Knowledge sharing in alliances and alliance portfolios*

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Abstract

This paper studies knowledge sharing in alliances and alliance portfolios. We develop a theoretical framework that encompass as special cases the problems of knowledge misappropriation and asymmetric learning and show that, once the issue of encouraging effective collaboration is put center-stage, many standard intuitions of the "learning race" view are overturned or qualified. Partners engage in "learning races" in some cases, but exhibit "altruistic" behaviors in other cases. They may reduce their own absorptive capacity, or increase the transparency of their own operations, to facilitate their partner's learning. Alliances between competitors can be more conducive to knowledge sharing than alliances between firms operating in different markets. In alliance portfolios, we distinguish between substitutability in common benefits and substitutability in rival benefits, and show that the latter can actually be conducive to knowledge sharing. Our work contributes towards putting the "learning race" view on a more solid foundation, by explicitly recognizing the importance of encouraging knowledge sharing between partners.

Keywords: knowledge sharing, learning alliances, knowledge misappropriation, learning races, alliance portfolios.
JEL Classification: D21, D23, L24.

1 Introduction

Learning alliances, where an important objective of the partners is the acquisition of new skills and capabilities, are difficult to manage. On the one hand, the partnering firms (who may also be competitors) must share knowledge to create new knowledge, products and innovations, and cooperatively exploit this jointly created new knowledge (Hennart, 1988; Mitchell and Singh, 1993, 1996; Gulati, 1998). This gives them a common purpose. On the other hand, the partners must divide the gains from collaboration. The

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negotiations are affected by the relative bargaining positions, which in turn depend upon how efficiently firms have learned from each other, and how well positioned they are to exploit that learning without the cooperation of the partner (Hamel, 1991; Yan and Gray, 1994; Lane and Lubatkin, 1998; Das and Teng, 2000).

In many cases, the new knowledge created cannot be accurately foreseen or adequately distinguished from what is already known by the partners. Thus, firms cannot contract or commit to jointly exploit it. Any existing contract or joint venture terms are subject to renegotiation under the threat that one partner or the other may walk away (Williamson, 1975; Grossman and Hart, 1986). We focus on the need to motivate partners to share knowledge in a setting where these competitive tensions are present, and study how alliances should be managed and partners selected.

Our focus on encouraging knowledge sharing yields predictions that are often very different, and sometimes diametrically opposed, from what some leading strategic management approaches would suggest. A key tenet of the learning race literature (Hamel, 1991; Yan and Gray, 1994; Inkpen and Beamish, 1997; Khanna et al., 1998) is that "participating firms [should] maximize their receptivity to the knowledge and skills of their partner while limiting the transparency of their own operations" (Mowery et al., 2002: 298). In our framework, firms can exhibit "learning races" behavior in some cases and "altruistic" behavior in other cases. This may help explain some apparently puzzling behaviors, such as Toyota's willingness to teach a competitor, GM, the "philosophy" and practice of lean manufacturing (Inkpen, 2005). It may also help explain why sometimes firms such as Cisco appear to deliberately reduce their own learning capability (Steinhilber, 2008), and why failure to do so may lead to disputes, such as in the case of Emisphere and Eli Lilly (Gibbons and Vogel, 2007; Gilson et al., 2009).

We also find that in some situations alliances between competitors are more conducive to knowledge sharing than alliances between firms operating in different markets. Whether competitive overlap hinders or facilitate knowledge sharing critically hinges upon whether learning favors the technological leader or the technological laggard. Competition in a contestable market becomes more or less intense depending on who learns faster.

We use our framework to examine alliance portfolios where a focal firm simultaneously manages multiple alliances (Gulati, 1998, 1999; Gulati et al., 2011; Vonortas and Zirulia, 2015). We are especially interested in the effect of partner substitutability on knowledge sharing. Existing research suggests that, when a firm is replaceable, its bargaining position is weaker and its incentive to collaborate lower (Pfeffer and Salancik, 1978; McEvily et al., 2000; Bae and Gargiulo, 2004; Lavie, 2007). However, empirical work has yielded largely inconclusive results (Goerzen and Beamish, 2005; Swaminathan and Moorman, 2009; Wassmer and Dussauge, 2011; Cui 2013).

We provide a potential explanation for these mixed results by distinguishing between two types of partner substitutability: substitutability in common benefits and substitutability in rival benefits. Two firms are substitutable (or replaceable) from the perspective of a focal firm F if they provide F with access to similar knowledge. This knowledge may be useful to activities related to F's existing alliances (the common benefits) or to activities that F can undertake in case one or more of its alliances break down (the rival benefits). We show that partner substitutability in rival benefits actually facilitates knowledge sharing in alliance portfolios. The risk of enhancing a focal firm's bargaining position via knowledge transfer is less prominent if access to similar knowledge is potentially provided by another partner. Thus, knowledge sharing in an alliance portfolio can be sustainable, while knowledge sharing in an individual (dyadic) alliance may not.

By contrast, in line with conventional wisdom, we show that substitutability in common benefits hinders knowledge sharing; however, its effect is less pronounced than one might initially think. In expectation, the non-focal partners lose bargaining power when their knowledge becomes less unique. Yet, they enjoy some benefits when they get to replace the other non-focal partner. From the focal firm's perspective, there is a non-linear, inverted-U relationship between alliance value and partner substitutability in common benefits. Conditional on knowledge sharing, having substitutable/similar partners benefits F because it strengthens its bargaining power. However, too much substitutability hinders knowledge sharing. As a result, the focal firm is better off when it chooses partners that are neither too similar nor too dissimilar to each other.

To conclude, this paper contributes to the literature on competitive tensions in learning alliances by putting it on a more solid foundation. Scholars have noted that many of the learning race view's recommendations suffer from a failure to recognize that the processes of value creation and value appropriation are inextricably linked. Indeed, "[e]fforts at increasing one's value extraction from a joint venture often damage cooperation and negatively impact value creation" (Zeng and Hennart, 2002: 193). Scholars have also argued that the notion of a race to learn is "largely unrealistic," for it is unclear what would motivate a likely loser to join the race (Inkpen, 2002: 272). This paper incorporates a knowledge sharing (or participation) constraint into a model of learning in alliances, and shows that its inclusion has important consequences for alliance management and partner selection. In particular, instead of engaging in learning races, some partners may deliberately choose to facilitate their partners' learning attempts, or may reduce their own absorptive capacity. Thus, the model may help explain why, although learning is an important goal in many alliances, only few firms actually appear to have a racing intent (Mowery et al., 1996; Hennart et al., 1999; Inkpen, 2000).

1.1 Related literature

The paper is related to several strands of the strategy and organization science literature. Resource dependence theory (RDT) is a leading theoretical framework that emphasizes the importance of power in inter-firm relations. RDT contends that power in a relationship is held by the partner that controls the most critical resources (Pfeffer and Salancik, 1978). RDT scholars have distinguished between joint dependence—where both parties hold critical resources—and dependence asymmetry—where power is asymmetrically distributed (Casciaro and Piskorski, 2007; Gulati and Sytch, 2007). However, to the extent that control over resources is a fixed attribute of the firm, both notions are essentially static.

A number of papers have examined the dynamics of power in alliances. One critical resource which is hard to protect effectively and may leak during collaboration is knowledge (Liebeskind, 1996). Knowledge misappropriation is often a concern when young technology ventures collaborate with more established incumbents (Diestre and Rajagopalan, 2012; Hallen et al., 2014; Katila et al., 2008). Sharing while protecting knowledge is a central challenge for many start-ups, and information leakage is frequently cited as a major drawback of alliances (Arora and Merges, 2004; Oxley and Sampson, 2004; Sampson, 2007; Li et al., 2012). In some cases, alliance partners may both be concerned about disclosing valuable information. In these cases, "learning races" may arise, with power shifting in favor of the partner that learns the fastest. Instabilities may also result (Hamel, 1991; Yan and Gray, 1994; Inkpen and Beamish, 1997).

Papers focusing on appropriability hazards and asymmetric learning have stressed (i) the importance of value creation relative to value appropriation, and (ii) the choice of appropriate safeguards. For instance, Katila et al. (2008) find that new firms enter corporate investment relationships when their financial and managerial resource needs are high, and can defend themselves against misappropriation through defense mechanisms. One important safeguard is the choice of partners with limited opportunistic intent, as measured for instance by "relative scope" (Khanna et al., 1998; Baum et al., 2000) or by alliance type (Dussauge et al., 2000). Other important types of safeguards include patents, secrecy, timing, social defenses and organizational firewalls (Cohen et al., 2000; Katila et al., 2008; Hallen et al., 2014).

Our theory recognizes the importance of value creation and safeguards, but also highlights a third set of issues—the need for a "strong" partner to encourage knowledge sharing ex ante. We show that apparently "altruistic" behaviors can naturally emerge when knowledge sharing constraints are accounted for. These altruistic behaviors can take many forms. Firms may voluntarily reduce their own absorptive capacity through "Chinese walls" or other means, or increase the transparency of their own operations.

Previous work has also mostly emphasized *unplanned* changes in a relationship, which may lead to premature alliance termination and failure (e.g., Das and Teng, 2000). In our model, partners are forward-looking. They anticipate how bargaining positions evolve. Thus, changes are not unplanned. But precisely because these changes are foreseen, suboptimal knowledge sharing may occur due to rational expectations of renegotiation. To the extent that firms are forward-looking, these foregone opportunities for knowledge sharing are likely to be the most important source of inefficiencies.

Finally, the paper contributes to research examining how network structure influences knowledge sharing (Hansen, 1999, 2002; Argote et al., 2003; Reagans and McEvily, 2003; Hansen et al., 2005; Gulati et al., 2011). Structural factors that have been found to be conducive to knowledge transmission in networks include social cohesion around a relationship (Hansen, 1999; Reagans and McEvily, 2003), the variety of knowledge sources within which a firm is embedded (Burt, 1992; Zaheer and McEvily, 1999; Baum et al., 2000; Reagans and McEvily, 2003) and competitive tensions among the members of a group (Gomes-Casseres, 1994; Baum et al., 2000; Dyer and Nobeoka, 2000). The redundancy of knowledge sources within a network has typically been seen as an obstacle to effective knowledge sharing, both because it reduces knowledge variety and because it creates competitive tensions (e.g., Baum et al., 2000). However, empirical findings have been mixed (Goerzen and Beamish, 2005; Swaminathan and Moorman, 2009; Wassmer and Dussauge, 2011; Cui 2013). Our work may help reconcile these mixed findings by highlighting a type of knowledge redundancy (substitutability in rival benefits) that can actually foster knowledge sharing. And even in the case of substitutability in common benefits, we show that countervailing effects are present. Overall, our results suggest that redundancy of information sources in a network is less likely to hinder knowledge sharing than previously thought.[1]

[1] On a more technical note, the present paper establishes a connection between the mutual dependency and learning races literatures in strategy, and the property-rights theory of the firm (e.g., Grossman and Hart, 1986; Hart and Moore, 1990). However, modern property-rights theory explains inefficiencies and underinvestment as the outcomes of a public good problem—the unwillingness of transaction partners to privately contribute to joint value creation. By contrast, we stress shifts in outside options and relative bargaining power.

The remainder of the paper is organized as follows. The basic model is outlined in Section 2. Section 3 focuses on asymmetric learning and the strategic choice of learning capabilities. Section 4 examines alliance portfolios, while section 5 discusses the role of contracts. Section 6 briefly concludes.

2 Model

There are two firms, A and B, that can collaborate. Collaboration involves two stages. In the first stage, A and B share information/knowledge about their technology and markets. In the second stage, they must decide whether to continue to work together and implement a project. An example would be a pharmaceutical firm and a biotech firm working together to develop a new drug. Implemention consists of bringing the new product to market.

If A and B do not share information, the collaboration does not get started, and A and B obtain their "baseline" payoffs, which are normalized to zero.

If A and B share their knowledge, what they can obtain depends on whether they implement the project. If they stop the collaboration before implementation, then A gets π_A and B gets π_B.

If the firms implement the project together, the joint value they create is V. We posit $V \geq \pi_A + \pi_B$. Thus, after knowledge sharing, it is efficient for the two firms to continue to work together. This could be because the partners have complementary capabilities in developing and commercializing the new product, but also because litigation or competition following the break-up can be detrimental to A and B.

Sharing knowledge is costly both in terms of time and effort. For simplicity, A and B are assumed to incur the same cost of knowledge sharing. A must pay $\frac{1}{2}I$ if it shares knowledge with B, and so must B.[2] Thus, $I \geq 0$ denotes the total cost of knowledge sharing. Knowledge sharing is efficient if $V - I \geq 0$.[3]

The key assumptions we make are that (i) it is impossible to contract on knowledge sharing, and that (ii) the firms cannot commit ex ante (before knowledge sharing) to implement the project together ex post. These two assumptions imply that the firms cannot be forced to collaborate, neither in the initial phase of knowledge sharing nor the subsequent implementation phase. This could be because it is impossible for a court to verify, for instance, that a firm has done its best to transmit its knowledge, or that a partner is performing in a consummate rather than perfunctory fashion during co-development. In countries with less developed institutions, these assumptions may also reflect the very high costs of using

[2] The assumption of equal costs of knowledge sharing can be easily relaxed without qualitatively changing any of the results of the paper.

[3] If only one firm invests in knowledge sharing, we assume that both A and B's payoffs remain 0. This implies that equilibria that only one firm invests cannot exists so long as $I > 0$.

the legal and judicial system.

If the firms decide to implement the project together, they must bargain over how to divide the resulting surplus $V - \pi_A - \pi_B$. We assume bargaining is efficient and determined according to the Nash solution with equal weights. Thus, the partners' payoff are given by

$$\Pi_i = \pi_i + \frac{1}{2}\left[V - \pi_A - \pi_B\right] - \frac{1}{2}I, \quad i = A, B. \tag{1}$$

That is, each firm gets its "outside option" π_i plus half of the surplus from implementation, minus the physical costs of knowledge sharing $\frac{1}{2}I$. Firm $i = A, B$ will only share information if its private gains from knowledge sharing are higher than the costs it would incur. These costs include not only the physical costs of information sharing, but also the possible reductions in bargaining power than may result from knowledge sharing.

Formally, firm $i = A, B$ will share knowledge if and only if

$$\Pi_i \geq \pi_i. \tag{2}$$

We refer to (2) as i's knowledge sharing (or participation) constraint. If this constraint holds, we say that knowledge sharing is privately profitable for firm i. After some manipulations, A and B's knowledge sharing constraints can be rewritten as:

$$V - I \geq \pi_B - \pi_A$$

$$V - I \geq \pi_A - \pi_B.$$

These conditions show that A and B are more likely to share knowledge if knowledge sharing leads to substantial value creation ($V - I$ large). However, in addition partners care about their relative bargaining positions. If $\pi_B > \pi_A$, then knowledge sharing shifts bargaining power in favor of B and therefore A is less likely to share knowledge with B and enter the alliance. Conversely, if $\pi_A > \pi_B$, then bargaining power shifts in favor of A and B is less likely to share knowledge and enter the alliance.

Note that these shifts only influence how the surplus generated by the alliance is divided between A and B. The condition for the efficiency of knowledge sharing is simply $V \geq I$.

We can summarize this discussion as follows.[4]

[4] Because knowledge sharing is assumed to be a highly complementary activity and firms choose whether to share their knowledge simultaneously and non-cooperatively, there is always the possibility of coordination failure. Even when condition (3) holds, partners may fail to invest in knowledge sharing because they hold expectations (correct in equilibrium) that the other partner will not invest. We rule out this implausible Pareto-inferior equilibrium on the grounds that partners that work together should be able to coordinate on a mutually beneficial outcome. Moreover, if investments in knowledge sharing were sequential, the equilibrium with knowledge sharing would be the only subgame-perfect Nash equilibrium if condition (3) holds.

Proposition 1. *Knowledge sharing is efficient when $V \geq I$. However, it is privately profitable for both firms only when*

$$V - I \geq |\pi_A - \pi_B| \,. \tag{3}$$

Thus, in equilibrium there is an inefficiently low level of knowledge sharing.

Proposition 1 captures the idea that some value-creating alliances may not be formed when knowledge sharing creates large shifts in bargaining positions. Value creation is important, as highly valuable alliances ($V - I$ high) tend to be formed, but asymmetries in the evolution of outside options create a wedge between efficient and inefficient knowledge sharing. Preserving the balance of power within the partnership (a low $\pi_A - \pi_B$ in absolute value) helps reduce the risk of low knowledge sharing.[5]

2.1 Example: knowledge misappropriation

Bargaining positions in an alliance can shift because one partner appropriates valuable knowledge that belongs to the other partner. The appropriating firm then becomes less dependent on its partner, and may even lose interest in the collaboration (Arora and Merges, 2004; Oxley and Sampson, 2004; Katila et al., 2008; Diestre and Rajagopalan, 2012; Hallen et al., 2014).

To examine the issue of knowledge misappropriation in the context of our model, suppose firm B possesses a valuable trade secret. Firms A and B's outside options in the absence of knowledge sharing are normalized to 0. If B reveals the trade secret to A, then A can generate an idea that, if implemented with B, yields joint value $\overline{S}$. The total cost of knowledge sharing is as before I.

We posit that, if the collaboration breaks down after knowledge sharing, all the rights over the use of any output generated using B's trade secret are contractually assigned to B. Nevertheless, A may still try to use B's trade secret without B's permission. Should A try to use the trade secret, let $p \in [0, 1]$ be the probability that B can block A from using the idea. Thus, p measures, among other things, how well courts protect B's intellectual property rights. Outside options are $\pi_A = (1 - p)\underline{S}$ and $\pi_B = 0$, where $\underline{S}$ is the value of the idea generated and implemented by A on its own using B's trade secret. We assume that $\underline{S} \in [0, \overline{S}]$, as firm B may add some value to A's idea beyond the knowledge incorporated in the trade secret.

Proposition 1 yields the following.

[5] This simple model can be extended to multiple rounds of knowledge sharing. In Appendix 2, we develop a multi-stage, optimal stopping game of knowledge sharing, and show that our key qualitative results are robust. Large shifts in bargaining positions lead to inefficiently premature alliance termination.

Proposition 2. *Knowledge sharing is efficient if* $\overline{S} \geq I$. *However, it is privately profitable for both firms only if*

$$\overline{S} - I \geq (1-p)\underline{S}. \tag{4}$$

Thus, knowledge sharing is underprovided, especially when IPR are weak (p low) and firm B adds little to the collaboration besides the trade secret ($\underline{S}$ *high).*

This result generalizes an idea first expounded by Arrow (1962): If there is no legal protection for ideas ($p \simeq 0$) and the only contribution B makes to the partnership is the technology ($\underline{S} \simeq \overline{S}$), then knowledge sharing does not occur for any strictly positive value of I. The "market for ideas" breaks down because ideas, once shared, can be easily stolen. Thus, strong IPR are an important precondition (albeit not a necessary one) for markets for ideas and technology to arise (Arora et al., 2001).

2.2 Uses of knowledge

We can use the model in Section 2 to distinguish among different uses of a partner's knowledge.

Private and common benefits. Khanna et al. (1998) distinguish between two types of benefits from collaboration: private benefits and common benefits. Private benefits are "those that a firm can earn unilaterally by picking up skills from its partner and applying them to its own operations in areas unrelated to the alliance activities" (Khanna et al., 1998: 195). Common benefits, by contrast, are "those that accrue to each partner in an alliance from the collective application of the learning that both firms go through as a consequence of being part of the alliance; these are obtained from operations in areas of the firm that are related to the alliance" (p. 195).

Private and common benefits can easily be described in our model. Let $\pi_A = a$, $\pi_B = b$ and $V = a + b + S$. Thus, partner A obtains private benefits a from picking up skills from partner B and applying them to its own operations, while partner B obtains private benefits b. S denotes the value of the project that A and B can undertake together—their common benefit.[6]

Proposition 1 implies that knowledge sharing is efficient whenever $a + b + S \geq I$, but it is privately profitable for both partners only when:

$$a + b + S - I \geq |a - b|\,.$$

[6] The model allows for the private "benefits" to be negative for one or both partners. This would be the case, for instance, if a firm poached some valuable resource (e.g., employees) from one of its partners.

Thus, inefficiencies arise when common benefits are low and private benefits are very asymmetrically distributed.

Rival benefits. A type of benefits not considered by Khanna et al. (1998) are rival benefits. We define rival benefits as benefits of learning that a firm can earn unilaterally *in addition to private benefits if the collaboration breaks down.* Thus, rival benefits can be obtained if and only if the common benefits are not realized.

Suppose, for concreteness, that the objective of the collaboration is to develop a new drug. After knowledge sharing, the collaboration may break up. In that case, payoffs are $\pi_A = a + r_A$, $\pi_B = b + r_B$, where (r_A, r_B) denote the rival benefits. These could be the benefits that the firms obtain if they try to introduce their own versions of the new drug. By contrast, if the firms stay together, they earn S by introducing the drug together (the common benefits). Thus, the total value of the collaboration is $V = a + b + S$. Importantly, (r_A, r_B) and S are *mutually exclusive.* This could be because firms are constrained in the number of projects they can undertake, or because the projects are connected (e.g., different versions of the same drug).

Applying Proposition 1, we can see that knowledge sharing is privately profitable for both firms when

$$a + b + S - I \geq |a + r_A - b - r_B| \, .$$

Thus, as a general rule, rival benefits tend to be detrimental to knowledge sharing, because they affect appropriation (the right-hand side of (3)) but not value creation (the left-hand side of (3)). However, rival benefits can in some situations be a blessing in disguise, for they can counterbalance significant asymmetries in private benefits (e.g., $a - b > 0$ but $a + r_A - b - r_B \simeq 0$).

Knowledge sharing as a bonding mechanism. Knowledge sharing is not always, and may not even be predominantly, a source of agency hazards. By sharing information, partners may strengthen their ties, foster trust, and raise the costs associated with switching partners (Gilson et al., 2009; Yam and Chan, 2015). One example is the "mutual hostages" strategy discussed by Williamson (1983). This strategy could also be easily incorporated in our framework, by adding costs to breaking up the collaboration that arise because of knowledge sharing.

3 A model of asymmetric learning

An influential literature in strategy stresses that attempts to appropriate the returns from collaboration may spur learning races, where partners try to absorb their partners' knowledge while attempting to protect their own (e.g., Hamel, 1991; Khanna et al., 1998). In reality, however, firms seldom appear to exhibit a racing intent (Mowery et al., 1996; Hennart et al., 1999; Inkpen, 2000) and their behavior is instead best described as cooperative (Inkpen, 2005). Cisco, for instance, is a firm that has successfully managed a large number of alliances in a variety of sectors, geographies and technological areas. Cisco recognizes that problems and conflicts can arise when partners are exposed to each other's knowledge. Steve Steinhilber, Vice President of strategic alliances at Cisco, notes that:

> One of the most contentious issues in negotiating the confidentiality terms of an alliance agreement is the treatment of residuals – that is, general knowledge, know-how, and the skills that each partner's employees will gain by being exposed to the other party's confidential information (2008: 101). [...] you face considerable risk [...]. You could open your doors to a company that could hurt you in your own market over time, gain competitive advantages, or acquire unique knowledge or skills that it could not have obtained otherwise (2008: 114).

Steinhilber recommends that partners establish ground rules to manage information security and intellectual property rights. These rules should not be enacted to simply protect the focal firm's resources, but should instead be designed to ensure that all the partners are treated fairly and nobody's knowledge is mishandled. In particular, Steinhilber suggests that firewalls may also be created to prevent Cisco from learning too much from its partners. Indeed, Steinhilber's rules include:

> Setting clear parameters in your agreements that identify the information to be shared and the permitted use of such information. In certain instances, it may be necessary to restrict information to some employees and to set up firewalls to prevent tainting other groups within the company that are developing similar technology independently. [Steinhilber further recommends:] Setting up training and procedures to protect your partner's confidential information and watching for actions by your partner that may signal an improper use of your own information (2008: 119).

In the next subsection, we develop a simple model of asymmetric learning in alliances. This model captures the intuition that asymmetric learning can be a source of instability in alliances. We then use the model to study strategic investments in learning capability. We show that, when the need of encouraging knowledge sharing is taken into account, firms do not always want to maximize their receptivity to their partners' knowledge. Instead, they may sometimes intentionally limit their own learning capability to encourage participation. Lastly, the model is extended to explore the effects of competition on partners' incentives to share knowledge.

3.1 Basic set-up

Consider two firms, A and B. Collaboration requires the firms to share knowledge at private cost $\frac{1}{2}I$. Collaboration may result in firms learning about their partner's capabilities. If the alliance is terminated after knowledge sharing but before the two firms bring together a new product to the market, A and B obtain, respectively, $\pi_A = \theta_A v_{AB}$ and $\pi_B = \theta_B v_{BA}$. Here θ_A denotes A's learning capability and v_{AB} is the value to A of learning B's competencies (analogous definitions apply to θ_B and v_{BA}). If instead the firms bring a product to the market together, the joint value they obtain is V.

Note that we assume that A and B can either obtain V together *or* obtain $(\theta_A v_{AB}, \theta_B v_{BA})$ on own their own. The use of knowledge is rival. We decompose i's learning capability θ_i, $i = A, B$, into two components: i's absorptive capacity α_i and the transparency of its partner's operations or knowledge base, τ_j, $j \neq i$: $\theta_A = \alpha_A \tau_B$ and $\theta_B = \alpha_B \tau_A$. Clearly, A learns fast when its absorptive capacity α_A is high and B's knowledge base or operations are transparent (τ_B high). The difference between θ_A and θ_B captures differences in learning capability between partners. If $\theta_A = \theta_B$, partners have equal learning capabilities. If $\theta_A > \theta_B$, then firm A learns faster than firm B.

To reduce notation, let $v_{AB} = v_{BA} = v$. We also assume that $V \geq (\theta_A + \theta_B)v$. Thus, after knowledge sharing it is efficient for A and B to bring the product to the market together. Proposition 1 implies the following.

Proposition 3. *Knowledge sharing is efficient when $V \geq I$. However, it is privately profitable for both firms only when*

$$V - I \geq |\alpha_A \tau_B - \alpha_B \tau_A| \, v.$$

Thus, knowledge sharing is likely to be inefficiently low when asymmetric learning is important ($|\alpha_A \tau_B - \alpha_B \tau_A| \, v$

big).

3.2 Strategic investments in learning capability

We can use the simple model above to study the firms' incentives to invest in learning capability. Assuming that knowledge sharing occurs, A and B's payoffs can be written as

$$\Pi_A(\theta_A, \theta_B) = \frac{1}{2}\left[V + (\theta_A - \theta_B)v\right] - \frac{1}{2}I \tag{5}$$

$$\Pi_B(\theta_A, \theta_B) = \frac{1}{2}\left[V - (\theta_A - \theta_B)v\right] - \frac{1}{2}I \tag{6}$$

where we write $\Pi_A(\theta_A, \theta_B)$ and $\Pi_B(\theta_A, \theta_B)$ to emphasize that the firms' payoffs depend on their learning capabilities (θ_A, θ_B).

For the rest of this section we will assume that knowledge sharing is efficient ($V \geq I$) and that partners can, prior to the knowledge sharing phase, invest in their learning capabilities. Specifically, A can select $\theta_A = \{\theta_A^H, \theta_A^L\}$ and B can select $\theta_B = \{\theta_B^H, \theta_B^L\}$, where $\theta_A^H \geq \theta_A^L$ and $\theta_B^H \geq \theta_B^L$. To reduce the number of the cases to consider, we also assume that $\theta_A^L \geq \theta_B^H$. This implies that A is the "stronger" or faster learning partner, while B is the one that might be adversely affected by knowledge sharing.

The learning race literature suggests that in an alliance, the "participating firms [should] maximize their receptivity to the knowledge and skills of their partner while limiting the transparency of their own operations" (Mowery et al., 2002: 298). Thus, this view suggests that A should select θ_A^H and B should select θ_B^H. To bias the results in this direction, we also assume that learning capability levels are all equally costly. Thus, any deviation from the outcome (θ_A^H, θ_B^H) will emerge not because of cost factors but from purely strategic considerations.

Proposition 4 below shows that the learning race intuition is in general incorrect. Partners do sometimes engage in learning races and maximize their learning capability (case (iii) below). However, in some circumstances they purposefully limit their absorptive capacity and increase their partner's payoff (case (ii)).

Proposition 4. Suppose knowledge sharing is efficient ($V \geq I$), firm A is always the faster learner ($\theta_A^L \geq \theta_B^H$), and all learning capabilities are equally costly to achieve. In equilibrium:

(i) If $\theta_A^L - \theta_B^H > \frac{V-I}{v}$, then the firms do not share knowledge. Inefficiencies occur. The choice of learning capability is inconsequential.

(ii) If $\theta_A^L - \theta_B^H \leq \frac{V-I}{v} < \theta_A^H - \theta_B^H$, then partner A selects learning capability θ_A^L and partner B selects learning capability θ_B^H. Knowledge sharing occurs.

(iii) If $\theta_A^H - \theta_B^H \geq \frac{V-I}{v}$, then partner A selects learning capability θ_A^H and partner B selects learning capability θ_B^H. Knowledge sharing occurs.

Proposition 4 shows that, when firms are very asymmetric in terms of their learning potential (case (i)), knowledge sharing does not occur. Asymmetries between firms are so strong that they lead to a breakdown of cooperation. The resulting outcome is inefficient.

By contrast, when the firms are sufficiently symmetric in terms of their learning potential (case (iii)), a learning race takes place. Firms maximally invest in learning, but this still leads to a fairly symmetric outcome. Both firms still find it privately profitable to share their knowledge.

The most interesting scenario arises when learning potential is asymmetric but not excessively so (case (ii)). A strategy of maximizing its own learning capability becomes self-defeating for the stronger partner A. By maximizing its learning capability, firm A discourages potential partner B from entering the alliance and sharing knowledge. A is better off by acting in an apparently altruistic fashion.

There are many examples of firms that deliberately appear to reduce their own absorptive capacity to mitigate the risk of conflicts with their partners. We have discussed the case of Cisco at the beginning of this section. Failure to create effective firewalls may also lead to acrimonious legal disputes, as exemplified by Emisphere versus Eli Lilly. As Gilson et al. (2009: 1377-1378) explain:

> [Emisphere and Lilly] agreed in 1997 to collaborate in research on new chemical "carrier" compounds. [...] The research relationship required Lilly and Emisphere to share valuable information. The relationship [broke] down in a dispute over whether Lilly breached the contract by pursuing its own secret research projects with Emisphere's proprietary carriers. [...] Emisphere contended that in 2000, Lilly began carrying out secret, independent research projects using Emisphere's carriers with proteins other than those committed to the collaborative project.

Interestingly, Lilly argued in court that it had erected firewalls between the work with Emisphere and the group it had assembled to study the action of Emisphere's carriers with other proteins (Gibbons and Vogel, 2007). Unfortunately for Lilly, the court found that there were significant problems with these firewalls. The example suggests that it may not be enough for a partner to say that precautions (e.g., firewalls, low θ's) have been taken. The credibility of such measures (which we assume in our simple model) is also important.

Finally, we would like to stress that the present framework (where firms can choose their own θ's) is equivalent to the case where firms can choose their own absorptive capacities (the α's in subsection 3.1). In Appendix 3, we develop a more complex model where firms can invest both in their absorptive capacities (the α's) and obfuscation (the τ's), and show that our main results are robust. This is important because in many examples (e.g., Toyota and GM), cooperative behavior appears to take the form of one partners making its operations more transparent to the other partner.

3.3 Asymmetric learning and competition

An important type of risk in alliances is that the alliance "may create a competitor or make an existing competitor more formidable through the transfer of expertise and market access" (Fuller and Porter, 1986: 326). The simple model of asymmetric learning developed above fails to satisfactorily capture the idea that asymmetric learning may over time affect the partners' relative competitive standing. This is because the partners' outside options, π_A and π_B, only depend on their own learning capabilities, not the learning capability of their partner. However, if A competes with B after the collaboration breaks up, then A's profits should also depend on how fast, relative to A, B has learnt.

Building on Khanna et al. (1998), we model the extent of partners' competitive overlap as follows. Consider three markets, M_A, M_B, and M_C. Firm A operates in markets M_A and M_C, while firm B operates in markets M_B and M_C. We call M_A and M_B the "captive" markets because only one firm is present, and M_C the "contestable" market, because both firms are present. Markets M_A, M_B and M_C are populated by m_A, m_B, and m_C customers respectively. All consumers have unit demand and reservation value v. Thus, m_C is a measure of competitive overlap between the partners. We assume that all markets are served: v is higher than the unit cost of production in any market (and fixed costs of production are "not too high").

Firms can decide to cooperate and share their knowledge to reduce their unit production costs. Let Δc_A denote the extent to which firm A can cut its unit production costs in market M_A as a result of knowledge sharing (i.e., by learning lean manufacturing). Similarly, let Δc_B denote the reduction in unit production costs that B can achieve in market M_B following knowledge sharing. Assume that firms are monopolists in their captive markets. Thus, by sharing knowledge firm A gains $\Delta c_A m_A$ in market M_A, and firm B gains $\Delta c_B m_B$ in market M_B.

In market M_C, firms A and B price compete.[7] We assume that firm A is initially the most efficient producer, and that it remains the most efficient producer even after knowledge sharing ("no overtaking"). Let $\Delta c_{A,C}$ (respectively, $\Delta c_{B,C}$) be the reduction in A's (respectively, B's) unit production costs in market M_C following knowledge sharing. A may be the most efficient producer, but this does not mean that it is also the faster learner. We say that A learns faster than B if $\Delta c_{A,C} > \Delta c_{B,C}$. Conversely, B learns faster than A if $\Delta c_{A,C} < \Delta c_{B,C}$.

Price (Bertrand) competition in market M_C yields the following outcome. The most efficient producer, firm A, changes a price equal to B's unit cost of production (minus an arbitrarily small amount) and wins the whole market.[8] The gains that accrue to firm A in market M_C when the two firms share knowledge are[9]

$$(\Delta c_{A,C} - \Delta c_{B,C})m_C. \tag{7}$$

These gains are positive when A is the faster learner ($\Delta c_{A,C} > \Delta c_{B,C}$) and negative when B is the faster learner ($\Delta c_{A,C} < \Delta c_{B,C}$). The intuition is that, when A is the faster learner, A and B's cost structures become more divergent. A's initial cost advantage in market M_C becomes even greater. More divergent

[7] This implies that there are no extra gains from collaboration beyond those created through knowledge sharing. In particular, A and B do not collude in market M_C after knowledge sharing. In terms of the model in Section 2, we posit $V = \pi_A + \pi_B$.

[8] This is a standard result with price (Bertrand) competition.

[9] To see this, let $\bar{c}_{A,C}$ (respectively, $\bar{c}_{B,C}$) be A's (respectively, B's) unit production cost in market M_C in the absence of knowledge sharing. After knowledge sharing, let these costs be $\underline{c}_{A,C}$ and $\underline{c}_{B,C}$, respectively. Thus, $\Delta c_{A,C} = \bar{c}_{A,C} - \underline{c}_{A,C} \geq 0$ and $\Delta c_{B,C} = \bar{c}_{B,C} - \underline{c}_{B,C} \geq 0$. Firm A (as well as industry) profits in market M_C in the absence of knowledge sharing are $(\bar{c}_{A,C} - \bar{c}_{B,C})m_C$. Firm A and industry profits in market M_C after knowledge sharing are $(\underline{c}_{A,C} - \underline{c}_{B,C})m_C$. Subtracting $(\bar{c}_{A,C} - \bar{c}_{B,C})m_C$ from $(\underline{c}_{A,C} - \underline{c}_{B,C})m_C$ yields equation (7).

cost structures "soften" competition and increase industry profits.

By contrast, when B is the faster learner, A and B's cost structures become more similar. A's initial cost advantage in market M_C is reduced. Knowledge sharing makes B a tougher competitor. Industry profits $(\Delta c_{A,C} - \Delta c_{B,C})m_C$ drop.

To assess whether knowledge sharing is privately beneficial, firms need to add all the gains they can obtain in different markets and compare them to the cost of knowledge sharing. Knowledge sharing is privately profitable for firms A and B if both these conditions hold:

$$\Delta c_A m_A + (\Delta c_{A,C} - \Delta c_{B,C})m_C \geq \tfrac{1}{2}I$$

$$\Delta c_B m_B \geq \tfrac{1}{2}I.$$

Proposition 5. *Knowledge sharing is more likely if*

(i) *the captive markets (m_A, m_B) are large*

(ii) *the contestable market m_C is large and the initially most efficient firm is the faster learner ($\Delta c^{KS}_{A,C} > \Delta c^{KS}_{B,C}$)*

(iii) *the contestable market m_C is small and the initially most efficient firm is the slower learner ($\Delta c^{KS}_{A,C} < \Delta c^{KS}_{B,C}$).*

The result that knowledge sharing is more likely when the captive markets (m_A, m_B) are large is intuitive. The greater (m_A, m_B), the greater the private benefits from knowledge sharing that the partners enjoy. This is in line with Khanna et al.'s (1998) analysis.

More surprising is the contingent effect of the contestable market. The learning races literature suggests that cooperation between partners is more difficult to sustain when partners are competitors (e.g., Khanna et al., 1998). The extent to which partners are competitors is captured in our model by the size of contestable market m_C (relative to the captive markets). Yet we find that larger competitive overlap between partners can sometimes facilitate knowledge sharing (case (ii)). The intuition is that, when the initially most efficient firm is also the faster learner, knowledge sharing actually softens competition. It makes the capabilities of the two firms more asymmetric, which raises price-cost margins. Of course, to the extent that one thinks that the initially most efficient firm is the one most likely to teach best practices to the other firm, case (iii) is the one most likely to occur. Thus a large contestable market may generally hinder cooperation between competitors. Nevertheless, our result provides a novel explanation for the common observation that often competitors do cooperate and share knowledge with one another.

4 Knowledge sharing in alliance portfolios

A recent literature on alliances has focused on alliance portfolios, and interdependencies among a focal firm's alliance partners. At the risk of simplifying a complex subject, this literature argues that overlaps among the alliance partners reduces value: overlaps reduce the potential for synergies and increase the potential for conflict among the partners. The result, according to this logic, is lower stability of alliances and lower value to the focal firm (e.g., Vasudeva and Anand, 2011; Wassmer and Dussauge, 2011). On the other hand, as Lavie (2007) notes, greater overlap among alliance-partners increases the relative bargaining power of the focal firm. Cui (2013) argues that similarity, or redundancy of resources, among alliance partners may benefit the focal firm by ensuring access in uncertain environments.

The empirical results have been similarly mixed. Wassmer and Dussauge (2011) find that airlines that enter into alliances which create resource combinations that are substitutes to resource combinations deployed by existing alliance partners are penalized by investors. Other researchers find an inverted-U relationship between the extent of overlap and value to the focal firm (e.g., Swaminathan and Moorman, 2009). Yet others report a negative relationship (e.g., Goerzen and Beamish, 2005; Cui 2013).

Our focus is on knowledge sharing in alliance portfolios. Overlap among alliance partners makes them substitutable from the focal firm's perspective. Resource dependency theory would suggest that substitutability among alliance partners increases the bargaining power of the focal firm. In turn, this would make the alliance partners more fearful of being exploited and hence less willing to share knowledge. In this section, we show that this intuition is incomplete. Under some conditions, substitutability among alliance partners may encourage rather than discourage knowledge sharing with the focal firm.

For simplicity, consider three firms, F, A and B. Firms A and B can collaborate and share their knowledge with F. We refer to firm F as the focal firm, as it can be involved in more than one alliance. We focus on the case when A and B are substitutes in that they allow F to access similar pools of knowledge. A contribution of this paper is distinguish between two notions of partner substitutability. These notions differ depending on whether the substitutability affects the value created when the partners work together (substitutability *in common benefits*) or the value that the focal firm F can obtain when the alliances break down (substitutability *in rival benefits*). We begin with the case of substitutability in common benefits (CB substitutability). Then we examine substitutability in rival benefits (RB substitutability).

4.1 Substitutability in common benefits

If only one partner (say A) shares its knowledge with F, the (gross) value that can be created by F and A working together is $\overline{S}$. (As always, I denotes the physical cost of sharing knowledge within an alliance, which is equally divided between the partners.) The value that can be obtained by F working alone after knowledge sharing is $\underline{S}$. As in subsection 2.1, the interpretation is that partner F can appropriate a trade secret owned by A and use it in a related project without involving A. We assume $\underline{S} \in [0, \overline{S}]$, since the collaboration with A may add value to F's operations besides the knowledge incorporated in the trade secret. The value that can be obtained by A working alone after knowledge sharing is 0. According to the terminology of subsection 2.2, $\overline{S}$ is a common benefit and $\underline{S}$ is a rival benefit.

Firm A has an incentive to share knowledge with F only if the equilibrium returns from knowledge sharing, $\Pi_A = 0 + \frac{1}{2}\left[\overline{S} - \underline{S}\right] - \frac{1}{2}I$, are greater than the payoff it can obtain by not sharing knowledge. Thus, knowledge sharing in an individual alliance requires

$$\overline{S} - I \geq \underline{S}. \tag{8}$$

Now consider the case when A and B both share knowledge with F. We need to describe the value that each coalition of firms can obtain after knowledge has been communicated. The value that can be created by F, A and B working together—the worth of coalition FAB—is $v(FAB) = 2\overline{S} + s$.[10] $s \geq 0$ captures a complementarity or synergy in A and B's contributions. By combining A and B's knowledge with F's capabilities, the coalition FAB creates s more value than it would be possible if A and B formed two individual alliances with F.

[10] We use the notation $v(S)$ for the coalitional value of each non-empty coalition S. The worth of the empty coalition $\varnothing$ is always zero: $v(\varnothing) = 0$.

The value that can be created by F and A working together without B—the worth of coalition FA—is $v(FA) = \overline{S} + (\underline{S} + k)$. $\overline{S}$ is the value created by F and A collaborating. Because knowledge sharing occurs between F and B and F can appropriate B's trade secret, F also obtains $\underline{S} \in [0, \overline{S}]$. The difference $\overline{S} - \underline{S}$ measures the contribution of B's knowledge or expertise in generating common benefits beyond the trade secret. The parameter k measures the extent to which B's knowledge can be replaced using A's knowledge. We assume that $k \in [0, \overline{S} - \underline{S}]$: replaceability is generally imperfect. Similarly, we assume that the worth of coalition FB is $v(FB) = \overline{S} + (\underline{S} + k)$.

Finally, the worths of firms A, B and F working independently after knowledge sharing are, respectively, $v(A) = 0$, $v(B) = 0$ and $v(F) = 2\underline{S}$. $v(F) = 2\underline{S}$ is what F can obtain by appropriating A and B's trade secrets and using this two pieces of knowledge on its own.

The worths of all the possible non-empty coalitions are summarized in Table 1.

[**Insert Table 1 here**]

Following Hart and Moore (1990), we use the Shapley value to assign payoffs to players. The "grand coalition" FAB is assumed to eventually emerge in equilibrium after knowledge sharing since it is the coalition that creates the greatest total value.[11] The Shapley value assigns each firm its expected marginal contribution assuming that the order in which they joint the grand coalition is random. Formally, for $i = F, A, B$ and any subset of firms $S \subseteq N = \{F, A, B\}$, the value assigned to firm i is:

$$\phi_i = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(|N| - |S| - 1)!}{|N|!} (v(S \cup \{i\}) - v(S))$$

where $|S|$ denotes the number of firms in S and, for any positive integer r, $r! = 1 \times 2 \times ... \times r$, and $0! = 1$.

The Shapley value yields the expressions for the firms' (gross) payoffs:[12]

$$\phi_F = \overline{S} + \underline{S} + \frac{1}{3}(s + k) \tag{9}$$

[11] Indeed, $\underline{S} + k \leq \overline{S}$ implies that coalitional values v satisfy superadditivity: $v(S \cup T) \geq v(S) + v(T)$ for any two disjoint set of firms S and T.

[12] To compute ϕ_F, one can proceed as follows. There are six possible ways in which firms F, A and B can be ordered: FAB, FBA, AFB, BFA, ABF and BAF. The marginal contribution of F when F is the first firm to join the grand coalition (orderings FAB and FBA) is $v(F) - v(\varnothing) = 2\underline{S}$. The marginal contribution of F when F is the second firm to join the grand coalition (orderings AFB and BFA) is $v(AF) - v(A) = v(BF) - v(B) = \overline{S} + (\underline{S} + k)$. The marginal contribution of F when F is the third firm to join the grand coalition (orderings ABF and BAF) is $v(ABF) - v(AB) = v(BAF) - v(BA) = 2\overline{S} + s$. Because all orderings are equiprobable, we obtain equation (9). ϕ_A and ϕ_B can be computed similarly.

$$\phi_A = \phi_B = \frac{1}{2}(\overline{S} - \underline{S}) + \frac{1}{3}s - \frac{1}{6}k. \tag{10}$$

Note that $\phi_F + \phi_A + \phi_B = v\,(FAB)$. This follows from the efficiency property of the Shapley value.

As in subsection 2.1, information leakage shifts the balance of power at the negotiating stage in favor of firm F: F gets an additional $\frac{1}{2}\underline{S}$ from each partner, and A and B lose the same amount. The synergistic value s is created only if all the firms work together; hence s is split equally among them. Partner replaceability has both costs and benefits for A and B. On the one hand, A (say) can be replaced by B. Hence, the bargaining power of A vis-à-vis F decreases. On the other hand, A may replace B. In this case, A will share the benefits of partner substitutability with F. The cost of lower bargaining power for A (and similarly for B) is $\frac{1}{3}k$, while the benefit of replacing B is just $\frac{1}{6}k$. The benefit is half the cost because the gains from replacing B does not just accrue to A, but must be split between A and F. Thus, both A and B lose as a result of partner substitutability, and F gains.

As before, knowledge sharing also involves direct costs. The net payoffs in the knowledge sharing scenario are $\Pi_F = \phi_F - I$, $\Pi_A = \phi_A - \frac{1}{2}I$, $\Pi_A = \phi_B - \frac{1}{2}I$. Knowledge sharing in both alliances requires $\Pi_i \geq 0$, $i = F, A, B$. Thus, we have knowledge sharing in both alliances if

$$\overline{S} - \underline{S} \geq I - \frac{2}{3}s + \frac{1}{3}k. \tag{11}$$

By contrast, knowledge sharing in a single alliance simply requires (8) to hold.

Let $AV_B = v\,(FAB) - v\,(FA)$ be the added value (or marginal contribution) of B to the grand coalition FAB. AV_B can be decomposed into two parts:

$$\begin{aligned} AV_B &= 2\overline{S} + s - [\overline{S} + (\underline{S} + k)] \\ &= \underbrace{(\overline{S} - \underline{S})}_{\text{Added value of } B \text{ to the } FB\text{-coalition}} + \underbrace{(s-k)}_{\text{Value of } A \text{ and } B\text{'s interactions}} \end{aligned} \tag{12}$$

The first component of (12) is the value that B adds to the FB-coalition: The added value of B to F if A is not present. The second component captures the value of interactions between A and B—the synergistic value s and partner replaceability k.

Proposition 6 shows that including a partner that contributes nothing beyond what it would bring to an individual alliance (i.e., $s - k = 0$) can nevertheless bring strictly positive benefits to all alliance partners compared to a situation when only individual alliances are formed. Thus, an alliance portfolio may engender knowledge sharing, even when knowledge sharing in an individual alliance may not be sustainable.

Proposition 6. *Given substitutability in common benefits, if the value of interactions between A and B is zero: $s = k$. Then:*

(i) *Forming an alliance portfolio creates at least as much value for all the partners than forming two independent alliances.*

(ii) *Knowledge sharing in a portfolio may be sustainable, while knowledge sharing in an individual alliance may not.*

That the focal partner F benefits from forming an alliance portfolio rather than a single alliance or no alliance at all (conditional on knowledge sharing) follows immediately from (9). Indeed, F benefits from a portfolio both because it gets a fraction of the synergic value s, and because substitutability strengthens its bargaining power *vis-à-vis* the non-focal partners A and B.

More surprising, the non-focal partner B also strictly benefits more from a portfolio than from an individual alliance with F, even when it contributes nothing to the coalition FA beyond what it would bring to an individual alliance. The reason is that, in writing the added value $AV_B = v(FAB) - v(FA)$, one assumes that if the coalition FAB does not form, the coalition FA will form. Thus, implicit in the computation of AV_B is the assumption that A replaces B. However, it could also be that B replaces A. The Shapley value accounts for this possibility. This implies that, even when $s = k$, B's incentives to share knowledge are higher than in the individual alliance case. As shown in (10), B gets a third of s, but only loses a sixth of k. Because knowledge sharing is determined by the incentives of the non-focal partners A and B, knowledge sharing is more likely in the portfolio scenario. Proposition 6 follows.

The theory has also implications for partner selection. We know that, conditional on knowledge sharing, F benefits from partner replaceability k (see equation (9)). However, too much partner replaceability will cause knowledge sharing to break down, as evident from (10). Because of these two combined effects, from F's viewpoint the optimum value of k will neither be too large nor too low.

Proposition 7. F benefits the most from collaborating with partners with "intermediate" levels of substitutability k.

A natural empirical counterpart of the parameter k is the degree of similarity between the alliance partner of a focal firm F. Proposition 7 suggests an inverted-U relationship between the alliance value of F and the similarity of its partners. The payoff of the focal firm is increasing in k, but only up to a point. If k exceeds $3[\overline{S} - \underline{S} - I] + 2s$, which is the optimum value of k from F's viewpoint, then A and B will not share their knowledge.

In the context of dyadic alliances, Mowery et al. (1998) and Vonortas and Okamura (2009) find evidence of an inverted-U relationship between partners' technological overlap and the probability of alliance formation. Vasudeva and Anand (2011) find an inverted U-shaped relationship between the technological diversity in a focal firm's alliance portfolio and the likelihood that the focal firm cites its partner's patents.

4.2 Substitutability in rival benefits

We now turn to the case of substitutability in rival benefits. In examining this case, we keep the model as similar as possible to the model in the previous subsection to highlight the differences between the two types of substitutability. If only one partner (say A) shares its knowledge with F, the (gross) value that can be created by F and A working together is $\overline{S}$. I is the physical cost of knowledge sharing within an individual alliance, and is divided equally between the partners. The value that can be obtained by F operating on its own after knowledge sharing is $\underline{S}$. The value that can be obtained by A operating alone is 0. As in the previous case, A has an incentive to share knowledge with F only if

$$\overline{S} - I \geq \underline{S}. \tag{13}$$

Now suppose that both A and B share knowledge with F. The value that can be created by F, A and B working together—the worth of coalition FAB—is $v(FAB) = 2\overline{S} + s$. The value that can be created by F and A working together without B—the worth of coalition FA—is $v(FA) = \overline{S} + \underline{S}$. The value that can be created by F and B working together without A is $v(FB) = \overline{S} + \underline{S}$. Note that we assume no substitutability in common benefits: $k = 0$.

Finally, the worth of F operating alone after knowledge sharing is $v(F) = \underline{S}$. The worths of A and B are $v(A) = v(B) = 0$. Note that in the CB substitutability case we had $v(F) = 2\underline{S}$. The reason for this difference is that we now assume that (non-focal) partners are substitutes *in rival benefits*—the benefits that the focal firm F can achieve when cooperation with one of its partner breaks down. The kind of situations we have in mind are ones where the non-focal partners are irreplaceable in their respective core capabilities: If F wants to develop product a, it must collaborate with A (yielding payoff $\overline{S}$), and if it wants to develop product b, it must collaborate with B (also yielding payoff $\overline{S}$). However, knowledge sharing with either A or B allows F to learn some non-core competence, which can be exploited if any of two alliances falls apart. (The payoff associated with exploiting this non-core competence is $\underline{S}$.)

The worths of all the possible non-empty coalitions are listed in Table 2.

[**Insert Table 2 here**]

The Shapley value yields the following expressions for the firms' (gross) payoffs:

$$\phi_F = \overline{S} + \frac{2}{3}\underline{S} + \frac{1}{3}s \tag{14}$$

$$\phi_A = \phi_B = \frac{1}{2}\overline{S} - \frac{1}{3}\underline{S} + \frac{1}{3}s. \tag{15}$$

The firms' net payoffs are $\Pi_F = \phi_F - I$, $\Pi_A = \phi_A - \frac{1}{2}I$, $\Pi_A = \phi_B - \frac{1}{2}I$. Knowledge sharing in both alliances requires $\Pi_i \geq 0$, $i = F, A, B$. We have knowledge sharing in both alliances when

$$\overline{S} - I \geq \frac{2}{3}(\underline{S} - s). \tag{16}$$

Recall that the corresponding condition with only one alliance is $\overline{S} - I \geq \underline{S}$.

Proposition 8. *In the substitutability in rival benefits case, suppose that there are no synergies between A and B so that $s = 0$. Then:*

(i) *Forming an alliance portfolio creates at least as much value for all the partners than forming two independent alliances.*

(ii) *Knowledge sharing in a portfolio may be sustainable, while knowledge sharing in an individual alliance may not.*

Propositions 6 and 8 are similar in that they both provide conditions for all alliance partners to benefit more from an alliance portfolio than from a set of individual alliances. However, the conditions are less stringent when substitutability is in rival benefits (Proposition 8) than when substitutability is in common benefits (Proposition 6).

In the rival benefits case, substitutability actually encourages knowledge sharing because, in the individual alliance case, a non-focal partner (say B) always provides knowledge that increases the focal partner's outside options (its rival benefit). By contrast, in the portfolio case, the other non-focal partner A may have already provided this knowledge. As a result, B's incentives to share knowledge (and its payoff, gross and net) are higher. This implies that knowledge sharing is easier in a portfolio with RB substitutable partners. A portfolio can be sustainable, while two independent alliances may not, even when the synergies between non-focal partners are absent ($s = 0$).

By contrast, there must be some synergistic value between partners in the common benefits case for a portfolio to be sustainable when two independent alliances are not. The synergies, however, are lower than what it could have been expected because partner substitutability to some extent also benefits the non-focal partners when they replace the other partner.

5 Contractual solutions

In this section, we briefly discuss why contractual solutions are of limited use.

5.1 Payments to share knowledge

Payments provided by the "strong" partner to the "weak" partner to encourage the weak partner to enter an alliance and share knowledge do not solve the problems associated with shifting bargaining positions. The reason is that knowledge sharing is not observable by a court. Thus, the weak partner would sign the contract, accept the payment, and then would not share knowledge if that was not in its own interest. This logic is similar to the problem with termination fee contracts.

5.2 Termination fee contracts

Termination fee contracts may appear to be a potential solution to the problems highlighted in this paper. However, they will work only under very stringent assumptions. To see this, consider a simple model with private and common benefits. After knowledge sharing, let the gross payoffs be $\pi_A = a$, $\pi_B = b$ and the payoff from joint exploitation, V, where $V \geq a + b$. Suppose also that A is the stronger partner: $a > b$.

After knowledge sharing, the actual gross payoffs that accrue to A and B are, respectively, $V/2 + a/2 - b/2$ and $V/2 - a/2 + b/2$. B would share knowledge only if $V/2 - a/2 + b/2 \geq I/2$, that is, if $V - I \geq a - b$. Suppose this condition fails.

If A offers a contract to B that pays x to B if A terminates the contract. In this case, once knowledge sharing has occurred, A's outside option is $a - x$. B's outside option is $b + x$.[13] The new gross payoffs that accrue to A and B after negotiations are thus, respectively, $V/2 + a/2 - b/2 - x$ and $V/2 - a/2 + b/2 + x$.

For knowledge sharing to occur, we need $V/2 - a/2 + b/2 + x \geq I/2$, that is

$$x \geq \frac{(a-b) - (V-I)}{2}.$$

By setting $x = \frac{(a-b)-(V-I)}{2}$, firm A can induce firm B to share knowledge.

The ability of termination fees to induce knowledge sharing, however, is limited. One important reason is that B may be tempted to renege from the very beginning. Specifically, B may not share knowledge, which may force A to terminate the alliance, resulting in a payment of x to B. Note that $x < V/2 - a/2 + b/2 + x - I/2$ only if $V/2 - a/2 + b/2 + x - I/2 > 0$. In other words, termination fees will not help unless the courts can indemnify A against reneging by B.

6 Conclusion

Firms enter into alliances for a variety of reasons: to facilitate collusion and increase market power (Porter and Fuller, 1986; Hagedoorn, 1993; Nakamura et al., 1996), to share risks and take advantage of new opportunities (Kogut, 1991; Gulati et al., 2000), to pool resources with other firms (Williamson, 1985;

[13]Here we assume that A is the only firm that has an incentive to terminate the alliance. It is easy to check that, given the contract, firm B has no incentive to prematurely terminate the alliance.

Hennart, 1988) and to acquire new skills and capabilities (Hamel, 1991; Mowery et al., 1996; Khanna et al., 1998; Lane and Lubatkin, 1998).

In this paper, we have focused on alliances where a primary objective is the acquisition of new skills and capabilities ("learning alliances"), but where contracts are incomplete and firms cannot commit to exploit the newly created knowledge jointly. Firms share knowledge to create value (e.g., new products). However, knowledge sharing also creates agency hazards. For instance, a firm may steal a partner's trade secrets, or asymmetric learning may occur. In the latter case, the faster learner may over time be able to reduce its dependency on the partner and appropriate a greater share of the collaborative pie. All these risk, if foreseen, can discourage knowledge sharing, unless contractual or other types of safeguards exist.

This paper contributes to the literature on learning in alliances, and provides a different perspective on learning races. Many if not most of the learning race view's recommendations suffer from a failure to recognize that the processes of value creation and value appropriation are inextricably linked. As Zeng and Hennart (2002: 193) put it, in fact, "Efforts at increasing one's value extraction from a joint venture often damage cooperation and negatively impact value creation." Scholars have also argued that the notion of a race to learn may be "largely unrealistic," for it is unclear what motivates a likely loser to join a race (Inkpen, 2002: 272). In this paper we incorporate a knowledge sharing constraint into a model of learning in alliances, and show that its inclusion has important consequences for both how alliances should be managed and how partner should be selected.

This perspective yields nuanced predictions. In some cases, the stronger partner may limit its own ability to learn, as Cisco does, or help enhance the learning ability of its partners. Indeed, In some cases, firms appear to go to great lengths to facilitate their partner's learning efforts, even when these partners are competitors in the product market. In a study of American-Japanese joint ventures in the automotive industry, Inkpen (1998) reports many instances of Japanese firms facilitating technology transfer to American partners through training of American engineers, temporary redeployment of personnel and transfer of equipment designs. We also find nuanced results regarding alliance portfolios. The simple intuition that alliance portfolios should be constructed to minimize overlap in technology among partners is potentially misleading when we consider learning alliances and incomplete contracts.

Alliances are by definition not zero-sum games. Instead, they have the potential to create value. Value capture strategies must be balanced against the need to ensure value creation. Our focus on the need to induce knowledge sharing by the weaker partner is, at the most abstract level, an attempt put the emphasis back on value creation.

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Appendix 1: Omitted proofs

The proofs of Propositions 1 and 7 follow from the analysis in the main body of the paper. Propositions 2, 3 and 5 are corollaries of Proposition 1. Below, we prove Propositions 4, 6 and 8.

Proof of Proposition 4. Assumptions $V \geq I$ and $\theta_A^L \geq \theta_B^H$ imply that A's knowledge sharing constraint is always satisfied. The only knowledge sharing constraint that may not be satisfied is B's. From (6), it is clear that, by selecting $\theta_B = \theta_B^H$, firm B will then maximize both the probability of knowledge sharing and its share of the alliance returns. Thus, if knowledge sharing takes place, firm B will select $\theta_B = \theta_B^H$.

Consider the problem firm A faces. The objective of firm A is to maximize its own payoff with respect to θ_A,

$$\max_{\theta_A \epsilon \{\theta_A^L, \theta_A^H\}} \quad \frac{1}{2}[V + (\theta_A - \theta_B)\, v - I], \tag{17}$$

subject to B's knowledge sharing constraint being met

$$V - (\theta_A - \theta_B)\, v - I \geq 0 \tag{18}$$

and firm B choosing $\theta_B = \theta_B^H$. (If B's knowledge sharing constraint is not met, then A's payoff is 0. This is clearly worse than what firm A can obtain with knowledge sharing.)

From (17), it is clear that firm A will choose the highest value of θ_A compatible with (18) being met when $\theta_B = \theta_B^H$. If

$$V - \left(\theta_A^L - \theta_B^H\right) v - I < 0 \quad \Leftrightarrow \quad \theta_A^L - \theta_B^H > \frac{V - I}{v},$$

then there is no value of θ_A for which B's knowledge sharing constraint is satisfied. Thus, knowledge sharing does not occur.

If

$$V - \left(\theta_A^L - \theta_B^H\right) v - I \geq 0 > V - \left(\theta_A^H - \theta_B^H\right) v - I \quad \Leftrightarrow \quad \theta_A^L - \theta_B^H \leq \frac{V - I}{v} < \theta_A^H - \theta_B^H,$$

then $\theta_A = \theta_A^L$ and knowledge sharing occurs.

If

$$V - \left(\theta_A^H - \theta_B^H\right) v - I \geq 0 \quad \Leftrightarrow \quad \theta_A^H - \theta_B^H \leq \frac{V - I}{v},$$

then $\theta_A = \theta_A^H$ and knowledge sharing occurs. This proves Proposition 4. ■

Proof of Proposition 6. In the individual alliance case, F and B (and similarly F and A) obtain (gross) payoffs $\phi_F^{SA} = \frac{1}{2}(\overline{S} + \underline{S})$ and $\phi_B^{SA} = \frac{1}{2}(\overline{S} - \underline{S})$. Thus, as noted in the main text, knowledge sharing occurs in the single alliance case when $\phi_B^{SA} \geq \frac{1}{2}I \Leftrightarrow \overline{S} - \underline{S} \geq I$.

In the alliance portfolio case, assuming $s = k$, we have that knowledge sharing is more likely since:

$$\phi_B = \frac{1}{2}(\overline{S} - \underline{S}) + \frac{1}{3}s - \frac{1}{6}k \geq \frac{1}{2}(\overline{S} - \underline{S}) = \phi_B^{SA}.$$

All partners benefit when firm B is added to the alliance portfolio since for F is better to have an alliance portfolio with both A and B than two single alliances with A and B:

$$\phi_F = \overline{S} + \underline{S} + \frac{1}{3}(s + k) \geq 2\phi_F^{SA} = \overline{S} + \underline{S}$$

and

$$\phi_A = \phi_B = \frac{1}{2}(\overline{S} - \underline{S}) + \frac{1}{3}s - \frac{1}{6}k \geq \frac{1}{2}(\overline{S} - \underline{S}) = \phi_A^{SA} = \phi_B^{SA}.$$

■

Proof of Proposition 8. In the individual alliance case, F and B (and similarly F and A) obtain (gross) payoffs $\phi_F^{SA} = \frac{1}{2}(\overline{S} + \underline{S})$ and $\phi_B^{SA} = \frac{1}{2}(\overline{S} - \underline{S})$. Thus, as noted in the main text, knowledge sharing occurs when $\phi_B^{SA} \geq \frac{1}{2}I \Leftrightarrow \overline{S} - \underline{S} \geq I$.

Now consider an alliance portfolio. Even when there are no synergies between A and B, $s = 0$, B's (gross) payoff is larger than B's (gross) payoff in the individual alliance case, $\phi_B \geq \phi_B^{SA}$, since

$$\frac{1}{2}\overline{S} - \frac{1}{3}\underline{S} \geq \frac{1}{2}(\overline{S} - \underline{S}).$$

This is because, in the individual alliance case, B always provides knowledge that increases F's outside option. By contrast, in the portfolio case, A may have already provided this knowledge, and hence B' incentives to share knowledge (and its payoff, gross and net) are higher.

Similarly, A's payoff is also larger in the portfolio case than in the individual alliance case.

Finally, F's payoff is higher in the portfolio case than in the single alliance case because

$$\overline{S} + \frac{2}{3}\underline{S} \geq \frac{1}{2}(\overline{S} + \underline{S}).$$

The intuition is that F's bargaining power is strengthened when there are two potential knowledge providers rather than just one.

Knowledge sharing is more likely in the portfolio case than the individual alliance case since the condition

$$\frac{1}{2}\overline{S} - \frac{1}{3}\underline{S} \geq \frac{1}{2}I$$

is weaker than the condition

$$\frac{1}{2}(\overline{S} - \underline{S}) \geq \frac{1}{2}I.$$

■

Appendix 2: A dynamic model of knowledge sharing

In the basic model in Section 2, there is only one round of knowledge sharing. In this appendix we develop a multi-stage, optimal stopping game of knowledge sharing, and show that our key qualitative results are robust.

Consider a collaboration between two infinitely-lived firms (or partners). Time is discrete. In each period $t = 1, 2... + \infty$, the firms decide whether or not they want to continue their collaboration. If the partnership is terminated at time t, then each partner $i = A, B$ receives a payoff $\Pi_{i,t}$. This payoff depends on whether the partners reach an agreement at time t concerning the division of the joint value. If they reach an agreement, then they split a joint payoff of R_t. If not, each party obtains its outside option $\pi_{i,t}$. As standard in the incomplete contract literature, R_t is assumed to be observable but not verifiable. Moreover, bargaining is assumed to be efficient and determined according to the Nash solution with equal weights. Thus, if the partnership is terminated at time t, i's payoff is given by

$$\Pi_{i,t} = \begin{cases} \pi_{i,t} + \frac{1}{2}\left[R_t - \pi_{A,t} - \pi_{B,t}\right] & \text{if } \; R_t \geq \pi_{A,t} + \pi_{B,t} \\ \pi_{i,t} & \text{otherwise} \end{cases}$$

This implies that when the agreement is efficient ($R_t \geq \pi_{A,t} + \pi_{B,t}$), the parties receive their outside options plus and equal fraction of the surplus. To focus on inefficient termination, we will typically assume unless otherwise specified that $R_t \geq \pi_{A,t} + \pi_{B,t}$ for all t.

Effective collaboration requires investment by both partners to create joint value. Specifically, effective collaboration requires each partner to exert unobservable effort at private cost $\frac{1}{2}I$, $I > 0$. If both parties exert effort (i.e., collaborate, invest), then in period $t+1$ the joint payoff and outside options are $(R_{t+1}, \pi_{A,t+1}, \pi_{B,t+1})$. We assume $R_1 < \infty$ and decreasing marginal returns to investment: $\Delta R_{t+1} \leq \Delta R_t$ for all t, where $\Delta R_t \equiv R_{t+1} - R_t$. If at t at least one party does not invest, then the partnership is terminated with payoffs $(R_t, \pi_{A,t}, \pi_{B,t})$.[14] Note that the assumptions that investment is unobservable and R_t is non-verifiable imply that partners cannot contract on effort.

[14] Note that, in equilibrium, if one party stops investing, then the other party will also stop investing since otherwise it would waste $I/2$. Our framework also rules out equilibria where both parties stop investing at some period t and then both restart at time $t+s$, $s \geq 1$. These equilibria do not exist if there is some small discounting.

To characterize the solution to this stopping game, some notation must be introduced. A policy is a rule for choosing when to stop. Let $V_{i,t}$ denote the i's maximum expected return at time t, *conditional on $j \neq i$ never stopping.* An optimal policy for i for this auxiliary problem exists and can be found by solving the optimality equation

$$V_{i,t} = \max\left[\Pi_{i,t}, -\frac{1}{2}I + V_{i,t+1}\right]$$

(see, e.g., Ross, 1983). Let

$$Z_i = \left\{t : \Pi_{it} \geq -\frac{1}{2}I + \Pi_{it+1}\right\}$$

be the set of periods t for which i finds that stopping is at least as good as investing for exactly one period and then stopping. The one-stage look-ahead policy for i is defined as the policy that stops the first time the process enters a state in Z_i. The following result is standard (see Ross, 1983: 54-55).

Result (*). *Suppose Z_i is a closed sets of states. Then the one-stage look-ahead policy for the auxiliary problem is optimal for $i = A, B$.*

Result (*) states that, provided that B (respectively, A) keeps investing, then for A (respectively, B) it is optimal to stop whenever stopping now is better than stopping the next period. Result (*) applies for instance, when Π_{it} is 'concave' in t (i.e., $\Delta\Pi_{it}$ is decreasing). Then in fact, if $\Delta\Pi_{it} \leq \frac{1}{2}I$ holds for some t', it must also hold for all $t'' > t'$ (Z_i is a closed sets of states). Obviously if $\Delta\Pi_{it}$ is decreasing, then as soon as $\Delta\Pi_{it} \leq \frac{1}{2}I$ partner i should stop investing.

Focusing on partner A and assuming that partner B always invests, Result (*) implies that A will stop at time T_A, where T_A is the smallest t such that

$$\Pi_{i,T_A} \geq \Pi_{i,T_A+1} - \frac{1}{2}I. \tag{19}$$

Let $\Delta R_t \equiv R_{t+1} - R_t$ and $\Delta\pi_{i,t} \equiv \pi_{i,t+1} - \pi_{i,t}$. Since $R_t \geq \pi_{At} + \pi_{Bt}$ for all t, (19) can be rewritten as

$$\Delta R_{T_A} - I \leq \Delta\pi_{B,T_A} - \Delta\pi_{A,T_A}.$$

Thus, A stops investing when the partnership is no longer very productive ($\Delta R_{T_A} - I$ is small) and bargaining power is shifting in favor of B ($\Delta\pi_{B,T_A} - \Delta\pi_{A,T_A}$ is large).

B's problem is symmetric. If A always invests, then B must stop at time T_B, where T_B is the smallest t such that

$$\Delta R_{T_B} - I \leq \Delta\pi_{A,T_B} - \Delta\pi_{B,T_B}.$$

Thus B stops earlier if the partnership is no longer very productive (as before) and its relative bargaining power starts to decline. Since the partnership terminates when either party stops investing, the actual stopping time is given by

$$T^* = \min[T_A, T_B]$$

or equivalently

$$\Delta R_{T^*} - I \leq |\Delta\pi_{A,T^*} - \Delta\pi_{B,T^*}|.$$

Note that if investment could be contracted upon, then the relationship would be terminated as soon as

$$\Delta R_T \leq I.$$

Proposition A2_1 summarizes our findings.

Proposition A2_1. *Suppose that an agreement is always efficient and Z_A and Z_B are closed sets of states. Then the collaboration is terminated at time T^*, where T^* is the smallest t satisfying*

$$\Delta R_{T^*} - I \leq |\Delta\pi_{A,T^*} - \Delta\pi_{B,T^*}|. \tag{20}$$

Thus, compared to an efficient solution, in the non-cooperative equilibrium the collaboration terminates inefficiently early.

This proposition is very similar to Proposition 1 in the main body of the paper. It shows that collaboration is more likely to be terminated inefficiently early if continuation creates large shifts in bargaining power.

Appendix 3: Strategic investment of absorptive capacity and obfuscation

In subsection 3.1, we assumed that firms can invest in their own learning capability but cannot influence the learning capability of their partners. In this appendix, we examine a setting where firms can invest both in their own absorptive capacity (thus influencing their own learning capability) and make their operations less transparent to their partners (thus influencing their partners' learning capability).

We assume knowledge sharing is efficient, $V \geq I$ and that, over the "relevant" range of parameter values, shifts in bargaining power favor partner A: $\theta_A > \theta_B$. Thus B is the "weaker" partner that may be reluctant to share information.

For now we fix B's absorptive capacity α_B and transparency τ_B, and focus on the actions of the "stronger" partner—partner A. In this setting, we derive Proposition A3_1 below. Then, we discuss how the results extend to the case where also B can choose its level of absorptive capacity and transparency.

Let $\left(\overline{\theta}_A, \overline{\theta}_B\right)$ be A and B's initial levels of learning capability absent any strategic investment. Let (θ_A, θ_B) be A and B's (ex post) levels of learning capability after investment. Let $\overline{\theta}_A = \overline{\alpha}_A \overline{\tau}_B$, $\overline{\theta}_B = \overline{\alpha}_B \overline{\tau}_A$, where $\overline{\alpha}_i$ and $\overline{\tau}_i$ denote, respectively, $i = A, B$'s initial levels of absorptive capacity and transparency. After investment, $\theta_A = (\overline{\alpha}_A + i_{abs,A})\overline{\tau}_B$ and $\theta_B = \overline{\alpha}_B(\overline{\tau}_A - i_{obf,A})$, where $i_{abs,A} \in [\underline{i}_{abs,A}, \overline{i}_{abs,A}]$ and $i_{obf,A} \in [\underline{i}_{obf,A}, \overline{i}_{obf,A}]$ measure, respectively, A's investment in absorptive capacity and A's investment in obfuscation. We assume $\underline{i}_{abs,A} < 0 < \overline{i}_{abs,A}$ and $\underline{i}_{obf,A} < 0 < \overline{i}_{obf,A}$.

We examine two scenarios: (i) B's knowledge sharing constraint is initially satisfied, $V - I \geq \left(\overline{\theta}_A - \overline{\theta}_B\right) v$, and (ii) B's knowledge sharing constraint is not initially satisfied, $V - I < \left(\overline{\theta}_A - \overline{\theta}_B\right) v$. Throughout, we assume that $i_{abs,A}$ and $i_{obf,A}$ can be costlessly changed by A, and that by changing only $i_{abs,A}$ or $i_{obf,A}$, B's knowledge sharing constraint can be met. Because there is a one-to-one mapping from $i_{abs,A}$ to θ_A and from $i_{obf,A}$ to θ_B, for ease of notation we will use θ_A and θ_B as A's choice variables.

The objective of firm A is to maximize its own payoff with respect to θ_A and θ_B,

$$\max_{\theta_A, \theta_B} \quad \frac{1}{2}[V + (\theta_A - \theta_B)\, v - I], \tag{21}$$

subject to B's knowledge sharing constraint being met:

$$V - (\theta_A - \theta_B)\, v - I \geq 0. \tag{22}$$

(If B's knowledge sharing constraint is not met, A's payoff is 0, which is clearly suboptimal.)

The solution to this problem is simple: Choose $\theta_A - \theta_B$ so that B's knowledge sharing constraint is met with equality:

$$(\theta_A - \theta_B)^* = \frac{V - I}{v}.$$

This choice implies that the whole surplus from the relationship, $V - I$, goes to partner A. How A's investments in absorptive capacity and obfuscation, $(i_{abs,A}, i_{obf,A})$, must be chosen depends on the initial conditions $\left(\overline{\theta}_A, \overline{\theta}_B\right)$. If B's knowledge sharing constraint is initially satisfied, $V - \left(\overline{\theta}_A - \overline{\theta}_B\right) v - I > 0$, then $i_{abs,A}$ or $i_{obf,A}$ (or both) must be increased. This conforms to the learning race's tenet that firms should maximize their receptivity to external knowledge while protecting/obfuscating their own knowledge. However, if B's knowledge sharing constraint is initially not satisfied, $V - \left(\overline{\theta}_A - \overline{\theta}_B\right) v - I < 0$, then setting $\theta_A - \theta_B$ equal to $(V - I)/v$ implies that $i_{abs,A}$ or $i_{obf,A}$ must be decreased. Thus, A must either reduce its own absorptive capacity (a strategy of "self-castration") or increase the transparency of its own operations, or both. This apparently "altruistic" behaviors are of course motivated by the desire to encourage B's participation and knowledge sharing.

Proposition A3_1. Suppose both θ_A and θ_B can be costlessly changed by partner A, and that by changing $\theta_A - \theta_B$, B's knowledge sharing constraint can be met.

(i) If B's knowledge sharing constraint is initially satisfied, then A should either increase its absorptive capacity ($i_{abs,A} > 0$) or invest in obfuscation ($i_{obf,A} > 0$), or both, until B's participation constraint is satisfied with equality.

(ii) If B's knowledge sharing constraint is initially not satisfied, then A should either decrease its absorptive capacity ($i_{abs,A} < 0$) or make its operations more transparent ($i_{obf,A} < 0$), or both, until B's participation constraint is satisfied with equality.

A limitation of this model is that it is not important how precisely A's absorptive capacity and obfuscation level are chosen, so long as in the end $\theta_A - \theta_B = \frac{V-I}{v}$. However, by introducing small costs of investing in absorptive capacity and obfuscation, this indeterminacy could be resolved. If the costs of obfuscation are lower than the costs of modifying the absorptive capacity level, then only the obfuscation level should be changed. If instead the costs of obfuscation are greater than the costs of modifying the absorptive capacity level, then all the adjustment should be borne by absorptive capacity.

A second limitation of the model is that B's levels of absorptive capacity and obfuscation are taken as given. It should be clear, however, that costless investments in absorptive capacity and obfuscation always benefit partner B, as they increase its payoff without preventing knowledge sharing. Thus, one way to interpret $\overline{\alpha}_B$ is as the maximum level of absorptive capacity that B can achieve, and $\overline{\tau}_B$ as its minimum level of transparency. Clearly, for the "weaker" partner, the learning races' tenet of maximizing receptivity while limiting internal transparency does hold. Altruistic behavior, if observed at all, should be undertaken by the "stronger" partner with the greatest incentive to encourage knowledge sharing.

TABLE 1: Coalitional values after knowledge sharing.

The CB substitutability case

$v(FAB) = 2\overline{S} + s$
$v(FA) = v(FB) = \overline{S} + (\underline{S} + k)$ $v\left(AB\right) = 0$
$v\left(F\right) = 2\underline{S}$ $v\left(A\right) = v\left(B\right) = 0$

TABLE 2: Coalitional values after knowledge sharing.

The RB substitutability case

$v(FAB) = 2\overline{S} + s$
$v(FA) = v(FB) = \overline{S} + \underline{S}$ $v\left(AB\right) = 0$
$v\left(F\right) = \underline{S}$ $v\left(A\right) = v\left(B\right) = 0$