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THE CHOICE OF ORGANIZATIONAL FORM FOR COLLABORATIVE INNOVATION

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Abstract

It is commonplace for firms to collaborate with others to gain access to technological components for innovation. This paper examines the choice of organizational form for such activities: when should a firm hire a technological expert as a temporary employee, transact through consulting spot markets, or engage in a long-term employment or supply relationship with the expert? Property rights theory is applied to examine the incentives and commitment created by different organization forms when the property rights of knowledge assets are incomplete. The model highlights the role of fallback options in sustaining socially efficient implicit contracts. Comparison of long-term employment and supply relationships shows that, contrary to received wisdom, an employment relationship is a less robust arrangement than a supply relationship in the presence of large knowledge spillovers. Nevertheless, the employment relationship is relatively more sustainable when there are complementarities between the parties' cooperation investments. Empirical implications for structuring R&D and consulting arrangements are discussed.

Key words: Implicit contracts, R&D cooperation

JEL Codes: D23, L22, O31

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1 Introduction

Economic historians have long emphasized the importance of institutional and organizational arrangements in economic performance of nations and industries (North 1990; Mokyr 1992; Mowery and Rosenberg 1989). Incentives to learn and innovate created by institutions and policies are recognized as critical prerequisites for sustained economic development (Johnson 1992, Landau and Rosenberg 1992). The effects of organizational choices on innovation performance of individual firms are less well understood. Transaction cost economists have investigated both theoretically and empirically the factors driving vertical integration, and particularly, the role of asset specificity (for a review of the empirical work, see Shelanski and Klein 1995). However, if organizational form affects firms' innovativeness, then organization may have dynamic, cumulative implications on economic performance, not only implications for static efficiency (North 1990).

Empirical studies of technological change emphasize that innovation often depends on the integration of key sources of knowledge. Indeed, Rothwell et al. (1974) found in an early empirical study that information exchange both within the firm—among functions and departments—and between the firm and its customers and suppliers is important for successful introduction of new products and technologies in the markets. Thus there appear to be complementarities among the diverse sources of knowledge (see Durlauf 1992; Jorde and Teece 1992, for analyses of the macroeconomic implications of positive complementarities among industries). Internal and external sources of knowledge interact in the innovation process exerting joint effects on firms' economic performance. Thus, at the level of firms, dynamic performance in terms of innovation can be seen to arise from firms' ability to collect, generate, and recombine useful knowledge (Schumpeter 1942). Therefore, the capacity to communicate and cooperate with external parties is critical for firms (Cohen and Levinthal 1989).

However, the question of how to combine knowledge from the various relevant sources has not been addressed. Firms can organize learning and innovation internally or through external outsourcing or cooperation arrangements. The choice is likely to depend on both the characteristics of underlying knowledge and the characteristics of the feasible organizational arrangements. This paper focuses on the latter. We examine how alternative organizational arrangements differ in their effects on the cooperative innovation process through analysis of a repeated property rights model. A particular focus is on the incentives to communicate and cooperate.

A stream of theoretical literature has examined the choice of organizational form for R&D activities (d'Aspremont and Jacquemin 1988; Kamien, Muller, and Zang 1992; and many others building on these seminal contributions). This approach focuses on the formation of horizontal research joint ventures (RJVs) in a duopolistic industry. The basic conclusion is that R&D cooperation is welfare improving, because it supports R&D investment. Individual firms' choices of whether to cooperate depend on the magnitude of knowledge spillovers in the industry: the larger the spillovers are the more beneficial is cooperative R&D, because it enables internalization of these externalities.

The RJV framework suggests that collaboration is costless and socially beneficial, but firms may choose not to collaborate because of the competitive situation—a firm's own R&D investments encourage the partner to produce more due to the knowledge spillovers, which are further intensified in the joint venture. R&D partners are thus competitors in the marketplace. However, according to recent innovation survey evidence from Belgium, Finland, and Germany (Cassiman and Veugelers 2000; Leiponen 2002; and Kaiser 2000, respectively), firms are more likely to collaborate vertically with customers or suppliers than horizontally with rivals. This is possibly because of the aforementioned competitive effect that makes it difficult to align the conflicting interests of rival firms. Unfortunately, RJV models do not lend themselves very well to the study of vertical relationships, although more recently some scholars (e.g., Kesteloot and Veugelers 1997) have begun analyzing R&D collaboration between asymmetric horizontal partners.

Collaborative innovation is often motivated by complementary technological capabilities, in addition to the sharing of risks and costs (Hagedoorn 1993). If we simply extrapolate from the RJV framework, then vertically related (non-rival) firms with complementary technologies should always collaborate. Of course, this is not observed in reality—something essential is missing from the model. Another, more empirically driven field of research argues that collaboration is associated with costs of organization and transaction (Pisano, Shan, and Teece 1988; Oxley 1997). Whereas the theoretical RJV literature posits frictionless cooperation, the transaction cost theory submits that firms choose the organization of R&D by minimizing the sum of production and transaction (organization) costs (Williamson 1985).

The focus on cooperation stems from the observation that close collaboration is essential in exchanging tacit knowledge which underlies much innovation (see e.g. Zucker, Darby, and Armstrong 1994; Senker 1995). The distinct, partly tacit competencies of various actors need to be integrated to create novel solutions to identified problems (Iansiti and Clark 1994; Iansiti 1995). Holmström and Milgrom (1994) have argued that internal organization supports cooperation better than arrangements across organizational boundaries, because cooperation is difficult to measure and reward, which aggravates incentive issues in inter-organizational settings. For instance, high-powered profit incentives for a team decrease the willingness of its members to cooperate with parties outside the team, unless specific incentive schemes are implemented to encourage cooperation across teams. Therefore, it may be better to internalize the actors with which a team needs to cooperate, even at the cost of lower-powered incentives.

In this paper we model the costs of cooperation more explicitly as an investment that affects the revenues from innovation projects. We examine a firm's problem of organizing an innovation project where an (outside) expert is an essential source of knowledge. The R&D project output, a new product or a process technology, is the good being exchanged. The firm can tap the expert's R&D capability through market-like one-time transactions. Alternatively, the firm can establish a relationship based on an implicit contract of repeated transactions. In this case, the expert's R&D effort is compensated through an incentive (profit sharing) contract.

Investment in cooperation has certain special characteristics. First, it is not measurable or verifiable and thus not contractible. However, the collaborating parties can observe the effort made by the other party, and thus will be aware of it even if no formal contract can be written and enforced. Second, communication during cooperation leads to involuntary spillovers of strategic knowledge. As a result, each party unwillingly improves the position of the partner. Under these circumstances, which organizational arrangement provides the most optimal incentives to invest in cooperation, and when is that arrangement likely to arise and be sustained?

These questions can be analyzed in the implicit contracting framework developed by Baker, Gibbons, and Murphy (2002) building on the property rights literature (Grossman and Hart 1986; Hart and Moore 1990). The basic property rights model (e.g., Hart 1995) examines trade in products that are incompletely defined and measured *ex ante*. There the focus is on the allocation of property rights, in other words, on the effects of vertical integration and its direction. Baker et al. (ibid.) specify a second instrument in addition to ownership: profit sharing incentive contracts that are credible only in a repeated (long-term) relationship. Consequently, there are four organizational forms.

Reminiscent of the classical dichotomy of markets and hierarchies, a market transaction is defined by the expert controlling the essential (knowledge) asset and the relationship is short-term in nature, while an employment relationship is a situation where the buyer controls the asset and the interaction is repeated. The novel organization forms include, first, supply relationships, where the expert owns or controls the essential asset, but now compensation is based on an incentive (profit sharing) contract, and interaction is repeated. Second, spot employment is a short-term employment relationship without any profit or benefit sharing, akin to temporal employment without benefits, bonuses, or chances of promotion. Following Baker et al. (2002) and Halonen (2002), we incorporate repeated interaction as an essential element of organizational choice. The repeated game approach makes it possible to take some intertemporal aspects of cooperation into account. An extended time horizon is required to make implicit contracts sustainable.

The present paper echoes the view by Hansmann (1996, p. 299) that the property rights approach overemphasizes the governance of *physical* assets (also Anand and Galetovic 2000; Pagano and Rossi 2002). For a large number of firms, particularly in the service sector but also in such innovative industries as biotechnology or computer software, physical assets are less critical for performance than the competencies possessed by employees and teams. Therefore, this paper addresses the organization of cooperation with firms operating in sectors such as knowledge-intensive business services (e.g., legal services, software design, R&D services, and various types of technical and management consulting), where the client firm cannot directly own the essential assets, namely the supplier's competencies. In such an environment, what defines the organization when there are no essential physical assets to be owned? The form of organization in these situations is likely to depend on what kinds of control rights can be established to the immaterial assets.

Allocation of intellectual property rights to innovation output was discussed by Aghion and Tirole (1994) in their model of an R&D project. They examined the incentives and allocation of ownership to an innovation project in a standard property rights framework (Grossman and Hart, 1986). The model in the current paper is richer in organizational forms due to the repeated contracting framework. Indeed, as Baker et al. argued, repeated implicit contracting captures some essential features of the firm, such as the creation of "trust" and viewing contracting in a long-term perspective. Moreover, the framework here incorporates some basic characteristics of technological knowledge, namely, the possibility of involuntary knowledge spillovers and complementary, or mutually reinforcing, efforts.

A central background assumption here is that revenues of the innovation project are measurable, for example, in the form of sales of the new product or production efficiency gains. Thus the analysis does not apply to the kind of informal, unstructured cooperation where no specific project is being carried out.

The next section introduces the modeling framework and specifies the alternative contractual forms available for firms. The third section examines the sustainability of implicit contracts, and section 4 introduces alternative assumptions about spillovers. Section 5 explores the empirical implications of the framework and, in section 6, the results are summarized.

2 The model

There are two parties, D and E, who first contract on collaboration, then invest in communication, and, in the last stage, share profits. D is a Downstream firm that wants to use some (technological) knowledge possessed by E, who is an Expert in a specific field. E's human asset cannot be bought directly: only through close collaboration can the relevant knowledge be communicated and applied in D's new technology or product. The research question concerns how to organize this communication.

Denote the payoffs with R_D and R_E. The revenue from trade realized by D is $R_D = R_D(c_D, c_E)$, a function of the cooperation investments c_D and c_E by D and E respectively. $R_E = R_E(c_D, c_E)$ is the value of the best alternative outside option for E. Thus the same efforts increase the inside and outside options, but, apart from this, the revenues are unrelated. Decisions about trade and investments are based on expected payoffs $E(R_D)$ and $E(R_E)$, associated with (for now unspecified) independent probability distributions.

There may be other providers of solutions to D's problem in the market, and E also has other interested buyers. E can take the R&D results to another downstream firm, but then the value of the completed R&D work is reduced because of the client-specific element in this innovation project. Thus the market is competitive, but not perfectly. Trade between D and E is socially efficient (see assumption A1 below) in the relevant range of investment levels.

(A1) $$R_D(c_D , c_E) > R_E(c_D, c_E) \geq c_D + c_E \quad \text{for given } c_D, c_E$$

The revenue schedules are fixed by assuming that if no investments are made, then no revenue can be expected, and that the gradient of the expected revenue function R_D is positive at the origin (A2). We will also make the standard assumption that the expected inside revenue function is strictly concave in investments (c_D, c_E).

(A2) $$E[R_D(0,0)] = 0,\ E[R_E(0,0)] = 0,$$

(A3) $$\frac{\partial E\left[R_D(c_D, c_E)\right]}{\partial c_i} > 0 \text{ for } i = D, E \text{ when } 0 < c_i < C_i;\ C_i > 0$$

$$\text{and } \frac{\partial^2 \mathrm{E}\left[\mathrm{R_D}(c_D, c_E)\right]}{\partial \mathrm{c_i}^2} < 0 \text{ for } i = \mathrm{D, E} .$$

Mutual dependence among the parties is reflected in the effects of investments on bargaining positions through E's outside option. The spillover assumption, A4, specifies that D's investment improves E's outside option, and E's investment improves D's bargaining position by reducing his own outside option:

(A4) $$\frac{\partial \mathrm{E}\left[\mathrm{R_E}(c_D, c_E)\right]}{\partial \mathrm{c_D}} > 0 , \quad \frac{\partial \mathrm{E}\left[\mathrm{R_E}(c_D, c_E)\right]}{\partial \mathrm{c_E}} < 0$$

The idea is that as D cooperates and communicates, valuable information leaks to E, who could take advantage of it in the external market. Similarly, E's cooperation effort leads to knowledge accumulation by D, which reduces D's dependence on E. As a consequence, investments by one party reduce the other party's dependence on him, represented by the outside option. Here, the outside option is defined as E's option, and it is assumed that "power cancels power" to keep the number of variables tractable: when E's position improves, his own outside option improves, and when D's position improves, E's outside option is reduced. Hence, for simplicity, both parties' investments have an effect on E's outside option. The presence of spillovers represents a departure from the Baker et al. model. Alternative assumptions concerning spillovers are discussed in section 4.

In the first-best world, which can be used as a benchmark, investments are chosen to maximize the expected total surplus:

(1) $$\max_{c_D, c_E} E(R_D) - c_D - c_E$$

In this case, the derivatives of the expected inside revenue with respect to c_D and c_E are set equal to one:

(2) $$\frac{\partial E(R_D)}{\partial c_D} = \frac{\partial E(R_D)}{\partial c_E} = 1$$

Assuming separable effects of c_D and c_E on R_D for now, the sufficient conditions for optimality are guaranteed by the concavity assumption.

Following Baker et al., there are four possible organizational arrangements: market (M), supply relationship (SR), employment relationship (ER), and spot employment (SE). In a market transaction, the price for the innovation depends on the bargaining powers of the parties. Compensation in a supply relationship is also driven by the bargaining powers, but there are two incentive instruments instead of just the price. The expert owns or controls the essential knowledge asset in these two arrangements. The incentive contract under the employment relationship is similar to that under a supply relationship, but now the downstream firm holds the contractual rights to the knowledge asset. This essentially transfers the right to control the knowledge asset (temporarily) to D.[2] Finally, under a spot employment arrangement, E works for D as a salaried employee with a short-term contract. The definitions of the long-term employment relationship and spot employment are rather extreme, but perhaps justified as an attempt to illustrate the fundamental differences among the organizational (or contractual) forms. The last sections of the paper discuss empirical equivalents of these contractual arrangements and their implications.

Market

In the market exchange, D and E maximize

$$\text{D: } \max_{c_D} \Pi_D^M = E(R_D) - p[E(R_D) - E(R_E)] - E(R_E) - c_D$$

[2] Baker et al. discuss "no compete clauses" between an employee and a firm that would transfer the control rights to the knowledge asset to the firm. Apart from a few states in the United States, we do observe employees agreeing to quarantine periods and other arrangements that significantly—and credibly—reduce their outside options. The employment relationship here could thus be interpreted as a long-term employment contract with opportunities for promotion and profit sharing as well as this kind of a credible commitment by the employee. Relatedly, Aghion and Tirole (1994) discuss the use of "trailer clauses" specifying that innovations made by the expert for some time period

(3)

$$\text{E: } \max_{c_E} \Pi_E^M = E(R_E) + p\left[E(R_D) - E(R_E)\right] - c_E$$

p denotes the sharing rule reflecting the bargaining powers of D and E. Here, D obtains the value of the good to be transacted R_D, and he has to compensate E for the outside value R_E. In addition, D and E split the gains from trade (difference between the two values). Usually *p* is assumed to be ½ following the Shapley (Nash) bargaining solution. We will follow this convention in what follows.

Now the first-order conditions (see equation 4 below) demonstrate a departure from social optimum. The sharing rule and the outside option divert cooperation decisions away from the first-best levels:

$$\frac{\partial E(R_D)}{\partial c_D} - \frac{\partial E(R_E)}{\partial c_D} = 2$$

(4)

$$\frac{\partial E(R_D)}{\partial c_E} + \frac{\partial E(R_E)}{\partial c_E} = 2$$

Under the assumption (A4) concerning involuntary knowledge spillovers, cooperation effort by D improves E's market position with respect to other potential partners, because D's strategies and technologies spill over to E during the relationship. Similarly, E's effort improves D's position because it obtains some of E's specialized knowledge. As a consequence, (4) implies that the stronger the unintended effects of c_D and c_E on R_E are (the steeper the gradients), the smaller the investments by D and E. This can be expressed more formally by parameterizing the spillover and using the theory of supermodularity. Let $R_E = R_E(c_D, c_E, t)$, where *t* is a parameter that represents the intensity of the

after the employment contract has terminated are owned by the employer. Also various kinds of exclusivity involuntary knowledge flow. Assume that R_E is supermodular in (c_D, t) and $(-c_E, t)$.[3] This specifies t as reinforcing the positive impact of c_D on R_E and the negative impact of c_E on R_E. c_D and c_E are assumed not to interact. Then the interaction effects on profits are the following:

specifications effectively limit the expert's ability to benefit from the knowledge asset.

[3] In the case of the twice differentiable functions here, supermodularity of R_E is equivalent to positive cross-partial derivatives of R_E with respect to c_D and t, and c_E and t, respectively (see Topkis 1998).

$$\frac{\partial^2 \Pi_D^M}{\partial c_D^M \partial t} = -\frac{1}{2}\frac{\partial^2 E(R_E)}{\partial c_D \partial t} < 0$$

(5)

$$\frac{\partial^2 \Pi_E^M}{\partial c_E^M \partial t} = \frac{1}{2}\frac{\partial^2 E(R_E)}{\partial c_E \partial t} < 0$$

Profit functions P_i are thus supermodular in (c_i, -t), where i = D,E. It follows that the optimal choices of c_i are decreasing in t (see Topkis, 1998). The more intensive the spillovers, the lower are the investments.

Spot employment

The spot employment contract is the following:

$$\max_{c_D} \Pi_D^{SE} = E(R_D) - c_D - s$$

(6)

$$\max_{c_E} \Pi_E^{SE} = s - c_E$$

Because (SE) is a short-term contract, D's promises of performance-related compensation are not credible and, therefore, E is compensated only with flat salary s. As a result, E has no incentives to invest in cooperation, and D gets all the revenue and has optimal investment incentives.

(7) $$\frac{\partial E(R_D)}{\partial c_D^{SE}} = 1$$
$$c_E^{SE} = 0$$

Concavity of E(R_D) suffices as the second-order condition in this case.

Implicit contracts

Both employment and supply relationships are implicit contracts. They entail separate compensation for the inside and outside trade and a flat *ex ante* salary. D and E maximize, respectively:

$$\max_{c_D} \Pi_D^I = (1-b)E(R_D) - \mathbf{b}\, E(R_E) - c_D - s$$

(8)

$$\max_{c_E} \Pi_E^I = s + bE(R_D) + \mathbf{b}\, E(R_E) - c_E$$

b is E's bonus for improving inside revenue, and $\mathbf{b}$ is the compensation for outside competition. s denotes the fixed salary payment. This incentive contract is another (slight) departure from the model by Baker et al. Here, the contract is assumed to be of the profit sharing kind instead of fixed payments associated with discrete outcomes.

Again, first-order conditions demonstrate the impact of the spillover externality whereby spillovers induce a departure from the social optimum:

$$(1-b)\frac{\partial \mathrm{E(R_D)}}{\partial \mathrm{c_D}} - \mathbf{b}\,\frac{\partial \mathrm{E(R_E)}}{\partial \mathrm{c_D}} = 1$$

(9)

$$b\frac{\partial \mathrm{E(R_D)}}{\partial \mathrm{c_E}} + \mathbf{b}\,\frac{\partial \mathrm{E(R_E)}}{\partial \mathrm{c_E}} = 1$$

With an implicit contract it is, in principle, possible to reach the first-best investment levels by choosing the compensation parameters in a specific way, provided that $\mathbf{b}$ is allowed to be negative.

Lemma 1 *With an implicit contract it is possible to attain first-best investment levels.*

Proof b and $\mathbf{b}$ can be solved from (2) and (9) yielding

$$b^{FB} = -\frac{\dfrac{\partial E(R_E)}{\partial c_D}}{\dfrac{\partial E(R_E)}{\partial c_E} - \dfrac{\partial E(R_E)}{\partial c_D}}$$

(10)

$$b^{FB} = \frac{1}{\dfrac{\partial E(R_E)}{\partial c_E} - \dfrac{\partial E(R_E)}{\partial c_D}}$$

The socially optimal b^{FB} and b^{FB} depend on the elasticity of R_E with respect to c_D and c_E. Under assumption (A4), b^{FB} is positive and b^{FB} negative. This contract elicits first-best levels of investment.

In the implicit contract with optimal parameters b^{FB} and b^{FB}, E is rewarded for increasing the inside revenue and punished for improving the outside option. D, in contrast, invests because he is rewarded for both higher R_D and higher R_E. Whether negative b has any empirical relevance is a different question. Even if the price p in the market case could be freely determined, first-best investments would still not be attained. Carrying out the above computation for the socially optimal p in the market case reveals that to attain the optimal investments would require that the partial derivative of R_E with respect to c_D must equal –1. This is never the case, since the partial is positive by assumption. The efficiency of implicit contracts follows from these observations:

Proposition 1 *The I contract can (a) replicate the M contract, and (b) improve on it (in the sense of shifting toward first-best actions).*

Proof When the effects of investment on the outside option are as assumed in (A4), (a) fix $b = b = p$; this will replicate the M contract. (b) Let b and b differ from one another, and decrease b. The cross-partials of profits with respect to communication efforts and b indicate that the optimal choices of c_D^I and c_E^I are decreasing in b:

(11)

$$\frac{\partial^2 \Pi_D^I}{\partial c_D^I \partial b} = -\frac{\partial E(R_O)}{\partial c_D^I} < 0$$

$$\frac{\partial^2 \Pi_E^I}{\partial c_E^I \partial b} = \frac{\partial E(R_O)}{\partial c_E^I} < 0$$

Thus, lower b will induce higher c_D and c_E. Adopting two separate incentive instruments and allowing b to decrease, in other words, reducing the spillover effects, will constitute a shift towards social optimum.

3 Sustainability of implicit contracts

Supply relationships

The (I) contract is sustainable if the expected payoffs from continued collaboration exceed the rewards from reneging in the current period. This comparison takes place after investments are made and stochastic revenues have been realized. We assume that reneging implies receiving the fallback payoff thereafter. In the supply relationship case, the fallback arrangement is market (M) exchange, which is the short-term contract with the expert controlling the critical knowledge asset. For D and E respectively, the individual rationality constraints are:

(12)

$$-bR_D - b\,R_E + \frac{1}{r}E(\Pi_D^{SR}) \geq \frac{1}{r}E(\Pi_D^M)$$
$$\Leftrightarrow E(\Pi_D^{SR}) - E(\Pi_D^M) \geq r\left(bR_D + b\,R_E\right)$$

(13)
$$bR_D + bR_E + \frac{1}{r}E(\Pi_E^{SR}) \geq \frac{1}{r}E(\Pi_E^M)$$
$$\Leftrightarrow r\left(bR_D + bR_E\right) \geq E(\Pi_E^M) - E(\Pi_E^{SR})$$

Here r is the discount interest rate. Immediately, we can see from the two rationality constraints that the *expected* surplus gain from an implicit contract

(14)
$$TS^{SR} - TS^M = E(\Pi_D^{SR}) + E(\Pi_E^{SR}) - E(\Pi_D^M) - E(\Pi_E^M)$$

can in principle be divided in a way that satisfies both parties if the total expected surplus from SR arrangement exceeds that expected from M arrangement. However, in the absence of renegotiation, to ensure the *actual* sustainability of the contract the above constraint must also apply for extreme realizations of R_D and R_E. Assume that R_D and R_E are realizations from a cumulative probability distribution $G(R_i; c_D, c_E)$ for i = D, E. Now c_D and c_E shift the marginal distributions in the sense of first-order stochastic dominance: $\frac{\partial}{\partial c_j} G_{cj}(R_i; c_D, c_E) \leq 0$ for j = D, E. The likelihood of extreme realizations increases with the variance of G thus making it more likely that the individual rationality constraint of either D or E breaks.

To express this familiar statistical property more formally for the case of R_D, define R_D^{max} and R_D^{min} as revenue realizations that just barely support the individual rationality constraints, holding R_E fixed at its expected value. R_D is normally distributed with mean m and variance s^2: $R_D \sim N(m, s^2)$

The probabilities of realizations larger than R_D^{max} or smaller than R_D^{min} are as follows:

(15)
$$\text{Prob}(R_D > R_D^{max}) = 1 - G(R_D^{max}; c_D, c_E)$$
$$\text{Prob}(R_D < R_D^{min}) = G(R_D^{min}; c_D, c_E)$$

As variance s^2 of R_D increases, the cumulative distribution G becomes flatter: Holding m constant, it is shown in the appendix that $\frac{\partial G(v)}{\partial s} > 0$ if $v < m$ (i.e., in the region below m) and that $\frac{\partial G(v)}{\partial s} < 0$ if $v > m$ (i.e., in the region above m). It follows that Prob($R_D > R_D^{max}$) and Prob($R_D < R_D^{min}$) increase with s. Similar analysis applies to the variance of R_E.

Finally, discount interest rate r specifies a region in which the relationship can be sustained. If the interest rate is "too low" or "too high," the implicit contract will break. The last subsection of this section explores numerically some parameter values that achieve this.

The sustainability of the SR contract thus depends on the gains from trade within the relationship, on the discount rate, and on the dispersion of the values that the inside and outside payoffs may take. The higher the probability that revenues higher than R^{max} or lower than R^{min} occur, the more likely the relationship is to break.

Proposition 2 *The smaller the expected gains from the relationship or the higher the variance of the payoff distributions, the more likely the implicit supply relationship is to break.*

Proof Follows directly from (12), (13) and the preceding discussion of variance of G. The normal distribution case is elaborated in the Appendix.

Proposition 1 demonstrated that it is useful to have two incentive instruments, because investment levels of both D and E are decreasing in b. Thus (M) is never socially optimal for the kind of transaction examined here. However, (M) can be individually optimal, if the discount interest rate r is very high or very low, or R_D or R_E have high variances.

Employment relationships

In the employment relationship, the incentive contract is the same as in the SR case, but the sustainability constraints are different. Now the fallback option is spot employment contract (SE). D can claim the contractual rights to use the asset by making E sign a "no compete clause" or in some other way contractually credibly commit to not utilizing his special asset to trade with D's rivals in case of breach. In essence, E has then temporarily transferred the rights to control the asset to D.

This ER contract will be honored if it is individually rational for D and E:

(16)
$$-bR_D - b\,R_E + \frac{1}{r}E(\Pi_D^{ER}) \geq \frac{1}{r}E(\Pi_D^{SE})$$
$$\Leftrightarrow E(\Pi_D^{ER}) - E(\Pi_D^{SE}) \geq r(bR_D + b\,R_E)$$

(17)
$$bR_D + b\,R_O + \frac{1}{r}E(\Pi_E^{ER}) \geq \frac{1}{r}E(\Pi_E^{SE})$$
$$\Leftrightarrow r(bR_D + b\,R_O) \geq -E(\Pi_E^{ER})$$

As before, the expected *ex post* profits under spot employment are zero for E. Knowing this, E has no incentives to invest.

Now we are in a position to compare the sustainability of ER and SR arrangements.

Proposition 3 *When investments have separable effects on* R_D,[4] *an employment relationship is a more robust arrangement than a supply relationship for small spillovers, while large spillovers make supply relationship a relatively more sustainable organization form.*

Proof Due to the same incentive schemes in SR and ER, expected total surpluses are equal in these two arrangements. (12) and (13) thus differ from (16) and (17), respectively, only by the fallback options. When $E(TS^M) > E(TS^{SE})$, there is less "slack" in the SR contract than

[4] The non-separable case is analyzed in proposition 4.

in the ER contract, making ER more robust to extreme realizations of stochastic revenues. This occurs when spillovers are not too large, as shown below.

Recall that $E(TS^M) = E(R_D^M) - c_D^M - c_E^M$ and $E(TS^{SE}) = E(R_D^{SE}) - c_D^{SE} = E(R_D^{SE}) - c_D^{FB}$ because E will not invest under SE, and then D is the residual claimant and will always invest optimally. To keep this in mind, let's denote $E(TS^{SE})$ $E(TS^{SE})^*$

To simplify, assume that R_D is separable in c_D and c_E: $R_D = R_{D(D)}(c_D) + R_{D(E)}(c_E)$. Moreover, $E[R_{D(D)}(0)] = 0$ and $E[R_{D(E)}(0)] = 0$ with positive gradients at the origin (cf. assumption A2). Then, $\exists \overline{c}_D < c_D^{FB}$ and $\exists \overline{c}_E < c_E^{FB}$ such that for $c_D < \overline{c}_D$ and $c_E < \overline{c}_E$, $E(TS^M) < E(TS^{SE})^*$ and for $c_D > \overline{c}_D$ and $c_E > \overline{c}_E$, $E(TS^M) > E(TS^{SE})$. To see this, recall that $E[R_{D(E)}(c_E^{FB})] - c_E^{FB} > 0$. Therefore, if both D and E invest optimally under the (M) contract: $c_D^M = c_D^{FB}$ and $c_E^M = c_E^{FB}$, then $E[R_{D(D)}(c_D^{FB})] + E[R_{D(E)}(c_E^{FB})] - c_D^{FB} - c_E^{FB} = E[TS^M] > E[TS^{SE}] = E[R_{D(D)}(c_D^{FB})] - c_D^{FB}$. On the other hand, $E[R_{D(D)}(0)] = 0$ and $E[R_{D(E)}(0)] = 0$ by assumption, therefore if neither D nor E invests: $c_D^M = 0$ and $c_E^M = 0$, then $0 = E[TS^M] < E[TS^{SE}]^*$. Thus for small investments, i.e., $c_D < \overline{c}_D$ and $c_E < \overline{c}_E$, $E[TS^M] < E[TS^{SE}]^*$ and for large investments, the opposite applies.

Let the parameter t, as defined previously, represent the exogenous appropriability environment. Profit functions of D and E are supermodular in $(c_D, -t)$ and $(c_E, -t)$, respectively. Then optimal choices of c_D and c_E are decreasing in t. It follows that for sufficiently large spillovers, $c_D < \overline{c}_D$ and $c_E < \overline{c}_E$, and consequently $E(TS^M) < E(TS^{SE})$. This creates more "slack" in (12) and (13) compared to (16) and (17): $E(TS^{SR})-E(TS^M) > E(TS^{ER})-E(TS^{SE})$ and thus SR is more robust than ER to extreme stochastic values for the payoffs. The opposite applies for sufficiently small spillovers.

This result has two interpretations. On the one hand, small spillovers may arise from low usefulness of spillover knowledge outside the relationship, or in other words, highly firm- or relationship-specific knowledge. If knowledge is highly specific, an employment relationship is a relatively more sustainable arrangement than a supply relationship. On the other hand, spillovers may be related to the broader technological regime of appropriability of the returns to innovation, including the possibilities to use patents and other intellectual property rights (IPR) (see Levin et al. 1987). If IPRs are efficient in protecting knowledge, then somewhat counter-intuitively, an employment relationship is a more robust organization form.

This outcome turns on the effects of investments on the fallback options. If spillovers are small, i.e., appropriability is high, M becomes a more feasible alternative reducing the sustainability of SR. For instance, when the variance of payoffs is high (say, risky technological environment) and intellectual property rights are strong, it may be difficult to sustain supply relationships, because market transactions offer a reasonable alternative. Thus in high appropriability environments one is likely to observe relatively more market and employment arrangements and fewer supply relationships. On the contrary, market transactions are disadvantaged under low appropriability, and there will be more supply relationships relative to employment relationships.

Complementarities between cooperation investments

This subsection studies the implications of cooperation that is mutually reinforcing. Reinforcing, in other words, complementary, investments imply that as partners know more about each other they can focus their efforts of collaboration to suit both parties' competencies and goals. As a result, cooperation becomes more productive over time. Then the more one participant invests, the more it pays off for the other to reciprocate. Proposition 4 examines optimal investments, and, in particular, the relative sustainability of ER and SR in the presence of mutually reinforcing cooperation.

Proposition 4 *Complementarity between cooperation investments (supermodularity of the inside payoff R_D with respect to c_D and c_E) expand the sustainability area for the employment arrangement compared to that for the supply relationship, making the employment relationship a relatively more robust organization form.*

Proof Assume that investments interact positively and thus R_D is not separable. Then R_D is supermodular in c_D and c_E, i.e., $\partial^2 E(R_D)/\partial c_D \partial c_E \geq 0$. For simplicity of exposition, assume that $\partial E(R_D)/\partial c_D = \partial E(R_D)/\partial c_E$ when $c_D = c_E$. Again denote $R_D(c_D,c_E) = R_{D/d}(c_D)+R_{D/E}(c_E)$ for the separable case. Define $c_D^M = c_E^M = \overline{c}$ as investment levels that make E(TS^{M}) = E(TS^{SE}) in the separable case:

(18) $$E[R_{D(D)}(\overline{c})]+E[R_{D(E)}(\overline{c})]-2\overline{c}=E[R_{D(D)}(c_D^{FB})]-c_D^{FB}.$$

However, under supermodularity of R_D (complementarity of c_D and c_E), by definition,

(19) $$R_D(\overline{c},\overline{c}) \geq R_D(\overline{c},0)+R_D(0,\overline{c})=R_{D(D)}(\overline{c})+R_{D(E)}(\overline{c}).$$

Now define $c_D^M = c_E^M = \overline{\overline{c}}$ such that $R_D(c_D^{FB},0)-c_D^{FB} = R_D(\overline{\overline{c}},\overline{\overline{c}})-2\overline{\overline{c}}$. Based on (18) and (19) above, $\overline{\overline{c}} < \overline{c}$. Hence, the breakpoint investments identified in Proposition 3, that is, investments above which E(TS^{SE}) < E(TS^{M}) and investments below which E(TS^{SE}) > E(TS^{M}), are lower under supermodularity than under separability. It follows that larger spillovers are required to make E(TS^{SE}) > E(TS^{M}) in the positive interaction case than in the separable investment case. Hence, positive interaction makes ER more sustainable relative to SR.

This result suggests that the ER contract becomes a relatively more robust organizational arrangement than the SR contract when cooperation investments are strongly complementary. This is because the positive interaction affects investments in market transactions but not in spot employment, and, hence, the sustainable range of outcomes is relatively larger under ER. In this scenario it can be productive for E to tie his hands by giving up control rights and commit to the ER arrangement, thus reducing his fallback alternative to spot employment.

Under mutually reinforcing investments, optimal investment levels are higher than in the separable investments case, other things being equal. However, it may be difficult to design incentives for agents to internalize this externality they impose on each others' investment choices. Without additional incentives, a decentralized solution to the problem thus may not yield optimal investments. This practical reason provides further justification for employment relationship arrangement when cooperation investments are mutually reinforcing: A "central planner" can better design incentives to take into account the externalities.

In addition to the sustainability of optimal long-term implicit contracts, there is yet another consideration when the downstream firm is choosing whether to offer the outside expert a supply or an employment contract. The firm and the expert will have to negotiate a price for exchanging the property rights to the asset, in other words, for the expert to accept the "no compete clause" or other contractual commitment stipulated in the employment contract. Then the choice between a supply relationship and an employment relationship is based on comparing the potential benefits of the better sustainability of the employment contract against the price of the commitment clause.

A numerical example

This subsection provides an example of how the model works with actual functional forms. We specify the following forms for revenue functions:

(20)
$$R_D = \sqrt{c_D} + \sqrt{c_E}$$
$$R_E = t\left(\sqrt{c_D} + a - \sqrt{c_E}\right)$$

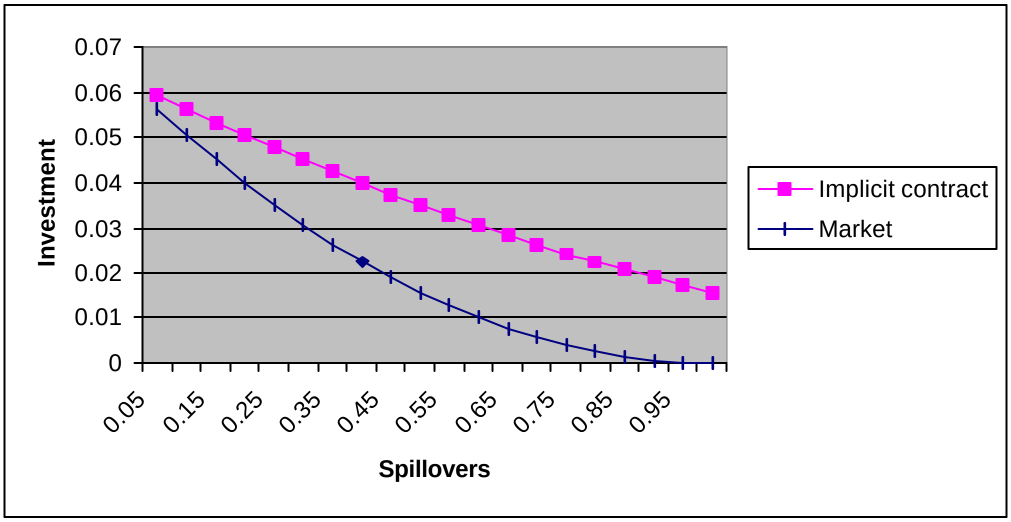
It is straightforward to verify that these functions are in line with the assumptions A1–A4. Here t represents spillovers. The specification above implies that as t grows, parties will benefit more from each others' investments. This, however, will reduce their incentives to invest, as we will see below. á is a constant that will ensure a positive but decreasing effect of c_E on R_E.

As for parameter values, we assume that p = ½ as before, and á = ¼, b = ½ and $\hat{a}$ = ¼. The latter two parameter values are aligned with the result that an implicit contract can replicate the market contract by setting $b = \hat{a}$ = ½ and improve on it by reducing $\hat{a}$.

Now we can demonstrate how investments, total surpluses, and sustainability of implicit contracts are affected by varying levels of spillovers. We let spillover parameter t vary between 0 (no spillovers) and 1 (full spillovers). Figure 1 plots the dependence of cooperation investments on spillover levels. In the current specification, optimal choice for c_D equals that for c_E in both implicit (employment and supply) and market contracts. Implicit contracts support higher investments for all spillover levels, but as spillovers increase, the gap between market contracts and implicit contracts grows. Spot employment, which does not depend on spillovers, supports investments by D at the level of 0.25. However, due to lack of credible commitments, E will not invest at all, and a total surplus of 0.25 is created.

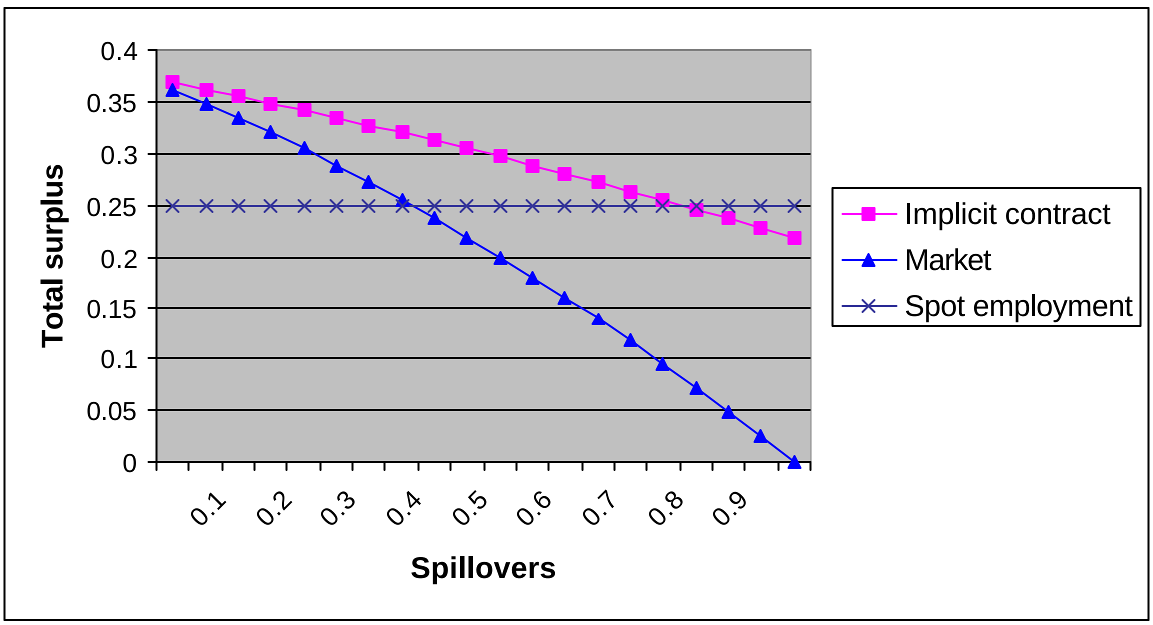
Figure 2 illustrates the impact of spillovers on total surpluses generated by market and implicit contracts. Total surpluses created by different arrangements, of course, fundamentally determine sustainability. When spillovers are low, the market arrangement is almost as efficient as implicit contracts. However, when spillovers increase, the surplus created by market contracts rapidly decreases. The surplus under spot employment is not affected by spillovers, however. In this specification, implicit contracts eventually become inferior to spot employment around t = 0.85.

Figure 1. Cooperation investments as functions of spillovers



Note: The graph depicts investments $c_D = c_E$ for market and implicit contracts. In the spot employment contract, only D will invest at the first-best level of $c_D = 0.25$, while $c_E = 0$. Under the ideal first-best outcome, $c_D = c_E = 0.25$.

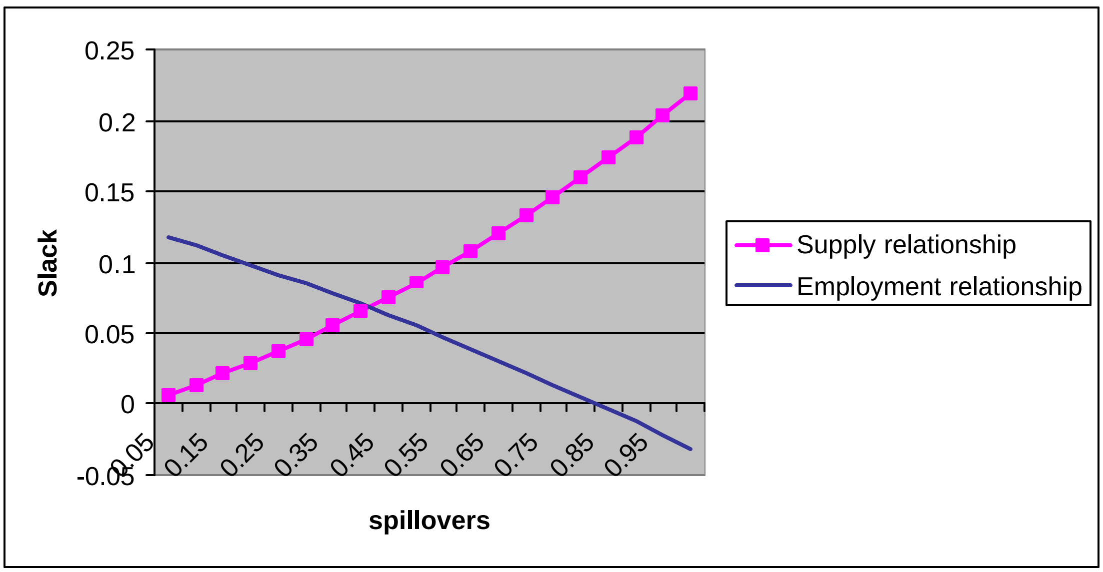
Figure 2 Total surpluses as functions of spillovers



Note: The first-best total surplus equals 1.

Sustainability measured as the difference between total surpluses created by an implicit contract and its fallback arrangement also depends on knowledge spillovers. Figure 3 demonstrates this relationship with the chosen functional forms. Because the market contract performs increasingly badly with high spillovers, the "slack" associated with supply relationships actually grows with spillovers. In contrast, because the fallback option of the employment relationship is spot employment, which is not affected by spillovers, the fact that surplus within the employment contract is reduced with higher spillovers means that slack in this arrangement grows thin and in this specification turns negative at about $t = 0.85$, as in figure 2. Thus, for very high spillovers, the employment relationship becomes unsustainable.

Figure 3 Sustainability of supply and employment relationships as functions of spillovers



Note: Slack for an employment contract equals $TS^{ER} - TS^{SE}$ and slack for a supply contract equals $TS^{SR} - TS^{M}$.

Finally, illustrating the sustainable discount rates requires fixing the level of E's fixed salary, *s*. In the supply relationship under certainty, individual rationality constraints of D and E, respectively, generate the following constraints if we keep parameter values as before and insert the formulas for profits:

(21) $$\begin{cases} r \le \dfrac{11}{64} - 4s \\ r \ge -\dfrac{3}{56} - \dfrac{32}{7}s \end{cases}$$

Assuming that $s = 0$, since with the chosen parameter values E is willing to participate even without fixed salary, the discount interest rate needs to be in the range of $0 \le r \le 11/64 \approx 0.17$ (excluding negative discount rates).

Fixed salaries play a slightly more complicated role in sustainability of firm contracts. The individual rationality constraints for D and E, respectively, become as follows:

(22) $$\begin{cases} r \le \dfrac{32}{7}(s^{SE} - s^{ER} - \dfrac{33}{256}) \\ r \ge \dfrac{32}{7}(s^{SE} - s^{ER} - \dfrac{47}{256}) \end{cases}$$

In this case, we assume that spot employment salary is slightly larger than that in the employment relationship: $s^{SE} = s^{ER} + 329/1792$, which yields a sustainable interest rate range of $0 \le r \le 1/4 \approx 0.25$. The relationship between the spot employment salary and the employment relationship salary is, of course, entirely arbitrary, this parameter choice merely fixes the lower end of the range at zero; the spread of the range remains 0.25 independent of the relationship between salary levels in the spot employment and the employment relationship contracts. While this exercise may be of little empirical relevance, it illustrates how the model works in practice.

4 Alternative assumptions on spillovers and outside options

If the inequalities in the assumption (A4) are reversed, i.e., cooperation efforts lead to internalization of partner's knowledge, and not to leakage of own knowledge, then it is possible that parties overinvest.

Under this new assumption (A4'), D's investment will reduce E's outside option, as he will adopt E's competencies and can, for instance, use them in cooperation with other suppliers. Similarly, E's investment increases his outside option, because the more he learns from D, the more time and effort he spends collaborating. Then the presence of an outside option, in fact, increases incentives to cooperate, and this can surpass the investment-reducing effect of the division of the surplus. The efficiency of implicit contracts SR and ER over spot (short-term) arrangements stems then from the possibility of separating b and b, and reducing b. In reality, investments are likely to work both ways: firms try to minimize spillovers and maximize learning and knowledge adoption, as suggested in the business literature (Hamel, Doz, and Prahalad 1989).

We could have modeled D's outside option separately from E's. Then, the assumption concerning spillovers would be that D's investment improves either E's or his own outside option, and similarly for E. In the first case (as under the original assumption A4), firms gradually learn from one another and build up their opponent's outside option. Investments will be suboptimal because each party will try to prevent his own knowledge from leaking, thus cooperating less than efficiently. Under the active knowledge adoption assumption (A4'), internalizing spillovers requires effort. In this scenario, first-best investment levels may follow, because the drawback from dividing the marginal surplus may be offset by the incentive to try to learn from the partner.

In both cases, the outside options will build up gradually, faster under (A4') than (A4), but eventually the setups lead to the unraveling of the relationship. If there is no generation of new knowledge in the relationship (and A1 is relaxed), sooner or later there will be no more useful things to learn from the partner, and the outside option becomes more appealing. As a result, the partners will split. This illuminates one possible reason behind the temporary nature of many technological alliances.

The dissolution of the alliance is often not a failure, but a built-in characteristic of the arrangement: when relevant knowledge exchange is completed, the parties go their separate ways.

5 Discussion

This paper asserts that some relevant aspects of innovation and technological cooperation can be analyzed with an incomplete contracting framework. The results lend support for Holmström and Milgrom's general argument about long-term implicit contracts being more conducive to cooperation than short-term (market) transactions. At the same time, the model yields some predictions that are at odds with the received transaction-cost-economic wisdom concerning the effects of knowledge spillovers on optimal organizational form. In our framework, large spillovers make supply relationships more sustainable than long-term employment contracts.

The framework by Baker, Gibbons, and Murphy (2002) does not posit “markets” and “hierarchies” as the extremes of a continuum of governance forms, with “hybrids” or long-term supply relationships as an intermediate solution, as is customary in transaction cost economics. Rather, behavior associated with supply relationships differs from that associated with long-term employment relationships because of different fallback options. These stem from the ownership of the critical knowledge asset.

Control of knowledge assets is at the heart of the definitions of organization forms in this setup. The employment relationship is the same as the supply relationship in terms of performance incentives, but, in the employment case, the downstream buyer holds the control rights to the essential knowledge assets (or output), while in the supply contract case, the upstream seller holds the rights. As a result, even relationships that are usually understood as employment contracts within a firm (long-term, open-ended employment contracts) can be supply contracts as defined here, if the control rights to the employee's essential skills are not or cannot be transferred to the employer.

Empirically, a key issue then is whether it is possible (or how costly it is) to enforce the control rights to the asset or even to the output of the joint project. This is a very real contracting problem particularly in knowledge- or skill-intensive business services, where the service consists essentially of knowledge transfer. For instance, it is not unusual that allocating property rights to the software created during an information technology outsourcing relationship leads to disputes at the end of the relationship, when the client wants to change suppliers. In contrast, in industrial design services, it is customary to agree *ex ante* that the designs produced during the collaboration process belong to the client firm.[5] It is more difficult, however, to expropriate the knowledge accumulated by the expert during the project or control the use of the expert's skills. This problem is often solved in engineering, management consulting, and other business services by writing a partial exclusivity contract where the consultants agree not to sell to rivals of the client firm for a specified time period. The service provider, then, partially yields the control over the use of its intellectual assets to the client.

Sometimes these knowledge provision relationships are more closely reminiscent of employment relationships than of supply relationships, even though the consultant is formally not employed by the client firm. An interesting case in point is a mid-sized engineering service firm in the field of shipbuilding[6] that voluntarily and strategically chooses not to apply for patents to appropriate the technologies developed during service relationships. A similar case is an R&D service provider in the food industry that switched away from a strategy of owning the intellectual property and licensing it to clients and

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[5] Based on interviews with four leading Finnish industrial design consultancies.

adopted a strategy of contract R&D, whereby it transfers all intellectual property rights to clients and receives compensation for hours worked on the project, as opposed to licensing revenue on technology. The reason, as argued by the CEO, was that under the first arrangement of strong intellectual property strategy, many clients were not willing to commit to a long-term relationship.[7] An interpretation of these situations based on the model here is that by enforcing strong property rights to its technologies, the service supplier imposes a supply relationship instead of an employment relationship. When spillovers between the parties are relatively low, which is likely the case here because the service providers operate with a very different knowledge base than their clients, market transactions are a feasible alternative, and the supply relationship may become difficult to sustain. The service providers may be better off not to adopt such aggressive intellectual property strategies and rely on more employment-like contracts, even though in the short-term they may not benefit fully from their intellectual property.

Incentives and property rights are thus specified as two separate dimensions of governance within the framework. Transaction cost economics, in contrast, argues that a more integrated governance has less intensive incentives and better protects knowledge from spillovers than hybrid forms of governance (see e.g. Oxley 1997). Additionally, transaction cost logic implies that internal organization involves more credible commitments and more intensive monitoring and administrative controls. In the model here, however, the two implicit contracts vary only by their fallback options, not incentives, i.e., administrative or monitoring technologies. A joint venture or any other kind of collaborative arrangement is assumed to be potentially monitored as effectively as a firm's internal department.

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[6] The names of these companies are not released for confidentiality reasons; more details about these case studies are available from the author.
[7] These anecdotes are based on interviews with the CTO and CEO of the two companies, respectively.

In this modeling approach the differences between the two forms of implicit contracts arise from the differences in their fallback options. This highlights that the most important drivers of long-term business relationships may not always be written in the contract itself, but stem from the alternatives available to the parties. An interesting research avenue within the economics of organization is to focus on the outside and fallback options as determinants of commitment in different types of governance structures, instead of studying incentive mechanisms within a given governance structure.

Fallback options reflect the agents' commitments to a long-term relationship. Williamson (1983) studied these in the transaction cost framework and showed that firms can deliberately manage commitments. In the present paper small spillovers (high appropriability of knowledge) decrease the commitment to a supply relationship since organization through market becomes more feasible. When spillovers are large, market organization is very inefficient, which supports implicit contracting. This accords well with the traditional transaction cost reasoning. In contrast, a move from a supply relationship to an employment one is not along the same "continuum" of governance forms. Employment and supply contracts have different outside options because of the differences in the ownership of critical assets. Thus, very large spillovers do not necessarily make long-term employment contract the most efficient. In fact, supply relationships are relatively more sustainable than long-term employment relationships under very large spillovers, because the fallback option of supply relationships, market transactions, becomes extremely unfeasible. This is not accounted for in the transaction cost framework.

6 Conclusion

This study has examined cooperative innovation activities that are often characterized by incomplete property rights in a repeated contracting framework. The main results from the model are as follows:

First, communication and cooperation investments are larger in implicit repeated contractual relationships, defined here as supply relationships or employment relationships, than they are in market-like, short-term transactions. The reason is related to Holmström's (1999) argument about access to complementary incentives in internal organization. One key benefit of implicit long-term contracts is the availability of additional incentive instruments, which makes it possible to better take into account the interactions between the compensations for multiple tasks, in this case, inside and outside options.

Second, high variances of revenue distributions, in other words, high likelihood of extreme realizations of inside and outside revenues, reduce the probability that implicit contracts are honored. This would also result from a high probability of such external shocks as changes in market conditions or technology. Even though implicit long-term contracts are always socially optimal, individual rationality may prevent them from being adopted and honored under these circumstances.

Third, large involuntary knowledge spillovers reduce the incentives to put effort into cooperation in innovative activities when cooperation causes knowledge leakage. Strong intellectual property rights (IPR), therefore, support investment in productive cooperation, as in the extant empirical literature. However, the organizational form of cooperation may also be affected by the IPR regime. If IPRs are strong in an environment with high variance of stochastic outcomes, the inefficient market arrangement may be "too" feasible. In this case, shifting to the employment relationship by transferring the property rights to the critical assets or output of the project to the downstream firm may make the implicit relationship more sustainable.

Finally, under positive interactions between the cooperation efforts, that is, mutually reinforcing (complementary) efforts, the employment relationship becomes relatively more robust (less vulnerable to extreme realizations of payoffs) compared to the supply relationship. The benefits of "internal organization" as represented by the employment relationship, according to this framework, are in enabling long-term mutually reinforcing cooperation and communication among organizational actors. Where this is important for innovative activities, the employment relationship is likely to be more efficient than the supply relationship. If the project goals are less long-term and, hence, the vulnerability of the relationship is less of an issue, a supply relationship offers an efficient alternative for innovative activities, particularly under high spillovers.

Policy conclusions from the model are not entirely straightforward. For instance, extending patent protection may make market transactions “too” feasible and shift contractual arrangements away from socially optimal implicit supply relationships. This reduces the incentives to cooperate. Policy-makers need to take into account the interactions between inside and outside payoffs by complementing the IPR protection policy with incentives to engage in long-term relationships, for example, by reducing their costs. Technological and institutional environments thus interact in their effects on firms’ organizational choices.

Appendix

Proof of proposition 2 for the normal distribution case

Revenue R_D is assumed normally distributed with mean m and variance s^2. The cumulative normal distribution function is thus:

$$G(v)=\int_{-\infty}^{v}\frac{1}{\sqrt{2\Pi}s}\exp\left[-\frac{1}{2}\left(\frac{x-m}{s}\right)^2\right]dx=\frac{-s}{\sqrt{2\Pi}(v-m)}\exp\left[-\frac{1}{2}\left(\frac{v-m}{s}\right)^2\right]$$

The effect of variance (or standard deviation) on the cumulative probabilities is:

$$\frac{\partial G(v)}{\partial s}=\frac{-1}{\sqrt{2\Pi}(v-m)}\exp\left[-\frac{1}{2}\left(\frac{v-m}{s}\right)^2\right]\left(1+\left(\frac{v-m}{s}\right)^2\right)$$

From the above equation it is seen that $\frac{\partial G(v)}{\partial s}>0$ if $v<m$ and $\frac{\partial G(v)}{\partial s}<0$ if $v>m$. In other words, higher variance shifts the cumulative distribution function up in the region below m and down in the region above m. Then, Prob($R_D > R_D^{max}$) = 1 - G(R_D^{max}) and Prob($R_D < R_D^{min}$) = G(R_D^{min}) increase with variance, since $R_D^{max} > m$ and $R_D^{min} < m$..

Bibliography

Aghion, P., and J. Tirole. 1994. "The Management of Innovation." *Quarterly Journal of Economics* 109 (4): 1185-1210.

Anand, B. N., and A. Galetovic. 2000. "Weak Property Rights and Holdup in R&D." *Journal of Economics & Management Strategy* 9 (4): 615-642.

Baker, G., R. Gibbons, and K. J. Murphy. 2002. "Relational Contracts and the Theory of the Firm." *Quarterly Journal of Economics* 117 (1): 39-84.

Cassiman, B., and R. Veugelers. 2000. "Complementarity in the Innovation Strategy: Internal R&D, Cooperation in R&D, and External Technology Acquisition." Universitat Pompeu Fabra Mimeo. Barcelona.

Cohen, W. M., and D. A. Levinthal. 1989. "Innovation and Learning: The Two Faces of R&D." *Economic Journal* 99 (Sept.): 569-596.

d'Aspremont, C., and A. Jacquemin. 1988. "Cooperative and Noncooperative R&D in Duopoly with Spillovers." *American Economic Review* 78 (5 (December),): 1133-1137.

Durlauf, S. N. 1992. "International Differences in Economic Fluctuations." Pp. 121-147 in *Technology and the Wealth of Nations*, edited by N. Rosenberg, R. Landau, and D. Mowery. Stanford CA: Stanford University Press.

Grossman, S. J., and O. D. Hart. 1986. "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." *Journal of Political Economy* 94 (4): 691-719.

Hagedoorn, J. 1993. "Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences." *Strategic Management Journal* 14: 371-385.

Halonen, M. 2002. "Reputation and the Allocation of Ownership." *Economic Journal* 112 (July): 539-558.

Hamel, G., Y. L. Doz, and C. K. Prahalad. 1989. "Collaborate with your Competitors - and Win." *Harvard Business Review* 67 (1): 133-139.

Hansmann, H. 1996. *The Ownership of Enterprise*. Cambridge: Harvard University Press.

Hart, O. 1995. *Firms, Contracts, and Financial Structure*. Oxford: Oxford University Press.

Hart, O., and J. Moore. 1990. "Property Rights and the Nature of the Firm." *Journal of Political Economy* 98 (6): 1119-1158.

Holmström, B. 1999. "The Firm as a Subeconomy." *Journal of Law, Economics and Organization* 15 (1): 74-102.

Holmström, B., and P. Milgrom. 1994. "The Firm as an Incentive System." *American Economic Review* 84 (4): 972-991.

Iansiti, M. 1995. "Technology integration: Managing technological evolution in a complex environment." *Research Policy* 24: 521-542.

Iansiti, M., and K. B. Clark. 1994. "Integration and Dynamic Capability: Evidence from Product Development in Automobiles and Mainframe Computers." *Industrial and Corporate Change* 3 (3): 557-605.

Johnson, B. 1992. "Institutional Learning." in *National Systems of Innovation -- Towards a Theory of Innovation and Interactive Learning*, edited by B.-Å. Lundvall. London: Pinter Publishers.

Jorde, T. M., and D. J. Teece (Eds.). 1992. *Antitrust, Innovation, and Competitiveness*: Oxford University Press.

Kaiser, U. 2000. "Research Cooperation and Research Expenditures with Endogenous Absorptive Capacity." Centre for European Economic Research Paper presented in the conference on supermodularity and innovation, UQAM, Montreal, June 2000. Mannheim.

Kamien, M. I., E. Muller, and I. Zang. 1992. "Research Joint Ventures and R&D Cartels." *American Economic Review* 82 (5): 1293-1306.

Kesteloot, K., and R. Veugelers. 1997. "R&D Cooperation between Asymmetric Partners." Pp. 97-125 in *Competition, Cooperation, Research and Development*, edited by J.A.P. Theotoky. London: Macmillan Press.

Landau, R., and N. Rosenberg. 1992. "Successful Commercialization in the Chemical Process Industries." Pp. 73-120 in *Technology and the Wealth of Nations,* edited by D.C. Mowery. Stanford, CA: Stanford University Press.

Leiponen, A. 2002. "Why Do Firms *Not* Collaborate? Competencies, R&D Collaboration, and Innovation under Different Technological Regimes." Pp. 253-277 in *Innovation and Firm Performance: Econometric Explorations of Survey Data*, edited by A. Kleinknecht and P. Mohnen. London: Palgrave.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity* (3): 783-820.

Mokyr, J. 1992. *Lever of Riches: Technological Creativity and Economic Progress*. Oxford: Oxford University Press.

Mowery, D. C., and N. Rosenberg. 1989. *Technology and the Pursuit of Economic Growth*. New York: Cambridge University Press.

North, D. C. 1990. *Institutions, Institutional Change, and Economic Performance*. New York: Cambridge University Press.

Oxley, J. E. 1997. "Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach." *Journal of Law, Economics, & Organization* 13 (2): 389-409.

Pagano, U., and M. A. Rossi. 2002. "Incomplete Contracts, Intellectual Property and Institutional Complementarities." p. Working paper no. 335. University of Siena.

Pisano, G. P., W. Shan, and D. J. Teece. 1988. "Joint ventures and collaboration in biotechnology industry." Pp. 183-222 in *International Collaborative Ventures in U.S. Manufacturing,* edited by D.C. Mowery. Cambridge: Ballinger Publishing Company.

Rothwell, R., C. Freeman, A. Horsley, V. T. P. Jervis, A. B. Robertson, and J. Townsend. 1974. "SAPPHO updated - Project SAPPHO phase II." *Research Policy* 3: 258-291.

Schumpeter, J. A. 1942. *Capitalism, Socialism and Democracy*. London: Unwin.

Senker, J. 1995. "Tacit Knowledge and Models of Innovation." *Industrial and Corporate Change* 4 (2): 425-447.

Shelanski, H. A., and P. G. Klein. 1995. "Empirical Research in Transaction Cost Economics: A Review and Assessment." *Journal of Law, Economics and Organization* 11 (2): 335-361.

Topkis, D. M. 1998. *Supermodularity and Complementarity*: Princeton University Press.

Williamson, O. 1983. "Credible Commitments: Using Hostages to Support Exchange." *American Economic Review* 73 ((September)): 519-540.

Williamson, O. E. 1985. *The Economic Institutions of Capitalism*. New York: Free Press.

Zucker, L. G., M. R. Darby, and J. Armstrong. 1994. "Intellectual Capital and the Firm: The Technology of Geographically Localized Knowledge Spillovers." NBER Working Paper #4946.