M@n@gement

ISSN: 1286-4892

Alan O'Sullivan 2005

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M@n@gement, 8: 4, 123-143.

M@n@gement, Vol. 8, No. 4, 2005, 123-143
Special Issue: Interorganizational Alliances and Networks

Network-Based Organizing for Product Innovation: How Power Imbalances Matter

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Where many organizations have to work together to execute a highly-interdependent task over a period of several years what is the likely fundamental basis to effectively governing inter-firm exchanges? The existing literature strongly asserts stable and trusting relations as the answer. Drawing on an ethnographic study of one such network form, this paper disputes this view to argue that power imbalances provide a fundamental and probably unavoidable basis for this form of organizing. To the extent that trusting relations arise, the paper argues that these will be as a response to how power is configured and used in the network.

INTRODUCTION

The great up-surge in the use by firms of close inter-firm relations to further their commercial aims has been accompanied by an equally considerable increase in published research on this topic (for reviews see e.g. Gulati, Nohria, and Zaheer, 2000; Takeishi, 2001). A significant focus of this research has been to explain how inter-organizational collaboration between a firm and its network of suppliers should be governed, and a strong consensus has developed that stable and trusting relations between the firms involved is the proper governance choice (e.g. Jones, Hesterly, and Borgatti, 1997; Dyer, 1996; Helper, 1991; Helper, MacDuffie, and Sabel, 2000). Crucial to this consensus has been the perception that repeated exchanges between firms imply that transactions between the firms are not discrete, and their not being discrete brings into play social factors, thereby altering the character of the exchanges such as to broaden and lengthen the cost-benefit calculus of the parties and to make the relationship more mutually beneficial and its terms more implicit and trusting (Granovetter, 1985; Gulati and Singh, 1998; Uzzi, 1997). Trusting and stable relations, it is argued, are especially desirable in situations where in-depth engagement of a supplier is desired. Such a situation arises, for example, where suppliers are co-designing with the buyer i.e. have a significant design role – say, the design and provision of a product subsystem, rather than just components made to the specifications of the buyer.

The consensus that has gathered around the need for stable and trusting relations is mirrored by a similar consensus about power-based

relations between a buyer and suppliers. Such relations are consistently presented in the literature as adversarial, unstable, low value-added exchanges that result in inferior outcomes for all parties, as illustrated by the many studies of the US auto industry showing the negative outcomes associated with the exploitation by a powerful buyer of relatively weak suppliers (trust vs. power-based governance comparisons may be found in, for example, Dyer, 1996, and Liker, Sobek, Ward, and Cristiano, 1996).

This long-standing research interest in buyer-supplier networks notwithstanding, the actual interaction processes between a firm and its suppliers have rarely been studied directly (Brown and Eisenhardt 1995; Gulati and Singh, 1998; Takeishi, 2001; Gerwin, 2004). Close study of these interaction processes is worthwhile because recent evidence indicates that the tendency towards homogenously stable and trusting relations that the existing consensus presumes may not be supported in practice. For example, both Ahmadjian and Lincoln (2001) and Brusoni, Prencipe, and Pavitt (2001) indicate that over time firms will reverse decisions to outsource design work; not only does such a reversal terminate the relation (and any stability and trust associated with it) but the prospect of it may also tend to limit the extent to which the relation ever assumes a high level of stability and trust. Furthermore, both Herrigel (2004) and Whitford and Zeitlin (2004) point to systemic barriers within firms to fully developing cooperative relations with suppliers, further indicating that stable and trusting relations may be an improbable governance outcome in buyer-supplier relations.

This paper argues that power imbalances between the central-buyer firm and its suppliers can function to adapt, coordinate and safeguard intensive exchanges in buyer-supplier networks, contrary to the existing literature. The deliberate use by the central-buyer firm of its relative power to configure suppliers' resources, processes, and values for the shared project is the focus of this study, and that its efforts to do this will make adversarial relations even in the presence of high value-added exchanges a probable outcome is the study's central finding.

The study indicates that the notion, widely accepted in the literature, that a stable set of mutually-trusting firms is the answer to governance challenges in complex product co-development may be misplaced. Rather, intensive inter-organization relationships can be based on stable histories of suspicion: power-based relations can have productive outcomes, and these outcomes can co-exist with relations that are adversarial to a quite significant degree for an extended period of time. For organizations attempting to innovate together, the study explains how and why the content of information flowing between organizations in the network depends on certain structural characteristics of the network, and attaches particular significance to the structural centrality of the buyer in this regard. The implication is that stability and trust are not necessarily superior or even practicable network-governance choices, and that adversarial relations cannot be easily equated with either inferior or low-value-added outcomes. The paper proceeds as follows. The next section reviews what the current literature has to say about the basis for inter-organizational network governance, especial-

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ly as this relates to complex product development. I then introduce my research setting and method, which is followed by a results section. A final section discusses the significance of my results, examines various strategies aimed at counteracting rent-seeking activity within buyer-supplier co-design networks, and suggests how the study's findings might be further tested and extended.

CONCEPTUAL BACKGROUND

Most theorists studying inter-organizational cooperation have emphasized the impact of interdependency, that is organizations cooperating when they depend on each other or share assets (Pfeffer and Salancik, 1978; Williamson, 1999). When such interdependency occurs simultaneously between several organizations and over an extended period of time, the basic conditions exist for a network organizational form, which is further characterized by customized exchanges in a setting of uncertainty (e.g., Jones et al., 1997).

While the specific objectives of inter-firm networks vary, product development is an important strategic focus for many. This is especially true for firms engaged in the development of products that incorporate large-scale and diverse technologies and which take a long time to develop (e.g., jet aircraft, telecommunications systems, software systems) because these characteristics impose resource and competency requirements that strain even the largest firms (Kane and Esty 2000; Singh, 1997). Involving suppliers in such complex product-development efforts allows the central-buyer firm to spread the costs of development and access diverse competencies, and ultimately engage in more frequent and effective product development (Hagedoorn, 1995; Doz and Hamel, 1998).

But this complex technological work will also demand highly detailed and frequent coordination between the firms involved due to the need to customize interdependencies between the subsystems that each supplier is providing (e.g., Singh 1997; Kazanjian, Drazin and Glynn, 2000). These technological contingencies or non-separabilities (Alchian and Demsetz 1972) make ex-ante cost and technical specification uncertain because they are difficult to predict, understand, or articulate at the time of contract signing, and persist well into the development cycle (Williamson 1999). Observability is limited —making performance stubbornly difficult to measure— because of the very technical and differentiated nature of the work, such that each firm must necessarily be allowed autonomy to do its work and considerable time to complete each iteration of it.

These characteristics of exchanges imply that a buyer-supplier network directed at complex product development must typically confront two distinct coordination-related issues : autonomy-control issues, and information-sharing issues. Some have argued that these may be addressed simultaneously because the need for information sharing produces cooperative patterns through increasing the need for relationship-specific assets, and asset specificity is linked to increased col-

laboration (Williamson, 1999). Interdependency between buyer and suppliers will also be deepened by customization increasing the difficulty of switching suppliers once work has begun as incumbent suppliers will have unique and significantly tacit knowledge of the associated technical interdependencies (Ahmadjian and Lincoln, 2001; Kane and Esty, 2000). More generally, the existing literature on interfirm networks affirms that these coordination-related issues may be best overcome by governing exchanges through informal social systems, rather than by bureaucratic structures within firms or through formal contractual relationships. Such social mechanisms as trust, macroculture, or a reputation for fair dealing promote norms of flexibility, solidarity, and information exchange, and these norms in turn facilitate mutual adaptation to contingencies and joint problem-solving, both of which will be important given interdependence and uncertainty (Jones et al 1997; Uzzi, 1997). The development and maintenance of these mechanisms also depend on frequency of contact, and the anticipated duration of the relationship (Heide and Miner, 1992), implying a need for relationship stability. In this way, fears of opportunism and the consequent need to contractually specify actions and performance are both reduced, which in turn reduces transactions costs associated with the writing of, and time spent monitoring and enforcing, complex contracts. And because the parties value the relationship (deriving relational rents from it: Dyer and Singh, 1998), they will be more inclined to make investments tied to it, which will tend to increase the productivity of the relationship.

Thus, complex product development is just the sort of situation where the existing literature would lead us to expect stable and trusting relations between a buyer and its suppliers. There are almost continuous exchanges between buyer and suppliers over the several years of the project (and on-going exchanges afterwards), the suppliers have considerable responsibility for work that is difficult to monitor, they need to make considerable project-specific investments, and they cannot be easily replaced once the project is well under way.

But there are several problems associated with this emphasis on informal social systems as a basis for buyer-supplier network governance for complex product development. Firstly, there are set-up and maintenance costs associated with this governance choice: for example, the time and resources necessary to build up trust between the parties (Larson, 1992). Secondly, there are probable disbenefits due to inertia: for example, a reduction of novelty due to the tendency to stick with each other rather than rely on novel outsiders, or associated over-investment in asset specificity (Ahmadjian and Lincoln 2001; Uzzi 1997). And in some settings, hazards may be so severe as to make a reliance on trust untenable —for example, the early stages of exchange, or where the costs of poor performance could be very high.

More fundamentally, though, nowhere in the very considerable literature on the network form have trust and relationship stability as a basis for governance been seriously questioned. The work of power theorists such as Lukes (1974) should encourage us to think otherwise, and to explicitly and seriously analyze how power is configured and

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used in inter-organizational networks as an important basis to understanding how such networks function and what they are capable of. Power imbalances might be significant to the apparent stability and trust that researchers have observed in these networks. For example, such stability may be due to power-based conflict prevention by legitimation, and the power-based production of acquiescence and amity of relationships (Lukes, 1974). Thus, in the existing buyer-supplier network literature the typical empirical subject is an automobile-industry network centred on a large buyer (e.g., Toyota). Such buyers must surely possess enormous power in the network as indicated by, say, the network in which Toyota is the large central buyer being known simply as the "Toyota Production System" (e.g., Liker et al., 1996). How do they use this power?

The existence of power imbalances in buyer-supplier networks seems obvious: for example, there are usually size differences that favour the central buyer as well as size differences between suppliers themselves, buyer and suppliers will have different areas of expertise, buyer and supplier may face different switching costs etc. All of these features are conceivable bases for power differences. Yet if power imbalances in buyer-supplier networks have not been ignored by existing research in favour of an emphasis on trust, they have been viewed as very negative (e.g., Helper 1991) or at best moderately negative (e.g., Mudambi and Helper, 1998); alternatively they have been regarded as so incompatible with sustained inter-firm coordination that a firm must absorb the tie and revert to hierarchical organizing (Williamson, 1975).

Helper's (1991) study of the US auto industry is one of the few buyer-supplier network studies that explicitly considers power asymmetry. However, it is a view of power imbalances solely as a basis of exploitation and as unmixedly dysfunctional, and seems heavily influenced by work in the tradition of the economics of industrial organization (e.g., Porter, 1980). Such work essentially reduces inter-firm exchanges to a zero-sum and dyadic exercise of relative bargaining power. Indeed, this view of organizational networks as essentially an agglomeration of dyads around the central firm is also characteristic of the wider literature on buyer-supplier networks (e.g., Gulati, 1998; Zajac and Olsen, 1993). Even though some of this work does emphasize the centrality of the buyer by identifying various roles for the buyer, such as rule setting and supplier selection and sanctioning (e.g., Ahmadjian and Lincoln, 2001; Lorenzoni and Baden-Fuller, 1995; Lorenzoni and Lipparini, 1999), it only weakly conceptualizes how the central buyer uses its power to orchestrate simultaneous multi-partite exchanges within the network. Such multi-partite exchanges are crucial to the quality of coordination that would need to be mobilized in the case of highly interdependent work. It seems a heroic assumption that such exchanges would not need to be deliberately orchestrated by some central and powerful agency.

The well-established literature on organizational capability suggests a framework for characterizing the role of a central and powerful buyer in a buyer-supplier network. Resource and capability constraints of innovation are the fundamental reasons why many buyer-supplier net-

works are formed, and buyer-supplier network performance can be conceived in terms of three classes of factors: resources, processes, and values (or, RPV; see e.g., Bower, 1970; Christensen, 2000; Conner, 1991). The RPV framework has been used, for example, to explain barriers to innovation both in mature organizations (e.g., Dougherty and Hardy, 1996) and once-highly successful firms (e.g., Christensen, 2000). These authors show that power resides in the control of resources, processes, and meaning and that how this control is configured in an organization determines whether and which innovation projects get proposed, whether resources flow to a given project, and whether innovation activity is continually sustained.

The framework's potential for understanding how a buyer-supplier network functions has, however, been overlooked. In this paper I apply this RPV framework to examine the central-buyer's role in ensuring suppliers' resources are continuously available to the project, in providing structures and processes so that suppliers solve problems creatively and integratively, and in having project objectives incorporated meaningfully into suppliers' work.

SETTING AND METHOD

This paper reports on a buyer-supplier network engaged in the development of a new commercial jet aircraft, the central-buyer firm in which I will call AeroCo. Jet aircraft incorporate a very diverse range of complex technologies, and their operational performance depends on customizing the integrated functioning of many subsystems which are themselves complex. For AeroCo's products, most of these subsystems are designed and manufactured by independent suppliers. Most of the project personnel were development engineers, but manufacturing engineers, procurement specialists, project-planning specialists, and marketing and financial analysts were also involved. For the project reported on here, only 4 (of close to 20) suppliers had had prior experience of 2 or more AeroCo projects, and 6 had had no prior relationship at all with AeroCo. Once selected, though, the relationship with a supplier endured for the several-year duration of the development period, the many years after that of on-going manufacturing and assembly, and for service requirements over the total life-cycle of the aircraft (stretching to 30 years or more). This project was AeroCo's fifth multi-supplier collaborative new product development project. Only the airframe and engine were entirely new designs, with other subsystems being evolutions or adaptations of existing designs.

Data collection covered a period of about 15 months, of which three were prior to Phase 1 of the project, and twelve in Phases 1 and 2 of the six-phase development process. The end of the period of my data collection roughly corresponded with the end of Phase 2; the project lasted about 3.5 years in total. While practical considerations made it impossible to study the project through to its end, reliance on data from just these two phases is justified because these first

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two phases were when suppliers committed to the most significant design choices for their subsystems and these choices were estimated by them to determine 80% of aircraft production costs. The dynamics around these choices were therefore highly significant to project outcomes and the interests of all concerned.

Seventy-eight semi-structured interviews (29 with supplier representatives) were conducted, over 160 meetings attended, and a considerable quantity of technical and administrative documentation reviewed. While most of the AeroCo and many of the supplier personnel who formed the subjects for this data collection had prior co-development experience, in order to better access issues later in the development process and to sharpen research questions, I also attended meetings for, and interviewed AeroCo personnel working on, an earlier project that was at the time entering Phase 5 (of 6) of its development.

About two-thirds of the interviews were conducted in Phase 2. The questions that guided these interviews were an outcome of prior iteration between data analysis and collection (some interviewing, a great deal of observation at meetings). The interviews ranged from 40 minutes to 3 hours (average 1.5 hours) and transcripts of these averaged 3,700 words (typed); the meetings I attended ranged from about 1 hour to 8 hours (average 2 hours), and the transcripts of these averaged 3,000 words (longhand). I interviewed at least one representative from almost every supplier, but from most suppliers I interviewed both the lead on-site engineer and the project manager. From AeroCo, I interviewed every “integrator” (a supplier-liaison role) and representatives of every function assigned to the project.

DATA ANALYSIS

Quite early in my data collection I had been struck by the pre-occupation among AeroCo personnel with directing the on-going evolution of the design. This pre-occupation was hardly surprising: the complex nature of the product and the distributed nature of the work made it difficult to anticipate design contingencies and to keep on top of the work of all of the various supplier teams. But an omission or flaw in one subsystem design could, if not caught early, propagate sufficiently to fatally undermine schedule and cost objectives, and ultimately even product performance. My observation of this pre-occupation caused me to question my initial presumptions about collaboration being trust-based and to focus on how AeroCo controlled the evolution of the design work. Contracts are typically limited in their ability to anticipate the contingencies of complex and interdependent work and yet, as I became more acquainted with suppliers’ views, I was left with the very strong impression of the extent to which they experienced their work as being controlled by AeroCo.

My first task was to reduce the data to a briefer, more manageable form. I made detailed literal abstracts of each interview transcript. These abstracts, 35-40% as long as the originals, included broad headings to summarize every topic discussed, so I could easily see what material

each interview covered. Using grounded-theory-building techniques (Strauss and Corbin, 1990) I then developed a scheme of codes, to tag themes and statements of interest in the margins of the condensed transcripts. Power imbalances emerged as my core category for organizing the data. Further analysis revealed structural centrality with respect to resources, processes, and values as dimensions of these power imbalances: how AeroCo controlled the resources suppliers made available to the project, the processes by which these resources were applied, and the meanings suppliers attached to project actions, problems, and outcomes. The stark contrast with the existing literature's emphasis on trust made AeroCo's use of its relative power to configure network resources, processes, and values the study's central finding.

RESULTS

In this section, I describe how resources, process, and values were configured in the AeroCo network. The purpose is to demonstrate how AeroCo managed supplier autonomy and information sharing in the interests of project objectives.

RESOURCES

AeroCo determined the basic product concept and devised an initial definition of the aircraft through a benchmarking comparison of existing AeroCo and competing product designs. Next, design work was decomposed into large subsystems (electrical, engine, avionics, etc.) for each of which a supplier was selected by AeroCo. Each supplier designated a team composed of its own personnel to work on the subsystem it had contracted to design and manufacture, and assigned some of this team to be on-site at AeroCo (typically a project manager, a lead engineer, and one or more designers). In total, about 300 AeroCo and supplier personnel were co-located for this period with many more supplier personnel working on the project off-site than on-site.

While AeroCo brought considerable resources of its own to bear on the project —including fundamental expertise in flight sciences, integrated testing, assembly, marketing, and procurement— project success depended to a very significant degree on the application of suppliers' resources: close to 90% of the project's bill of material was outsourced by AeroCo, including a great deal of the design work associated with this bill of material. AeroCo does not retain large in-house design staffs duplicating those of suppliers.

I identified three distinct, though mutually reinforcing, means by which AeroCo compelled the application of supplier resources to the project: contracts, access to the aircraft-design regulatory authority, and final-market position.

THE CONTRACT

Suppliers contracted separately with AeroCo, but AeroCo contracted with each according to a broadly similar contract template that it com-

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posed. The specific details of both this template and of each supplier's contract were closely guarded by AeroCo and each supplier. AeroCo, therefore, was more practiced in the composition and interpretation of the contract and more knowledgeable with respect to the contracts as a whole than any given supplier. AeroCo placed a lot of emphasis on its contracts with suppliers, as the following quote suggests:

«The contract is worth the paper it's written on. I'd love to see one of our competitor's contracts! There's a lot of strong wording, remedies. [Pointed to a thick document: the contract boilerplate.] But we don't want to take anyone to court: at the end of the day the intent is to get the parts on time so we can fabricate and sell. The intent is not to sue but to make him respect his agreement. A court of law will never get us the parts and it could hurt us… [AeroCo] has good contracts, well thought out. It's not long since I signed the contract, so maybe my views are skewed. There are still teeth marks on my neck. Everything is squeezed so tight that no-one can just pick it up if something falls through the cracks… weight, electrical consumption —AeroCo will have problems optimizing. As soon as you reach the spec weight, people have no desire to go further. It will only cost us —not a lot, but… if procurement hadn't beaten suppliers' costs down, there wouldn't be a program.» (AeroCo/supplier composite[1]).

This quote indicates both the power and limitations of AeroCo's contracts with suppliers: these were complex documents that set demanding standards for suppliers —but also discouraged suppliers from exceeding these standards or being otherwise adaptable. The tough bargaining by AeroCo provoked inflexibility on the part of suppliers when faced with an unanticipated design contingency, and a readiness to claim that such design work was beyond the scope of the contract. Because of the highly evolutionary nature of design work in Phases 1 and 2, the timely and cumulative resolution of design contingencies would be crucial to project success. But their resolution raised issues of interpretation of the contract and neither AeroCo nor the suppliers wanted to take such issues to their ultimate venue for resolution i.e. a court of law. AeroCo needed additional means to compel commitment of suppliers' resources: these were AeroCo's access to the regulatory authority, and AeroCo's final-market position.

1. "Composite" denotes a quotation constructed from the words of more than one individual. Only complete thoughts have been combined, with ellipsis indicating a change of informant.

ACCESS TO THE REGULATORY AUTHORITY

The need for high reliability in the operation of jet aircraft has given rise to a considerable regulatory framework surrounding their development. State-sponsored design authorities must certify that every commercial aircraft is airworthy in its design before the aircraft can enter service, and set stringent regulatory standards that govern their design, manufacture, operation, and maintenance.

AeroCo made it a contractual requirement that each supplier was responsible for all design work and changes necessary to secure regulatory approval for the supplier's subsystem. And it was a design reality that meeting certification standards for one subsystem at least partly depended on how standards were met in the design of another interacting subsystem. This means that certification requirements were difficult

to anticipate and contingencies due to these significantly drove design evolutions.

Only airframers (i.e. the aircraft manufacturers, such as AeroCo) deal directly with the regulator: the regulator will not deal directly with suppliers. Moreover, given the breadth and depth of technical knowledge involved, and the iterative interaction necessary between designers and those guiding certification compliance, monitoring designers' attention to certification issues requires considerable manpower. This has led the regulatory authorities to delegate a considerable amount of the compliance work to the airframer. That is, selected AeroCo personnel, after a period of training and probation, become representatives of the regulator, with authority to review on-going design work and compel design changes on behalf of the regulator in anticipation of the regulator's actual review of the work. Each subsystem, as well as various of the AeroCo technical disciplines, is assigned a regulator representative. This asymmetrical access by AeroCo meant that AeroCo was essentially the conduit for the regulatory decision-making that compelled design changes, as emphasized by this supplier:

«The problem is that if you disagree with the [regulator representative], he is the one who gets to decide overall. He defends it in front of the certification authorities. If he says it's unacceptable, you can't argue —he won't certify it, and we don't see the certification authorities… Certification is the main thing that causes us to change our system in ways we had not expected. It's a way of [AeroCo] keeping a hand over us. Changing that would mean less control for [AeroCo]...» (Supplier).

That is, certifiability is a basis for AeroCo's insisting on its particular interpretation of a design issue, and compelling action based on this: suppliers do not get to defend their view of certifiability before the regulatory authority, and disagreeing with the regulator representative counts for nothing.

FINAL MARKET POSITION

AeroCo also acted as the conduit for market information to suppliers - not just in terms of identifying an aircraft at the right price point and mission capabilities, but also in giving detailed feedback on the evolving design from its own pilot personnel and market focus groups. Suppliers' designs therefore also needed to be continually adapted in order to assure the ultimate marketability of the aircraft.

AeroCo's increased frequency of product launches (through co-development with suppliers), both absolutely and relative to its rivals, has significantly increased its attractiveness to suppliers:

«We knew the [AeroCo aircraft] was where we wanted to be. We competed for [AeroCo's competitors'] programs too but we didn't show them this [system]. We bet on [AeroCo's aircraft]: our and [AeroCo's] marketing people were on the same page. This was a must win for us… We have never been disappointed in [AeroCo's] selling capabilities… We don't go in looking for work on a once-off basis: [AeroCo] is the customer and [our work] must be acceptable to them. It was very important to us to win a contract with [AeroCo].» (Supplier composite).

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Suppliers' confidence in AeroCo's capability as an airframer whose aircraft sell well encouraged the suppliers' betting their technological resources on AeroCo rather than on an AeroCo competitor in order to leverage AeroCo's final-market position.
For suppliers this meant pliability at time of contract signing in order to win the AeroCo contract. But it also meant pliability in an on-going post-contract sense. This was so because future business flowed from present conduct, which encouraged suppliers to be accommodating and to apply sufficient resources to make their work «acceptable to [AeroCo]». Suppliers «don't go in looking for work on a once-off basis» and wanted to be performant so that they might enjoy the fruits of repeat contracting. This inter-temporal influence on contract performance was a form of contract non-separability due to the belief that the program would be a commercial success and that AeroCo would continue to enhance its final-market position through what had historically been a frequent rate of successful new product launches.
AeroCo was, then, a project-information hub, and used this position to compel the application of suppliers' resources to the project.

PROCESSES

The process by which the resources of the many suppliers and AeroCo were applied to the project is the subject of this sub-section. The necessary process commitments from suppliers had similar bases to those identified in the discussion of resources. Thus, contractually-specified deliverable requirements defined process outcomes (phase by phase), certifiability depended on the regulator's confidence in the integrity of a well-specified and shared design process, and AeroCo's final-market position encouraged suppliers' on-going adaptability to AeroCo's process requirements.
The project was organized in terms of a highly articulated application of the well-established «waterfall» approach for resolving design uncertainty over a sequence of stages. This took the form of episodes of advance specification of design outputs for each phase, iteration around the development work in that phase, closing out the work of that phase through «exit reviews», and revising advance specifications for subsequent phases.
There were six project phases. Subsystem design work by suppliers began upon the arrival of their design representatives on-site at AeroCo at the start of Phase 1. Phase 2 focused on interface definition across subsystems. Interferences between subsystems (such as parts of different subsystems occupying the same coordinates in space, but also, for example, competing demands for electrical-power consumption) are typically the major cause of interface problems in complex-product design (Sabbagh, 1995; Adler, Goldoftas and Levine, 1999) and are evidence of poor information exchange. A great deal of the design work was completed by the end of this phase (a particular objective was the freezing of these interfaces), and most supplier design personnel returned to their home bases. These two phases comprised the major period of iterated co-design with suppliers, with Aero-

Co's provisional specification being significantly improved upon and fully articulated during this period (a period of about 14 months).

Phase 3 was the period of detail design for each subsystem i.e. the definition by each supplier of production drawings, culminating in a "critical design review" (spread over several weeks at the AeroCo facility) after which these detailed drawings were "frozen" and formally released to each supplier's manufacturing unit. This release initiated the "final assembly phase" (Phase 4) in which suppliers began to ship finished subsystems to the AeroCo assembly facility, after which integrated product testing occurred (Phase 5; each supplier's on-site manpower presence increased again for this phase) at the AeroCo testing facility. In Phase 6 —delivery into service— the interior and exterior finishing according to customer orders was completed by AeroCo, the aircraft entered into service, and the project was formally completed.

This was an administrative system that broke down the work on every subsystem by phase and specified what the work in each phase was meant to produce in terms of common categories of formalized documents (or "phase deliverables"). The rationale of such a system is that though much technical detail (in particular how subsystems interface with each other) must be worked out as the project unfolds, the resolution of design contingencies could be significantly programmed through the advance specification of the form and timing of design outputs for every subsystem.

A key coordination task for the AeroCo-assigned integrator (an engineering employee) for each supplier team was managing the exchange of technical information through an "action items" database. This database centralized all actions suppliers and AeroCo raised for each other —which they could only do via a (standardized) "coordination memo". Weekly meetings between an integrator and his subsystem team formalized the continual roll-up of decisions on design issues for the subsystems, and bi-weekly and periodic phase reviews for all of the subsystems did likewise for the product as a whole.

The following quote indicates how onerous these process demands were for suppliers:

«The schedule and format of deliverables [is what's hardest for suppliers]. Technically, they're no big deal : [the suppliers] are all smart. But you take [the technical tasks], add [just] 6 months [for Phase 2], ask for 200 [deliverables] in a specific format? So we're hunting to crank them out... There's a review process and a monitoring process —CDRs, PDRs[2]. There are spectators there to listen. Issues are raised and addressed. The rest is cross my fingers. But if we can do all that, and have a good clean well-reviewed [Phase 2] exit, then you just ride the wave… I can't see how else [AeroCo] could do it. We almost need a full-time person just for meetings and learning the system. But once we learn, it will be good…» (AeroCo/supplier composite).

That is, the provision of subsystem-level resources was not sufficient to achieve project success. Rather, the challenge of merging and applying the many suppliers' resources into a coherent process of AeroCo-defined standards and time-lines is what this quote emphasizes. Extensive standardization of work content and flow, and relent-

2. CDR: Critical Design Reviews; PDR: Preliminary Design Reviews. These occurred in Phases 3 and 2 respectively.

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less communication of this, were crucial contextual aspects for cuing appropriate supplier behaviours. By requiring each team to import a standardized administrative basis for its work AeroCo hoped to significantly influence the format and timing of the teams' on-going information exchanges such as to program integration into the design effort to a quite considerable degree. This distributed implementation of a shared work process achieved similarity in the form of the design work —the types and formats of drawings, analyses, and models— and the timing of these. This common basis for comprehending and verifying the status of each team's design work reduced the range of uncertainty that any given subsystem posed to the project. It shaped what information to exchange, when to do so, and how to react to it. This provided a basis for convergent expectations about the emerging design, making information outputs more readily exchanged and acted upon across the many teams. The perception was that more and more design changes —and escalating resource needs— would be the alternative to satisfying the process needs of getting it in the right format at the right time.

The structure of the technological problem was such that, looked at as an isolated subsystem, no subsystem design was especially daunting, but looked at as part of a closely-configured product system, every subsystem design was. The quality of product performance would emerge from how well adapted the functioning of each subsystem was with respect to the functioning of every other subsystem with which it interacted. The technical specifications that ultimately coordinated interdependencies between subsystems emerged as a result of the activity in Phases 1 and 2. The design problem was one of known interdependencies (in a general sense) that were unknown because of the need for customized interaction. This was so even for those subsystems the parts of which were entirely off the shelf, as these nonetheless had to be configured in a novel way. To take just one example, the controller unit for the fire extinguishing system was moved from one structural subsystem to another several times before arriving at its final location in the aircraft. Each move required fresh design work for the interface. Solving this technological problem required a coordination process that continually multi-varied the evolution of subsystem designs with respect to particular aspects of product functionality (for example, speed, weight, or safety).

The previous two sub-sections emphasized AeroCo's extracting ongoing resource and process commitments from suppliers as a means to influencing project outcomes. The next sub-section presents more explicitly on how AeroCo influenced the values that suppliers attached to co-development, and thereby further directed supplier behaviour.

MEANING AND VALUES OF CO-DEVELOPMENT

There is evolving co-specialization between AeroCo and suppliers that is re-allocating work across the make-buy partition. The logic underpinning AeroCo-supplier transactions is significantly influenced by the calculus of joint value maximization (Zajac and Olsen, 1993). That is,

through co-development AeroCo can offer suppliers a larger stake in any given project, and together they can jointly enhance the value to be created through a faster rate of product launches. Suppliers are up-grading their capabilities to become "subsystem integrators" i.e. they are assuming increasing responsibility for the design, parts procurement, manufacture, and integration into the overall product of an entire subsystem. In conversation with me, they emphasized this as a necessary adaptation to how the industry is evolving. Suppliers viewed participation on AeroCo product developments as important in their on-going up-grading of capabilities and exploitation of prior learning investments, as the following quote indicates:

«We used to build to specification. Now, we have to allow a lot more system engineering time. [Company] has learned a lot in terms of organization—at the component level we're the best. But 'What has to be done and by when? What is an [integrated] test?': we knew none of that. That's true of all of the suppliers: [it used to be] that you'd just receive the drawings and not have to think… [AeroCo] is good at integrating —[AeroCo competitor] is nowhere near as organized. [AeroCo] is good at capturing lessons learned— each time they launch a new program it's better organized. Managing this phase [i.e. Phase 2] is probably key to success of the program. We've used the [AeroCo] system on our other programs [i.e. when supplying to other airframers]… You need a strong pilot to drive decisions. You need someone above with a clear view and who will make a decision [and] take the role of arbitration.» (Supplier composite).

That is, suppliers viewed the AeroCo work context as a context for learning, and this made suppliers positively pre-disposed to adaptations that seemed necessary not just to the project but to a desired strategic direction: becoming better at subsystem integration for a variety of airframers. This made more meaningful the provision of increased resources to a given AeroCo project and adaptation to AeroCo product-development processes, given AeroCo's demonstrated capacity for integrating suppliers' resources into coherent projects and successful new product introductions. On-going adaptation of suppliers was also made more meaningful by their view of AeroCo as a necessary mediator between them, describing this role as "referee", "pilot", and "arbitrator". Achieving a high level of integration of suppliers' technologies early in the development process would significantly reduce suppliers', and not just AeroCo's, associated risk, the awareness of which made suppliers' adaptation to AeroCo's strictures still more meaningful. AeroCo leveraged these suppliers' beliefs about the respective roles of itself and suppliers to shape the form, content, and pace of design decisions.

Negative attention from AeroCo was a constant incentive to adapt, but it also generated a widely-shared feeling among suppliers that AeroCo beat them down on price during contract negotiations and then sought to get them to apply maximal resources to the project. This feeling was reinforced by suppliers' eagerness for a long-term relationship not being matched on the AeroCo side. It was earlier noted how AeroCo demonstrated no clear pattern of repeated supplier participation on its

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development projects. AeroCo also avoided giving any business guarantees to suppliers beyond a single project: in the words of one supplier, it was “strictly one program at a time, boys”. This suggests that any given supplier, despite significantly increased design, manufacturing, and testing capabilities, needed AeroCo more than AeroCo needed the supplier.

Suppliers, then, wanted AeroCo’s business but also wanted to limit their resource commitments to any given project. Given AeroCo’s apparent ability to extract these resources, coalition-forming between suppliers arose as a countervailing response:

«We’ll defend [interfacing suppliers] if [AeroCo] is asking too much of them. We’re happy to give something so that when we’re stuck they’ll give something back. They [other supplier] know what we are doing and that we take account of their problems… we have a lot of interaction with [other supplier] —we have a good working relationship maybe because [they] find an ally against the enemy— [AeroCo]!» (Supplier composite).

This quote demonstrates that however much suppliers shared the values of collaborative development work and however meaningful was the division of roles and responsibilities, they remained fully alive to the need to protect their own interests, an important aspect of which was their mutual interests with other suppliers. The quote also demonstrates supplier behaviour as a response to beliefs about AeroCo: despite the variety of organizational affiliations of participants and a generalized absence of prior interactions between them, shared identification and informal collaboration nonetheless arose, but in no small measure due to perceptions of excessive resource and process demands by AeroCo.

DISCUSSION AND CONCLUSIONS

Management scholars have often argued that “trust” must play a key role in economic exchanges in inter-firm networks, emphasizing this as the solution to the risks of opportunistic behavior and incomplete monitoring or to problems due to moral hazard or asymmetric information. These risks are almost always present in the case of inter-firm networks, and were present in the network reported on here. Yet power imbalances between the central buyer and suppliers seem to be the key organizing dynamic for exchanges in this network.

Knowledge stocks and flows were crucial to project outcomes but these same knowledge stocks and flows created the potential for buyer–supplier opportunism and hold-up (Williamson, 1975). That is, because intra-network coordination required multilateral bargaining, and was characterized by specific investments and high levels of uncertainty, the payoff to supplier opportunism rose. Suppliers were independent firms each with their own objectives, objectives which diverged from those of AeroCo as well as from each other, and one important objective was to increase one’s bargaining power within the network. The bargaining power of any party to maintain and increase

its share of the rents generated by the operations of the buyer-supplier network as a whole depended on its ability to influence the nature and pattern of knowledge flows. The previous section identifies how AeroCo acted on resources, processes, and values to influence the nature and pattern of knowledge flows in the network.

The complexity of the design problem, and the asymmetrical nature of subsystem expertise —whether in terms of AeroCo relative to a given supplier, or a given supplier relative to another (interfacing) one— made it impossible for any individual or team to think about everything or work with everyone at once. This generated crucial knowledge gaps in the network which AeroCo bridged. AeroCo configured the resources and capabilities of suppliers by acting as a kind of clearing house for knowledge flows between them. Not only did AeroCo connect the suppliers' resources and capabilities to each other, it also connected these to the regulatory framework surrounding their application to product development, as well as to the market needs that provided the basis for their creating value. AeroCo's asymmetrical knowledge of contracting, regulatory considerations, and market needs mobilized suppliers' resources and made sensible the processes that organized network participation and exchanges. It was through this configuring of resources, processes, and values that AeroCo preserved its value added in the network, and the value added as a whole of network organizing as the governance mode for the development of its complex products[3].

AeroCo accessed flexible market arrangements and simultaneously exercised control over even the most capable of suppliers while avoiding fixed hierarchical structures. But despite the heavy reliance on market-based relationships, the co-development was still characterized by an authority system, a common standardized operational basis, non-market pricing (such as inter-temporal influences on contract pricing and performance), and a dispute-resolution system (a function performed by, for example, the wide range of meetings between AeroCo and supplier teams, and a formalized process for design changes). All of this created a quasi-hierarchical structure of development that connected AeroCo to the supplier and the suppliers to each other such that the need to achieve adaptive design evolutions could be made authoritative and certain. Clarity in whether design decisions were authoritative or not was crucial because the interactivity of these decisions could lead to the rapid propagation of errors and escalation of costs. Subsystem designs had to be continually multi-varied in order to design for the many —sometimes contradictory— aspects of product functionality. Design information had to be continuously pooled, queried, and updated by means that guaranteed the reliability of the information. Meeting all of these challenges depended on a network of hierarchical and lateral information exchange. AeroCo, as it were, sat on top of the network as a means to guaranteeing the optimality of the design work through making decisions authoritative and with an eye to trade-offs and their impact on the performance of the product as a whole. This exercise of authority was central to the configuration of resources, processes, and values that defined this network of inde-

3. At least judged in terms of the market success of this complex development project. Publicly, AeroCo senior management viewed performance for this project as "very successful". The aircraft met or exceeded all major project goals in terms of price and functionality, and orders for the product comfortably met targets. However, while the time between project launch and first delivery significantly improved on earlier projects, time-to-market estimated from the beginning of Phase 1 was actually several months longer than anticipated. Engineering-change orders (i.e. design changes after Phase 2) were also significantly higher than anticipated, and ultimately resulted in some margin compression for AeroCo.

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pendent firms, many of whom had never previously worked together, and all of whom had independently developed their own processes and design philosophies over many years, and which had to be mutually adapted.

Knowledge stocks and flows were therefore directed through a control structure that could not arise autonomously but had to be designed. This control structure involved achieving coordination through balancing centralization with the provision of incentives derived from suppliers' pursuit of their own objectives. Standard-setting facilitates interaction and exchanges but also gives the standard-setting organization control over those who follow the standards (Brunsson, Jacobsson and associates 2000). On-going convergence of the work of these disparate supplier organizations relied on AeroCo's specification of technical and administrative standards and if suppliers wanted to do business they had to commit to AeroCo's standards[4].

It is worth emphasizing that neither size asymmetry nor small-numbers' bargaining really explain the power imbalances between AeroCo and a given supplier[5]. Nonetheless, AeroCo's strategic attractiveness as a customer further reduced any exposure to small numbers bargaining and increased suppliers' willingness to make asset-specific investments for co-development. Such supplier investments included the adaptation of their work and work processes to AeroCo's strictures, and such purely project-specific investments as non-recurring engineering (i.e., design work) and manufacturing-tooling specific to a given project. While AeroCo also had to make investments for co-development, these were amortized more quickly relative to the average supplier (who participated only on some programs). And though AeroCo must return to the same supplier who produced the original subsystem to ensure that new orders will be homogeneous with earlier ones, I found no evidence to indicate that this permitted the supplier to exploit AeroCo – no doubt because of contractual agreements and the hope for repeat participation on future AeroCo projects.

The existing literature's emphasis on governance through stable and trusting relations seems a distinctly over-socialized view of these self-interested economic actors (Granovetter, 1985). It may be that rather than, or in addition to, trust developing directly between all parties (a very demanding organizing criterion) mutual trust may be substituted by trust in the central firm and the exchange processes that it devises i.e. a party may be trusted because they have been selected by and may be sanctioned by the central firm in terms of adhesion or not to centrally-defined work standards. This again emphasizes the significance of centralized standard setting and selective intervention by the central buyer to the performance of a buyer-supplier network.

Finally, control over resources, processes, and values in this network, and probably any network, is necessarily more differentiated than in the intra-organizational context. Interestingly, the power imbalance between suppliers and AeroCo encouraged collaboration (between suppliers themselves) which is contrary to what others have concluded about the effect of power imbalances inside an organization (e.g., Dougherty and Hardy, 1996). In one sense this collaboration can be vie-

4. However, as is typical for commercial-aircraft developments, many of the fine-grained technical standards, especially those intended to implement fail-safe operation of the aircraft, were "Mil" standards i.e. derived from military specifications.

5. AeroCo was larger than most but not all suppliers. While a smaller supplier might complain to me of being pushed around because of relative size, a relatively large supplier equally would complain of being imposed upon by AeroCo due to its size relative to other suppliers (such as having to "eat additional costs")! With respect to small-numbers bargaining, switching costs were equally discouraging to AeroCo and a given supplier, and for passenger-carrying jet aircraft there are on average only three or four possible suppliers in the world for any given subsystem, and a similar number of airframers.

wed as unsurprising coalition-forming: supplier cooperation was partly a deliberate countervailing effort of mutual protection against perceived exploitation (or was itself an attempt at exploitation of AeroCo's dependence). But it was also an instrumental response to the task demands placed upon suppliers: task interdependence made cooperation essential in executing their work and the relentless pressure exerted by AeroCo energized this cooperation. This further points to the complementarity rather than substitutability of power imbalances and trust as different governance forms (see also Poppo and Zenger, 2002). This is a finding that demonstrates how any given exchange is affected by common exchanges each firm in the network has with other firms in the network. The existing literature's emphasis on the buyer-supplier network as an agglomeration of dyads around the central buyer is ill-suited to elucidating such a finding.

FURTHER RESEARCH

This study has provided significant details of how a particular buyer-supplier network actually functioned in terms of the central buyer's use of its power to configure resources, processes, and values in the network. The study suggests that intensive inter-organization relationships can be based on stable histories of suspicion, and that each party needs to understand how relative power may be used to drive network outcomes. As with any study, but particularly a case-based study such as this one, further research is necessary to test, refine and generalize the findings reported here.

The significance of different kinds of structural holes deserves further examination —for example, regulation, and access to the regulatory authority, is much more significant for some industries than others. In addition, technologies in other industries will differ in terms of their complexity, architectural maturity, and need for reliability. How such differences might affect power imbalances through affecting the levels of resource and process commitments associated with the development of the product would be worth studying.

Further research is also needed to fully answer why the existing literature has overlooked the significance of power imbalances. Could the answer lie in characteristics peculiar to the world auto industry, which has been the empirical subject for the bulk of extant studies in this area? Thus, the "power is bad" view depends on inferences about the performance of North American automakers. But if the low value-added exchanges (i.e., suppliers having very limited design responsibility) that have been identified with these firms are treated as deliberately chosen, then adversarial relations, or at least the depreciation of collaborative relations, flow fairly obviously without in themselves being deliberately chosen. On the other hand, the 'trust is good' view depends on inferences about the vaunted trust and stability of Japanese automaker-supplier relations. But might these relations not be attributable to wider cultural norms of harmony and collaboration, with the nature of (relatively high value-added) exchanges an effect of these? In both of these archetypical cases, then, the central buyer is not delibe-

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rately configuring the nature of relations and the value of exchanges but rather just one or the other. Therefore, existing findings might well be expected to depart from the situation such as that reported in the present study where both relations (power based) and exchanges (high value added) are being deliberately configured. A recent study by Ahamdjian and Lincoln (2001) supports this interpretation but is not conclusive.

The role of power imbalances in other inter-organization forms is another avenue for further research. In particular, in a horizontal network, as opposed to the vertical network described here, structural centrality is less probable because participants are less likely to be distinguishable in terms of their knowledge bases. Rather, each participant could be expected to have well-established views about the product system as a whole, and not be disposed to assimilate unifying standards devised by another for the integration of product subsystems. Moreover, extensive collaboration across several functions (not just design engineering) would likely need to be negotiated, which would further complicate the standardization of work context as a means of enabling distributed work patterns.

The impact of the climate of inter-organizational relations on industry structure is also a topic that needs further research. An emphasis on cost, and the antagonism that this can create, likely militates against suppliers' pursuit of innovation in the medium to long term. Might this lead to a loss of competitiveness by AeroCo and other firms that de-emphasize long-term relations, such as that experienced by U.S. auto firms (e.g., Helper, 1991), or will issues of complexity and regulation, and the significance these give to structural centrality, out-weigh such considerations? Industry structure ultimately results from the answers to such a question. That is, suppliers' willingness to spend in order to learn cannot be counted on as open-ended, and may anyway ultimately allow them to substitute to some degree for the knowledge of the central buyer (as has happened in the PC industry). This would result in a shift in the balance of power away from the buyer or alternatively prompt a reversal of outsourcing, such as suggested by Ahmadjian and Lincoln (2001) and Brusoni et al. (2001).

In conclusion, this study should contribute to improving understanding of how inter-organizational networks function. Framing network functioning in terms of the configuration of resources, processes, and values presents a coherent framework for questioning and extending the existing literature. It illustrates how these networks may be deliberately designed. It shows that power imbalances are important to network functioning and that these can be studied systematically. Continued research into how power imbalances influence network functioning and evolution should enhance our understanding of this important inter-organizational form.

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