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R&D outsourcing and contractual governance: An empirical study of commercial R&D projects[1]

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Abstract

Three complementary models derived from transaction-cost economics and property rights theory are constructed to explore the boundary between internal and external R&D projects and the governance mechanisms of external R&D projects contracted out by private business firms. Whereas the boundary between external and internal projects is explained with sunk cost potentials, the uses of governance mechanisms for external projects in terms of control and property rights are explained with reference to both potential sunk costs, technical novelty in the R&D work, and expected resale value of the final R&D outputs. The models are empirically tested on 80 projects from the Norwegian information technology industry, half of which are contracted out to non-profit research institutes and half of which are made in-house by private manufacturing firms. The results support both the boundary hypotheses and three of four control-incentive hypotheses. The theoretical implications involved in choosing between internal and external R&D projects, and in designing control and property rights for external projects are discussed.

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1. Introduction

In this paper, the choices of boundary and governance mechanisms of R&D outsourcing are framed as cost-benefit trade-offs, and analyzed through the lenses of

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transaction cost economics (Williamson (1985, 1991)) and recent versions of property rights theory (Grossman and Hart, 1986, Hart (1990, 1991)). Since R&D outsourcing is vulnerable both to supplier opportunism and creativity degradation, our main concern is how *supplier opportunism may be curbed and creativity promoted by matching project attributes on the one hand with outsourcing decisions and governance mechanisms (administrative control and property rights) on the other.* According to transaction cost economics (TCE), the buyer's extended rights to control the supplier's production process are traded for lower financial risks and thereby weaker incentives for the seller as uncertainty and asset specificity keep building up. As the value of specific assets reaches upper levels, external contracting (outsourcing) is increasingly replaced by internal contracting or hierarchy (insourcing). In previous TCE studies, this kind of trade-offs between *intermediate* contract modes have been relatively neglected compared to trade-offs between the *extreme* forms of market and hierarchy. Although the transaction cost differentials between extreme forms are normally larger than between intermediate contract modes, similar trade-offs may be associated with each, the determinants of which are more closely examined in this paper.

The choice between insourcing (hierarchy mode) and outsourcing (market or hybrid mode) has long been considered important, both with respect to the supply of mature goods and services (Coase, 1937, Williamson, 1985) and to the supply of innovation (Arrow, 1962), although the former have lately been analyzed more extensively than the latter. In spite of an increasing amount of R&D outsourcing (Fusfeld and Haklisch, 1985), little empirical research has been done on what constitutes efficient governance mechanisms of R&D projects. This lack of research applies both to the choice between market, hybrid and hierarchy (one exception is Pisano, 1990) and to the design of more detailed control and incentive mechanisms (one exception is Tapon, 1989). More recently the choice of different types of contracting as a substitute for vertical integration is also being observed and analyzed, along with more detailed dimensionalization of the governance features of market, hierarchy and hybrid forms (Bradach and Eccles, 1989, Macneil, 1980, Stinchcombe, 1985, Williamson, 1991b).

Drawing on the above stream of research, this paper analyzes both the boundary and the governance of R&D outsourcing. We argue that important trade-offs have to be addressed both when choosing between internal and external R&D projects, and when choosing between control and incentive mechanisms for external R&D projects. Our purpose is to analyze how these trade-offs are affected by transaction cost factors such as technical novelty (outcome uncertainty), potential sunk costs and the value of client-specific final outputs (resale value).[2] Accordingly, the following two research questions will be asked: (1) How do transaction cost factors affect the choice between R&D outsourcing and insourcing, (2) When outsourcing is chosen, how can administrative controls be combined with higher-powered incentives so that transaction costs are

[2]Due to insufficient data, the effects of asset specificity in terms of accumulated firm-specific competence will not be examined. When analyzing the choice between outsourcing and insourcing, only the effects of potential sunk costs will be examined. Given outsourcing, however, the choice of different governance mechanisms (control and property rights) will be analyzed with reference both to uncertainty (technical novelty) and assets specificity (potential sunk costs, low resale value).

restricted without also restricting the supplier's creative efforts. The examined projects include both external projects that are contracted out to non-profit research institutes by for-profit business firms, and internal project carried out by the private firms' own employees. All our projects belong to the information technology field.[3]

2. Transaction cost economics on R&D

In R&D-intensive industries like the information technology industry, private manufacturing firms regularly contract out parts of their R&D work to universities and R&D companies in order to tap into advanced knowledge and technology. Although superior knowledge may thereby be accessed in a timely manner, additional transaction costs in terms of control losses, maladaptations and technology leakage may also be incurred.[4] For example, by contracting out major parts of R&D over a longer period to the same R&D supplier, valuable technology may not only leak out from the client to various competitors sharing the same supplier, but with such contracting the client may also have created and made himself dependent upon an external monopoly supplier with substantial control over his future R&D activities. To the degree the supplier himself has invested in client-specific know-how and equipment in order to customize his supplies, a bilateral rather than a unilateral dependency relation is created. In both cases, however, difficult contracting and hold-up problems may ensue. To avoid these, internal organization should be reserved for the major core projects, and outsourcing chosen only for complementary smaller-scale projects, including tapping into superior external knowledge and technology when necessary. In other words, R&D projects constitute this study's transactions for which governance structure should be designed with a view to minimizing transaction costs. As pointed out by Williamson, 1985 (p.1), a transaction occurs "when a good or service is transferred across a technologically separable interface," indicating here that one stage of activity terminates (e.g. R&D) and another begins (e.g. detail engineering and production). Transaction costs will arise in external R&D projects due to uncertainties and non-redeployable efforts, against which contractual safeguards should be designed such as stronger administrative control rights and more exclusive property rights. As argued below, however, these relationships are not strictly linear. Important trade-offs are implied both when choosing between alternative governance mechanisms for external projects and when choosing between external and internal projects (hybrid and hierarchy).

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[3]Information Technology (IT) is a rather composed and applied form of modern technology, made up of several more basic elements, mostly electronics and computer technology, for the purpose of measuring, transmitting, processing, and presenting information. Like in most other fields of technology, (i.e. biotechnology, see Pisano, 1990), R&D contracting in the IT field is shot through with transaction cost hazards both due to considerable degree of endogenous project uncertainty and significant amount of non-redeployable assets.

[4]While ex ante transaction costs of searching and negotiation, and ex post transaction costs of executing, enforcing and correcting are both important, the primary focus here will be on the latter. The ideal is not to avoid, but rather to economize on transaction costs by choosing the least costly from the set of available governance mechanisms for executing the contract.

Although particulars differ, most of the underlying sources of transaction costs of R&D projects are similar to those of mature goods and services (Williamson, 1991b, p.293), including bounded rationality combined with uncertainty, and opportunism combined with non-redeployable assets (such as R&D sunk costs, customized R&D output and co-specialized complementary assets). Important differences also exist such as technical uncertainty that is higher, the need for creative solutions that is stronger, and technology leakage that is more critical in the the supply of R&D than in the supply of mature goods and services. As a consequence, R&D-specific transaction problems will occur that need special considerations and contractual solutions, but these problems are not so special that they cannot be treated within the expandable framework of transaction cost economics, here also including recent versions of property rights theory.

To avoid transaction costs from escalating and technology leakage from obounding in external R&D projects, the client may secure himself stronger rights to control the supplier's R&D process *and* to exclude others from using the resultant R&D outputs, in exchange for carrying most of the financial risks. Under the most hierarchical of these contracts, external R&D suppliers may actually be turned into temporarily quasi-integrated units which the client may attempt to control almost as closely as his own R&D teams. But then another problem is created. Like vertical integration,quasi-integration may also suffer from disincentive effects when the client, rather than the supplier, is made residual claimant of the profit generated by the supplier's creative efforts. For example, when successful performance is strongly dependent on the supplier's creative effort, negative incentive effects of hierarchical contracts that transfer control over R&D process and output assets from supplier to client, may actually exceed the positive adaptability and cost saving effects of such contracts. If so, some off-setting mechanisms are clearly needed, such as transferring some of the property rights back to the supplier, while still controlling the process almost as carefully as before. But this solution too is not without problems due to the "impossibility of selective interventions" (Williamson, 1985). That is, intervening in matters that only concern fine-tuning and gap filling (where coordinated adaptation is superior) without also intervening in matters that concern creativity and innovativeness (where autonomous adaptation is superior), is difficult, making hierarchical governance less suitable for innovation. As a compromise, hybrid contracts could be chosen rather than purely hierarchical or non-hierarchical contracts.

Similar predictions can also be derived from agency theory (Harris and Raviv, 1978). According to agency theory, behavior-based contracts will be preferred to outcome-based contracts as the costs of measuring outcome and transferring risk to the agent (e.g. to a university-based research institute) exceed the costs of measuring agent behavior (Eisenhardt, 1989, p.61). Since both *outcome uncertainty* that increases financial risk, and *monitoring problems* that increase the cost of measuring behavior, characterize most R&D projects, hybrid contracts will often be more pertinent than the purely behavior-based or outcome-based contracts. Not only is intellectual activity (the core activity in most R&D projects) difficult to monitor and evaluate, but intensive monitoring and evaluation of intellectual activitity is also likely to elicit negative reactions from those being supervised. Additionally, early-phase outcomes of R&D projects are rather ambigious and often scantily reported. Progress and final outcome is therefore difficult to evaluate until later in the process when substantial amount of money is sunk into the project, and compelling demands for consecutive funding may be difficult to refuse (Northcraft and Wolf, 1984, Staw, 1976). R&D project management is therefore a rather difficult task, and hybrid contracts are probably a more useful tool than strictly outcome-based or behavior-based contracts. Combining the client's rights to control the supplier's R&D process with the supplier's property rights to the final R&D outputs is one such hybrid solution to be more closely examined in this paper.

We consider R&D contracts to be hierarchical to the degree that they provide the client with (i) extensive rights to control the supplier's R&D process and (ii) exclusive rights to control (own and use) the resultant output assets, usually as a compensation for bearing most of the risk. In accordance with our combined TCE and property rights approach, we expect that for-profit firms contract out R&D to the degree that extra transaction costs do not exceed extra benefits from such outsourcing. As asset specificity deepens and contractual hazard increases, the probability of this net benefit turning negative also increases. Net benefit may also turn negative due to uncontrolled leakage of valuable R&D information. The likelihood of outsourcing may decrease as a consequence of both. Given outsourcing, however, we argue below that the client's rights to control the research institute's R&D work and its subsequent output assets will depend upon the attributes of such work and assets. While TCE argues that the client's rights to control the supplier's R&D process will increase as sunk costs accumulate and technical novelty increases, property rights theory suggests that the client's rights to control the supplier's output assets will decrease as expected resale value and technical novelty increases, because of the accompanying disincentives among suppliers (research institutes).[5]

All our external R&D contracts will be treated as belonging to the hybrid form which is characterized by governance mechanisms that are similar to, but still distinctly different from unified hierarchies in terms of (1) incentive intensities that are stronger, (2) administrative controls that are weaker, (3) adaptations that are less coordinated, and (4) excuses for unsatisfactory results that are usually less tolerated in the hybrid than under the hierarchy mode (Williamson, 1991b; see Fig. 1).

First, *incentive intensity*, determined by price formats (cost-plus versus fixed price) and property rights (non-exclusive versus exclusive rights), is normally stronger in hybrid mode than in hierarchy mode, but weaker than in market mode. As already noted above, since the client normally pays by installments most of the supplier's expenses before the project is finished, he also carries most of the risk, thereby lowering the incentive intensity among suppliers. Should the client refuse to pay the final amount upon delivery of unsatisfactory results, the supplier risks losing only a small amount of money or an equally small amount of unpaid extra work to make the results more satisfactory to the customer. The supplier's reputation may also be at risk, but since R&D is uncertain and

[5]These hypotheses may also be traced back to the ideas of Coase (1960) and Demsetz (1967). The latter formulated his basic thesis as follows: "*Property rights develop to internalize externalities when the gains of internalization become larger than the cost of internalization. Increased internalization, in the main, results form changes in economic values, changes which stem from the development of new technology and the opening of new markets, changes to which old property rights are poorly attuned.*" Demsetz then argued that property rights in land will first emerge in areas where the most valueable animals were less mobile, corresponding to our customized R&D outputs of low resale value.

	Market	Hybrid	Hierarchy
1. Incentive intensity	Strong	Medium	Weak
2. Administrative control	Weak	Medium	Strong
3. Coordinated adaptation	Low	Medium	High
4. Excuse doctrine	Weak	Medium	Strong

Adapted from Williamson (1991b).

Fig. 1. Dimensions of generic governance forms.

failures therefore excusable, unsatisfactory results will, in general, not ruin the supplier's reputation unless severe malpractice is detected which hardly ever happens.

By installment payment, fixed price contracts are therefore transformed into something close to ordinary cost contracts. Even if the choice of price format still matters, the difference in risk bearing between a fixed price contract and cost-plus contract is probably too small to be of any significance for our purpose. By acquiring stronger property or licensing rights to the R&D outputs, the client may bring the supplier's incentive intensity down further, and the hybrid form even closer to the hierarchy mode.

Second, *administrative controls* (mechanisms for monitoring, evaluating and correcting the R&D process) are normally stronger in hybrid than in market mode, but still weaker than in hierarchy mode. By bearing most of the financial risk, the client will normally acquire stronger rights to control the supplier's R&D process in hybrid than in market mode. However, lacking the same degree of loyalty and informal support, the effectiveness of administrative control is normally weaker in hybrid mode than in hierarchy mode. The relations between formalized administrative control and project attributes in the hybrid case will be examined more closely below.

Third, due to lower-powered incentive and stronger control, *adaptations to changing opportunities* are likely to be more coordinated in hybrid than in market mode, but still be less coordinated than in hierarchy mode. At regular intervals the supplier reports to the client about current and expected results upon which the client can decide to redefine, continue or terminate the project. In hybrid mode such corrective actions (adaptations) will normally proceed in a relatively coordinated step-wise fashion, but due to conflicting incentives and weaker control abilities, the corrections will generally be less coordinated and more autonomous in hybrid than in hierarchy mode.

Fourth, due to relatively high level of endogenous project uncertainty arising from novel work and ex ante unspecified outputs, appeals to neoclassical *excuse doctrine*s are easier to justify for the most incompletely specified contracts such as R&D contracts than for the more completely specified ones such as standard construction contracts. This makes the legal difference between external and internal R&D projects somewhat less fundamental (Williamson, 1991b, p.273), and the need for integration due to endogenous project uncertainty less pressing. Claims for refunding or remaking the whole project are only warranted in cases of severe malpractice. Being very difficult to prove, cases of malpractice from R&D outsourcing are almost never brought to court. Within this kind of private contract framework, the client may rather autonomously terminate failing projects as well as extend the funding of more promising ones. The need for integration due to large amounts of non-redeployable assets, however, still matters.

3. Models and hypotheses

Three simple models derived from transaction cost economics (Williamson (1985, 1990)) and the closely related property rights approach (Grossman and Hart, 1986, Hart (1990, 1991)) will be constructed below to analyze the boundary and governance of R&D outsourcing. While model 1 predicts the choice between *hybrid form* (outsourcing) and *hierarchy* (insourcing/vertical integration), models 2 and 3 explain the use of *administrative control rights* and *property rights* in the hybrid case (i.e. the client's rights to control the supplier's R&D process and the resultant R&D outputs, respectively). We distinguish between vaguely and clearly defined rights to monitor and direct the supplier's R&D process (model 2), and also, between non-exclusive and exclusive rights for the client to own and use the supplier's R&D outputs (model 3). While property rights theory emphasizes efficient incentive alignment, transaction cost economics includes both incentive alignment and governance issues (Williamson, 1985, p.29, Williamson, 1991a).[6] Being the most inclusive of the two, TCE is chosen as base model.

First, input resources that are consumed are preliminary sunk (non-redeployable or non-transferrable) to the degree that preliminary results are either naturally hidden (tacit), deliberately concealed, or too specialized or unique to be finished by any other supplier (Northcraft and Wolf, 1984, Teece (1980, 1982), Williamson, 1985). The market for specialized research is very small (Mowery and Rosenberg, 1989, p.244), especially in small countries like Norway. Furthermore, government subsidies that in Norway are regularly awarded to private R&D projects contracted out to independent research institutes, act as a trade barrier, preventing these R&D projects from being transferred from domestic to foreign suppliers. If transferred, further payment of government subsidies will usually be stopped.

Thus, when the market for research is very small (monopolized) due to specialization and various trade barriers, most of the project inputs that are consumed and paid for, will be sunk into the supplier (non-redeployable) until finally made transferrable in the form of useful results (if successful). The higher the sunk costs, the more compelling the request for extra funding to complete promising projects. While realized sunk costs are less than total costs in most cases, but otherwise difficult to predict, total projected costs constitute the maximum *sunk cost potential* at the start of the project, against which farsighted clients should take contractual precautions (such as stronger rights to control the supplier's R&D process, or even insourcing as potential sunk costs become excessively large). As more potential sunk costs are added, the hybrid form will gradually

[6] One important difference concerns court ordering whose effectiveness is more heavily disputed by transaction cost economics than by the property rights approach. Another difference concerns opportunistic behavior. While property rights theory assume that high-powered incentives and opportunistic bargaining from market contracting are carried over into the firm, transaction cost economics assume that high-powered incentives are replaced with low-powered incentives, and opportunistic bargaining with administrative control, when separate units integrate. After integration, opportunistic inclinations may still persist, but are now more efficiently constricted than under any of the external contract modes.

be less suited to protect against opportunistic recontracting, and will therefore gradually be replaced by hierarchy or complete vertical integration. Thus, the following two hypotheses are formulated.

Hypothesis 1. Potential sunk costs in external R&D projects are positively related to the client's administrative control rights.

Hypothesis 2. Potential sunk costs in R&D projects are positively related to vertical integration (insourcing).

Contractual hazards are also raised in novel projects where the supplier has insufficient information about the time or resources needed to solve the client's problem. R&D projects can be characterized by uncertainties related to output specifications, performance and accomplishment (Stinchcombe, 1985), of which only the latter kind, determined by *technical novelty*, will be analyzed here. Technically novel projects need creative problem solving, but they may also cause unwanted delays and cost overruns (outcome uncertainty). While high-powered incentives are needed to stimulate creativity, hierarchical governance is needed to guard against delays and cost overruns. Since high-powered incentives cannot be fully retained under hierarchical control, a trade-off seems unavoidable.

In particular, hierarchical control that is helpful in preventing deviation from known courses toward prespecified outcomes, is not equally helpful in promoting the exploration of unknown courses toward innovative solutions. Although hierarchical contracts have the advantage of more coordinated adaptation, they also have the disadvantage of weaker incentives due to risk reduction and the impossibility of selective interventions (Williamson, 1985, p.135–138, Williamson, 1991a). By more frequent intervention and stronger control the client might actually "kill the goose that lays the golden egg" (Williamson, 1985, p.159). Extensive use of hierarchical governance may therefore have negative incentive effects, especially for novel and creativity-demanding projects. To counter this possibility, hybrid contracting can be chosen under which hierarchical control over technically novel R&D projects is supplemented with higher-powered incentives such as stronger property rights. In other words, by combining the client's rights to control the supplier's R&D process with the supplier's rights to control the future use of the resultant R&D outputs, the above disincentives may actually be corrected. Although this is not the only conceivable correction mechanism, it surely is one of the most pertinent. We do not exclude the possibility that dominant clients may claim and succeed in getting exclusive property rights also in the technically most novel projects. To the degree they succeed in getting such rights, however, this is likely to have negative incentive effects on the supplier's effort, and consequently should be avoided. Thus, the following two hypotheses may be postulated.

Hypothesis 3. Technical novelty in external R&D projects is positively related to the client's administrative control rights.

Hypothesis 4. Technical novelty in external R&D projects is negatively related to the client's property rights.

R&D projects often suffer from technology leakage especially under weak appropriability regimes (Arrow, 1962, Ouchi, 1988, Teece, 1987, Williamson, 1991a, p.292), and even more so when projects that are expected to generate high *resale value* are carried out by external suppliers. The problem here is that after the project has ended and outputs are delivered, the supplier can still earn extra income by selling modified copies of non-specific and highly-valued R&D outputs to the client's competitors without compensating the client for his future income loss. If all clients benefitted equally from this way of sharing R&D suppliers, nobody would suffer. Equal benefit, however, is unattainable. Some projects are client-specific in the sense that alternative buyers are missing, while others are non-specific, highly valued by external buyers, and consequently in need of stronger property rights. Although intellectual property law provides only weak judicial protection for information technology (Levin et al. 1987), exclusivity clauses acting as additional safeguards can be written into private contracts. That is, the expertise in research institutes that might be able to copy and resell non-specific R&D outputs, cannot freely exploit the weakness of property law after having signed a private contract in which they have explicitly committed themselves to refrain from such practice (Stinchcombe and Heimer, 1988, p.201). Even if chances of being caught may still be small and the efficacy of court ordering weak, one observed violation may be enough to destroy reputation and future business prospects for R&D suppliers that rely heavily on trust. When supported by ordinary contract law and market-based reputation, exclusivity clauses in R&D contracts will therefore operate preventively even under weak intellectual property law. Thus, while stronger rights to control the supplier's R&D process may protect the client against opportunistic recontracting in the development period, stronger property rights in the supplier's R&D assets in the commercialization period may enable the client to appropriate a larger share of the project's future income stream.

However, exclusivity clauses in R&D contracts are two-edged swords. They tend to weaken the research institute's performance incentives, and subsequently to reduce the total appropriable income from the project (equivalent to Grossman and Hart, 1986). By selling his property rights to the coming R&D outputs, and thereby refraining from doing future business based on these outputs, ex ante investment (creativity) disincentives may thereby be created, reducing output quality and subsequently the client's future income based on these results. While some moderation of these disincentive effects is possible by offering the supplier a higher price, complete elimination is hardly likely.

Besides, when expected resale value is large, the supplier has alternative buyers and therefore sufficient bargaining power to refuse restrictive property rights claims from demanding clients. When the project outputs are more client-specific and expected resale value is lower, the supplier's loss from selling his property rights is negligible in comparison, while the client may still gain from buying these rights. A market is therefore likely to appear where the R&D suppliers specialize in developing non-specific marketable assets partially owned by the suppliers, and client-specific outputs primarily owned or controlled by the clients. Retaining their property rights in resalable assets will not only affect investment incentives in a positive way, but will also contribute to the accumulation of valuable know-how and technology that subsequently will feed back to the clients as well as to their competitors in later projects. Although free-riders will

	Dependent variables		
	Client's administrative control rights ***(model 2)***	Client's property rights ***(model 3)***	Client's decision of vertical integration (insourcing) ***(model 1)***
Independent variables			
Technical novelty	+	-	?
Potential sunk costs	+	?	+
Expected resale value	?	-	?

Fig. 2. Summary of hypotheses.

benefit more from such spillover effects than most contributing clients, an increasing number of the most experienced and competent clients will also benefit in the longer run. Besides, the customers of these competing clients and free-riders may benefit even more, after which the practice of granting suppliers stronger property rights in their most resalable assets will be further sustained. In fact, this was exactly what happened in the computer industry after Intel and Microsoft initially retained their property rights in the IBM-PC microprocessor and operating system software, respectively. Similar transfer of property rights from a downstream system producer to upstream component suppliers now underlies the ongoing outsourcing trend found in most network industries such as the computer and communication industries (Garud and Kumaraswamy, 1993).

In other words, by bestowing stronger property rights upon external research institutes, the same institutes are more likely to develop, accumulate and dissipate common technology in their own self-interest, and thereby contribute to solving the externality problem that would otherwise have led private production firms to underinvest in R&D. As emphasized above, two prerequisites must be satisfied: First, violation of exclusivity clauses must be detected and verified. Second, some kind of negative reactions must follow. Although not every violation is detected, some will, after which both legal and reputational sanctions may ensue. If so, efficient distribution of property rights should depend on the attributes of the R&D assets in question. Thus, given at least a moderate degree of effectiveness of exclusivity clauses in private contracts, the following hypothesis may be stated (see also Fig. 2).

Hypothesis 5. Expected resale value of external R&D projects is negatively related to the client's property rights.

4. Research methods

4.1. Data

The models explaining outsourcing decision and contractual governance are tested on a subset of survey data from the Norwegian information technology industry. In the larger survey three major IT-research institutes, some private IT-consulting firms and several major IT-manufacturing firms were invited to participate. All the research institutes (n=3) and about half the private firms (n=24) decided to participate with various numbers of R&D projects. Upon request we received from the department managers in the participating institutes and firms a list of project managers who could serve as key informants. Questionnaires were then mailed to each project manager who answered and returned the completed questionnaires directly to us. After two reminders the data collection was ended, resulting in 222 completed questionnaires and a response rate of 67%.

Since our study includes only private manufacturing firms as clients (buyers or users), only a subset of the data (N_1=80) can be analyzed. Of this subset, 40 projects were carried out by external non-profit research institutes, and 40 by the clients' own employees. By relying on self-selection, relatively successful projects and firms are likely to be overrepresented. Due to this and similar selection biases, the sample should be considered a convenient sample without any strong claims of being representative for more than itself.

Information technology (IT) is distinguishable from more science-based technology along several transaction cost-relevant dimensions. First of all, its applied character and rapid development make the patenting of innovations a less effective safeguard against technology leakage compared to a more science-based and more slowly developing technology like biotechnology (Levin et al. 1987). This deficiency has not prevented a growing R&D market from developing, neither has it prevented inventors from patenting. Although patents seldom give efficient protection against technology leakage, patents can serve other important functions, such as documenting technological competence and facilitating cross-licensing and technology trade (Merges and Nelson, 1992). Besides, contract law can, to some extent, compensate for the weakness of patent law. In particular, exclusivity clauses that specify the intended distribution of property rights between individual buyers and sellers are regularly written into private contracts to avoid early technology leakage and costly ex post disputes.

Secondly, due to their applied and composite character, IT-based R&D projects will cover a wide range of activities, from scientific research to product development, testing and engineering, and a corresponding wide range of endogenous project uncertainties. While incompletely specified projects are likely to increase the possibility of deficient solutions, working on new and previously unresolved problems is likely to increase the possibility of cost overruns and unwanted delays. Contracts should therefore be provided with incentives and control mechanisms that prevent this kind of maladaptation.

4.2. *Measurement*

The study contained three independent variables (technical novelty, potential sunk costs, and expected resale value of R&D outputs):

Technical novelty was measured with two items representing the project's degree of technical newness and one variable capturing the R&D content of the project. Two of the items belonged to the following question: "Was (A) The main technical problems, and (B) The main technical solutions, new or well known to the engineers/researchers who worked on the project?" Each of these items were answered with a 4-point scale: (1) well known, (2) partly new, (3) quite new, (4) completely new. The R&D variable was measured with the following question: "Estimate the percentages of the engineers/ researchers' total working hours on the project that were spent on the following types of professional work: (A) Technical research, (B) Development of new technology, (C) Application of known technology, (D) Testing, and (E) Engineering." The percentages of A and B were summarized into an R&D newness variable. The three measurement variables were then standardized and summarized into a novelty index reflecting the degree of technical novelty of the R&D project.

Potential sunk costs were measured with the natural logarithm of total expected project costs (value added tax not included), estimated by the project manager. The logarithm of total costs was used to allow for the fact that some of the resources put into large projects are not sunk, but delivered as preliminary results that may be of some use to the client, or to alternative suppliers if they have to finish the project. The important variable, however, is not the exact amount of realized sunk costs, but rather the potential sunk costs which at the start of the project will appear as higher in high-cost projects than in low-cost projects, against which the clients should take contractual precautions.

Expected resale value was measured with a 5-point scale which evaluated the revenue from selling the project outputs in the market as larger or lesser than project costs. The question was framed as follows: "If you could freely choose, how large an income could you at the most get from selling current and expected project results to buyers in the market?" Estimates were given on a 6-point scale: (1) no revenue, (2) much less than current project costs, (3) somewhat less, (4) equal to, (5) somewhat larger, (6) much larger than current project costs. When multiplied by project costs, supplied with a constant and transformed to a logarithmic scale (to avoid outlier effects), the measurement variable becomes an indicator of net expected resale value, ranging from zero to large positive values.

Three dependent variables (administrative control rights, property rights and vertical integration) and two control variables (price contract and incompleteness) are included:

Client's administrative control rights were measured with six 3-point scales, indicating the use of clearly defined progress plans and routines for progress and cost control. The items belonged to the same question they we used for measuring the two control variables (incompleteness and price contract): "In the project documents, how clearly defined were the following points: .....(E) Requirements about the progress plan (deadlines, milestones, etc.), (F) Requirements about how to report according to progress plan, (G) Rules for monitoring and calculating costs, (H) Rules for additional funding in case of cost overruns, (I) Client's rights to audit project costs, (J) Client's rights to terminate the project." Each item was answered with a 3-point scale: (1) not defined, (2) vaguely defined, (3) clearly defined. An additive index was then created reflecting the client's administrative control rights or his rights to control the supplier's R&D process. By this operationalization, a more hierarchical contract is also defined to have more formalized (clearly defined) control procedures. Although we can think of hierarchical contracts with vaguely defined control procedures, such external contracts will not be considered truly hierarchical. Neither are the client's control rights considered to be strong if such rights are not explicitly written into the contract.

Client's property rights were measured with two 3-point scales, indicating the degree of exclusive ownership and user rights transferred by contract clauses. The following question was asked: "What kind of rights do the clients have on the results of the project, (A) Exclusive ownership rights (patent rights), (B) Exclusive user rights (license rights)," and answered with a 3-point scale: (1) Yes, (2) Partly, (3) No. Unfortunately, the question does not discriminate between contract clauses and patent rights as the legal basis for exclusivity. Unless explicitly stated in the contract, however, the client will not have exclusive rights on the results of the R&D project. To the degree the client has acquired such exclusive rights, as measured by our question, these must then be transferred by contract clauses. The two question items can therefore be summarized into one index measuring the client's exclusive property rights transferred by contract clauses and protected by contract law.

Vertical integration was measured with an indicator variable separating internal from external customers or clients. The wording was as follows: "By the term "client" we refer to the unit responsible for having given you this project and with the authority to terminate or change it. An internal client is a unit belonging to your employer (e.g. product manager, division manager, executive officer), and an external client is a customer or something similar. If both categories are involved, choose the one that has had the principal responsibility, from now on called the principal client." The project manager was then asked to indicate whether the principal client was an external or an internal client.

As discussed above, since the difference between fixed price and cost-plus contract is small in risk and incentive respect due to payments by installment, price contract is not included as dependent variable (governance mechanism), only as control variable. The reason for including price contract as a control variable is that a supplementary relation may exist between different governance mechanisms in the sense that using one may condition or affect the use of the other.

Price contract was measured with two questions. The first distinguished between contracts where the price was agreed upon in advance and those where the price should cover costs and be settled afterwards. The second question measured with a 3-point scale the degree of clearly defined financial limits for the project. The wording of the first question was as follows: "How did you decide the price that your client had to pay?" (A) The payment was decided upon before the work was started, (C) The payment should be decided later, and cover all costs, (D) The payment should be decided later, not exceeding a specific amount, (E) The payment should be price-adjusted according to inflation, (F) Net earnings should be adjusted according to the value of the results achieved, (G) Net earnings should amount to a certain percentage of total costs. Each alternative was answered with yes or no. Alternative A was chosen to represent fixed price contract. In the second question, the project manager was asked: "In the project documents, how clearly defined were the following points:..... (D) Total financial limit for the project," answered with a 3-point scale: (1) not defined, (2) vaguely defined, (3) clearly defined. Contracts where the price was clearly defined and agreed upon beforehand, were classified as fixed price contracts, and the remaining as flexible cost contracts.

The second control variable, *incompleteness*, was measured with four items reflecting the degree of incomplete specification of technical solutions and results. Two of the items were part of the following question: "Often projects have to be started before technical solutions and output requirements are completely clarified. As far as this project is concerned, how much would you say was clarified beforehand concerning (A) Technical solutions, and (B) Technical output requirements?" Each item was answered with a 5-point scale: (1) nothing clarified, (2) little clarified, (3) some clarified, (4) much clarified, (5) everything clarified. The remaining two items were part of the following question: "In the project documents, how clearly defined were the following points: (A) Requirements concerning specific technical results from the project, (B) Listing of concrete results to be delivered." Each of these was answered with a 3-point scale: (1) not defined, (2) vaguely defined, (3) clearly defined. The four items were reversed scaled, standardized and summarized into an incompleteness index.

The constructs and scales used are summarized in Table 1 which also reports the internal reliability coefficients (Cronbach's alpha).

4.3. Descriptive statistics

Descriptive statistics for the variables included are reported in Tables 2–4. The results from the reliability tests and correlation analysis indicate a reasonably high degree of

Table 1
Independent, dependent and control variables

	α	n	N
Technical novelty	0.61	4	80
Potential sunk costs	—	1	80
Expected market value	—	2	80
Vertical integration	—	1	80
Client's administrative control rights	0.74	6	40
Client's property rights	0.45	2	40
Price contract	—	2	40
Incompleteness	0.67	4	80

α: Cronbach's alpha, n: number of items, N: number of observations.

Table 2
Descriptive statistics

	Mean	S.D.	Min	Max	N
Independent variables					
Technical novelty	0.12	2.30	−3.40	5.03	80
Potential sunk costs	7.50	1.30	4.32	10.31	80
Expected resale value	9.75	1.13	0.00	10.13	80
Control variables					
Incompleteness	−0.20	2.91	−5.34	6.65	80
Fixed price contract	0.70	0.46	0.00	1.00	40
Dependent variables					
Vertical integration	1.49	0.50	1.00	2.00	80
Client's administrative control rights	14.45	2.95	7.00	18.00	40
Client's property rights	4.78	1.14	2.00	6.00	40

Mean=arithmetic average, S.D.=standard deviation, Min=minimum value, Max=maximum value.

Table 3
Correlations among independent variables and control variables

Variables	1	2	3	4	5
Technical novelty	1.00	—	—	—	—
Potential sunk costs	0.48 [a]	1.00	—	—	—
Expected resale value	−0.03	−0.29	1.00	—	—
Incompleteness	0.25 [b]	0.20 [c]	0.09	1.00	—
Fixed price contract	0.01	−0.09	−0.12	−0.16	1.00

Pearson's r, [a] $p<0.001$, [b] $p<0.01$, [c] $p<0.05$, 1-tailed t-test.
External and internal projects ($N=77$).

Table 4
Correlation among dependent variables and one control variable

Variables	1	2	3
Fixed price contract	1.00	—	—
Client's administrative control rights	0.29 [a]	1.00	—
Client's property rights	−0.08 [b]	−0.14 [b]	1.00

Pearson's r, [a] $p<0.001$, [b] $p<0.01$, [c] $p<0.05$, 1-tailed t-test.
External projects ($N=40$).

intramethod convergent and intramethod divergent validity. In particular, measurement items of the same variable are on the average more strongly correlated than items of different variables (not shown here). Only the intercorrelations between the final variable indexes are shown in Table 3 and Table 4. None of the independent nor dependent variables are particularly strongly correlated, suggesting a reasonably high degree of concept validity. Nevertheless, considerable method and measurement error may still be involved. With these reservations in mind, the subsequent results should be interpreted with caution, and considered as suggestive more than conclusive.

Relatively low intercorrelations between the dependent governance variables clearly show that these variables do not represent a simpler one-dimensional market-hierarchy structure. The positive correlation between fixed price contract and the client's administrative control rights indicates that fixed price contracts do not transfer contractual risk and control responsibility in the way ordinary fixed price contracts are supposed to do. If they had, the correlation between fixed price contract and the client's administrative control rights should have been negative. One possible explanation of this non-negative relation is the widespread use of installment payment (discussed above), that transfers substantial amount of risk from the supplier to the client even under most fixed price contracts. Common method error may also have contributed to this non-negative correlation.

5. Results

The study's hypotheses were tested using linear and logistic regression analysis for continuous and dichotomous dependent variables, respectively. Independent variables that are not explicitly hypothesized to affect the respective dependent variables are included as control variables along with the remaining dependent variables (the latter inclusion due to the possibility of supplementary interrelationships among several dependent governance variables). The results are presented in Tables 5 and 6. As shown, potential sunk costs (natural logarithm of total cost budget) are positively related both to the client's administrative control rights and to his decision of vertical integration (insourcing). That is, both our hypotheses about using administrative control rights and vertical integration to safeguard against the threat of opportunistic recontracting (prolongation and cost-escalation) in large projects with high potential sunk costs are empirically supported. As could be expected, the control variable "incompleteness" is negatively related to the client's administrative control rights, reflecting underlying inabilities or reluctances to specify not only final outputs, but also administrative control rights.

Technical novelty is negatively and significantly related to the client's property rights, but unrelated to his administrative control rights. That is, hypothesis 4 concerning the supplier's disincentives for granting the client exclusive property rights in technically novel projects, is significantly supported. Hypothesis 3, however, about granting the client stronger administrative rights in technically novel projects is not supported, perhaps due to negative incentive effects of hierarchical control over innovative work.

Table 5
Empirical results: Logistic regression analysis

	Vertical integration	
	(1)	(2)
Constant	22.063 [a]	48.527
	(33.118) [b]	(50.823)
Independent variable		
Potential sunk costs	0.620	1.212
	(0.234) [c]	(0.379) [c]
Control variables		
Incompleteness	−0.124	−0.554
	(0.091)	(0.176) [c]
Technical novelty	−0.088	0.006
	(0.119)	(0.165)
Expected resale value	−2.707	−5.294
	(3.356)	(5.153)
Fixed price contract	—	−1.577
	—	(0.692) [d]
Client's administrative control rights	—	−0.391
	—	(0.147) [c]
Client's property rights	—	0.136
	—	(0.248)
−2 Log-likelihood	99.019 [d]	66.317
Chi-square	11.835 [d]	34.211 [e]
N	80	73

[a]Logit-coefficients, [b]Standard errors of the coefficients, [c] $p<0.01$, [d] $p<0.05$, [e] $p<0.001$, 1-tailed significance test for the coefficients.

Table 6
Empirical results: Linear regression analysis

	Client's administrative control rights		Client's property rights	
	(1)	(2)	(1)	(2)
Independent variables				
Technical novelty	0.07	0.04	−0.42 [a]	−0.38 [b]
Potential sunk costs	0.47 [a]	0.53 [a]	−0.21	−0.32
Expected resale value	0.13	0.29 [b]	−0.22	−0.31 [b]
	—	—	—	—
Control variables				
Incompleteness	−0.57 [c]	−0.48 [a]	0.10	0.14
Client's administrative control rights	—	—	—	0.20
Client's property rights	0.17	—	—	—
Fixed price contract	0.34 [b]	—	−0.20	—
R^2	0.39	0.47	0.35	0.38
p(F)	0.001	0.001	0.004	0.010

[a] $p<0.01$, [b] $p<0.05$, [c] $p<0.001$, 1-tailed t-test on standardized regression coefficients; R^2 explained variance; p(F) significance test of the regression equation, $N=40$.

Finally, resale value of R&D outputs is negatively and significantly related to the client's property rights (after controlling for remaining supplementary governance mechanisms). This result supports hypothesis 5 concerning the research institutes' disincentives for granting the client exclusive property rights to R&D outputs with high expected resale value.

Besides the self-selection bias of the sampling procedure, the study's main weakness is that only one main method and a restricted number of items have been used in the measurement of what are rather complex concepts. Therefore, some caution should be taken when interpreting our empirical findings. Additional research is needed, preferably using multiple items, multiple methods and other empirical settings to provide more conclusive evidence.

6. Discussion and implications

Nevertheless, the results from our study do suggest some interesting implications for the different cost-benefit trade-offs involved in R&D outsourcing and in the governance of external R&D projects. First, our results suggest that net benefit of R&D outsourcing is negatively affected by potential sunk costs. The benefits of R&D outsourcing in terms of quicker access to more advanced technology can seldom be achieved without additional transaction costs. However, such costs can either be managed or avoided. As supported by our data, by strengthening his administrative control rights and switching to vertical integration as a last resort, the client can protect himself against the threat of costly recontracting of R&D projects with high sunk cost potentials.

Secondly, our results suggest that the net benefit of stronger control and property rights is affected by technical novely and expected resale value of R&D outputs. More specifically, by acquiring exclusive property rights, the client is attempting to appropriate a larger share of the future income stream from the R&D project. To the extent that exclusivity clauses are effective, however, they cannot be used without the added costs of diluted creativity incentives among suppliers ex ante and reduction in application value for the clients ex post. The larger the expected resale value of R&D outputs, the larger the disincentives among suppliers arising from the client's acquired property rights. Similarly, the more novel and creativity-demanding, and therefore incentive-demanding the work, the stronger the disincentives among suppliers arising from the client's exclusive property rights. Thus, the client's property rights to R&D outputs supplied by external research institutes should be employed in a rather discriminatory way, i.e. negatively related to expected resale value and technical novelty.[7]

Although the conditional use of formalized structures such as administrative control rights and property rights supports the idea that such structures have economizing effects, their exact effects still remain largely unresearched and therefore uncertain. Formalized structure may also have symbolic or legitimizing functions in addition to the purely economic ones. The significance of the latter compared to the former is likely to vary with such factors as the strength of intellectual property law, the value of non-redeployable assets, the degree of competitive pressure, and the number of potential buyers and sellers. Modelling and testing such functions and effects, however, must be relegated to subsequent studies.

7. Conclusions

This paper has presented an empirical study of contractual governance of R&D projects which lends support both to transaction cost economics and property rights theory (i.e. the process and incentive branch of the New Institutional Economics respectively). We have found that this combined approach may explain both the choice between hybrid contracting and hierarchy (outsourcing versus insourcing) and the finer calibration of governance instruments (control and property rights) that brings the hybrid contract gradually closer to the hierarchy mode. The hypothesis that potential sunk costs limit outsourcing was supported, and so were three of the four hypotheses linking control and property rights with project attributes.

Therefore, when substantial externalities are involved, like in the supply of R&D services, transaction cost economics should be combined with property rights theory to

[7] Our finding that potential large sunk costs motivate internalization of R&D, supports the vertical integration hypothesis in transaction cost economics. That only potential sunk costs, and not resale value (control variable in our model), motivates internalization of R&D, also corresponds well with Pisano's (1990) finding that the choice of internal projects was negatively related to the number of competing suppliers (i.e. low sunk cost potentials), but not positively related to the number of possible buyers (i.e. high resale value). Informed by our approach and results, this should no longer come as a surprise. Although a larger number of competing buyers makes technology leakages a more likely outcome (worsens the appropriability problem), and therefore vertical integration a more likely protection mechanism, valuable information and technology might under the contract mode also flow the other way, benefitting the client and reducing his net loss. Besides, a larger number of potential buyers will also provide the R&D supplier with investment incentives, alternatives, and bargaining power helping him to acquire stronger property rights and to further reduce his chances for a net technology loss. An even stronger demand for such a solution may arise among end users who are likely to benefit most from a more open and competitive upstream R&D market.

explain the use of governance mechanisms. Arguably, providing the client with stronger rights to control the supplier's R&D process and the subsequent R&D outputs, may have more than cost economizing effects as potential sunk costs increase (the standard transaction cost argument). Such features may also have negative incentive effects on creativity and resource allocation as the projects' creativity demands and expected resale value increase (according to property rights theory). In particular, while more extensive rights to control the supplier's R&D process through hierarchical (hybrid) contracting and vertical integration may protect the client against opportunistic demands for extra time and money to finish R&D projects with high potential sunk costs, more extensive rights to control the supplier's R&D output assets by means of exclusivity clauses, and more completely by acquisition, may enable the client to appropriate a greater share of the projects' income stream in the subsequent commercialization period. However, the latter benefits will only come at the costs of reduced effort and weakened creativity incentives among suppliers in the development period with subsequent reduction in quality and appropriable surplus for the client in the subsequent commercialization period. While several factors may cause such disincentive effects, the two focused in this study were technical novelty and expected resale value. Thus, by providing the supplier with stronger property rights to the most novel and highly valued marketable R&D projects, the chance of striking a favorable benefit-cost balance should increase.

Although the above disincentives might be attenuated by compensating the supplier more generously, complete elimination of creativity disincentives is rather unlikely. Hence, contractual governance structures that include both control rights and property rights may not only have transaction cost economizing effects, but also important creativity effects dependent upon the associated transaction attributes. Hopefully, our results should motivate further studies of how the choices between R&D outsourcing and insourcing, as well as between the underlying control and incentive mechanisms (control and property rights), may be influenced, not only by traditional transaction cost factors, but also by creativity considerations and expected resale value of R&D outputs.

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