y$ or $P_2(\underline{x}) < z_2^X + z_2^Y$; that is, if and only if one of the following inequalities holds:

$$\overline{x} + \frac{1}{2}m^Y - d_1 \quad < \quad \Delta(\overline{x}), \tag{8}$$

$$\left(m^X - \underline{x}\right) + \frac{1}{2}m^Y - d_2 \quad < \quad -\Delta(\underline{x}). \tag{9}$$

Hence, we have the following more general characterization result:[9]

Lemma 2 (General Inefficiency Conditions). *In equilibrium, at least one of the players will refuse to negotiate at date 0 (and the inefficient status quo remains in place) if and only if either inequality 8 or inequality 9 is satisfied.*

When will the conditions in these propositions be satisfied? We now turn to an exploration of this question in order to determine which environments lead to these results. There are, fundamentally, three avenues which could contribute: the role of bargaining power itself, both ex-ante and ex-post; the size of the efficiency gains ($m^X + m^Y - d_1 - d_2$); and the change (or shift) in relative bargaining power on issue Y following implementation of the institutional arrangement on issue X.

On the latter point, it is easy to verify (as a preliminary observation) that if $f_i(x) = z_i^Y$ for all $x \in [0, m^X]$ and all $i = 1, 2$, then neither inequality 8 nor inequality 9 are satisfied. That is, in the (benchmark) case where there are no shifts, or changes, in bargaining power on issue Y (following agreement on issue X), the players will negotiate an agreement on issue X (and then on issue Y), and hence the productivity-enhancing institutional arrangement on X is implemented, and the inefficient status quo is replaced by an efficient arrangement and outcome. Indeed, this result is valid for any initial distribution of bargaining power, as reflected in the status quo. We state this result in the following:

Proposition 1. *For any ex-ante distribution of bargaining power, some shift in the players' relative bargaining power is necessary for the persistence of inefficient institutional arrangements.*

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[9] This derivation did not use continuity of f_i either, and so also covers the case where the bargaining power on the second issue may jump or flip at certain critical values of the first.

4.2. Equal Bargaining Powers.

Consider, first, the benchmark case of perfect equality in both ex-ante and ex-post bargaining powers. That is, the case in which (i) for $k = X, Y$, $z^k_1 = z^k_2$, and (ii) for any $x \in [0, m^X]$, $f_1(x) = f_2(x)$. The latter implies that $\Delta(x) = 0$ for all $x \in [0, m^X]$. For these parameter values inequality 3 holds and thus Proposition 1 is applicable. Letting the identical inside option over issue k be denoted by z^k, and the identical new inside option on issue Y be denoted by the function f, it is easy to verify that both Inequalities 6 and 7 then collapse to

$$m^X + \frac{1}{2}m^Y - z^X - z^Y < 0$$

which cannot hold (since, by assumption, $m^k > 2z^k$ for $k = X, Y$). Hence, we have established the following result:

Proposition 2. *If the players have equal ex-ante bargaining powers and equal ex-post bargaining powers, then, in equilibrium, agreement is reached over both issues, and the inefficient status quo is replaced by an efficient outcome.*

Perhaps not surprisingly, in an environment in which players are symmetrically placed — that is, have equal bargaining power in the inefficient status quo and would continue to have equal bargaining power after reaching agreement over issue X but before reaching agreement over issue Y — each of them has an incentive to get rid of the inefficient status quo and benefit from the efficiency-enhancing institutional change. Notice that this conclusion holds even if the players' ex-post inside options are adversely (or positively) affected by the agreement on X, provided that they are affected in an identical manner — preserving the relative bargaining powers of the players. Also note that the size of the possible efficiency gains does not matter here. Furthermore, the presence of the transaction costs are immaterial. Despite the limits on contracting and the wealth constraint, the inefficient institution is replaced.

An important implication of Proposition 2 is that inequality in the players' bargaining powers is necessary for the persistence of inefficient institutions, an insight that we now explore in more depth.

4.3. Unequal Bargaining Powers.

We begin the analysis of the general case of unequal bargaining powers by first studying the special case in which the players' ex-ante bargaining powers are unequal, but their ex-post bargaining powers are equal. That is, the case in which for any $x \in [0, m^X]$, $f_1(x) = f_2(x) = f(x)$. This

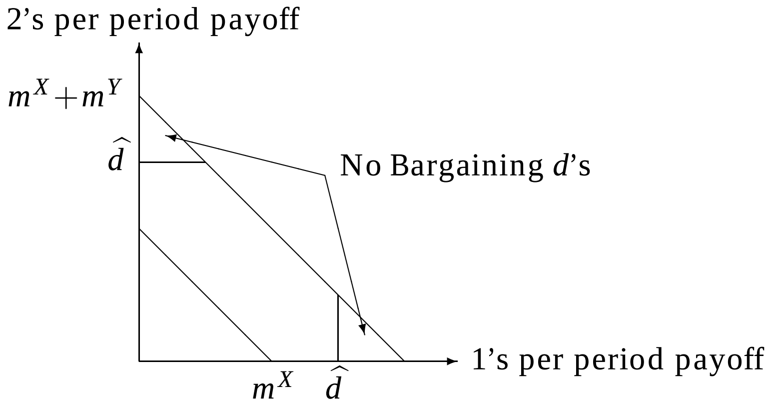

FIGURE 1. Illustration of Corollary 2

special case is the (approximately) relevant case for many real-life situations (such as the land redistribution situation) in which (i) there is a relatively large degree of inequality in the players' ex-ante bargaining powers, and (ii) the institutional change implied by an agreement over issue X eliminates (or significantly reduces) the inequality in bargaining power over issue Y. As such this special case may be of some interest in its own right, besides being instructive. In fact, as we shall show, the main qualitative results and insights obtained in this special case carry over to the general case of unequal ex-ante and unequal ex-post bargaining powers.

4.3.1. *Equal ex-post, but unequal ex-ante bargaining powers.* For any $x \in [0, m^X]$, let $f_1(x) = f_2(x) = f(x)$, which implies that $\Delta(x) = 0$. Recall that we defined, for each $i = 1, 2$,

$$d_i = z_i^X + z_i^Y,$$

which can be interpreted as a measure of player i's aggregate ex-ante bargaining power. Inequality in the players' aggregate ex-ante bargaining powers can be plausibly measured by, or interpreted as, the "distance" between d_1 and d_2 — defined, for example, by the absolute value of the difference between d_1 and d_2.

In this special case under consideration, inequality 3 holds, and thus Proposition 1 is applicable. It is easy to verify that inequality 6 and 7 respectively become:

$$m^X + \frac{1}{2}m^Y - d_1 < 0, \tag{10}$$

$$m^X + \frac{1}{2}m^Y - d_2 < 0. \tag{11}$$

Since the sum of the left-hand sides of these two inequalities exceeds zero (by assumption), both of them cannot hold. This implies that in equilibrium at most one player would refuse to bargain. Denoting, for notational convenience, $\widehat{d} = m^X + m^Y/2$, we have established that if, for some $i = 1, 2$, $d_i > \widehat{d}$, then player i would refuse to bargain; and moreover, $d_j < m^Y/2$ ($j \neq i$) — since (by assumption) $d_1 + d_2 < m^X + m^Y$. This analysis implies that for any pair $d = (d_1, d_2)$ in the indicated regions of Figure 1, there will be no negotiations in equilibrium (and the inefficient status quo remains in place). In summary, we have established the following result:

Proposition 3. *Assume that the players have equal ex-post bargaining powers, but have unequal ex-ante bargaining powers. Then, in equilibrium, negotiations do not commence and the inefficient status quo remains in place if and only if the degree of inequality in the players' aggregate ex-ante bargaining powers is sufficiently large.*

The intuition behind this result comes from noting that when there is a sufficiently large degree of inequality in the players' aggregate ex-ante bargaining powers, an agreement on issue X would destroy the ex-ante bargaining power advantage of one player (given the hypothesis of Proposition 3 of equal ex-post bargaining powers), and thus that player has an incentive to refuse to bargain.

It should be noted that Proposition 3 shows that what matters for the question at stake are the players' aggregate ex-ante bargaining powers (as defined by d_1 and d_2). A player's ex-ante bargaining powers over individual issues matter only to the extent that they determine his aggregate ex-ante bargaining power. For example, if player 1 has most of the ex-ante bargaining power over issue X (i.e., $z_1^X >> z_2^X$), while the opposite is the case over issue Y (i.e., $z_1^Y << z_2^Y$), then whether or not the efficient outcome obtains depends on the relative magnitudes of their aggregate ex-ante bargaining powers. If d_1 and d_2 are close to each other (which may happen in this example), then it follows from Corollary 2 that the players would negotiate, and the inefficient status quo would be replaced by an efficient outcome.

However, in some situations (such as in the land redistribution situation), a player who has most of the bargaining power over one issue may well have most of the bargaining power on the other issue as well. In that situation, the degree of inequality in the players' aggregate ex-ante bargaining powers will be large, and may well be large enough to induce the inefficient outcome.

A key message of Corollary 2 is as follows: a small degree of inequality in the players' aggregate ex-ante bargaining powers is conducive for efficient institutional change, but not a large degree of such inequality; in that case, inefficient institutional arrangements are likely to persist.

What role, if any, do the other parameters have? First, notice that the players' equal (by hypothesis) ex-post bargaining powers have no role to play on whether or not, in equilibrium, negotiations would commence. This is formally implied by the fact that the function f does not appear in inequalities 10 and 11. The intuition for this result comes from the observation that the players' incentives on whether or not to negotiate are influenced by the relative magnitudes of their respective ex-post bargaining powers. If they are equal, then, irrespective of the absolute magnitude of this common ex-post bargaining power, it has no role on incentives to bargain.

Finally, note the fairly intuitive but important result — which is immediate from the above analysis — that, the larger are the efficiency gains associated with institutional change the more likely it is that such change will take place. In other words, even with a large ex-ante bargaining power advantage for one party, which does get lost in negotiations, if there is enough of a payoff to redistribute, the party will come to the table. This suggests, for example, that in order to promote efficiency-enhancing institutional change ways should be found to enhance the associated gains from such change.

4.3.2. *Unequal ex-post and unequal ex-ante bargaining powers.* Here we impose no restrictions on the parameters. As such we apply the characterization result stated in Proposition 2 and investigate 8 and 9, restated here for convenience.

$$\begin{aligned} \overline{x} + \frac{1}{2}m^Y - d_1 &< \Delta(\overline{x}), \\ (m^X - \underline{x}) + \frac{1}{2}m^Y - d_2 &< -\Delta(\underline{x}). \end{aligned}$$

It follows immediately from these inequalities that if $\Delta(\overline{x})$ is sufficiently large then player 1 would refuse to bargain, and if $\Delta(\underline{x})$ is sufficiently small then player 2 would refuse to bargain. This is not surprising. If under the best possible scenario for player 1 (namely, when $x = \overline{x}$) his ex-post bargaining power is significantly smaller than that of player 2 (i.e., $\Delta(\overline{x})$ sufficiently large), then he would have no incentive to bargain. Symmetrically for player 2. An implication of these observations is that if, for all $x \in [0, m^X]$, the absolute value of $\Delta(x)$ is sufficiently large, then at least one of the above inequalities would hold, and thus at least one of the players would refuse to bargain. We state this result in the following:

Proposition 4. *Fix the players' (potentially unequal) ex-ante bargaining powers. If the degree of inequality in the players' ex-post bargaining powers is sufficiently large, then, in equilibrium, negotiations don't commence and the inefficient status quo remains in place.*

On the other hand, if the degree of inequality in the players' ex-post bargaining powers is sufficiently small, then Proposition 3 applies. Again note that the size of efficiency gains plays a role in this, and the larger the gains the more likely is change. In the above this can be seen by the fact that the left hand side of the inequalities is decreasing in the ex-ante disagreement payoffs of the players.

As a final check on the role of changing bargaining power versus asymmetric bargaining power, consider the monotonic case with equal *ex ante* power (hence $d_1 = d_2 \equiv d$) but unequal *ex post* power. Inequalities 6 and 7 then become

$$\begin{aligned} m^X + \frac{1}{2}m^Y - d &< \Delta(1), \\ m^X + \frac{1}{2}m^Y - d &< -\Delta(0). \end{aligned}$$

Since $\Delta(\cdot)$ is bounded in absolute value by $m^Y/2$ while d is bounded above by $(m^X + m^Y)/2$ by assumption, the LHS of these inequalities is greater than $m^X/2$. It follows that the status quo will likely be changed in this situation if the initial issue is large relative to the second issue. If, however, the initial issue is small compared to the second issue, and the bargaining power in the second issue moves significantly against a player, then that player will not want to negotiate.

A central message of our analysis can be put as follows. A small degree of inequality in the players' bargaining powers — both ex-ante and ex-post — is conducive for efficient institutional change, but not a large degree of such inequality. If the degree of inequality of either their ex-ante or their ex-post bargaining powers is sufficiently large, then inefficient institutions are likely to persist. Furthermore, the larger are the gains in efficiency compared to the differences in bargaining powers, the more likely is institutional change.

5. CONCLUDING REMARKS

There is a close connection between, on the one hand, inequality in bargaining (or market) power, shifts in relative bargaining power and the persistence of inefficient institutional arrangements (eg. absence of R&D joint ventures).[10] In particular, we unearthed a positive relationship between the degree of such inequality and the likelihood of the persistence of inefficient institutional arrangements, and between the latter and shifts in relative power following a productivity-enhancing institutional arrangement.

APPENDIX: OMITTED COMPUTATIONS OF THE NUMERICAL EXAMPLE OF SECTION 2

The low cost firm's expected payoffs in the non-cooperative R&D game with both firms investing in one laboratory are

$$\begin{aligned} -k \quad + & \quad p_2^2 \frac{(1-c)^2}{8} + (1-p_2)^2 \left(\frac{(1-c_1)^2}{8} + \frac{(c_2-c_1)(1-c_2)}{2} \right) \\ + & \quad p_2(1-p_2) \left(\frac{(1-c)^2}{8} + \frac{(c_2-c)(1-c_2)}{2} \right) \\ + & \quad p_2(1-p_2) \left(\frac{(1-c_1)^2}{8} - \frac{(c_1-c)(1-c_1)^3}{2(1-c)^2} \right) \end{aligned}$$

Note that no investment in R&D by the low cost firm would lead to expected profits of

$$\begin{aligned} & (1-p_2) \left(\frac{(1-c_1)^2}{8} + \frac{(c_2-c_1)(1-c_2)}{2} \right) \\ & +p_2 \left(\frac{(1-c_1)^2}{8} - \frac{(c_1-c)(1-c_1)^3}{2(1-c)^2} \right) \end{aligned}$$

so that investing is optimal if

$$\begin{aligned} k \quad < & \quad p_2^2 \frac{(1-c)^2}{8} - p_2(1-p_2) \left(\frac{(1-c_1)^2}{8} + \frac{(c_2-c_1)(1-c_2)}{2} \right) \\ + & \quad p_2(1-p_2) \left(\frac{(1-c)^2}{8} + \frac{(c_2-c)(1-c_2)}{2} \right) \\ - & \quad p_2^2 \left(\frac{(1-c_1)^2}{8} - \frac{(c_1-c)(1-c_1)^3}{2(1-c)^2} \right) \end{aligned}$$

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[10] Of course, as we discussed and as is captured in our model, this connection is possible by the presence of various kinds of frictions (or transaction costs); for otherwise Coase's Theorem applies, and efficiency would be compatible with unequal and shifting bargaining powers.

or

$$\begin{aligned} k &< p_2\frac{(1-c)^2}{8} - p_2\frac{(1-c_1)^2}{8} - p_2(1-p_2)\frac{(c_2-c_1)(1-c_2)}{2} \\ &+ p_2(1-p_2)\frac{(c_2-c)(1-c_2)}{2} + p_2^2\frac{(c_1-c)(1-c_1)^3}{2(1-c)^2}. \end{aligned}$$

Similarly, the high cost firm will have payoffs of

$$\begin{aligned} -k &+ p_2^2\frac{(1-c)^2}{8} + (1-p_2)^2\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c_1)(1-c_2)^3}{2(1-c_1)^2}\right) \\ &+ p_2(1-p_2)\left(\frac{(1-c)^2}{8} + \frac{(c_1-c)(1-c_1)}{2}\right) \\ &+ p_2(1-p_2)\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c)(1-c_2)^3}{2(1-c)^2}\right) \end{aligned}$$

if investing, and

$$\begin{aligned} &(1-p_2)\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c_1)(1-c_2)^3}{2(1-c_1)^2}\right) \\ &+p_2\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c)(1-c_2)^3}{2(1-c)^2}\right) \end{aligned}$$

if not. Thus investment requires that

$$\begin{aligned} k &< p_2^2\frac{(1-c)^2}{8} - p_2(1-p_2)\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c_1)(1-c_2)^3}{2(1-c_1)^2}\right) \\ &+ p_2(1-p_2)\left(\frac{(1-c)^2}{8} + \frac{(c_1-c)(1-c_1)}{2}\right) \\ &- p_2^2\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c)(1-c_2)^3}{2(1-c)^2}\right) \end{aligned}$$

or

$$\begin{aligned} k &< p_2\frac{(1-c)^2}{8} - p_2\frac{(1-c_2)^2}{8} + p_2(1-p_2)\frac{(c_2-c_1)(1-c_2)^3}{2(1-c_1)^2} \\ &+ p_2(1-p_2)\frac{(c_1-c)(1-c_1)}{2} + p_2^2\frac{(c_2-c)(1-c_2)^3}{2(1-c)^2}. \end{aligned}$$

Now consider the cooperative investment game. If they operate n labs they will fail to get the innovation with probability $(1-p(n))^n$. Otherwise they get it. Expected payoffs before allocation of costs then are

$$(1-(1-p(n))^n)\frac{(1-c)^2}{8} + (1-p(n))^n\left(\frac{(1-c_1)^2}{8} + \frac{(c_2-c_1)(1-c_2)}{2}\right)$$

for the low cost firm and

$$(1-(1-p(n))^n)\frac{(1-c)^2}{8} + (1-p(n))^n\left(\frac{(1-c_2)^2}{8} - \frac{(c_2-c_1)(1-c_2)^2}{2(1-c_1)^2}\right)$$

for the high cost firm.

Suppose for the moment that it is optimal to invest in only one lab jointly. That means that parameters are such that

$$\begin{aligned}
&(1-p(1)-(1-p_2)^2)\frac{(1-c)^2}{4} \\
&+ \quad ((1-p_2)^2-(1-p(1)))\left(\frac{(1-c_1)^2}{8}+\frac{(c_2-c_1)(1-c_2)}{2}\right) \\
&+ \quad ((1-p_2)^2-(1-p(1)))\left(\frac{(1-c_2)^2}{8}-\frac{(c_2-c_1)(1-c_2)^2}{2(1-c_1)^2}\right) < k.
\end{aligned}$$

The low cost firm would never agree to a joint investment if, even if the high cost firm were to pay all costs, the low cost firm's payoff is lower than without cooperation, that is,

$$p(1)\frac{(1-c)^2}{8}+(1-p(1))\left(\frac{(1-c_1)^2}{8}+\frac{(c_2-c_1)(1-c_2)}{2}\right)$$

less than

$$\begin{aligned}
-k \quad &+ \quad p_2^2\frac{(1-c)^2}{8}+(1-p_2)^2\left(\frac{(1-c_1)^2}{8}+\frac{(c_2-c_1)(1-c_2)}{2}\right) \\
&+ \quad p_2(1-p_2)\left(\frac{(1-c)^2}{8}+\frac{(c_2-c)(1-c_2)}{2}\right) \\
&+ \quad p_2(1-p_2)\left(\frac{(1-c_1)^2}{8}-\frac{(c_1-c)(1-c_1)^3}{2(1-c)^2}\right)
\end{aligned}$$

This requires that

$$\begin{aligned}
k < (p(1)-p_2)&\frac{4c_2-6c_1+2c+c_1^2-c^2-4c_2^2+4c_1c_2}{8} \\
- \quad p_2(1-p_2)&\frac{(c_1-c)(1-c_1)^3}{2(1-c)^2}.
\end{aligned}$$

The question now is if we can find a parametrization for which all these conditions hold, so that it is an equilibrium for both firms to invest if they do not cooperate, that it is efficient to invest in one lab jointly, but that Firm 1 will refuse to bargain on this.

The following values will work: $c = 0.25$, $c_1 = 0.3$, $c_2 = 0.4$, $k = 0.002$, $p(1) = 0.3$, $p_2 = 0.2$, and $p(3)$ can be determined to make it optimal for firms to only choose 1 lab.

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