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"Collusive Agreements in A Cooperative Setting"

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Contents

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Introduction

This work investigates the profitability of four types of collusive integration by which two players pool their research activities. The parties can either integrate all their assets (merger) or pool their complementary R&D sectors. In this case, the contract gives rise to a Research Joint Venture (RJV) whose control can be assigned to one of the parents (dominant parent), to both them (joint ownership) or to an independent board (independent target). We study the bargaining effects of these contracts in a cooperative game solved by an asymmetric random order value. Different types of complementarities are considered: two players can be either complements or substitutes with respect to all their assets or to only a share of them. Advantages from integration depend on which of these settings is used and, much more, on the ownership structure that parties choose. Thus, we provide profitability conditions for various complementarity relationships between contracting parties and third players. In our model we also include the players' bargaining abilities by using a path value. This is a solution concept in which the bargaining attitudes of players affect the probabilities of coalitions and the strategic effects of integration. Depending on the colluding players' abilities, the joint profits may increase or decrease. The work is organized as follows. In chapter one we present the basic model and the solution concept that will be adopted to analyze the integration contracts profitability. In chapter two we define the assets complementarity as their ability, once combined together, in reducing the total production costs and increasing the players' efficiency level. Profitability conditions are provided for those collusive contracts in which players have the same technological relationships.

In chapter three we split the players' assets into different sets, complementary and substitutable, and then we explore the effect of these partial complementarities on the bargaining among players. Moreover, we solve the bargaining game by using an asymmetric value. This allows to evaluate the integration profitability in the presence of different players' complementarities and individual bargaining abilities. The final conclusions offer a synthesis of the main results.

Part I

A cooperative game approach to the collusive agreements

Chapter 1

R&D integration contracts in a cooperative setting

1.1 Recent developments on collusive R&D contracts

The Research Joint Ventures (RJVs) belong to a wider class of cooperative agreements called "strategic alliances". One common view looks at these contracts as agreements whereby two or more agents commit to reach a common goal by a pool of their resources and coordinating their activities. In practice, vast majority of alliances involve high technology sectors, that is why economists very often named this set of agreements "strategic technology alliances", where a prominent role is played by the research in new technical advances (Dodgson, 1993). A neoclassical perspective on JVs, interprets the JV formation as a phenomenon which is strictly related to transaction costs and the contract incompleteness. The transaction costs stem from the human behavior (opportunism and bounded rationality) and the constituent elements of transactions, mainly the asset specificity (Williamson 1975, 1985; Hart and Holmstrom, 1987). It is particularly true for the intangible assets, such as technological knowledge and workers know-how, which represent the main source of spillovers (e.g., Jaffe 1996).

In such a context, cooperative agreements aim at reducing all transaction costs by establishing organizational forms where potential rivalry is transformed into profitable partnership. However, these contracts have an impact on the bargaining power with third parties. Under this point of view, the integration is profitable if provides positive strategic effects in the bargaining process with third parties, especially if increases the integrated parties' ability to hold up them. Mergers, acquisitions, joint ventures and many other collusive agreements, can be investigated by using a cooperative game theoretical setting, where the control of collective resources changes the agents' ability to get larger payoffs from bargaining. In many cases, conclusions coming from the old literature are reversed.

In the fifties, for example, the conventional literature emphasized the positive role of the firm size on its bargaining power and performance (see Galbraith 1952), but later contributions showed as a positive correlation between size and profitability does not represent the general rule. Pioneer of this new wisdom is Aumann (1973), who demonstrated as even the monopoly might be unprofitable if some requirements are not satisfied. Later works analyzed additional specific settings, such as vertical integration (Stole and Zwiebel 1998), horizontal integrations (Gardner 1977, Legros, 1987), unions formation (Horn and Wolinsky 1988, Stole and Zwiebel 1996a). The common purpose of these papers is drawing profitability conditions for well defined agreements to be advantageous in bargaining, but very often results are conflicting with each other and very context specific.

Recently, Segal (2003) applied the theory of random order values to study the bargaining effects of generic integration contracts. In cooperative game theory a random order value is a solution concept assigning to each player a weighted average of his contributions to the preceding players in different orderings. The weights are represented by the probabilities of all orderings of players once a corresponding distribution is known. In particular, if all the orderings are equally likely, the random order value is equivalent to the Shapley value, where all coalitions form with the same probabilities because players have the same bargaining attitude. Using this approach, Segal draws some general conditions for the exclusive, inclusive and collusive contracts to be profitable.

An exclusive contract ensures to a player i the right to exclude a player j's from using his own resources, but not the right to use them. In other words, player j does not contribute to generate value in any coalition until the arrival of player i. By an inclusive contract, instead, both players can use the j' assets, so coalitions including i do not need to wait for j. A collusive contract, finally, makes i a proxy player who always brings with him the j' resources, achieving the total control. The nature of these contracts relies to the ownership rights that players decide over the joint resources. This setting reflects the Grossman and Hart's approach (1986): no distinction is made between ownership and control, since what matters is the veto power over the assets rather than the ownership itself.

A collusive agreement, which is in our interest, applies both the exclusive and the inclusive contract, because proxy player can use the other player's assets and exclude him from using. Such an agreement is profitable if the complementarity between colluding players is reduced by the third parties, therefore the joint profits from collusion do not depend on the substitutability degree of partners but on how this is affected by external players, and in Segal's work this result is independent from the probability distribution of orderings in random order value. In present paper we go beyond. We extend his setting by including the presence of divisible assets that make players partially complementary to each other. Moreover, we admit possibility of joint ownership on the integrated resources and investigate the role of players' bargaining abilities. These changes are applied to a particular set of agreements by which two players can decide to merge either all their physical assets or a share of them. The endowment of each colluding agent is divisible into complementary or substitutable assets, according to the technological relationships with those of other agents. In detail, we investigate the profitability of contracts by which two firms pool their complementary R&D activities. The integration in R&D aims at increasing the joint productivity of the parties and getting advantages in bargaining. We assume that two competitors can cooperate in R&D either by integrating all their resources, and this is equivalent to a merger or an acquisition contract, or by limiting the cooperation to a specific RJV. In our framework, a RJV agreement is a contract giving rise to the entry of a new player (we call him target) whose assets are the parents' R&D sectors. Contracting parties choose the control structure over the RJV in order to make the collusion as much as profitable. The joint research activities can be managed by one of the parents (RJV contract with a dominant parent), by both them (RJV with joint ownership) or by an independent board (RJV with independent target). These contracts are examined in two technological settings. The first one only admits full players' complementarities, that is the assets of any player are either complementary or substitutable to the other players' assets, while the second gives any agent two different sets of activities, complementary or substitutable, depending on how their productivity changes when used jointly with the assets of other players. Hence a player i can be complementary to a share λ of player j's assets but substitutable to j when j brings with him all his resources. Let's provide an example. Consider two companies, Nokia and Matsushita, owning a variety of activities that can be distinguished between complementary and substitutable with those of competitors. Nokia, for example, works in the sector of telecommunications, and produces both mobile phones and the related accessories, while Matsushita is a bigger corporation in the industrial electronics sector. It produces batteries and many other electric materials, but also competes in the mobiles sector by using the brand Panasonic. Suppose that both them devote a share λ of their assets to the R&D activities in their complementary sectors (software and batteries), and the remaining share $(1 - \lambda)$ mainly include substitutable assets (mobiles and accessories). They can form a strategic alliance finalized to the development of new energy saving technologies that guarantee larger duration of the batteries and greater efficiency for mobiles Nokia (or Panasonic).

Among the multiple options, they may decide to directly merge all their assets (or, equivalently, Matsushita might acquire Nokia and result would be the same). This merger contract would imply a full control of Nokia's activities by Matsushita. Too see the bargaining effects, imagine that a third consumer electronics producer, Philips, is interested in the same research project, because it could have many profitable applications, but needs the cooperation of Nokia.

Before integration the third company would have bargained with Nokia on revenues sharing from the subsequent innovations, but after merging the Nokia R&D sector is managed by Matsushita, which now is able to hold up Philips, since the latter needs its consensus to succeed in cooperation. Thus, Matsushita enjoys an additional bargaining power on the third competitor, because controls resources that are complementary to its activities. Not only, third party is further limited in his choice, since it needs the Matsushita' permission also for contracting the use of Nokia's assets that are different from the R&D sectors. However, the Philips' gains increase when some agreement is reached with Matsushita, because it can rely on a larger amount of expertise and spillovers.

Therefore merger yields two opposite effects in bargaining: on the one hand, he guarantees a hold up power to the proxy player when external players needs the agreement of dummy player Nokia, on the other hand it increases the productivity and the gains of complementary third parties when they cooperate with him. In this case the proxy player is hold up in bargaining by the noncontracting agents.

Suppose, as an alternative, that first two companies funded a RJV which is still controlled by Matsushita. The RJV contract with dominant parent joins the Matsushita's skills in the battery sector and the Nokia's expertise in the software and mobiles development. The larger owner, now, controls the integrated research activities, but Nokia is still independent in the use of remaining share $(1-\lambda)$ of its own resources, thus the third rival Philips can bargain with Nokia the revenue sharing from any agreement based on these assets. The dominant parent's hold up ability decreases with respect to the previous contract, but a similar effect occurs for Philips when cooperating with Matsushita, because now it brings only a share of Nokia's resources, thus its contribution is smaller in all agreements with the third player.

Last effect is enhanced if the contract does not confer to Matsushita all the ownership rights on the target's activities. Think of a RJV integration with parents' joint ownership. The Matsushita's bargaining power with third parties is reduced whenever it has less than fifty percent of decisional power on the target, that is when a dominant position is conferred to Nokia, while increases in the opposite case. Not only. When a player is dominant under integration, the strategic effects on third parties are strictly related to the ex-ante complementarity relationships. Let us be clearer. Whenever Philips signs an agreement with dominant parent Matsushita, and enjoys gains from the additional RJV assets, this positive externality is larger if that parent is complementary, meaning that remaining share $(1-\lambda)$ of his assets too is productive and indispensable to the third party. On the contrary, when Phillips cooperates with Nokia, and is suffering the hold up effect from dominant player, the losses are decreasing in the substitutability degree of the RJV assets, because they become less indispensable to Philips.

Then, the strategic effects of partial integrations result in a trade-off between positive and negative externalities on the other parties, and how it is solved depends on the technological links between third players, colluding parties and integrated resources. We explore most part of possible cases by including partial complementarities among players. Further, we address to the issue of control-performance relationship. For instance, if the parties sign a contract with independent target, that is a contract assigning the RJV management to an independent board, they avoid opportunistic behaviors from the part of any parent. We compare this solution with the formers to see how much the ownership matters in bargaining. In our random order perspective, this solution may reveal unprofitable if some requirements on the probability distribution of orderings are satisfied. Anyway, the bargaining effects of contracts are not affected only on the technology adopted, but also on the players' bargaining abilities. If a player is very likely to enter coalitions because his attitude to accept proposed agreements is high, and we say that he is enthusiastic (see Passarelli, 2007), then all coalitions including him become more likely than coalitions with reluctant players, that is players with lower attitude to negotiate.

Consider, in our example, the players' bargaining game once the integration contract made Matsushita dominant on the RJV management. If Philips is complementary to the Nokia's R&D sector, the productivity of its resources decreases in all coalitions including Nokia, because this player cannot rely on the share λ of his assets. Then, if Nokia is very enthusiastic in negotiations, those coalitions in which Philips loses competitiveness are very likely and its bargaining position get worse. Instead, the third player's bargaining power goes up if dominant player is very enthusiastic in bargaining, since it increases the probability that Philips enter coalitions with Matsushita, which brings additional complementary resources. However, the bargaining ability of Matsushita can be detrimental to Philips if this is substitutable to the integrated assets, because it makes more likely coalitions where Philips is less efficient. In this bargaining game the relative probability of coalitions (hence the players' bargaining attitudes) is relevant because players are rewarded according to their expected marginal contribution to a random coalition. For this reason, we take into account the asymmetric players' attitudes by using the path values (Owen, 1972).

The path value is a solution concept based on the idea that coalitions probabilities can be represented in terms of players' entry paths, where a path is a function that assigns to each player his probability of entering any given coalition. The value of a player increases if he contributes more to coalitions that are more likely than others, and decreases if he contributes more to coalitions with reluctant players, because these latters are more unlikely to form. Of course, if all players are symmetric in bargaining (they have the same entry paths) then the bargaining solution corresponds to the original Shapley value, where all coalitions with the same size are equally likely.

In this work we apply the random order values to contracts in which the parties' R&D sectors are pooled in the presence of full or partial complementarities, while we use path values to include the interaction between technological relationships and asymmetric bargaining abilities of players. Especially, we study four kinds of contracts: merger (or acquisitions), RJVs with a dominant parent, RJVs with independent target and, finally, RJVs with joint ownership.

The analysis is limited to bilateral contracts between two players A and B which can be identified, in our example, by Matsushita and Nokia respectively, while we call J the target of contract and ks all the third parties (think of Philips in the example above).

1.2 The model

Segal (2003) explored the collusive contracts in a setting where bargaining solution is a random order value. In his work, collusion is viewed in a quite general way: one player (proxy) receives the right to fully control the assets of other colluding players (dummies) and the contract profitability depends on the complementarities with third parties. We extend his model to investigate integrations by which players pool only complementary activities and the bargaining abilities affect the contract profitability.

1.3 Cooperation and complementarities

We consider an economy where operates a set $N = \{1, ..., n\}$ of firms with a corresponding vector $a = (a_1, ..., a_n) \in \mathbb{R}^n_+$ of asset endowments. At a given price $p \in \mathbb{R}$, the output demand $D(p)$ can be served by the N players by using assets in a as inputs, where activities a_i's ($i = 1, ..., n$) are divisible and include $R\&D$ sectors. The use of these assets in production activities involves a monetary cost which is measured by a cost function $C(a(S))$, where $a(S) : \mathbb{R}^n_+ \rightarrow \mathbb{R}^{|S|}$ is an asset structure showing that a coalition S enjoys full control power on the subset a_S of a. Therefore $C(a(S))$ is the total cost associated with the output generated by S once a structure $a(S)$ has been defined. We make a first assumption.

A. 1. $C(a(\emptyset)) = C(0) = 0$ and C is twice differentiable for all $a(S) = (a_1, ..., a_S)$ and any S.

The A.1 simply claims that cost function and its derivatives are continuous and no output can be produced at zero cost.

Once the cost is known, the timing is the following. At date 0 players learn the level of demand $D(p)$. At date 1, they may sign integration contracts which reallocate the ownership rights over their resources. At date 2 the production and trade take place, while at date 3 a bargaining process is necessary to decide how to share the total net revenues among the producers. Similarly to Hart and Moore (1990), we assume that transaction costs are high enough that players cannot coordinate their production plans directly at date 0. Rather, such costs are reduced at date 1 by the integration, and this contract also has a second effect: it increases the players' production efficiency by pooling complementary assets.

Definition 1 *For all $i, j \in S \subseteq N$, the assets a_i, a_j are complementary if*

$$\frac{\partial^2}{\partial a_i a_j} C(a(S)) \leq 0 \tag{1}$$

and substitutable if

$$\frac{\partial^2}{\partial a_i a_j} C(a(S)) \geq 0$$

If technology yields economies of scope then player's assets are complementary to each other, instead they are substitutable in the presence of diseconomies of scope. In our framework, with constant price and demand, net revenues from production increase only if total costs decrease, that is when players integrate their complementary resources. On the contrary, costs increases if players join substitutable assets. The ability of players in reducing the total costs of production when joining their assets is a measure of their productivity. In the rest of paper we assume that each unit of players' assets has the same ability in reducing (or increasing) the joint costs, thus the more complementary assets they bring with them the more they are productive, and vice versa in case of substitutability. Below, we describe the bargaining game taking place at date 3 and we show how it is affected by the integration contracts at date 1.

1.3.1 The game

A *cooperative game* is a pair (N, v) where $N = \{1, ..., n\}$ is a finite set of players and $v : 2^N \to \mathbb{R}$ is a real-valued characteristic function defined on every subset S of N. The value $v(S)$ is the net return to any coalition S of players acting together as a single organization, with $v(\emptyset) = 0$. A player i is a *dummy* if there exists a number $c \in \mathbb{R}$ such that $v(S \cup \{i\}) - v(S) = c$ for every $S \subseteq N \setminus \{i\}$, with $\{i\} = i$ from here on. Particularly, if $c = 0$, then i is a *null* player.

We assume that utility is transferable[1] and $v(S) = -C(a(S))$. The joint payoff of any S is a negative function of the corresponding production costs, therefore maximizing the net revenues is equivalent to minimizing costs.

By definition 1 the function v is convex (concave) if players in N are complements (substitutes) to each other, and we use these properties to evaluate the level of efficiency related to the player set inclusion. Let us function $C(a(S \cup i)) - C(a(S))$ define the *marginal cost of* i, denoted by $c_i(S)$. The lower is $c_i(S)$ the higher will be the net revenues of coalition $S \cup i$, and the more i is expected to be rewarded. Following Itsiishi (1993) and Segal (2003), we denote the i's marginal contribution to a coalition S by the first order difference operator

$$\begin{aligned} \Delta_i v(S) &= v(S \cup i) - v(S) \\ &= -\left[C(a(S \cup i)) - C(a(S))\right] \\ &= -c_i(S). \end{aligned} \tag{2}$$

The cost of using player i's assets decreases when they are joined with those of a coalition S of complementary players, while increases if S is substitutable to i. Denoting by $C(a(i))$ the cost from assets $a(i)$ when he works alone, the variation is

$$c_i(S) - C(a(i)) \begin{cases} < 0 \text{ if } i \text{ complementary to } S \\ > 0 \text{ if } i \text{ substitutable to } S \end{cases}$$

Of course, gains from cooperation with complementary (substitutable) players increase (decrease) both with the coalition size and the owned assets $a(S)$. By the second order difference operators we measure the change in any player i's marginal contribution due

[1] Any coalition S can divide its worth $v(S)$ in any possible way among its members. That is, S can achieve any payoff vector $\sum_{i \in S} x^i \leq v(S)$. This is possible because it's assumed that players' von Neumann-Morgersten utilities functions are linear and increasing in money (quasilinear preferences), so side monetary payments may affect the corresponding payoff utility vectors. In this sense utility is transferable.

to enlarging S to an additional player j by

$$\begin{aligned}
\Delta^2_{ji}v(S) &= \Delta_j\left[\Delta_i v\right](S) = \\
&= C(a(S\cup i)) - C(a(S\setminus i)) - [C(a(S\cup i\cup j)) - C(a(S\setminus i\cup j))] = \\
&= c_i(S) - c_i(S\cup j) = \\
&= -\Delta^2_{ji}c(S) \\
\text{for all } S &\subseteq N\setminus i\setminus j
\end{aligned}$$

where the order of players does not matters. One could think that any player i's resources are highly productive if $\Delta_i v(S)$ is high and that productivity increases if $\Delta^2_{ji}v(S) > 0$. Then value $\Delta^2_{ji}v(S)$ is positive if players are complements ($\Delta^2_{ji}c(S) < 0$), while is negative with substitutes ($\Delta^2_{ji}c(S) > 0$). The third difference operator is defined as $\Delta^3_{kji}v(S) = \Delta_k[\Delta^2_{ji}v](S)$ and represents the effect of an external player k on the asset complementarity between i and j:

$$\begin{aligned}
\Delta^3_{jki}v(S) &= \Delta^2_{ki}v(S\cup j) - \Delta^2_{ki}v(S\setminus j) = \\
&= -[\Delta^2_{ki}c(S\cup j) - \Delta^2_{ki}c(S)] = \\
&= -\Delta^3_{jki}c(S).
\end{aligned} \tag{3}$$

The (3) measures the change in $\Delta^2_{ji}v(S)$ due the inclusion of a third player k, and this concept will be crucial in our analysis. Suppose that players in N are complementary to each other, such that $\Delta^2_{ji}v(S) > 0$. This operator shows that production technology has increasing returns in the joint use of assets, because the marginal cost of production is decreasing in the size of S and $a(S)$, at the same time the third difference operator $\Delta^3_{jki}v(S)$ provides the rate at which marginal cost decreases when additional assets are made available.

We impose that marginal cost of joint production cannot go to zero for an infinitely large amount of assets, and it implies that scale effects from complementarities are decreasing. On the contrary, with substitutable players $\Delta^2_{ji}v(S) < 0$, and marginal cost increases at an increasing rate. Given the sign of $\Delta^2_{ji}v(S)$ in the two situations, the following assumption holds for both cases.

A.2.

$$\Delta^3_{jki}v(S) < 0 \quad \text{for all } i,j,k \in N \tag{4}$$

Next paragraph shows the implications of A.2. on the growth rate of players' marginal contributions when a coalition S increases either in size or in the available assets. We derive some fundamental properties that will be used in sections 3 and 4 to draw profitability conditions for R&D contracts.

1.3.2 The effects of a collusive contract

A collusive contract between two players i and j gives i full control of a share $\lambda \in (0,1)$ of the j's assets. While the usual definition of collusion only implies a complete transfer of players' resources, here players can integrate only a part of their activities. The presence of parameter λ extends our model in two directions. First, we can investigate R&D contracts where the parties choose to integrate only a share of their complementary (hence, productive) assets and remain independent in the use of the other activities. Second, it guarantees the possibility of including partial asset complementarities among players (see chapter 3). In this paragraph we consider the effects of a collusion on the asset structure and the characteristic function of the bargaining game. It implies a transformation $a^C_{ij}(S)$ of $a(S)$ by which all coalitions $S \setminus j \cup i$ can rely on the additional assets λa_j. Thus, because of contract, the new asset vector is

$$\left\{a^C : a^C_i = a_i + \lambda a_j,\ a^C_j = (1-\lambda)a_j, \text{ and } a^C_k = a_k \text{ for any } k \neq i,j\right\}$$

Game (N,v) changes in (N,v^C), with characteristic function $v(a^C)(S) = v^C(S)$. In the case In the case of complementary players in N, the marginal contribution of a third player k to a coalition $S \setminus k \setminus j \cup i$ increases, while decreases with coalitions $S \setminus k \setminus i \cup j$. These differences can be expressed in terms of players' productivity:

$$\begin{cases} \Delta_k v^C(S) - \Delta_k v(S) = c_k(S) - c_k(S \cup j^\lambda) \text{ for all } S \subseteq N \setminus k \setminus j \cup i \\ \Delta_k v^C(S) - \Delta_k v(S) = c_k(S) - c_k(S \setminus j^\lambda) \text{ for all } S \subseteq N \setminus k \setminus i \cup j \end{cases} \tag{5}$$

The proofs of propositions we present in next sections are based on changes above, therefore we generalize the notation in (5) by using the function $\Delta c_k(S, a_i, \lambda)$[2]. For example, the value $\Delta c_k(S, a_j, \lambda) = c_k(S) - c_k(S \cup j^\lambda)$ denotes the k's marginal cost reduction when the asset structure $a(S)$ increases by a share λ of j's resources brought by player i, and is positive. Instead, $-\Delta c_k(S, a_j, \lambda) = c_k(S) - c_k(S \setminus j^\lambda)$ represents the loss in productivity when those resources are not available to j in S. Of course,

[2] In (5) we make an abuse of notation by introducing player j^λ in coalitions a player k enters. In first line all S can use the resources λa_j brought by player i, in second line player j enters only with a share $1-\lambda$ of his activities.

$$\Delta_k v^C(S) - \Delta_k v(S) = \Delta c_k(S, a_j, \lambda) \begin{cases} > 0 \text{ with complementarities} \\ < 0 \text{ with substitutability} \end{cases} \tag{6}$$

Recalling the (4), the reduction in marginal cost $\Delta c_k(S, a_j, \lambda)$, for complementary players, is decreasing in the size of coalition S or the amount of available assets, since increasing returns are bounded above. With substitutable players, instead, the (4) implies that negative losses $\Delta c_k(S, a_j, \lambda)$ are increasing in absolute value. If follows that function $\Delta c_k(S, a_j, \lambda)$ exhibits decreasing (increasing) differences in (S, a_j, λ) for all $j \in N$, $S \subseteq N \setminus k$ and $\lambda \in (0, 1)$ whenever some (dis)economies of scope are at work. That is,

$$\Delta c_k(S, a_j, \lambda) - \Delta c_k(S', a_j, \lambda) > (<) \Delta c_k(S, a'_j, \lambda) - \Delta c_k(S', a'_j, \lambda) \tag{7}$$

and

$$\Delta c_k(S, a_j, \lambda) - \Delta c_k(S', a_j, \lambda) > (<) \Delta c_k(S, a'_j, \lambda') - \Delta c_k(S', a'_j, \lambda') \tag{8}$$

with $S \subset S'$, $a_j < a'_j$ and $\lambda < \lambda'$. The (7) and (8) simply say that productivity of a player's assets increases (decreases) more (less) when those assets are joined with a smaller (larger) amount of complementary (substitutable) resources.

1.3.3 The bargaining solution

We solve the game (N, v) by a random order value in which the coalition formation is viewed as a sequential process of players entering coalitions at random (see Owen, 1968 and Weber, 1988). This results in the ordering of players being random. Following the usual notation, let Π denote the set of orderings of N (the group of permutations of $N = \{1, \ldots, n\}$), and $\pi(i)$ the rank of player $i \in N$ in ordering $\pi \in \Pi$. We call $S = \{j \in N : \pi(j) < \pi(i)\}$ the set of players coming before player i in ordering π. The probabilities of random orderings are assigned by a distribution function $\alpha \in \mathcal{F}$, where $\mathcal{F} = \left\{\alpha \in \mathbb{R}_+^{\Pi} : \sum_{\pi \in \Pi} \alpha_\pi = 1\right\}$ denotes the set of all probability distributions over Π. The solution concept is based on the idea that each player $i \in N$ gets a payoff corresponding to a weighted average of its marginal contributions to any S, where the weights are the probabilities of random coalitions. Let's give a formal definition.

Definition 2 *Let $a = \{a_1, ..., a_n\}$ be an asset structure in $\mathbb{R}_+^n$, N a set of players $i = 1, ..., n$ and $\alpha \in \mathcal{F}$ a probability distribution over Π. Then, solution $\phi^\alpha(v) = \{\phi_1^\alpha, ..., \phi_n^\alpha\}$*

is a random order value for game (N, v) *if and only if*

$$\begin{aligned}\phi_i^\alpha(v) &= \sum_{\pi\in\Pi} \alpha_\pi \left[v(S\cup i) - v(S)\right] \qquad (9)\\ &= \sum_{\pi\in\Pi} \alpha_\pi \left[C(a(S)) - C(a(S\cup i))\right] = -\sum_{\pi\in\Pi} \alpha_\pi c_i(S) \text{ for all } i\in N.\end{aligned}$$

Weber has shown that the Shapley value (Shapley, 1953) is a random order value where all orderings have equal probability. $\alpha_\pi = 1/n!$. In this case the symmetry axiom holds. If orderings are not equally likely, the solution is an asymmetric Shapley value, or a quasivalue (Weber, 1988).

Moreover, the following lemma ensures that values $\{\phi_1^\alpha, ..., \phi_n^\alpha\}$ defined by (9) do not change when the set of players is enlarged to one (or more) null players, because they increase the power set $P(N)$ of the game but do not affect the marginal contributions of players is for $i = 1, ..., n$. Lemma 1 turns to be useful in our analysis in that we explore the effects on the bargaining coming from RJV contracts that involve the entry of a new player in game (N, v). We avoid to change the players set of the game, after contracting, simply by including it in the original game as null player. The effect of the contract itself will only be a change in the asset structure of the original player set.

Lemma 1 *The random order value* $\phi^\alpha(v)$ *for game* (N, v) *is invariant to the addition of a null player.*

Proof. Consider the addition of a null player j to a game (N, v). This gives rise to a new game (N, v_j), with $v_j : P(N+1) \to \mathbb{R}$. Let a^j the asset structure $a^j = \{a_1, ..., a_n, a_j\} \in \mathbb{R}_+^{n+1}$ for function v_j. By definition, $v_j(S\cup j) - v_j(S) = 0$ for all $S \subseteq N$. Consider the marginal contribution of $i \in N$ to any coalition $S \cup j$ that includes player j. We can write $\Delta_i v_j(S\cup j) = v_j(S\cup j\cup i) - v_j(S\cup j)$. Since $v_j(S\cup j) = v_j(S)$, we can rewrite $\Delta_i v_j(S\cup j) = v_j(S\cup i) - v_j(S) = \Delta_i v(S)$. Consider now how orderings probabilities are affected by the addition of j. Let π^j denote a random ordering in Π^j, that is the new set of permutations for J. Keep fixed $\pi^j(i)$ for all $i \neq j$. Then, Π^j associates $(n+1)$ orderings π^j depending on the relative position of j. Each of them occurs with probability $\alpha_\pi^j = \alpha_\pi \cdot \theta(\pi^j(j))$, where θ is the probability that j has a rank $\pi^j(j) \neq \pi^j(i)$. The payoff of any i is constant across the $(n+1)$ new orderings π^j where only $\pi^j(j)$ changes. Therefore,

$$\phi_i^{\alpha^j}(v_j) = \sum_{\pi\in\Pi} \alpha_\pi \left[v(S\cup i) - v(S)\right] \cdot \textstyle\sum_{\pi^j(j)\neq\pi^j(i)} \theta\left(\pi^j(j)\right) = \phi_i^\alpha(v),$$

since summation over θ's takes value 1 for any $\pi \in \Pi$ with constant $\pi^j(i)$s. ■

In order to analyze the profitability of a collusion contract, consider constant-sum games with $v(S)+v(N\backslash S) = v(N)$ for all $S \subseteq N$. This means that if a collusive contract C is signed by a group G of players, total payoffs available to the grand coalition for division are not affected by the contract. Hence $v^C(G) + v^C(N\backslash G) = v(G) + v(N\backslash G) = v(N)$ for all $G \subseteq N$. Correspondingly,

$$\phi_G^\alpha\left(v^C\right) + \phi_{N\backslash G}^\alpha\left(v^C\right) = \phi_G^\alpha\left(v\right) + \phi_{N\backslash G}^\alpha\left(v\right) = v(N) \text{ for all } G \quad (10)$$

where $\phi_G^\alpha\left(v\right)$ and $\phi_G^\alpha\left(v^C\right)$ are the joint expected payoffs of members in G before and after integration. Thus we can evaluate the profits from contract by looking at how third players' payoffs change. We do this in the following sections. Following Segal (2003), a contract will be advantageous if causes a negative externality on noncontracting players $N\backslash G$, that is if $\phi_{N\backslash G}^\alpha\left(v\right) < \phi_{N\backslash G}^\alpha\left(v^C\right)$.

Chapter 2

Pooled R&D sectors with full players' complementarities

2.1 Introduction

In this chapter we analyze the profitability of four different ways to pool R&D activities by collusive contracts. Consider two players (firms) A, B and denote by a_A and a_B their assets, with a share $\lambda \in (0, \frac{1}{2})$ represented by their R&D sectors. Further, make the following assumption.

A.3. $a_A > a_B$ with $a_B > (1-\lambda)a_A$.

In our cooperative game perspective, the two players may decide either to join all their activities by a merger (or equivalently an acquisition) or to form a Research Joint Venture J with assets $a_J = \lambda(a_A + a_B)$. In all cases, the integration contracts differentiate from each other by the ownership structure that parties agree on assets a_i for $i = A, B, J$. At date 0 player J is included in the player set, but brings with him zero assets ($a_J = 0$). Any contract at date 1 can be viewed as a reallocation of players A and B's resources between J and themselves, depending on the type of integration they have chosen. Player J is then a virtual dummy player whose role activates only if required by the contract. This setting allows to avoid the player set enlargement in post contract bargaining game (date 3) and simplifies the whole notation.

By a merger contract the ownership rights on B's assets are conferred to player A. Using the Segal's definitions, this contract corresponds to a collusive agreement with A proxy player and B, J dummies. A second contract gives to one of the parents the right to manage the joint R&D sectors in J and we define such contract as a RJV with a dominant parent, because one of the parents gets the full control of the joint activities. A third integration prefigures the decisional independence of J, that is a RJV contract where none of the parents have a real control over the R&D activities. Think, for example, of a research joint venture which is led by an independent managerial board. Its work does not directly depends on the parents, even if the returns from innovation belongs to them. We use this contract as counterpart for the dominant parent case, in order to compare the effects of extreme changes of ownership. Finally, a fourth option is made available to the parties: a RJV with joint ownership, where the rights on the J's activities can be shared at 50% level.

Below we derive some profitability conditions for these contracts and we assume that all third players can be either complements or substitutes to A and B, while in chapter 3 this assumption is removed and possibility to have partial complementarities with respect to the integrated parties is introduced..

2.2 Merger contracts

A merger contract between players A and B is a transformation $a^M_{A,B}(S) : \mathbb{R}^n_+ \to \mathbb{R}^{|S|}$ of $a(S)$ such that

$$\begin{cases} a^M_{A,B}(S) = a(S \cup B \cup J) \text{ if } A \in S. \\ a^M_{A,B}(S) = a(S \setminus B) \text{ if } B \in S \\ a^M_{A,B}(S) = a(S) \text{ otherwise} \end{cases} \tag{11}$$

and the characteristic function changes in $v(a^M(S)) = v^M(S)$[1].

By integration of A and B, resources $\lambda(a_A + a_B)$ are transferred to J, and player A (the proxy) has full control over J's participation into coalitions, thus he gets full control over B and J's resources. The corresponding asset vector is such that $a^M_A = a_A + a_B$, $a^M_B = a^M_J = 0$, and $a^M_i = a_i$ for all $i \neq A, B, J$, therefore the asset structure $a^M(S \cup A)$ is equivalent to $a(S \cup A \cup B \cup J)$, because it also includes the additional assets controlled by A. Notice that now the proxy player A can contribute more than before to any coalition S he may enter, since he brings with him the other parties' resources. B and J, instead, are dummy. In new game (N, v^M), the players' marginal contributions are valued by the function $v^M(S)$ as follows:

$$\begin{cases} \Delta_A v^M(S) = \Delta_A v(S \cup B \cup J) \\ \Delta_B v^M(S) = \Delta_J v(S) = 0 \\ \Delta_i v^M(S) = \Delta_i v(S) \end{cases} \tag{12}$$

for all $S \in N \setminus A \setminus B \setminus J$.

By definition, $v^M(S) = -C(a^M(S))$, so the marginal contributions of any player can be measured in terms of ability to reduce the marginal cost due to the use of his own assets. Using the notation above, the integrated parties' productivity changes by

$$\begin{cases} \Delta_A v^M(S) - \Delta_A v(S) = c_A(S) - c_A(S \cup B \cup J) \\ \Delta_B v^M(S) - \Delta_B v(S) = -c_B(S) \\ \Delta_J v^M(S) - \Delta_J v(S) = 0 \end{cases} \tag{13}$$

Suppose that all players are complementary. The marginal cost of any player, when entering a coalition S, is lower when that coalition includes more players or can rely on a larger amount of assets, because of the increasing returns from complementarities. Thus $c_A(S) > c_A(S \cup B \cup J)$ and differences in (13) translate into positive gains only for player

[1] Since we'll consider only contracts between these two players, hereafter we avoid using A and B in indexing transformation $a^M_{A,B}(S)$.

A, while B loses from integration, and nothing changes for J, since his resources are now available to A. The contract also affects the productivity of external players k's. Too see this let us consider the figure 1. Looking at relative ranks of players $A, B, J \in G \subset N$, the arrival sequences of these players generate six classes of orderings in the set Π. The merger produces a positive effect on the k's payoff whenever he enters a coalition S including the proxy player A, because available assets in those coalitions are greater and the productivity of a_k^M increases for all ks. On the other side, the payoff of any k decreases with coalitions including B and excluding A, because player B has to wait for A in order to use his own assets, thus player k cannot exploit the advantages of his complementarity with B. At same time, nothing changes for k when J arrives before him and A and B later, because $a_J^M = a_J$. Formally, the effects of the contract on the bargaining power of k can be expressed as

$$\Delta_k v^M(S) - \Delta_k v(S) =$$
$$\begin{cases} c_k(S \cup A) - c_k(S \cup A \cup B) = -\Delta^2_{Bk} c(S \cup A) \text{ for all } S \subseteq N \setminus G \setminus k \\ c_k(S \cup B) - c_k(S) = \Delta^2_{Bk} c(S) \text{ for all } S \subseteq N \setminus G \setminus k \\ 0 \text{ for all } S \subseteq N \setminus G \setminus k \cup J \end{cases}$$

and the net effect on his expected payoff is

$$\phi_k^\alpha \left(v^M\right) - \phi_k^\alpha(v) = \sum_{S \subseteq N \setminus k} \alpha^k_{(S)} \left[\Delta_k v^M(S) - \Delta_k v(S)\right],$$

with $S = \{j \in N : \pi(j) < \pi(k)\}$ for all $\pi \in \Pi$ and

$$\alpha^k_{(S)} = \sum_{\substack{\pi \in \Pi : \pi(j) < \pi(k) \\ j \in S}} \alpha_\pi \tag{14}$$

In a random order perspective, $\alpha^k_{(S)}$ represents the probability of all orderings in which only the relative position of players $j \in S$ is exchanged. Look at the figure 1. The k's payoff is affected by the merger only when this player joins coalitions that include either player A or player B, while no effect arises if both A and B have already entered, since the total available assets would be the same as without contract. For example, if k enters a coalition including only the proxy A, his expected payoff increases by $-\alpha^k_{(S \cup A)} \Delta^2_{Bk} c(S \cup A)$, that is by the cost reduction due to the presence of complementary A, with $\alpha_{(S \cup A)}$ being the probability that a coalition $S \cup A$ formed before the arrival of player k. By a similar reasoning, when only B has joined S the expected change is $\alpha^k_{(S\cup B)}\Delta^2_{Bk}c(S)$, that is the increase in coalition production costs when B's assets are missing. From this, it follows that profitability of a merger contract does not depend on the type of complementarity among players (see proposition 1 below).

Proposition 1 *A merger contract between two players A, B is always profitable.*

Proof. Consider the classification of orderings in figure 1. The merger integration produces the following change in the expected payoff of each k:

$$\phi^\alpha_k\left(v^M\right) - \phi^\alpha_k(v) = \tag{15}$$

$$-\sum_{S\subseteq N\backslash\{G\cup k\}}\left[\alpha^k_{(S\cup A)}\Delta^2_{Bk}c(S\cup A) - \alpha^k_{(S\cup B)}\Delta^2_{Bk}c(S)\right]$$

With a $\{A, B, J\}$-symmetric (or G-symmetric) distribution $\alpha \in \mathcal{F}(\Pi)$, $\alpha^k_{(S\cup A)} = \alpha^k_{(S\cup B)}$ for all S. Using the (3) and the fact that null player J is irrelevant, the (15) can be rewritten as

$$\phi^\alpha_k\left(v^M\right) - \phi^\alpha_k(v) = -\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup B)}\Delta^3_{ABk}c(S) \tag{16}$$

Applying the (4) all $\Delta^3_{ABk}c(S)$ are positive for any S, thus $\phi^\alpha_k\left(v^M\right) - \phi^\alpha_k(v) < 0$ for all ks, whatever is their complementarity relationship with A, B. ■

The proposition 1 shows that integration between A and B has two opposite hold-up effects on each player k. He receives a positive externality when he enters coalitions where the proxy A is in, therefore he is able to hold-up player A and to enjoy the benefits from the integrated R&D activities (think of the related spillovers). On the contrary, when the coalitions include only B, the proxy player holds-up k, and this represents a negative externality for k. However, since marginal contributions are increasing in the size of coalitions, the second effect is larger than the first one. Notice that contract profitability is independent of the complementarity relationships between each k and colluding players. Indeed, when the ks are substitutable, the presence of player A in S provides a negative externality on them ($-\Delta^2_{Bk}c(S\cup A) < 0$), because now the cooperation is based on a higher level of costs, but a reversed effect comes from entering coalitions including B: in this set of orderings the third players' productivity increases because their resources are joined to a smaller amount of substitutable assets ($\Delta^2_{Bk}c(S) > 0$). Nevertheless, the final result is negative, as the first effect is larger than the second ($|-\Delta^2_{Bk}c(S\cup A)| > |\Delta^2_{Bk}c(S)|$). An interesting conclusion looks at how the players' incentives change with the used technology. When the agents are complementary with each other, for instance, the integrated parties gain more when the proxy agent postpones his agreements, so increasing their hold-up power on the external players. With substitutability, on the contrary, the incentive is reversed: the more the A's entry is delayed the larger are the losses from bargaining.

2.3 RJV contracts with a dominant parent

An alternative way to pool the R&D activities consists of forming a Research Joint Venture (RJV) whose resources are managed by one of the parents, in our case the player A again[2]. This contract is a transformation $a^D(S)$ of $a(S)$ such that

$$\begin{cases} a^D(S) = a(S \cup B^\lambda) \text{ if } A \in S \\ a^D(S) = a(S \setminus B^\lambda) \text{ if } B \in S \\ a^D(S) = a(S) \text{ otherwise} \end{cases} \tag{17}$$

and the new characteristic function is $v(a^D(S)) = v^D(S)$.

The dominant player A brings with him the additional assets λa_B, while J is still a null player. Using the notation from chapter 1, the terms B^λ and $B^{1-\lambda}$ in the inclusion sets remind that those coalitions can rely on the shares λ and $(1-\lambda)$ of B's assets. The new asset vector a^D is such that $a^D_A = a_A + \lambda a_B$, $a^D_B = (1-\lambda)a_B$ and $a^D_J = 0$. Of course, nothing changes for remaining players $i \in N \setminus \{A, B, J\}$.

Now the dominant player brings with him the integrated R&D assets, therefore the entry time of player J is determined by that position of A. The player J always arrives together with A, meaning that the only ranks he can take are those before or after the rank $\pi(A)$, and no external player can enter between the two. The set of all possible orderings is depicted in figure 2, where the k's bargaining power is affected when he arrives between A and B. Being the role of J irrelevant in this contract, we assume that J anticipates or follows the dominant agent A with the same probability, what matters is the relative position of A and B.

Similarly to the analysis for merger contracts, in new game (N, v^D) the characteristic function $v(a^D(S))$ assigns to the integrating parties the contributions

[2] Later it will be clear that it is convenient to the integrating parties to choose the more enowned agent as dominant parent in case of substitutable resources, while the contrary is true in case of complementarities.

$$\begin{cases} \Delta_A v^D(S) = \Delta_A v(S \cup B^\lambda) \text{ for all } S \subseteq N \setminus A \\ \Delta_B v^D(S) = \Delta_{B^{1-\lambda}} v(S) \text{ for all } S \subseteq N \setminus B \\ \Delta_J v^D(S) = \Delta_J v(S) = 0 \text{ for all } S \subseteq N \setminus J \end{cases} \tag{18}$$

If production technology exhibits complementarities, whenever A enters a coalition S the unit cost of the joint output decreases by a higher amount than without contract, because A owns a larger amount of activities. The contrary occurs for player B, whose productivity decreased ($c_{B^{1-\lambda}}(S) > c_B(S)$). Of course, the integration does not modify the role of J, which still contributes zero. The efficiency gains of A, B and J are

$$\begin{cases} \Delta_A v^D(S) - \Delta_A v(S) = c_A(S) - c_A(S \cup B^\lambda) \\ \Delta_B v^D(S) - \Delta_B v(S) = c_B(S) - c_{B^{1-\lambda}}(S) \\ \Delta_J v^D(S) - \Delta_J v(S) = 0 \end{cases} \tag{19}$$

hence the effects on the bargaining, for any complementary k, are positive in all orderings where A enters earlier, and negative when B enters before A and k (he's less productive). Changes in k's marginal contributions are:

$$\Delta_k v^D(S) - \Delta_k v(S) =$$
$$\begin{cases} c_k(S) - c_k(S \cup B^\lambda) = \Delta c_k(S, a_B, \lambda) \text{ for all } S \subseteq N \setminus k \setminus B \cup A \\ c_k(S) - c_k(S \setminus B^\lambda) = -\Delta c_k(S, a_B, \lambda) \text{ for all } S \subseteq N \setminus k \setminus A \cup B \\ 0 \text{ otherwise} \end{cases}$$

where the terms $\Delta c_k(S, a_B, \lambda)$ is positive when some economies of scope are at work, and negative with substitutable assets.

Proposition 2 *If two players A and B enter a RJV contract with a dominant parent, then their joint profits increase.*

Proof. The bargaining effects on each player k are

$$\phi_k^\alpha\left(v^D\right) - \phi_k^\alpha(v) =$$
$$\sum_{S \subseteq N \setminus \{G \cup k\}} \alpha_{(S \cup A)}^k \Delta c_k(S \cup A, a_B, \lambda) - \sum_{S \subseteq N \setminus \{G \cup k\}} \alpha_{(S \cup B)}^k \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda) \tag{20}$$

If distribution α is G-symmetric, coalitions $S \cup A$ and $S \cup B$ are equally likely and the (20) becomes

$$\begin{aligned} \phi_k^{\alpha}\left(v^M\right) - \phi_k^{\alpha}(v) &= \\ &= \sum_{S \subseteq N \setminus \{G \cup k\}} \widetilde{\alpha}\left[\Delta c_k(S \cup A, a_B, \lambda) - \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)\right] \end{aligned} \tag{21}$$

The (8) ensures that difference in (21) is negative for all S whatever is the type of complementarity among all players. Hence $\phi_k^{\alpha}\left(v^M\right) - \phi_k^{\alpha}(v) < 0$ and the integration is profitable for A and B. ■

The proposition 2 comes from the same intuition as that for mergers, with the following clarifications. First, in the case of complementarities the hold-up ability of player A is lower than in the previous contract. In fact, whenever the external players enter coalitions $S \cup B$ they still enjoy some gains in efficiency, thanks to the assets $(1-\lambda)a_B$. Second, by the same argument the player k's hold-up ability also goes gown, since A brings with him assets λa_B instead of a_B, and this reduces the productivity of assets a_k as well as the k's expected payoff. In terms of profitability, however, he net effect of integration is positive because the gains in productivity are decreasing in the amount of joined assets, that is $\Delta c_k(S \cup A, a_B, \lambda) < \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$. With substitutable players, instead, these changes become negative, with $|\Delta c_k(S \cup A, a_B, \lambda)| < \left|\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)\right|$, and the power that players ks save when following B does not compensate what they loose by entering after A.

2.4 RJV contracts with independent target

The two integrating parties can decide to furnish the target J the ownership rights over its R&D activities. For example, they could deliver the decisional power to a managerial board which is completely independent in its action.[3] Then, a RJV contract with independent target is a transformation $a^T(S)$ of $a(S)$ such that

$$\begin{cases} a^T(S) = a(S \setminus A^{\lambda}) \text{ if } A \in S \\ a^T(S) = a(S \setminus B^{\lambda}) \text{ if } B \in S \\ a^T(S) = a(S \cup A^{\lambda} \cup B^{\lambda}) \text{ if } J \in S \\ a^T(S) = a(S) \text{ otherwise} \end{cases} \tag{22}$$

[3]Of course, this hypotheses is extreme, because the parent firms always exert their influence on the target. However, it allows to analyze cases where a competitor reaches agreements with some players without knowing whether he will really enjoys the advantages from RJV.

and the new characteristic function is $v(a^T(S)) = v^T(S)$.

In this contract both contracting players have the ownership over a share $(1-\lambda)$ of their own assets and the target J achieves the role of active player with resources $\lambda(a_A + a_B)$. As consequence, the productivity of contracting players decreases, but J now stops to be a dummy. The changes in their marginal costs are

$$\begin{cases} \Delta_A v^T(S) - \Delta_A v(S) = c_A(S) - c_{A^{1-\lambda}}(S) \\ \Delta_B v^T(S) - \Delta_B v(S) = c_B(S) - c_{B^{1-\lambda}}(S) \\ \Delta_J v^T(S) - \Delta_J v(S) = c_J(S). \end{cases} \tag{23}$$

thus players A and B become less productive in the presence of complementarities ($c_i(S) - c_{i^{1-\lambda}}(S) < 0$ for $i = A, B$), and the target J achieves a strategic role. The third parties increase their power when they accept agreements that include J, but their payoff decreases if A or B are involved. The orderings where the bargaining power of any k changes are shown in figure 3. In order to take into account the two possible sets of coalitions that a third player might enter, we distinguish between those coalitions S where only one of the elements in $G = \{A, B, J\}$ and coalitions S' where two players from G already got to an agreement. Indeed, the presence of one more element from set G changes the probabilities of corresponding orderings. The set of coalitions in which a third player k might receive an externality enlarges, and below we define the possible effects of integration on his payoffs.

$$\Delta_k v^T(S) - \Delta_k v(S) = \tag{24}$$
$$\begin{cases} c_k(S) - c_k(S \setminus A^\lambda) = -\Delta c_k(S, a_A, \lambda) \text{ if } A \in S \\ c_k(S) - c_k(S \setminus B^\lambda) = -\Delta c_k(S, a_B, \lambda) \text{ if } B \in S \\ c_k(S) - c_k(S \cup A^\lambda \cup B^\lambda) = \Delta c_k(S, a_A + a_B, \lambda) \text{ if } J \in S \\ c_k(S') - c_k(S' \cup A^\lambda) = \Delta c_k(S', a_A, \lambda) \text{ if } B, J \in S' \\ c_k(S') - c_k(S' \cup B^\lambda) = \Delta c_k(S', a_B, \lambda) \text{ if } A, J \in S' \\ c_k(S') - c_k(S' \setminus A^\lambda \setminus B^\lambda) = -\Delta c_k(S', a_A + a_B, \lambda) \text{ if } A, B \in S' \end{cases}$$

In the case of complements, the (24) says that because of the contract a third player becomes less productive in coalitions S that includes either player A or player B. By integration, assets of those coalitions decreased by λa_A and λa_B respectively, thus k loses productivity $\Delta c_k(S, a_A, \lambda)$ in one case and $\Delta c_k(S, a_B, \lambda)$ in the other. Instead, when coalition S includes player J, which now brings activities $\lambda(a_A + a_B)$ with him, k increases his contribution by $\Delta c_k(S, a_A + a_B, \lambda)$. For larger coalitions S' the productivity changes are reversed, because now their available assets increase by λa_A if $B, J \in S'$ and by λa_B if $A, J \in S'$.[4] In last type of orderings, where $A, B \in S'$, each player k becomes less efficient, in fact coalition S' looses activities $\lambda (a_A + a_B)$ because of the integration.

In bargaining game (N, v^T) the new asset vector

$$\left(a_j^T = (1-\lambda)a_j \text{ for } j = A, B;\ a_J^T = \lambda(a_A + a_B);\ a_i^T = a_i \text{ for } i \neq A, B, J\right)$$

affects the players' hold-up ability in a different way. This power can be exerted only through the presence of target J, whose position makes a third player k more (less) powerful in bargaining, depending on whether $\pi(J) < (>) \pi(k)$. When third players follow J, they hold A and B up by using the J's assets, but this ability is reduced in orderings where J arrives later or A and B arrive before. In other words, both in coalitions S and S' the net effect of integration is represented by a trade-off between the k's expected gains and his expected losses. Of course, the relationship between the relative rank of any k in the orderings and corresponding payoffs is reversed if players are substitutes. In this case any of them has incentive to enter any coalition as soon as possible, in order to avoid a larger detrimental competition. We find a sufficient condition on the probabilities that each k enters S or S' making the integration unprofitable to the contracting parties. The result is presented in the proposition below.

Proposition 3 *If players A and B form an independent RJV in the presence of complementarity (substitutability), then integration is unprofitable if the third parties enter with higher probability coalitions with one (two) of players A, B, J.*

Proof. Look at the figure 3. By (24) this contract affects the expected payoff of a player k as follows.

[4] Notice that players B and J, together, bring $(1-\lambda) a_B + \lambda (a_A + a_B) = a_B + \lambda a_A$, while players A and J can rely on $a_A + \lambda a_B$.

$$\phi_k^{\alpha}\left(v^T\right)-\phi_k^{\alpha}(v)=$$

$$\left[\begin{array}{c}\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S'\cup A\cup J)}\Delta c_k(S'\cup A,a_B,\lambda)+\sum_{S'\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S'\cup B\cup J)}\Delta c_k(S'\cup B,a_A,\lambda)\\ -\sum_{S'\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S'\cup A\cup B)}\Delta c_k(S'\cup A^{1-\lambda}\cup B^{1-\lambda},a_A+a_B,\lambda)\end{array}\right]$$

$$-\left[\begin{array}{l}\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup A)}\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)+\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup B)}\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\\ -\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup J)}\Delta c_k(S,a_A+a_B,\lambda)\end{array}\right] \tag{25}$$

If $\alpha\in\mathcal{F}(\Pi)$ is G-symmetric, then the probability α^k of coalitions where only the presence of players in G changes is constant, therefore $\alpha^k_{(S'\cup B\cup J)}=\alpha^k_{(S'\cup A\cup J)}=\alpha^k_{(S'\cup A\cup B)}=\widetilde{\alpha}'$ and $\alpha_{(S\cup A)}=\alpha_{(S\cup B)}=\alpha_{(S\cup J)}=\widetilde{\alpha}$. Thus the externality on k can be rewritten as

$$\begin{aligned}&\phi_k^{\alpha}\left(v^T\right)-\phi_k^{\alpha}(v)= \\ &\qquad\widetilde{\alpha}'\sum_{S'\subseteq N\backslash\{G\cup k\}}\left[\begin{array}{c}\Delta c_k(S'\cup A,a_B,\lambda)+\Delta c_k(S'\cup B,a_A,\lambda)\\ -\Delta c_k(S'\cup A^{1-\lambda}\cup B^{1-\lambda},a_A+a_B,\lambda)\end{array}\right]\\ &\qquad-\widetilde{\alpha}\sum_{S\subseteq N\backslash\{G\cup k\}}\left[\begin{array}{c}\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)+\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\\ -\Delta c_k(S,a_A+a_B,\lambda)\end{array}\right]\end{aligned} \tag{26}$$

with $S\subset S'$.

Consider now the differences in square brackets. With economies of scope, the (7) gives

$$\Delta c_k(S'\cup A^{1-\lambda}\cup B^{1-\lambda},a_A+a_B,\lambda)>\Delta c_k(S'\cup A,a_B,\lambda)+\Delta c_k(S'\cup B,a_A,\lambda)$$

and

$$\Delta c_k(S,a_A+a_B,\lambda)>\Delta c_k(S\cup A,a_A,\lambda)+\Delta c_k(S\cup B,a_B,\lambda)$$

respectively, therefore those differences are lower than zero. Applying the (7) again, the difference between values in square brackets is positive, and the sign of (25) depends on the probabilities $\widetilde{\alpha}$ and $\widetilde{\alpha}'$. A sufficient condition to have $\phi_k^{\alpha}\left(v^T\right)-\phi_k^{\alpha}(v)>0$ is

$\widetilde{\alpha}' \leq \widetilde{\alpha}$, in such case the integration would be unprofitable. With substitutable players the differences above are positive, but the net effect coming from coalitions S' prevails on the expected gains from coalitions S, so $\phi_k^{\alpha}\left(v^T\right) - \phi_k^{\alpha}(v) > 0$ if $\widetilde{\alpha}' \geq \widetilde{\alpha}$. ■

The integration unprofitability in proposition 3 is conditional on the probabilities $\widetilde{\alpha}$ and $\widetilde{\alpha}'$ that a player k enters coalitions S and S' respectively. With independent target the hold-up power of players A and B depends on the relative position of J: whenever k enters before J, he loses the advantages from the cooperation with a RJV, while the opposite occurs in orderings where his entry follows that of J, because he holds up the integrated parties. In such case his productivity increases by $\Delta c_k(S, a_A + a_B, \lambda)$ if only J belongs to S and by $\Delta c_k(S' \cup A, a_B, \lambda)$ or $\Delta c_k(S' \cup B, a_A, \lambda)$ if J is in S' together with A or B respectively. Thinking of situations with substitutability, it makes advantageous for each player to anticipate his entry and, here, the role of the target becomes relevant again. By the increasing differences argument the losses from following J (now $\Delta c_k(S, a_A + a_B, \lambda) < 0$) are higher than the savings from entering with A or B $(-\Delta c_k(S \cup A^{1-\lambda}, a_A, \lambda)$ and $-\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda))$. The net effect on k is greater in absolute value for larger coalitions S', while with complementarities is larger with all S. Hence, the sufficient conditions on $\widetilde{\alpha}$ and $\widetilde{\alpha}'$.

Therefore when no contracting player is able to bring with him the joint resources, the trade-off between positive and negative effects on external players makes the integration always unprofitable if the game is solved by a symmetric Shapley value ($\widetilde{\alpha} = \widetilde{\alpha}'$). Moreover, in the case of asymmetry this negative conclusion can be enhanced by the relative probability of coalitions with one or more integrated players inside.

2.5 RJVs with joint ownership

Assume now that the two parent firms share equally the control over the RJV, in the sense that 50% of decisional power relies on player A and 50% on player B. In our framework this ownership solution can be interpreted as if with probability one half J enters with A and with probability one half he enters with B. In other words, the joint ownership consists of an integration contract where the dominant parent may be either A or B with probability one half each. Once the contract is signed, the target J plays again the role of a dummy.

The figure 4 illustrates all possible orderings where player J arrives together with player B (meaning that B is dominant). The set of corresponding coalitions may occur with the same probability as the alternative in which the dominant is A. Now all players give an expected marginal contribution which depends on the probabilities that A or B exert the control over J, or equivalently, the probability that either A or B enters with J's resources. We denote by α_π^A and α_π^B the probabilities to have orderings $\pi \in \Pi$ where either A or B is dominant. Assuming a $G-$symmetric distribution α, if $\alpha_\pi^A = \alpha_\pi^B = \alpha_\pi^{AB}$ then all orderings in figure 4 are equally likely, and this implies $\alpha_{(S\cup A)}^k = \alpha_{(S\cup B)}^k$ for all S.

Recalling the asset structure in (17), the joint ownership RJV contract (denoted by JO) results in a transformation $a^{JO}(S)$ of $a(S)$ such that

$$\begin{cases} a^{JO}(S) = \alpha_\pi^{AB}\left[a(S\cup B^\lambda) + a(S\setminus A^\lambda)\right] \text{ if } A\in S \\ a^{JO}(S) = \alpha_\pi^{AB}\left[a(S\cup A^\lambda) + a(S\setminus B^\lambda)\right] \text{ if } B\in S \\ a^{JO}(S) = a(S) \text{ otherwise} \end{cases} \tag{27}$$

and the new characteristic function is $v(a^{JO}(S))$ or more simply $v^{JO}(S)$.

In game (N, v^{JO}), players' contributions are given by randomizing over the two alternative situations in which either one of the players is dominant.

$$\begin{cases} \Delta_A v^{JO}(S) = \alpha_\pi^{AB}\left[\Delta_A v(S\cup B^\lambda) + \Delta_{A^{1-\lambda}} v(S)\right] \text{ for all } S\subseteq N\setminus A \\ \Delta_B v^{JO}(S) = \alpha_\pi^{AB}\left[\Delta_{B^{1-\lambda}} v(S) + \Delta_B v(S\cup A^\lambda)\right] \text{ for all } S\subseteq N\setminus B \\ \Delta_J v^{JO}(S) = \Delta_J v(S) = 0 \text{ for all } S\subseteq N\setminus J \end{cases} \tag{28}$$

As for a third player$k$, his expected marginal contributions depend on α_π^A and α_π^B. For example, think of a complementary k joining a coalition $S\cup A\setminus B$. Player A brings with him J's resources with probability α_π^A, and he brings only a share $(1-\lambda)$ of his original activities with probability α_π^B. In the first case, k's marginal contribution increases by $\Delta c_k(S\cup A, a_B, \lambda)$, in the second case it decreases by $\Delta c_k(S\cup A^{1-\lambda}, a_A, \lambda)$. Suppose, instead, that player k arrives after B but before A. k's marginal contribution changes by $\Delta c_k(S\cup B, a_A, \lambda)$ with probability α_π^B and by $-\Delta c_k(S\cup B^{1-\lambda}, a_B, \lambda)$ with probability α_π^A. Proposition 4 shows that if both A and B have the same power, i.e., the same chance to take control over J's resources, the RJV integration is profitable. Not only, in chapter 3 we demonstrate as advantages to the parties are independent from the relative probabilities of dominance.

Proposition 4 *If A and B enter a RJV contract and equally share the control on the target J, then collusion is profitable if all third players show the same type of complementarity with A, B.*

Proof. By (27) the change in each player k's expected payoff is

$$\begin{aligned}&\phi_k^\alpha\left(v^{JO}\right)-\phi_k^\alpha(v)=\\&\sum_{S\subseteq N\setminus\{G\cup k\}}\alpha_{(S\cup A)}^{k,A}\Delta c_k(S\cup A,a_B,\lambda)-\sum_{S\subseteq N\setminus\{G\cup k\}}\alpha_{(S\cup B)}^{k,A}\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\\&+\sum_{S\subseteq N\setminus\{G\cup k\}}\alpha_{(S\cup B)}^{k,B}\Delta c_k(S\cup B,a_A,\lambda)-\sum_{S\subseteq N\setminus\{G\cup k\}}\alpha_{(S\cup A)}^{k,B}\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)\end{aligned} \tag{29}$$

With joint ownership at 50% and a $G-$symmetric distribution α, all coalitions where players A and B are exchanged have the same probability $\widetilde{\alpha}$, therefore the (29) is equivalent to

$$\phi_k^\alpha\left(v^{JO}\right)-\phi_k^\alpha(v)=$$

$$\widetilde{\alpha}\sum_{S\subseteq N\setminus\{G\cup k\}}\left\{\begin{array}{c}\left[\Delta c_k(S\cup A,a_B,\lambda)-\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\right]\\+\left[\Delta c_k(S\cup B,a_A,\lambda)-\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)\right]\end{array}\right\}$$

where both differences are negative by (7) and by assumption A.3. It implies $\phi_k^\alpha\left(v^{JO}\right)-\phi_k^\alpha(v)<0$ for all $k\in N\setminus G$, thus the integration is profitable, and the same holds for the case of substitutable players. ■

With complementarities, the dominant position of a contracting party makes the competitors' hold up ability lower than that of contracting parties (for example $\Delta c_k(S\cup A,a_B,\lambda)<\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)$). With substitutability, all ks gain when they avoid competition with the dominant player, for instance when they enter coalitions $S\cup B$, and get losses in the opposite case, that is by entering coalitions $S\cup A$.

2.6 Increasing the RJV size: the role of λ

From analysis above, it has become clear that profitability from joining complementary activities is strictly conditional to three main factors: i) the ownership structure that players decide over total assets, ii) the relative probabilities of all orderings, iii) the share of players' assets that come to be integrated.

In this paragraph we focus on the third element. We have defined $\lambda\left(a_A+a_B\right)$ as the complementary R&D activities that parties A and B can devote to the Research Joint Venture. We look at how the choice of λ affects the gains from integration. Consider the variation $\Delta c_k(S,a_i,\lambda)$. We have defined it as the change in k's contribution to a coalition S when the included players can rely on the additional assets λa_i for $i \in \{A, B, J\}$. It is positive if player k is complementary to the assets λa_i, and negative if he's substitute. In both cases, it is decreasing in (S, a_i, λ), and this property can be used to compare the changes in the gains that players receive from their hold up abilities (or, alternatively, from a lower competition) due to an increase of λ. Let us discuss the case of complementary assets. Consider the case with A dominant player. A third party k gets advantages from integration when he enters coalitions that include dominant player A, because the latter is bringing with him the complementary resources of J, so increasing the k's productivity. Nevertheless, the larger is the contribution of A (that is the larger is the share λ) the lower is the productivity gain of k, since the returns from complementarities increase at a decreasing rate. Of course, it implies that hold up power on A became less profitable. Think now to a player k entering a coalition with $S \setminus A \cup B$. In this situation the dominant player A holds k up, because B have no access to the share λ of his assets, and the change in k's productivity is $-\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$. An increase in λ yields two opposite effects. First, it reduces the losses of k, since the productivity change $\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$ decreases as before, so the hold up ability of contracting party becomes less profitable. Second, the assets $a\left(S \cup B^{1-\lambda}\right)$ decrease, because B contributes with less resources than before. It implies that marginal contributions of k would have been more productive, and this effect tends to compensate the first one, thus $\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$ decreases less. When all players are substitutable to each other a similar trade-off arises. In coalitions where A brings more resources it makes worse the bargaining position of player k, because the third party has to reach agreements with more endowed substitutable players. On the contrary, the growth of λ is desirable to k when he enters coalitions that include player B but not A. He can avoid, now, a stronger competition, in fact a larger share of assets remains outside with player A. However, what he saves may have a smaller impact on his payoff, since an increase in λ reduces the amount of substitutable assets that are available to $S \cup B^{1-\lambda}$, and this implies less competition for k (recall the (8)). The same reasoning applies to the other forms of integration except for mergers. Indeed, by these contracts the proxy player brings with him all other players' resources, therefore the amount of integrated assets does not depend on the parameter λ.

After giving the intuition on how the decisions over λ affect the contracts profitability, the proposition below provides some conclusions for different ownership solutions.

Proposition 5 *If players A and B pool a share λ of their resources, then the contract profitability is increasing (decreasing) in λ whenever the parties exert some (no) control* *on the integrated activities.*

Proof. Consider RJV integrations with a dominant parent. With complementarities, the gains for a player k are evaluated by $\Delta c_k(S \cup A, a_B, \lambda) - \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda) < 0$ for all $S \setminus \{A, B, J\}$ (see proof of proposition 2). Ceteris paribus, if λ increases both the terms decrease. Notice also that asset structure $a\left(S \cup B^{1-\lambda}\right)$ is reduced, while $a\left(S \cup A\right)$ not. By (8) the value $\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$ decreases less than $\Delta c_k(S \cup A, a_B, \lambda)$, and difference $\Delta c_k(S \cup A, a_B, \lambda) - \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$ is decreasing in λ too. The contract is more profitable. With substitutability, the same difference is still negative and both terms decrease with λ. Anyway, the growth of λ is desirable to k when he enters coalitions that include player B, in fact a larger share of assets remains outside with player A. The term $\Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$ decreases less, thus difference $\Delta c_k(S \cup A, a_B, \lambda) - \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)$ is still negative and contract profitability increases.

Consider now the contract with independent target and look at (25). By the same reasoning as above, if λ grows and players are complements, then the value of each difference in square brackets decreases as well by (8), but according to (7) the effect on the second difference is larger. Ceteris paribus, the (25) is still greater than zero and integration is more unprofitable. In the presence of substitutability, all values take an opposite sign but result is the same.

For integrations with common ownership, finally, consider the (28). With equally shared control, the same proof as that for contracts with dominant parent applies. ■

Essentially, the hold up abilities of contracting players depend on the amount of additional assets they can control after integrating, thus the larger is λ the more advantageous is the integration. In the extreme case in which no contracting party gets additional assets the integration is unprofitable, and increasing the pooled resources make them worse in bargaining.

Part II

Partial asset complementarities and players' enthusiasm

Chapter 3

Players' partial complementarities and asymmetric random order values

3.1 The effects of partial complementarities among players

In previous sections we have assumed that all players' assets were either complementary or substitutable with each other. In this section, instead, we consider a more general situation in which players own divisible assets of two types: complementary to some players and substitutable to others. Let's think of two players $i, j \in N$. If player i owns a share λ of his assets a_i which is complementary (or substitutable) to a share λ of j's endowment a_j, then remaining share $(1-\lambda)$ is substitutable (or complementary) to assets $(1-\lambda)\,a_j$. The level of complementarity among agents is not asset specific, but it is simply proportional to the amount of those activities. Then, we derive new profitability conditions when the contracts allow for partial complementarities between colluding and external players. A third player k is, say, substitutable to A and B if all endowments are considered, but he may be complementary only with assets λa_A, λa_B. In this case, k's marginal contribution to a coalition that includes both A and B is positive if A and B are using only the fraction λ of their assets (so including A^{λ} and B^{λ}), but it is negative if they participate with the remaining assets $(1-\lambda)\,(a_A + a_B)$. Below, we show the effects of partial complemetarity on the profitability conditions of propositions 1-4, and highlight whether the kind of R&D activities that players choose to integrate may have some strategic effect on the third parties.

3.1.1 Merger contracts

The news that a pair of agents can be complementary with each other but substitutable with other (or vice versa) has some implications. For example, the change in marginal cost $\Delta^2_{ij}c(S)$, which is negative for two complementary players $i, j \in N$, goes up if group S includes some players that are substitutable to i and j. In other words, the presence of substitutable agents reduces the complementarity degree between i and j. On the other hand, it enhances the relationship between the two if they are substitutes, that is when $\Delta^2_{ij}c(S) > 0$. Formally,

$$\Delta^2_{ij}c(S \cup k) - \Delta^2_{ij}c(S) > 0 \ \text{ if} \begin{cases} i, j \text{ complements and} \\ k \text{ substitute of } i, j. \end{cases} \tag{30}$$

and

$$\Delta^2_{ij}c(S\cup k)-\Delta^2_{ij}c(S)>0 \ \text{ if}\begin{cases} i,j \text{ substitutes and} \\ k \text{ substitute of } i,j. \end{cases} . \tag{31}$$

We use the relations (30) and (31) to study the merger contracts in which external players can also be substitutable or complementary with only one of the integrating parties. We find a general result for all possible cases in which the third parties can be considered substitutes of each other but have different relationships with A and B.

Proposition 6 *Profits increase by a merger if all third players are complementary at least with one of the integrating parties. Profits decrease if third players are substitutes to both A and B or complements to them when A and B are substitutes.*

Proof. With a G-symmetric distribution $\alpha\in\mathcal{F}(\Pi)$ the integration is (un)profitable if $\Delta^3_{ABk}c(S)=\Delta^2_{AB}c(S\cup k)-\Delta^2_{AB}c(S)>(<)0$ for all $S\subseteq N\setminus G$ and any $k\in N\setminus G$.

Case 1 - k either complement or substitute to both A and B

Suppose that A and B are complements of each other. With a complementary k term $\Delta^3_{ABk}c(S)$ is positive, as implied by (4), while with k substitutable an opposite result holds by (30). Suppose now that A and B are substitutable with each other. If k is complementary then he reduces the substitutability between A and B, and $\Delta^2_{AB}c(S\cup k)-\Delta^2_{AB}c(S)<0$, instead with k substitutable the relationship is enhanced and contract becomes profitable.

Case 2 - k complement to A and substitute to B

$\Delta^3_{ABk}c(S)$ can be written as $\Delta^2_{Ak}c(S\cup B)-\Delta^2_{Ak}c(S)$, where both the terms are negative and relation between A and B does not matter. Note that $|\Delta^2_{Ak}c(S\cup B)|<|\Delta^2_{Ak}c(S)|$ because B reduces the complementarity between A and k. Thus $\Delta^3_{ABk}c(S)>0$.

Case 3 - k complement to B and substitute to A

Now $\Delta^3_{ABk}c(S)=\Delta^2_{Bk}c(S\cup A)-\Delta^2_{Bk}c(S)$ and the same proof as before applies. ■

Proposition (6) claims that profitability from pooling R&D activities by a merger is disadvantageous only in two cases, that is when the k's productivity from joining one of the contracting parties decreases, and it simply means that his hold-up power goes down in favor or A,B.

3.1.2 RJV with dominant parent

In a RJV contract with a dominant player the partial transferring of resources from player B to player A (when A dominant) implies an enlargement of the asset endowment for all coalitions that player A might enter. This transferring has some further implications when we admit the possibility for external players to have different relationships with the integrated assets and each parent as whole. Let's think of productivity growth rate $\Delta c_k(a(S), a_j, \lambda)$ expressed as function of the asset structure of S. It is positive if the additional assets λa_j are complementary with those of k, that is a_k, but is decreasing (increasing) in the level of assets in $a(S)$ which are substitutes (complements) to a_k. So,

$$\begin{gathered}\Delta c_k(a(S \cup i), a_j, \lambda) - \Delta c_k(a(S), a_j, \lambda) < (>) 0 \\ \text{if } a_i \text{ and } a_k \text{ substitutes (complements)}\end{gathered} \tag{32}$$

when k and j complementary with each other.

Suppose, on the contrary, that k and j are substitutable with each other. Now $\Delta c_k(a(S), a_j, \lambda)$ is negative, and decreasing for larger amounts of assets that are substitutable to k, but increasing if those assets are complementary. For instance,

$$\begin{gathered}\Delta c_k(a(S \cup i^\lambda), a_j, \lambda) - \Delta c_k(a(S \cup i), a_j, \lambda) > (<) 0 \\ \text{if } \lambda a_i \text{ and } a_i \text{ substitutes (complements) to } a_k\end{gathered} \tag{33}$$

when k and j substitutable with each other.

Of course, once combined, (32) and (33) entail the (34).

$$\begin{gathered}\Delta c_k(a(S \cup i), a_j, \lambda) - \Delta c_k(a(S \cup j^{1-\lambda}), a_j, \lambda) > 0 \\ \text{if } k \text{ complementary with } i \\ \text{and } k \text{ substitutable with } (1-\lambda)\, a_j\end{gathered} \tag{34}$$

when k complementary with λa_j.

The formula above says that when k is complementary with λa_j the presence of complementary assets a_i boosts its productivity growth rate, while the latter decreases at the presence of substitutable assets $(1-\lambda)\, a_j$. Correspondingly,

$$\begin{gathered}\Delta c_k(a(S \cup i), a_j, \lambda) - \Delta c_k(a(S \cup j^{1-\lambda}), a_j, \lambda) < 0 \\ \text{if } k \text{ substitutable with } i \\ \text{and complementary with } (1-\lambda)\, a_j\end{gathered} \tag{35}$$

when k substitutable with λa_j.

We use the properties above to investigate the profitability of integration when players have different complementarities relationships with a share (or the totality) of their assets.

Proposition 7 *If players A and B sign a RJV contract with a dominant parent which is (complementary) substitutable to all third players, then integration is (un)profitable.*

Proof. From proof of prop. 2 it follows that integration is (un)profitable if $\Delta c_k(a(S \cup A), a_B, \lambda) - \Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda) < (>) \, 0$ for any S and k. We distinguish four possible cases.

Case 1 - k complementary with λa_B *and substitutable with A.*

It is implied that k is substitute with the share of assets $(1-\lambda)a_B$. Both $\Delta c_k(a(S \cup A), a_B, \lambda)$ and $\Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda)$ are positive, but $\Delta c_k(a(S \cup A), a_B, \lambda) - \Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda) < 0$ because a_A reduces the complementarity between k and B more than $(1-\lambda)a_B$ (recall assumption A.2).

Case 2 - k complementary both with λa_B *and A.*

Both $\Delta c_k(a(S \cup A), a_B, \lambda)$ and $\Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda)$ are positive, but $\Delta c_k(a(S \cup A), a_B, \lambda) - \Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda) > 0$ because $(1-\lambda)a_B$ is substitutable with k (complementarity decreases).

Case 3 - k substitutable both with λa_B *and A.*

The two growth rates are negative and $\Delta c_k(a(S \cup A), a_B, \lambda) - \Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda) < 0$ because $(1-\lambda)a_B$ is complementary with k.(substitutability decreases).

Case 4 - k substitutable with λa_B *and complementary with A.*

Now $\Delta c_k(a(S \cup A), a_B, \lambda) - \Delta c_k(a(S \cup B^{1-\lambda}), a_B, \lambda) > 0$ because a_A reduces the substitutability between k and B more than $(1-\lambda)a_B$.

Thus, integration is always (un)profitable if all k's are (complementary) substitutable with the dominant parent. Notice that such result is true whatever is the complementarity degree between B and k. ■

Such proposition adds an important contribution to our analysis, because it shows that concept of profitability does not depend on the kind of resources the contracting parties decide to integrate, but is mainly related to the relationships between the dominant parent and the external players. The intuition directly follows from our hold-up power perspective. With a complementary k, the additional assets that dominant A brings with him guarantee an increase in the k's assets productivity when he enters coalitions $S \cup A$ (look at the term $\Delta c_k(a(S \cup A), a_B, \lambda)$). Obviously, this is equivalent to an increase of external players' power to exploit advantages from actions of A, or what is the same, an increase in k's hold-up ability. Therefore the most profitable contracts are those in which the two players A and B choose to pool complementary R&D activities and to give more ownership rights to the party which is substitutable with all ks.

3.1.3 RJV with independent target

The main characteristics of this contracts are the independence of RJV entity and the fact that contracting players can exert their hold-up power by exploiting the relative position of J. However, the unprofitability condition in proposition 3 is based on the relative probability that a player k has to enter coalitions with one or two players in set $G = \{A, B, J\}$ (recall the probabilities $\widetilde{\alpha}$ and $\widetilde{\alpha}'$). In this paragraph, we explore the effectiveness of that conclusion in the presence of partial complementarities, and it comes out that the same result is still valid when conditions on $\widetilde{\alpha}$ and $\widetilde{\alpha}'$ are preserved.

Proposition 8 *Suppose that players A and B form a RJV with an independent target J, and third players are more likely to enter coalitions that include (one) two of them when they are substitutable (complementary) to A, B. Then the contract is unprofitable regardless the complementarity between J and the third players.*

Proof. Consider the proof of prop. (3). Advantages from integration depend on the probabilities $\widetilde{\alpha}$, $\widetilde{\alpha}'$ and the relative size of differences

$$\left[\begin{array}{c} \Delta c_k(S' \cup A, a_B, \lambda) + \Delta c_k(S' \cup B, a_A, \lambda) \\ -\Delta c_k(S' \cup A^{1-\lambda}B^{1-\lambda}, a_A + a_B, \lambda) \end{array}\right] \tag{36}$$

and

$$\left[\begin{array}{c} \Delta c_k(S \cup A, a_A, \lambda) + \Delta c_k(S \cup B, a_B, \lambda) \\ -\Delta c_k(S, a_A + a_B, \lambda) \end{array}\right] \tag{37}$$

Assuming that S' is more substitute to any k than S, we study the following cases by applying (32) and (33) to (36) and (37).

Case 1 - k complement to λa_A, λa_B and substitute to A, B.

Players A, B are substitutes of k when they contribute with a share $1-\lambda$ of their assets, that is when the are denoted by $A^{1-\lambda}$ and $B^{1-\lambda}$, and differences (36) and (37) are negative by (32), (33) and (8). Indeed, in (36) the productivity growth rate decreases in the presence of substitutes A, B more than with complements $A^{1-\lambda}$ and $B^{1-\lambda}$, thus $\Delta c_k(S' \cup A^{1-\lambda}B^{1-\lambda}, a_A + a_B, \lambda) > \Delta c_k(S' \cup A, a_B, \lambda) + \Delta c_k(S' \cup B, a_A, \lambda)$ and $\Delta c_k(S, a_A + a_B, \lambda) > \Delta c_k(S \cup A, a_A, \lambda) + \Delta c_k(S \cup B, a_B, \lambda)$. Being any coalition S' more substitutable to k than S^1, by (8) the difference between (36) and (37) is positive, since all variations in (36) are smaller, and condition $\widetilde{\alpha}' \leq \widetilde{\alpha}$ enhances this effect. If it holds for any k then integration is unprofitable.

Case 2 - k complement to λa_A, λa_B and complement to A, B.

The proof is similar, and differences (36) and (37) are negative. Use the condition on S, S' and the (8) to get $(36) - (37) > 0$, therefore the contract is still unprofitable.

Case 3 - k substitute to λa_A and λa_B *and complement to A, B.*

All terms in (36) and (37) are negative and players $A^{1-\lambda}$, $B^{1-\lambda}$ are complements of k. Applying the (7), (8), (32), (33) it turns out that

$$\left|\Delta c_k(S' \cup A^{1-\lambda}B^{1-\lambda}, a_A + a_B, \lambda)\right| > |\Delta c_k(S' \cup A, a_B, \lambda) + \Delta c_k(S' \cup B, a_A, \lambda)|$$

and

$$|\Delta c_k(S, a_A + a_B, \lambda)| > |\Delta c_k(S \cup A, a_A, \lambda) + \Delta c_k(S \cup B, a_B, \lambda)|$$

thus (36) and (37) are positive. With any coalition S' more substitute to k than any S, the players' substitutability in (36) increases, and difference with (37) is positive by (7). A sufficient condition to get the unprofitability of integration is $\widetilde{\alpha}' \geq \widetilde{\alpha}$.

Case 4 - k substitutable to λa_A and λa_B *and substitute to A, B.*

The proof is identical to that of case 3. ■

Conclusions above are still based on the relative influence of the contracting and noncontracting players' hold-up abilities, and it is shown that, if some coalitions are more likely than some others, then integration is not advantageous.

In particular, the presence of J in those groups becomes crucial for the analysis. Just as example, consider a situation in which players ks are complementary to A, B and J. They receive a big advantage from entering coalitions $S \cup J$ (effect $\Delta c_k(S, a_A + a_B, \lambda)$), and it prevails on the damage that they receive when entering coalitions $S' \cup A^{1-\lambda}B^{1-\lambda}$, because $S \subset S'$. In practice, the integration of A and B makes a favor to the competitors in bargaining. On the other side, when the ks are substitutable to J, the first effect translate into a loss in productivity, while the second effect into positive gains, but now the latter prevails because $S' \supset S$. Therefore in both cases the integration is unprofitable, and a similar trade-off can be applied if the ks are substitutable to A and B, with the only difference that in such case the third parties gain when anticipate J and vice versa. As in the previous contract, substantially, we have shown that what matters is how the

[1](The change $\phi_k^{\alpha}\left(v^T\right) - \phi_k^{\alpha}(v)$ must have the same sign for any k, thus the latter is substitutable with all players different from A, B, J).

ownership rights are distributed by the parents and which are the relationships between them and the other players, while no relevance can be attributed to the characteristics of integrated resources.

3.1.4 RJV with joint ownership

The contracts with independent target allow to investigate how the bargaining power is redistributed among players when the external competitors do not know which of the two parents A and B is bringing the J's resources. However, in most of contracts each colluding party has a certain degree of influence on the RJV activities, and this power is distributed according to the ownership rights on assets $\lambda\left(a_A + a_B\right)$. An interesting issue, in a setting with joint ownership, is whether the post integration profits increase when a larger control is assigned to a specific parent. Not only. The advantages from choosing a specific dominant player may depend on the complementarities relationships among the involved players. Below, we address to this issue by proposition 9, which provides a link between ownership structure, complementarities and post contract gains.

Proposition 9 *Suppose that players A and B enter a RJV contract with joint ownership on J. Then*

1. *the integration is (un)profitable if the third players are complementary (substitutable) to A, B;*

2. *with the third players complementary to B but substitutable to A, the joint profits are negative if player B has a larger control on J and losses decrease with the A's ownership;*

3. *with the third players complementary to A but substitutable to B, the joint profits are positive if player B has a larger control on J and decrease with the A's ownership.*

Proof. Look at the proof of proposition (4). The collusion profitability strictly depends on the sum

$$
\begin{aligned}
&\phi_k^\alpha\left(v^{JO}\right) - \phi_k^\alpha(v) = \\
&\sum_{S\subseteq N\backslash\{G\cup k\}} \alpha^{k,A}_{(S\cup A)} \Delta c_k(S\cup A, a_B, \lambda) - \sum_{S\subseteq N\backslash\{G\cup k\}} \alpha^{k,A}_{(S\cup B)} \Delta c_k(S\cup B^{1-\lambda}, a_B, \lambda) \\
&+ \sum_{S\subseteq N\backslash\{G\cup k\}} \alpha^{k,B}_{(S\cup B)} \Delta c_k(S\cup B, a_A, \lambda) - \sum_{S\subseteq N\backslash\{G\cup k\}} \alpha^{k,B}_{(S\cup A)} \Delta c_k(S\cup A^{1-\lambda}, a_A, \lambda)
\end{aligned}
\tag{38}
$$

and the probabilities $\alpha^{k,A}_{(S)}$, $\alpha^{k,B}_{(S)}$ reflect the share of ownership the parties A and B have decided on the RJV activities. Anyway, if distribution α is $G-$symmetric, then $\alpha^{kA}_{(S\cup A)} = \alpha^{kA}_{(S\cup B)}$ and $\alpha^{kB}_{(S\cup B)} = \alpha^{kB}_{(S\cup A)}$ for all S, and it implies

that gains from integration are related to the value of differences

$$\Delta c_k(S \cup A, a_B, \lambda) - \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda) \tag{39}$$

and

$$\Delta c_k(S \cup B, a_A, \lambda) - \Delta c_k(S \cup A^{1-\lambda}, a_A, \lambda) \tag{40}$$

for any k.

We consider the following cases.

Case 1 - k complement to λa_A, λa_B and A, B

The shares $(1-\lambda)\, a_B$ and $(1-\lambda)\, a_A$ (substitutable with the k's assets) reduce the complementarity of k, hence both (39) and (40) are positive by (32) for any S. If it is true for all ks, then collusion is unprofitable.

Case 2 - k complement to λa_A, λa_B and substitute to A, B.

Players A and B reduce the complementarity of k more than their participation with a share $(1-\lambda)$ of resources, hence (39) and (40) are negative. Ceteris paribus, collusion is profitable.

Case 3 - k substitute to λa_A, λa_B and A, B

Expressions (39) and (40) are negative by (34). If it holds for any k the joint profits are positive.

Case 4 - k substitute to λa_A, λa_B and complement to A, B

Applying the (34) the same differences become positive. The integration is unprofitable.

Case 5 - k complement (or substitute) to λa_A, λa_B, substitute to A and complement to B

Whatever is the relation between k and λa_A, λa_B the (34) and (35) ensure that (39) is negative and the (40) is positive, with

$$\left|\Delta c_k(S \cup B, a_A, \lambda) - \Delta c_k(S \cup A^{1-\lambda}, a_A, \lambda)\right| > \left|\Delta c_k(S \cup A, a_B, \lambda) - \Delta c_k(S \cup B^{1-\lambda}, a_B, \lambda)\right|$$

by (8). Thus (38) is positive whenever player B gets a larger control over J (that is $\alpha^{k,A}_{(S)} < \alpha^{k,B}_{(S)}$ represents a sufficient condition for the collusion to be unprofitable) but decreases with $\alpha_{(S)}^{k,A}$.

Case 6 - k complement (or substitute) to λa_A, λa_B, complement to A and substitute to B

The proof comes from case 5, but now (39) is positive and (40) negative, so collusion is profitable if $\alpha_{(S)}^{k,A} < \alpha_{(S)}^{k,B}$ and joint profits decrease with $\alpha_{(S)}^{k,A}$. ■

The sentences above confirm two main results. First, the ownership structure established by the contracting players does not matter when the third parties have the same relationship with both A and B. Second, when the third players are complementary to one parent but substitutable to the other, the integration is (un)profitable if the (complementary) substitute player gets a larger control. Indeed, if a player k is complementary or substitutable with both A and B, the strategic effects of integration work in the same direction, and for any ownership structure the case for contracts with dominant player applies. Instead, when the k's assets have different utilities for A, B the hold-up effect from complementarities is greater with A dominant, and the damage to k from substitutability is larger with a dominant B. A final remark is about the R&D sectors. In this contract, again, the type of pooled assets does not play any role. Our results are robust to whatever are the complementarities between the research activities of A and B and the other players' assets. As further step, in chapter 3 we study the influence of players' attitudes on the sufficient conditions we found in propositions 1-8, that is we include the players' bargaining abilities as determinants of profitability.

3.2 Contracts profitability with asymmetric random order values

3.2.1 Asymmetric path entries and path values

Previous results established a link between complementarity and RJV profitability when contracting players are equally likely to enter the same coalitions. In other words, when they show the same propensity to cooperate with external players before and after integration. Since each economic agent has specific preferences and attitudes, the assumption that random order values are symmetric with respect to some players might seem very strong and few truthful . In a random order value the probability that a coalition S formed at time $t \in [0, 1]$ can be expressed as a function of the players' entry probabilities. For all $k \in N$, we call $\gamma_k(t)$ the probability that at t the player k already arrived, with $\gamma_i(0) = 0$ and $\gamma_i(1) = 1$. Thus, the probability that a coalition S formed at time t is given by $\prod_{j\in S}\gamma_j(t)\prod_{j\notin S}\left(1-\gamma_j(t)\right)$, while the probability that a player $k\notin S$ joins S at t is $\prod_{j\in S}\gamma_j(t)\prod_{j\notin S}\left(1-\gamma_j(t)\right)\gamma_k'(t)$. Taking the expectation on $\gamma_k(t)$, we get the k's expected probability to join S:

$$\gamma^k(S)=\int_0^1\prod_{j\in S}\gamma_j(t)\prod_{j\notin S}\left(1-\gamma_j(t)\right)d\gamma_k(t)$$

In a random order setting, the $\gamma^k(S)$ is equivalent to the probability $\alpha(S)$ that a given player $k\notin S$, at time t, joins a group of players preceding him who reached a certain agreement in bargaining, that is the coalition S.

By this reason, the $\gamma_i(t)$'s $(i=1,...,n)$ can be interpreted as the players i's *entry (*or *bargaining) attitudes* for different arrival times, that is the probabilities of players to accept some agreements proposed by the coalitions of preceding rivals.

Owen (1972) uses this concept of random entry to define the path value, a solution concept which is equivalent to the random order value we introduced by (9) except that each probability $\alpha(S)$ is expressed as a function of the players' attitudes $\gamma_i(t)$'s.

Definition 3 *A function $\gamma:[0,1]\to[0,1]^N$ is a path if it assigns a distribution function $\gamma_j(t)$ on $[0,1]$ to each $j\in N$, and for each $i\neq j$ the discontinuity sets of $\gamma_i(t)$, $\gamma_j(t)$ are disjoint.*

Once a path is established on a set N of players, a random order value can be rewritten as function of players' entry attitudes.

Definition 4 *Given a path γ on N, the solution $\varphi_\gamma(v)=\left\{\varphi_\gamma(v)(1),...,\varphi_\gamma(v)(n)\right\}$ is a path value for game v if*

$$\varphi_{\gamma_i}(v)=\sum_{S\subseteq N\backslash i}\int_0^1\left\{\prod_{j\in S}\gamma_j(t)\prod_{j\notin S}\left(1-\gamma_j(t)\right)\left[v(S\cup i)-v(S)\right]\right\}d\gamma_i(t)$$

for all $i\in N$.

This solution concept assigns to each player the same expected payoff as the random order value, indeed $\varphi_{\gamma_i}(v)=\phi_i^\alpha(v)$, but it allows for including the players' heterogeneity in terms of their propensities to cooperate with different coalitions and for different entry times.

The two contracting players A,B have asymmetric path entries if the probability $\gamma_A(t)$ that a player A entered a coalition at time t is larger (or smaller) than the corresponding $\gamma_B(t)$ for any $t\in[0,1]$. Suppose, for instance, that $\gamma_A(t)>\gamma_B(t)$ for all t: we say that lottery t for player A strictly first-order stochastically dominates lottery t for player B and we denote it by $\gamma_A(t) >_1 \gamma_B(t)$. According to the following lemma, the sthocastic dominance for distribution $\gamma_A(t)$ makes the entry of player A in all S more likely than the entry of B, and this implies that a third player k is more likely to enter a coalition $S \cup A$ rather than a coalition $S \cup B$. Of course, it is true the contrary if $\gamma_B(t) >_1 \gamma_A(t)$.

Lemma 2 *If $\gamma_A(t) >_1 \gamma_B(t)$ for $A, B \in N$, then the difference $\alpha^k_{(S\cup A)} - \alpha^k_{(S\cup B)}$ is positive for all $S \subseteq N \setminus \{A, B, k\}$ and increasing in $\frac{\gamma_A(t)}{\gamma_B(t)}$.*

Proof. The probabilities $\alpha^k_{(S\cup A)}$ and $\alpha^k_{(S\cup B)}$ can be written as

$$\alpha^k_{(S\cup A)} = \int_0^1 \prod_{\substack{j\in S \\ S\subseteq N\setminus k}} \gamma_j(t) \cdot \gamma_A(t) \prod_{\substack{j\notin S \\ S\subseteq N\setminus k}} \left(1-\gamma_j(t)\right)\left(1-\gamma_B(t)\right) d\gamma_k(t)$$

and

$$\alpha^k_{(S\cup B)} = \int_0^1 \prod_{\substack{j\in S \\ S\subseteq N\setminus k}} \gamma_j(t) \cdot \gamma_B(t) \prod_{\substack{j\notin S \\ S\subseteq N\setminus k}} \left(1-\gamma_j(t)\right)\left(1-\gamma_A(t)\right) d\gamma_k(t)$$

With $\gamma_A(t) >_1 \gamma_B(t)$ the difference $\alpha^k_{(S\cup A)} - \alpha^k_{(S\cup B)}$ is positive, because $\gamma^A(t)/\gamma^B(t) > [1-\gamma^A(t)]/[1-\gamma^B(t)]$, and increases in $\gamma^A(t)/\gamma^B(t)$. ■

Whenever lemma 2 applies for some agents in game (N, v), the probability distribution of coalitions becomes asymmetric with respect to the relative position of those players. Following Passarelli (2007), we use the asymmetric entry paths to differentiate players in game (N, v) according to their level of enthusiasm towards the bargaining. We say that player A, in the example above, is more *enthusiastic,* while player B is *reluctant*, because A is more likely than B to accept agreements with any coalition S. In this section we investigate how the links between complementarities and contract profitability are affected by differences in the bargaining attitudes of players A, B, J, that is when the solution concept turns to be $G-$asymmetric.

3.2.2 Gains from integration with heterogeneous bargaining attitudes

When the symmetry assumption is removed, the conclusions of propositions 1 - 8 depend on the relative probability of third players to enter coalitions including either A or B. In the particular case where the RJV is supposed to be autonomous, the J's enthusiasm too is involved. Below, we reconsider the four integration contracts in sections 3 and 4 to explore how the links between the contracting parties' enthusiasm level and the assets characteristics affect the advantages from collusion. Results are presented in propositions 9 and 10. The first one concerns situations with full complementarities between third parties and colluding players, the second one takes into account the possibility of players to have different sets of assets and partial complementarities with A and B.

Proposition 10 (*Full complementarities*) *Consider the contracts in propositions 1-4 If the solution of game may be an asymmetric path value, then the profitability of integration is*

[merger+dominant parent] *increasing in* $\gamma_B(t)/\gamma_A(t)$ $(\gamma_A(t)/\gamma_B(t))$ *if all* k*s are complementary (substitutable) to* A, B.

[independent target] *increasing in* $\gamma_A(t)$, $\gamma_B(t)$ *and decreasing in* $\gamma_J(t)$

[joint ownership] *increasing in* $\gamma_A(t)/\gamma_B(t)$

Proof. *Merger*

See proof of proposition 1. By lemma 2, with any k complementary to A and B the difference

$$\alpha^k_{(S\cup A)}\Delta^2_{Bk}c(S\cup A)-\alpha^k_{(S\cup B)}\Delta^2_{Bk}c(S)$$

is positive if $\gamma_B(t)>_1\gamma_A(t)$, and the joint profits of A, B increase in $\gamma_B(t)/\gamma_A(t)$. With players ks substitutable the result is still positive with $\gamma_A(t)>_1\gamma_B(t)$, and the joint profits increase in $\gamma_A(t)/\gamma_B(t)$.

RJV with a dominant parent

See proof of proposition 2. By lemma 2 the difference

$$\alpha^k_{(S\cup A)}\Delta c_k(S\cup A, a_B,\lambda)-\alpha^k_{(S\cup B)}\Delta c_k(S\cup B^{1-\lambda}, a_B,\lambda)$$

is negative with complementary players if $\gamma_B(t)>_1\gamma_A(t)$, and negative with substitutable players if $\gamma_A(t)>_1\gamma_B(t)$, therefore conclusions are the same as for mergers.

RJV with independent target

By proof of proposition 3 the contract profitability depends on

$$\phi_k^\alpha\left(v^T\right)-\phi_k^\alpha(v)=$$

$$\left[\begin{array}{c}\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S'\cup A\cup J)}\Delta c_k(S'\cup A,a_B,\lambda)+\sum_{S'\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S'\cup B\cup J)}\Delta c_k(S'\cup B,a_A,\lambda)\\ -\sum_{S'\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S'\cup A\cup B)}\Delta c_k(S'\cup A^{1-\lambda}B^{1-\lambda},a_A+a_B,\lambda)\end{array}\right]$$

$$-\left[\begin{array}{l}\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup A)}\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)+\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup B)}\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\\ -\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^k_{(S\cup J)}\Delta c_k(S,a_A+a_B,\lambda)\end{array}\right]$$

which is greater than zero with a $G-$symmetric distribution α and complementary ks. The first difference (negative) is lower in absolute value and decreases in $\alpha^k_{(S'\cup A\cup B)}$, while the second difference in square brackets (also negative) is greater in absolute value and increases in $\alpha^k_{(S\cup J)}$. By lemma 2 the losses from integration decreases with $\gamma_A(t)$ and $\gamma_B(t)$ but increase with $\gamma_J(t)$. If the ks are substitutable the sign of differences is reversed, but conclusions still hold.

RJV with joint ownership

From proof or proposition 4 consider the

$$\begin{array}{l}\phi_k^\alpha\left(v^{JO}\right)-\phi_k^\alpha(v)=\\ \sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^{k,A}_{(S\cup A)}\Delta c_k(S\cup A,a_B,\lambda)-\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^{k,A}_{(S\cup B)}\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\\ +\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^{k,B}_{(S\cup B)}\Delta c_k(S\cup B,a_A,\lambda)-\sum_{S\subseteq N\backslash\{G\cup k\}}\alpha^{k,B}_{(S\cup A)}\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)\end{array}\quad(41)$$

where differences in each line are negative if there are complementarities, and the relative position of A, B only matters. Since

$$\begin{array}{c}\left|\Delta c_k(S\cup B,a_A,\lambda)-\Delta c_k(S\cup A^{1-\lambda},a_A,\lambda)\right|\\ >\left|\Delta c_k(S\cup A,a_B,\lambda)-\Delta c_k(S\cup B^{1-\lambda},a_B,\lambda)\right|\end{array}$$

the players' enthusiasm is more effective in second line of (41), thus joint profits increase with $\gamma_A(t)/\gamma_B(t)$ by lemma 2. With substitutability the (41) is still negative but each difference above turns to be larger than zero, with the first one dominant, thus the same conclusion holds by lemma 2. ■

Notice as, for merger contracts and solutions with dominant player, the impact of A and B's relative enthusiasm changes if players are substitutable with each other, while in remaining cases the effect does not depend on the adopted technology. For instance, if all the assets are complementary to those of noncontracting parties then it is convenient choosing as dominant parent the one who is more reluctant, that is the party with lower bargaining ability. This choice would reduce the probability that external players hold-up the parents, but would produce a negative effect with ks substitutable. Not only. The impact of players' asymmetry is conditional on the ownership structure decided by colluding players. Let's think of joint ownership integrations. The profits from this contracts increase with a more enthusiastic A and a reluctant B, but when the control on the joint activities goes down (independent target can be viewed as an extreme case) the profitability grows if both the two players are highly inclined to cooperate. However, the most important remark is that players' enthusiasm can mitigate or cancel the negative bargaining effects coming from an unprofitable collusion. Let's consider, again, an integration with dominant parent A. If the technology exhibits economies of scope and partners are equally enthusiastic, then the contract is profitable (see proposition 2) because the hold-up effect on k $(-\alpha_{(S\cup B)}\Delta c_k(S\cup B^{1-\lambda}, a_B, \lambda))$ prevails on the same effect on players A and B $(\Delta c_k(S\cup A, a_B, \lambda))$. Nevertheless, if the difference between the two effects is low enough and the enthusiasm of A is sufficiently high relative to that of B, then the contract might become unprofitable.

When the possibility of partial complementarities is included, the relative enthusiasm of players A, B, J has a different impact on their joint profits. Results are summarized by the following proposition.

Proposition 11 (*Partial complementarities*) *Consider the contracts in propositions 6-9. If the solution of game may be an asymmetric path value, then the profitability of integration is*

[merger] *increasing in $\gamma_B(t)/\gamma_A(t)$ if all ks are complementary to at least A or B, decreasing otherwise.*

[dominant parent] *increasing in $\gamma_B(t)/\gamma_A(t)$ if all ks are substitutable to the dominant player, decreasing otherwise.*

[independent target] *increasing in $\gamma_A(t)$, $\gamma_B(t)$ and decreasing in $\gamma_J(t)$ if all ks are complementary to the RJV's activities, the opposite holds if they are substitutable.*

[joint ownership] *increasing in $\gamma_A(t)/\gamma_B(t)$ whenever player B has a larger ownership.*

Proof. For each contract, look at the corresponding proofs of propositions 1-4 and 6-9.

- *Merger*

Apply lemma 2 to verify that whenever the third player k is complementary to at least one contracting party the profitability of collusion increases in $\gamma_B(t)/\gamma_A(t)$, while the opposite holds in all remaining cases.

- *RJV with a dominant parent*

Cases 1 and 3 - k complementary or substitutable with λa_B but substitutable with A.

By lemma 2 a sufficient condition for

$$\alpha^k_{(S\cup A)}\Delta c_k(S\cup A, a_B, \lambda) - \alpha^k_{(S\cup B)}\Delta c_k(S\cup B^{1-\lambda}, a_B, \lambda) < 0$$

is $\gamma_A(t) < \gamma_B(t)$, therefore profitability of collusion is decreasing in $\gamma_A(t)/\gamma_B(t)$.

Cases 2 and 4 - k complementary or substitutable with λa_B but complementary with A.

Now the opposite conclusion holds if $\gamma_A(t) < \gamma_B(t)$, and losses from integration decrease with $\gamma_A(t)/\gamma_B(t)$.

- *RJV with independent target*

Consider the proofs of propositions 3 and 7.

Case 1 and 2 - k complement to λa_A, λa_B and complement or substitute to A, B

Differences in (25) are negative and their sum is positive, thus integration is unprofitable. The losses decrease if $\alpha^k_{(S'\cup A\cup B)}$ grows and $\alpha_{(S\cup J)}$ goes down. Thus by lemma 2 their are decreasing in $\gamma_A(t), \gamma_B(t)$ and increasing in $\gamma_J(t)$.

Case 3 and 4 - k substitute to λa_A, λa_B and complement or substitute to A, B

Now the same differences are positive and from cases 1 and 2 it follows that losses increase with $\gamma_A(t), \gamma_B(t)$ while decrease with $\gamma_J(t)$.

- *RJV with joint ownership*

We consider cases 1-6 supposing that player B is more likely to be dominant, thus difference (40) has larger weight in the expected payoff of any k.

Case 1 and 4 - k complement or substitute to λa_A, λa_B and complement to A, B

From proof of proposition 9 it follows that difference (40) is positive and collusion unprofitable. By lemma 2 losses from integration are decreasing in $\gamma_A(t)/\gamma_B(t)$.

Case 2 and 3 - k complement or substitute to λa_A, λa_B and substitute to A, B

The (40) is negative, thus by lemma 2 the profits of A, B are increasing in $\gamma_A(t)/\gamma_B(t)$.

Case 5 - k complement (or substitute) to λa_A, λa_B, substitute to A and complement to B

The collusion is unprofitable, and by lemma 2 losses decrease with

$\gamma_A(t)/\gamma_B(t)$.

Case 6 - k complement (or substitute) to λa_A, λa_B, complement to A and substitute to B

The integration is profitable, and joint profits increase with $\gamma_A(t)/\gamma_B(t)$. ■

We showed as the role of players' bargaining abilities depends on the interactions between the ownership structure and the external players' complementarities.

Particularly, if there exist some complementarities, then a merger is more profitable if the proxy player is the less endowed but more enthusiastic player. Indeed, it reduces the hold-up ability of each k. If the third parties are substitutable to A and B, they lose more from integration when coalitions that include A become more likely. In this case the competition with A is detrimental. Conclusions in proposition (11) come from the same intuition, with the only difference that, in contracts with independent target, also the relative enthusiasm of J matters. Further, in this contract colluding players can increase their expected payoff by conveniently choosing the type of pooled activities. For instance, if both the two have a higher probability to accept agreement with third parties, then it is more profitable to engage in research activities which are complementary to the external agents. It should be also noted that it is the only integration where the k's relationship with the pooled assets accounts for profitability, while in remaining contracts it is absolutely irrelevant. Therefore we deduce that strategic effect of integration are independent from the pooled activities in so far as the colluding players have some effective control on them. In this occurrence, it's better to attribute a larger ownership to the smaller contributor when he's more reluctant in accepting proposals.

Given all the considerations above, we think that our model provides some intuitions to improve the profitability of strategic alliances. Our framework takes into account the interactions between asset complementarities and players' abilities under different ownership solutions. By this reason, the results offer some useful hints in choosing the optimal partner, the assets to be pooled and, finally, the convenient contract. Although we only dealt with bilateral integrations, this model can be easily extended to multiagent collusive agreements.

3.3 Conclusions

We study the bargaining effects of integrations by which players merge only a share of their resources and choose different ownership solutions over their assets. Four types of contracts are examined, aiming at pooling the R&D assets of two firms, but our model could be easily extended to include more participants. These contracts are viewed as an application of more general collusive agreements where players put all their resources in the hands of one proxy player. The collusion is advantageous in future bargaining with third parties if the complementarity between colluding players is reduced by third parties, while becomes not profitable if it is increased (Segal, 2003).

We show that effectiveness of this condition strongly depends on the specific setting used. Our model adds a players' asset structure where the resources of any agent can be split into complementary and substitutable, depending upon the partial complementarity relations with the assets of his rivals. To see the effects of this change we examine the profitability of integration in two different settings. The first one only admits full complementarities among players, that is all of them are either substitutable or complementary to each other, while in the second setting each player has two sets of assets and partial complementarities are included. In order to limit the set of possible cases, we make two basic assumptions. First, one contracting player (in our contracts the proxy player A) owns a larger amount of assets. Second, the productivity of complementary resources increases at a decreasing rate when they are pooled, while the costs from joining substitutable activities (detrimental competition) increase at an increasing rate. Both these assumptions are expressed by a negative third difference operator.

Let's consider the first scenario with full complementarities. We look at the externality produced on a third player k by a contract merging the assets of A and B in the hands of player A. If k is complementary to them, then he gains from integration when he enters coalitions that include A, because the latter brings also the B's assets (we say that k holds A up). At same time, he loses from entering coalitions with B, who brings no resources (player A holds k up). As player A owns more assets, the k's hold up ability is lower. Thus, the merger is profitable. Consider now the same contract but k substitutable to A and B. The third party loses in efficiency from entering coalitions that include A (detrimental competition), but gains when entering coalitions where dummy player B is inside, because now he avoids competition with B. However, the competition with a "bigger" A is more costly, therefore merger is still advantageous. A similar reasoning holds for RJV contracts with a dominant parent, where player A is still assumed to be the proxy.

On the contrary, when the integration assigns independent power to the RJV (that is to player J) the results are reversed. In the presence of complementarities, the integration is always unprofitable, because the third players achieves a large hold up ability in coalitions with J, while each contracting partner contributes with lower resources than before. With substitutabilities, all ks lose from a greater competition with J, and they gain when entering coalitions with A and B (competition is now less costly). The trade-off is still positive for k if some conditions on the probability distribution of orderings are satisfied. By these results, we demonstrate that the ownership structure is crucial for the integration profitability, and the same holds in the second scenario, where players have two different sets of assets. The effects of complementarities can be easily reversed according to how the ownership rights are distributed by the contract. A merger is profitable if third parties are complementary to at least one contracting party. A RJVs with a dominant parent, instead, is convenient if they are substitutable with that player, and vice versa. Whenever the ownership is shared by the two parents, we find that substitutability with the "smaller" player is desirable if the latter's decisions prevails more frequently, while the control is irrelevant if third players are complementary or substitutable to both the parents. In particular, the contract is profitable if all of them are substitutes, but this conclusion would be reversed in case of merger. Again, the ownership matters more than complementarities, thus firms can get advantages in future bargaining by choosing a suitable control mechanism.

Not only. In this paper we provide two further results. First, the integration profitability does not depend on the type of R&D that come to be integrated, therefore no strategic effect arises from choosing activities that are complements or substitutes of the third parties' assets. Second, and more important, the individual attitudes towards bargaining can increase or decrease the integrated parties' joint profits. We analyze the role of bargaining abilities by using an alternative concept of solution: the asymmetric path value (Owen, 1968, 1972 and Passarelli, 2007). A player i is more enthusiastic in bargaining than player j if he's more likely to accept any type of agreement, while j is said reluctant. In a path value the probabilities of coalitions are increasing in the level of enthusiasm of included players, that is their bargaining ability. Using these different weights, we study how the interaction among partial complementarities, ownership structure and players' abilities affects the joint profits from integration. Particularly, we find that it is convenient to increase the probability of coalitions where contracting parties can hold up the third players, and this is equivalent to have a more enthusiastic player A, or B, depending on the specific contract. In the cases where integration allows for an independent target, the RJV too plays an active role in bargaining game. Therefore, using path values, the enthusiasm level of J turns to be relevant.

However, the bargaining game in this paper embodies some limitations that need further research. First, we restricted our analysis to cases in which contracting parties have different amounts of assets and the largest owner is made proxy when it is required.

We conjecture that, after merged, two equally endowed parents get no extraprofits in bargaining, while nothing changes for remaining contracts. At the same time, we think that making proxy player the party with fewer resources might reverse our conclusions in some cases but not in others, depending on the players' complementarities.

Second, we assumed to our scope that players integrate complementary resources. However, the bargaining game may produce different results when players are allowed to integrate their substitutable resources to avoid competition.

Third, in our cooperative model the R&D integration does not change the value can be generated by the grand coalition. The RJV contracts might be inefficient if the extra profits were hold up by third players.

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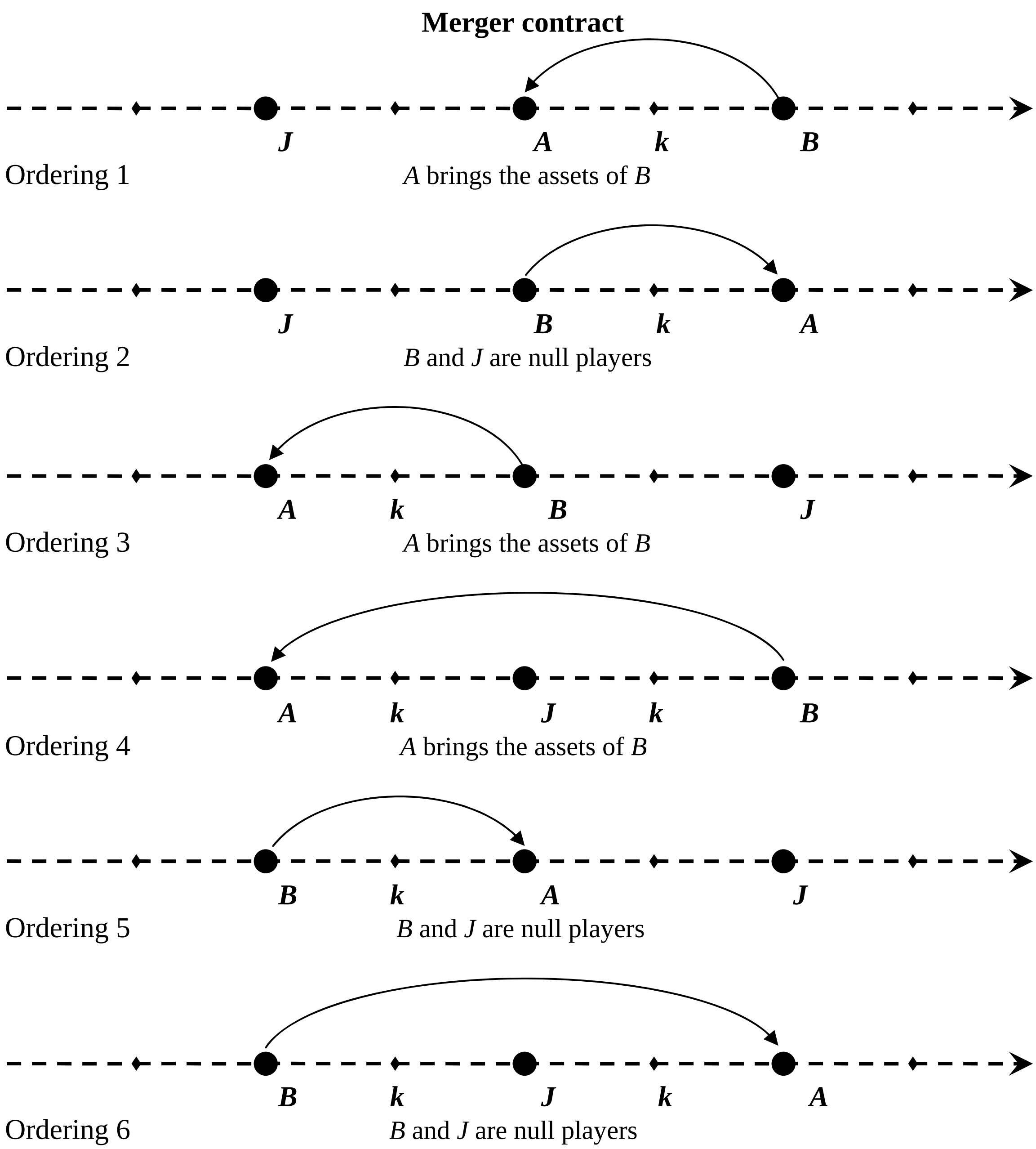
Merger contract
J
A
k
B
Ordering 1
A brings the assets of B
J
B
k
A
Ordering 2
B and J are null players
A
k
B
J
Ordering 3
A brings the assets of B
A
k
J
k
B
Ordering 4
A brings the assets of B
B
k
A
J
Ordering 5
B and J are null players
B
k
J
k
A
Ordering 6
B and J are null players

Figure 1

RJV integration when dominant parent is *A*

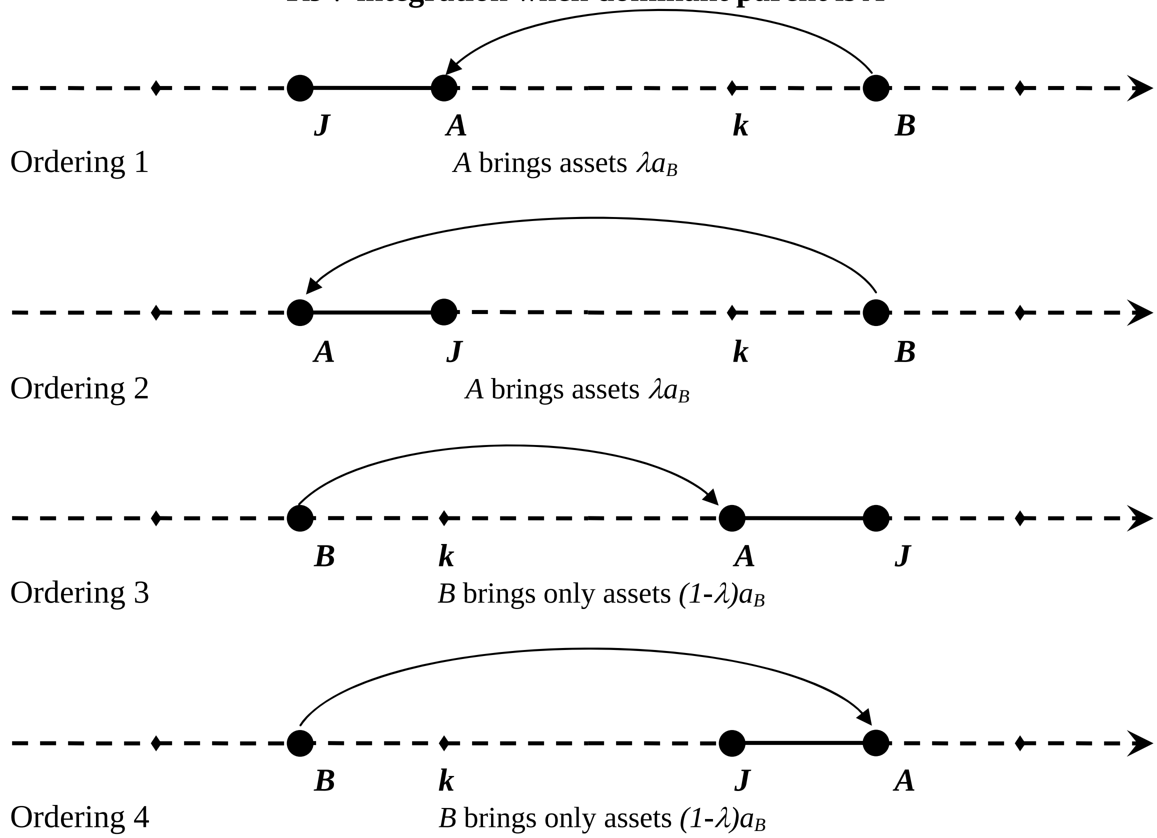

Figure 2

RJV integration with independent target

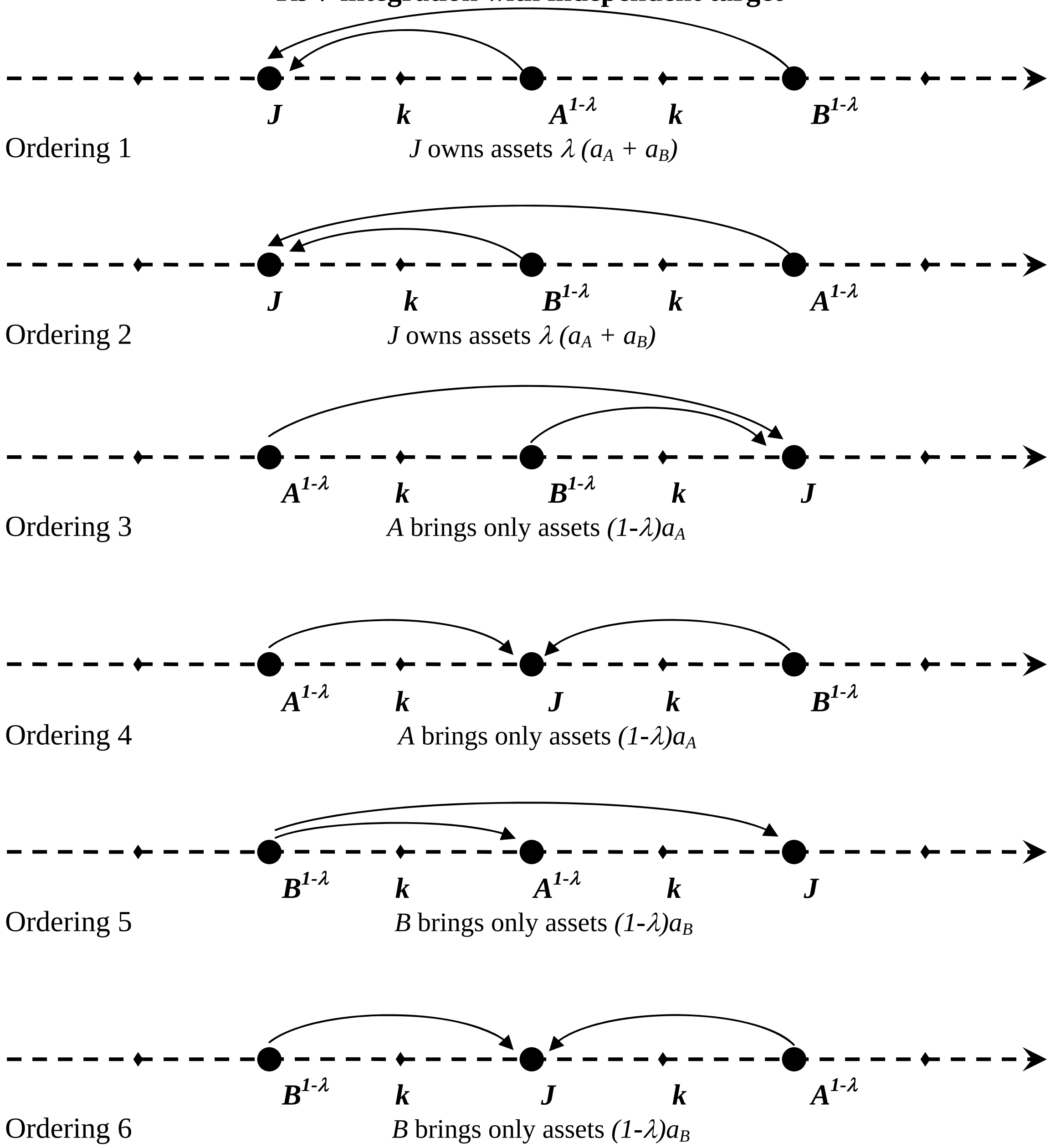

Figure 3

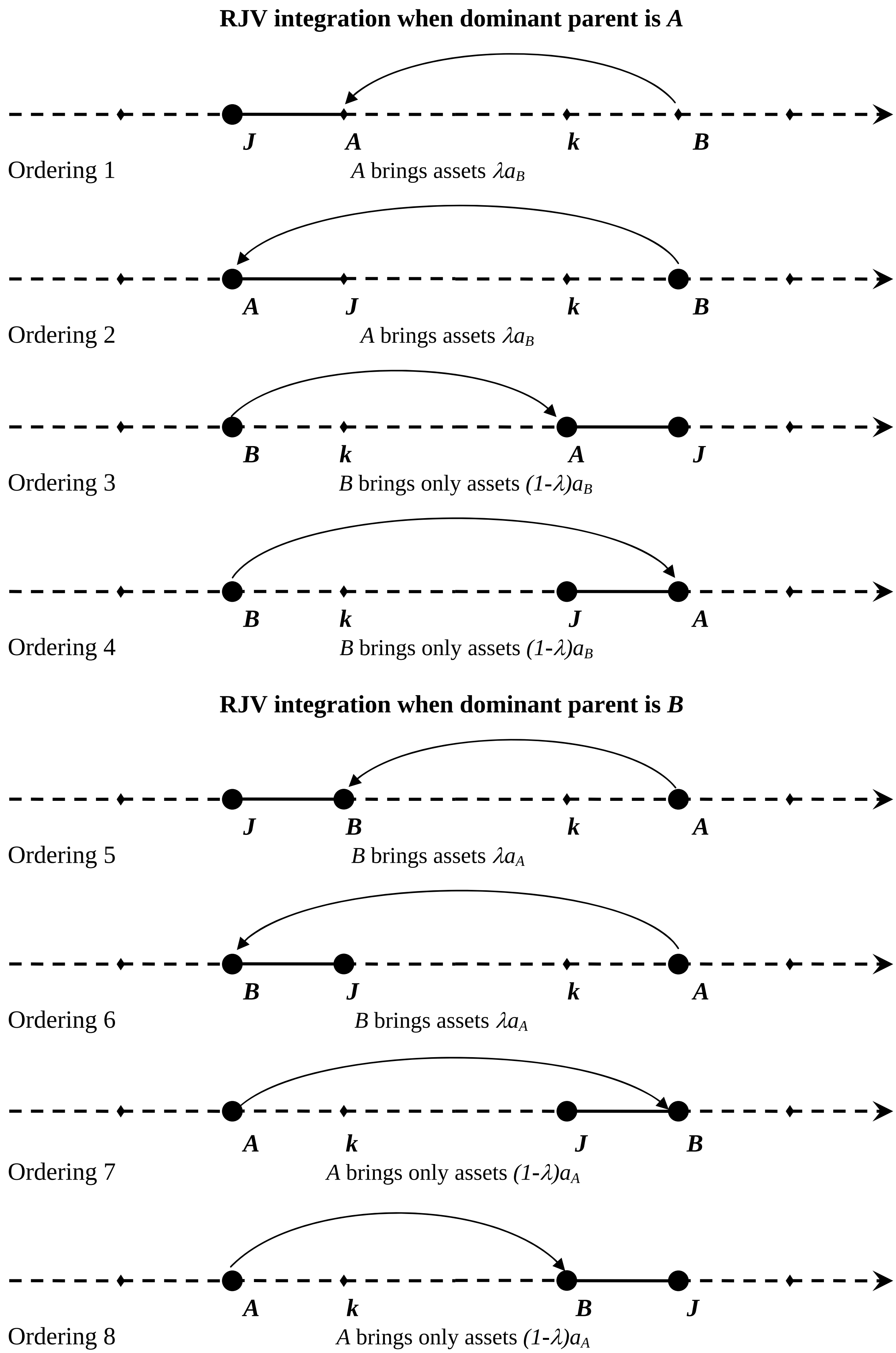
RJV integration when dominant parent is A
J
A
k
B
Ordering 1
A brings assets λa_B
A
J
k
B
Ordering 2
A brings assets λa_B
B
k
A
J
Ordering 3
B brings only assets (1-λ)a_B
B
k
J
A
Ordering 4
B brings only assets (1-λ)a_B
RJV integration when dominant parent is B
J
B
k
A
Ordering 5
B brings assets λa_A
B
J
k
A
Ordering 6
B brings assets λa_A
A
k
J
B
Ordering 7
A brings only assets (1-λ)a_A
A
k
B
J
Ordering 8
A brings only assets (1-λ)a_A

Figure 4