Delegation and Contracting Hierarchies: An Overview

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1 Introduction

Delegation is a pervasive phenomenon in firms, procurement contracting, financial and regulatory institutions. Owners frequently delegate management of the firm to top level managers, who in turn delegate management of divisions to middle level managers. In procurement contracting, the purchaser often contracts with a single 'prime' contractor, delegating the responsibility of subcontracting with diverse upstream suppliers. Trading intermediaries such as wholesalers and retailers are delegated decisions concerning distribution and pricing of products. Financial intermediaries are delegated authority by depositors to make loans and supervise lenders. Regulated firms are often delegated authority by regulators to select their own production levels and contract with their upstream suppliers. These are but a few instances of how decision-making typically gets dispersed among a large number of agents, instead of being concentrated in one central authority. Those delegated authority may themselves be directly involved in

production or distribution, or may be intermediaries or professional managers whose role is to select, monitor and coordinate agents involved in production.

Whether or not to delegate is a matter of conscious choice, at least to some extent. The owner of a firm may decide instead to retain control and contract personally with all employees and suppliers; purchasers can try to contract personally with producers rather than go through intermediaries, and regulators can regulate production and sourcing decisions of utility firms they regulate. Such changes in the nature and extent of reliance on intermediaries appears to be occurring within firms as well as procurement contracting in recent years. Corporate 're-engineering' involved elimination of middle layers of management in order to create more direct links between customers, top managers and production centers (Hammer and Champy (1993)). 'Supply chain management' involves more extensive outsourcing, and reduced reliance on intermediaries.

An important task of contract theory is to provide an analytical framework for discussing the costs and benefits of delegation, which helps explain delegation decisions. And thereafter to study comparative performance of different contractual networks and forms of internal organization of firms that involve distinct patterns of authority and responsibility. Yet classical incentive theory based on the Revelation Principle does not provide such a framework. Under a certain set of assumptions, this Principle establishes that centralized control cannot be dominated by any delegation arrangement. The outcomes of any delegation can be mimicked by an upfront comprehensive centralized contract in which the responsibility of each agent is merely to communicate their information to a central authority and await instructions on what to do.[1]

The main assumptions underlying the Revelation Principle include the following:[2]

- Absence of: (i) costs of communication between agents and principal, (ii) information processing costs for the principal, and (iii) contract complexity costs.
- Absence of collusive behavior among agents

[1]For the most general statement of this Principle, see Myerson (1982). For a wider discussion, see Williamson (1986).

[2]In what follows we refer to the 'principal' as the *de facto* designer and residual claimant, and 'agents' as all others with a production or information generation role.

- Ability of principal to commit upfront to a mechanism and not renegotiate it later

In light of this Principle, there are two possible ways of constructing a theory of delegation and contractual hierarchies.

The first approach stays within the framework of the Revelation Principle, and studies conditions under which delegation is an optimal mechanism, i.e., where a hierarchical mechanism with delegation replicates the performance of the best centralized mechanism. This approach has been pursued by Baron-Besanko (1992), Melumad-Mookherjee-Reichelstein (1992, 1995) and Severinov (1999), among others. The main problem with this approach is that the conditions may be restrictive, and even if they are not, it cannot explain why delegation can be superior to centralization.

The second approach departs from the comfortable premises of the Revelation Principle. Different theories can be classified by the precise avenue of departure from the set of assumptions underlying the Revelation Principle:

(a) Information processing costs (Radner (1993), Mount-Reiter (1995), Bolton-Dewatripoint (1994), van Zandt (1996, 1997))

(b) Costly communication, contract complexity (Melumad-Mookherjee-Reichelstein (1992, 1997), Laffont-Martimort (1998), Segal (2001))

(c) Collusion among agents (Baliga-Sjostrom (1998), Laffont-Martimort (1998), Faure-Grimaud-Laffont-Martimort (2002), Celik (2002), Mookherjee-Tsumagari (2002))

(d) Incomplete Commitment and Renegotiation (Beaudry-Poitevin (1995), Poitevin (1995), Dessein (2000), Faure-Grimaud-Martimort (1999)), Incomplete Contracts (Aghion-Tirole (1997))

In this paper I will present an overview of the first approach, and avenues (b) and (c) of the second approach. The emphasis will be on papers that deal with the costs and benefits of delegation relative to centralization, in which incentive considerations play an active role. I thus exclude discussion of avenue (a) of the second approach since it has so far abstracted from incentive considerations. I also do not discuss the important avenue (d) based on incomplete commitment mainly because an excellent survey of this approach is already available in Poitevin (2000).

Some caveats are in order. The literature I shall discuss does not seem relevant to the question of boundaries of the firm, where the incomplete con-

tract framework seems more fruitful.[3] It applies to delegation arrangements that may or may not be intra-firm, and has little to say on whether and why firms should outsource some production rather than in-house. Agents in this framework cannot be distinguished by whether they happen to be within or outside a firm.

Moreover, my intention is to provide a selective guide to the literature that I am familiar with for interested readers, rather than an exhaustive survey. So important papers may have been missed or glossed over. I also want to keep the overview brief and readable, so will eschew formalism of any kind and try to communicate the essence of key results and ideas. Those interested in more detailed statements of model assumptions and results should consult the original sources.

Section 2 will describe the canonical setting of production with multiple agents that are privately informed about their own costs, which is employed in most of the literature. Section 3 will describe literature falling into the 'first' approach described above, which explores conditions for optimality of delegation within the traditional confines of the Revelation Principle. Section 4 will then discuss avenue (b) within the second approach, based on costs of communication or contract complexity. Section 5 will discuss implications of allowing agents to collude. Finally, Section 6 will conclude with a summary of the principal insights and shortcomings of this literature, and suggests directions for future research.

2 The Canonical Setting of Joint Production with Adverse Selection

Most of the literature focuses on models where agents have private information about their costs, rather than moral hazard, and we will do the same. The typical model is usually of the following kind. There is a single principal (P), one or two producing suppliers (A_1, A_2), plus one manager/middleman/monitor M who plays no role in production. The gross benefit of P depends on joint output whose production depends on contributions or supplies of the two agents, described by the production function $q = f(q_1, q_2)$, where A_i produces q_i at private cost $C_i(q_i, \theta_i)$ satisfying a set of single-crossing conditions.[4] The parameter θ_i affects the productivity or

[3] For an overview see Hart (1995).

[4] The key condition is that marginal production costs are increasing in θ_i, but these are usually supplemented by conditions that total costs and the rate of increase of marginal

cost of the agent, and A_i is privately informed about realization of θ_i. The cost shocks θ_1, θ_2 are independently distributed, and satisfy a monotone hazard rate condition that allows one to ignore non-local incentive constraints in the classical setting. The manager or monitor M observes signals η_1, η_2 which are informative about θ_1, θ_2 respectively. P, A_1, A_2 are risk-neutral, while M is risk neutral or risk averse. Outside options for all agents are normalized to 0. Agents observe their costs prior to contracting and so earn information rents. The main tradeoff in designing contracts or delegation is between productive efficiency and paying information rents to agents.

Many papers employ considerably restricted versions of this model, e.g., where there is one productive agent rather than two, or particular production functions — e.g., perfect complementarity between q_1, q_2, indivisibility of inputs or outputs, linear cost functions, or two point distribution for cost shocks and signals.

The role of M in the organization is informational 'expertise' relative to the principal, acquired either through prior expertise or from ability to monitor cost realizations of the agents. The process by which M acquires this information is treated as exogenous; the theory explores the implications of such informational specialization. This contrasts with an earlier literature on contracting hierarchies (e.g., based on Calvo-Wellisz (1978)) focused on moral hazard in supervision, but not on delegation questions.[5] Some of the interesting questions addressed by the theory concern the relative desirability of delegating to M rather than the productive agents themselves. This concerns the widespread phenomenon of 'management' being divorced from 'production' as a specialized activity (as argued persuasively by Radner (1992)). Accordingly, the organizational alternatives usually compared include the following (see Figure 1:

Centralization without Supervision (C): P retains all control, contracts and communicates with A_1, A_2

costs are also increasing. For the most general statement, see Melumad-Mookherjee-Reichelstein (1995).

[5]In that literature, supervisors are not delegated any authority to contract with those they supervise. The focus was on whether moral hazard in supervision creates organizational diseconomies of scale. Indeed, Calvo-Wellisz and others found that explaining scale diseconomies through this channel was typically not as straightforward has had been originally imagined, e.g., by Williamson (1967). The literature on delegation described here in contrast does provide conditions for emergence of 'control loss' in hierarchies under suitable conditions, so can be thought of as an alternative formalization of this phenomenon.

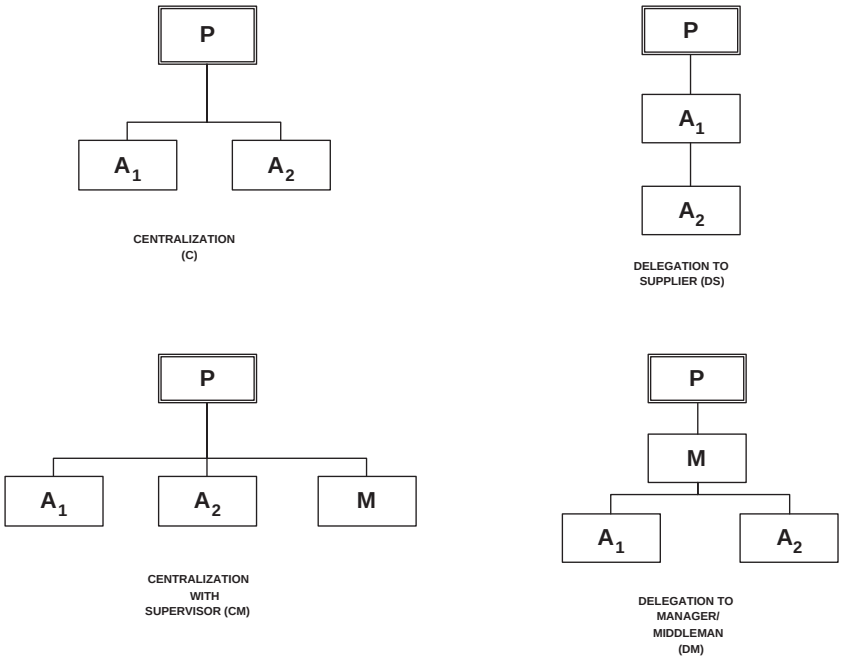

Figure 1: ORGANIZATIONAL ALTERNATIVES

Centralization with Supervision (CM): P retains all control, contracts and communicates with A_1, A_2 and M

Delegation to Supplier (DS): P contracts only with A_1, delegates authority over contracting with A_2

Delegation to Manager/Middleman (DM): P contracts only with M, delegates authority to M over contracting with A_1, A_2.

Many papers pose the question of delegation versus centralization as DS versus C; others pose it as DM versus CM; yet others as DM versus C. Accordingly to understand the relation between different papers, we shall make this explicit in discussing their results using this terminology. It is also useful to clarify that we use the term 'delegation' to connote a setting of hierarchical contracting with multiple vertical layers, where contracting and communication restricted only between adjacent layers. For instance, in DS P does not contract or communicate with the subcontractor A_2 at all.

With only two productive agents, most of the literature compares the centralized two layer hierarchy with a three layer one where the agent at the intermediate layer is delegated authority over contracting with those at the third layer. The main focus is thus on problems of vertical control. Problems of horizontal coordination across different branches of a hierarchy inherent in delegation have therefore received little attention (with few exceptions, described in Section 3.4). Issues concerning design of more complex hierarchies (e.g., span of control versus number of vertical layers, trading off horizontal coordination problems and vertical control loss), or comparison with nonhierarchical forms of delegation, must await future research.

Additional details concerning delegation concern exactly what is observed by the principal and the sequence of contracting in the hierarchy. Insofar as they help determine the nature of control loss from delegation, these will be described in subsequent sections. Collusion between agents is modeled as hidden side-contracts between the agents, and further details of observability and timing are involved here, which will be explained in Section 5.

3 First Approach: Conditions for Optimality of Delegation within the Traditional Framework

3.1 Conditions for DS=C

Consider first the optimality of delegating to a 'prime' supplier the authority to subcontract with the other supplier, i.e., comparison of DS with C. When the Revelation Principle applies, we know that C weakly dominates DS, so the question is when DS achieves the outcome under the optimal centralized mechanism. In this case delegation entails no control loss at all. Insofar as contracting with one agent rather than two is simpler or easier for the principal, this can provide a rationalization of delegation as a way of implementing the optimal outcome.

The potential control problem with delegatin involves a form of 'moral hazard': the 'prime' supplier's incentive to allocate production and payments between himself and the subcontractor may differ from what the principal desires. In particular the prime contractor has monopsony power over the subcontractors, and the principal in turn has monopsony power over the prime contractor. Both sets of relationships are subject to adverse selection, so monopsony will generate distortions in production and payments that will raise contracting costs for the principal. The vertical

control problem inherent in delegation therefore is essentially that of 'double marginalization of rents' (DMR), stressed in the context of sequences of monopoly relationships in the industrial organization literature.

The monopsony power of the prime contractor (A_1, say) over the subcontractor (A_2) results in two problems. First, there tends to be 'too little outsourcing' from subcontractors (or too low a supply price offered by A_1). This results from the attempt by A_1 to garner maximal informational rents for himself at the expense of A_2 and P. Roughly speaking, the volume of information rents are proportional to the level of production allocated to an agent, so A_1 allocates himself a larger share of production than either A_2 or P would desire. Second, A_1 is privately informed about subcontracting cost (what he has to pay A_2) *vis-a-vis* the Principal, owing to the lack of direct communication between P and A_2. This adds a dimension of adverse selection in A_1's relationship with P, over and above privacy of information about his own cost of production. There is a consequent 'cascading' of information rents: first such rents are paid to A_2 by A_1, and then this is subject to an additional markup owing to privacy of A_1's information vis-a-vis P regarding subcontract costs. This is as far as the principal's welfare is concerned; from the standpoint of social efficiency only the production misallocation matters.

An important result in the literature is that these control problems can be eliminated in DS under the following conditions:

(3.1) **Observability of subcontract costs or allocation:** either q_1 the amount produced by the prime supplier, or x_2 the subcontracing cost incurred.

(3.2) **Top-Down Contracting:** P contracts with A_1 *before* A_1 communicates or contracts with A_2

(3.3) **Risk-neutrality, absence of limited liability constraints:** for A_1

The main idea underlying this result is that condition (3.1) enables the principal to subsidize outsourcing or tax in-house production by A_1 to correct the productive misallocation between the two agents. Moreover (3.2) and (3.3) allow P to 'tax' away upfront information rents deriving from privacy of the prime contractor's knowledge of subcontract cost.

These conditions are not only sufficient but necessary as well, except in special cases. The production misallocation can arise only in the presence of some substitutability between the inputs supplied by the two agents. Otherwise if there is perfect complementarity, there is no scope for a monposony

distortion between A_1 and A_2, and condition (3.1) is unnecessary (Baron-Besanko (1992), Gilbert-Riordan (1995)). Otherwise, conditions (3.1) and (3.2) are necessary (given risk-neutrality ((3.3)) if the production function is smooth (Melumad-Mookherjee-Reichelstein (MMR, hereafter) (1995)). The necessity of (3.3), risk-neutrality is also suggested by MMR 1995, and reinforced by the literature to be described next.

3.2 Comparison of DM with C

Another way of posing the question of optimality of delegation is to compare DM (rather than DS) with C. McAfee-McMillan (1995) consider the case with only one productive agent, and a single monitor M who has no better information than P about the agent's cost. They focus on the costs of intermediation arising from delegation of procurement to M who is subject to limited liability. The main idea here is that M can earn information rents with respect to privacy of knowledge of subcontract costs, since there is no direct communication between the supplier and the principal. These rents cannot be taxed away upfront owing to limited liability constraints. This is very similar to the implications of violation of (3.2) — wherein A_1 can contract or communicate with A_2 before responding to the contract offered by P (MMR(1995)).

Faure-Grimaud-Martimort (2000) replace limited liability by risk-aversion of M, and obtain an agency cost of delegation (with a single productive agent) that is qualitatively similar (though different in detail). Inability of M to costlessly bear risk prevents congruence of interests of M with P at the time M designs sub-contracts for productive agents. This is somewhat akin to a classical moral hazard problem that trades off risk sharing and incentives with a single agent.

3.3 Effects of Supplier Consolidation: Comparing DM with C with Two Productive Suppliers

Now consider the related question of how DM relates to C in the case of two productive agents A_1, A_2. Assume M is perfectly informed *ex ante* about realization of the agents' costs: so there is no upfront uncertainty faced by M. Now delegation to M implies that A_1, A_2 do not earn any rents, but instead M does (owing to privacy of his information concerning subcontract costs *vis-a-vis* P). The principal now contracts with a single supplier of *both* inputs who incurs supply cost equal to the sum of the two agents' cost. The

comparison of C with DM is thus really a question of effects of consolidating the two suppliers into a single supplier.

The main result here is that *such consolidation benefits P if the inputs are perfectly complementary in production, under some added distributional conditions* (Baron-Besanko (1992), Gilbert-Rordan (1995)), *but hurts P if they are substitutes* (Severinov (1999), Mookherjee-Tsumagari (2002)).[6] The intuitive idea underlying this result is the following. In C there are externalities between the two separate suppliers, which are internalized with consolidation. If they supply substitutes, then competition is suppressed and cost reports increase (on average) with consolidation. Consolidation also converts a pair of one-dimensional incentive problems into a single two-dimensional one (both in terms of dimensions of information and number of goods delivered). This tends to strengthen incentive constraints (owing to the ability of the single consolidated agent to coordinate reports). On both counts the principal is worse off when the two inputs are substitutes. If they supply complements instead, the internalization of bidding externalities causes cost reports to fall on average with consolidation. But opposing this is the problem that the adverse selection problem is a higher dimensional one with consolidation. Under particular distributional conditions the higher dimensionality poses no additional problems, and then P attains superior expected profit from DM.[7]

That delegation scores above centralization here may occasion some surprise, since the Revelation Principle still applies. However the set of agents is not the same between DM and C: in the former there is an additional agent M who is better informed than P. The superiority of DM thus flows from access to this additional source of information that is not available in C by assumption. Indeed, the relevant centralized benchmark for DM is CM rather than C, where M belongs to the organization and P retains all control and contracts with M, A_1 and A_2. In such a setting M is relegated to the status of a supervisor or consultant, rather than as a manager with control rights over the suppliers. The Revelation Principle asserts that CM always weakly dominates DM. Moreover, in CM the principal can costlessly acquire all of M's information, given the absence of any collusion between

[6]The definition of substitutes and complements is in terms of the way that the demand for input delivered by one supplier varies with the cost reported by the other supplier. Mookherjee and Tsumagari show how this relates to notions of substitutes and complements in terms of the elasticity of substitution of the production function.

[7]The distributional condition is however quite restrictive: i.i.d. exponential cost shocks with a lower bound of 0. Extensions to a wider class of distributions remains an open question.

M and the productive agents supervised. Whereas in DM the principal has to encounter the problem of controlling M. Hence in general P would be strictly better off retaining control (CM) rather than delegating (DM).[8] This implies that explanations of the widespread phenomenon of delegation to intermediaries uninvolved in actual production must perforce depart from the traditional setting of the Revelation Principle. We shall return to this point below.

3.4 More Complex Hierarchies: Organizational Diseconomies of Scale; Horizontal Coordination

Now suppose there are more than two productive agents. Then there is a choice between different hierarchical patterns of delegation. Abstracting from the possibility of employing supervisors or intermediaries, the n producing agents could be organized in a linear vertical chain, with agent A_i authorized to contract with A_{i+1}. Or they could be organized into two horizontal departments, each of which contains a subset of producers, and involves a vertical linear chain within the department. Or we could have a hierarchy where each agent is authorized to contract with m subordinates (with k vertical layers). See Figure 2 for examples. And so on: there are a large number of possible hierarchical structures, with varying spans of control (horizontal branches) and vertical layers. The questions that can be posed in this framework involve both questions of the design with a given number of agents (e.g. span of control versus vertical layers, how to group agents into departments, how to organize communication and contracting systems), as well as how the performance of the organization changes as the number of agents increases. The latter question is of interest to understanding limits to the size of firms or networks that arise solely from incentive and coordination problems.

Delegation is now potentially prone to problems both of vertical control loss (cascading across vertical layers) and coordination across horizontal branches. The latter problem is not addressed by any of the models described so far, though it has received some attention in the team-theoretic literature which has abstracted from incentive considerations (e.g., Marschak and Reichelstein (1995, 1996)). Cremer and Riordan (1987) represents one of the first attempts to deal with complex hierarchies (and also non-hierarchical contract networks), wherein conditions for implementability of first-best efficient allocations with *ex ante* contracting with risk-neutral agents were

[8] This is easiest to see when M has perfect information about costs – then CM attains the first-best, which DM cannot.

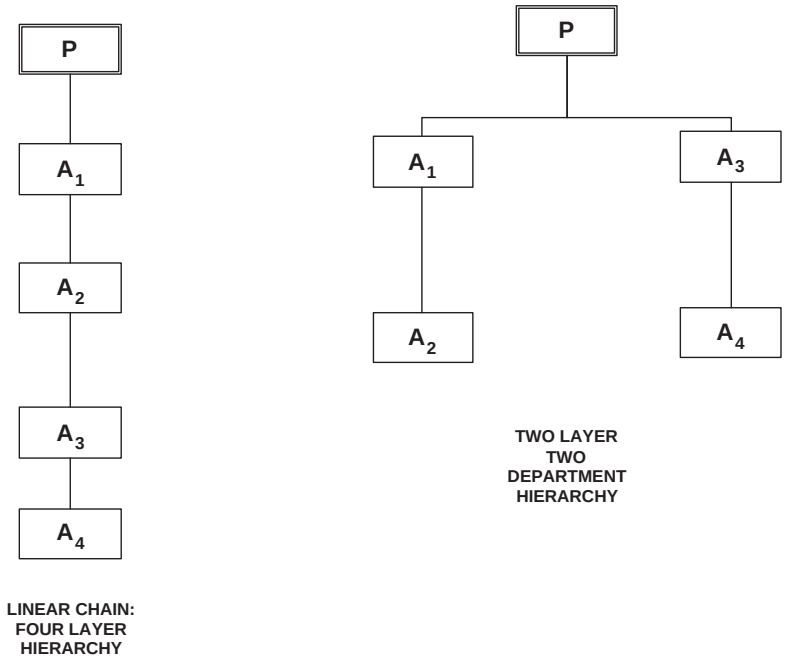

Figure 2: Hierarchies with More Than Two Agents

established.[9] In particular they describe a sophisticated system of contracting and communication that enables such a contracting network to resolve both incentive compatibility and coordination to achieve *ex post* efficient outcomes.

Extensions of the theory to implementation of optimal mechanisms for a principal (rather than *ex post* efficient outcomes) in the presence of adverse selection are considered in Mookherjee and Reichelstein (1997, 2001). They confine attention to contracting hierarchies that are 'consistent' with the technology in the sense that one dimensional reporting would help the same hierarchy achieve first-best outcomes in the absence of any incentive problems. In other words, the production technology has a constant returns recursive structure, wherein production is hierarchically decomposed into departments and subdepartments. In the absence of incentive problems, coordination across different departments can be achieved by a hierarchical communication system, where each manager receives (one-dimensional) cost reports from subordinates, aggregates them into a departmental cost and reports this to his superior in turn. Cost reports flow up the hierarchy

[9] *Ex ante* contracting refers to the situation where contracts are negotiated before agents receive any private information, so adverse selection problems do not arise.

in this way, uptil the very top. There aggregate output decisions are made, which are subsequently disaggregated into departmental targets, with these flowing subsequently down the hierarchy.

This mechanism can be extended to incorporate incentive problems as well, under exactly the same conditions (3.1)–(3.3) that enables DS to achieve optimal outcomes in the two agent case. Specifically, Mookherjee-Reichelstein show that *if assumptions (3.1)–(3.3) hold, any hierarchy 'consistent' with the technology (in the sense defined above) can achieve the same expected profit and production allocation as the optimal centralized mechanism.* This implies that conditions (3.1) – (3.3) as well as 'consistency' are sufficient (as well as necessary) for hierarchical delegation to implement optimal centralized outcomes. Once vertical control problems can be overcome with one level of delegation, they can be overcome with multiple vertical layers. Moreover horizontal coordination across departments can also be costlessly assured by the mechanism.

The mechanism involves three stages: first contracts flow down the hierarchy, then cost reports flow up and get aggregated along the way, determining production targets which flow down at the third stage. Specifically:

- At each layer an agent manages a 'profit center'
- managerial incentive schemes are linear in a measure of profit of the center
- departmental costs equal aggregate payments authorized to subordinate departments
- departmental output is valued at willingness to pay (*a la* Groves-Vickrey) of the manager at next higher level
- managers self-select profit targets for themselves at the first (contracting) stage, then report cost (bid on projects) to their bosses at the second stage after receiving cost reports from their subordinates

Some of these features resemble performance budgeting systems described in management accounting textbooks (e.g., Horngren and Foster (1991)). The mechanism distributes information processing tasks throughout the hierarchy, as managers aggregate cost reports for their respective departments and allocate production between subordinates and themselves. With incentive problems overcome, design of the hierarchy can be based on considerations of efficient distribution of information processing *a la* theories of Radner (1993) or van-Zandt (1996, 1997). In particular, these considerations explain why

the two extreme organizational forms (a 'flat' two layer centralized mechanism, and a 'steep' linear chain) would be dominated by intermediate forms with a number of vertical layers and horizontal branches. Note finally that the result provides a set of benchmark conditions under which there are no organizational diseconomies of scale.

3.5 Shortcomings of the First ('Traditional') Approach

As we have seen above, the conditions for optimality of delegation are restrictive. For instance, absence of risk-aversion or limited liability constraints limits applicability to managerial hierarchies. Implementability of second-best allocations via delegation may be more relevant in procurement settings where the prime contractor is a large firm with deep pockets. On the flip side, the theory explains information rents of managers that cascade across vertical layers. If intermediate managers are more risk-averse than the owners, this makes it difficult to ensure coincidence of their objectives. These results suggest that costs will grow with the scale of the firm's operations, causing organizational diseconomies of scale, though explicit models of this phenomenon are still awaited.

A more serious problem with this approach is that it cannot ever explain why delegation may dominate centralization. This is simply a consequence of staying within the confines of the Revelation Principle.

Moreover, the constructed delegation mechanisms (e.g., under assumptions (3.1)–(3.2) of observability and top-down contracting) are vulnerable to collusion between agents. This is because the principal has to subsidize outsourcing from subcontractors, creating incentives for artificially exaggerating outsourced cost by the prime contractor. The prime contractor also would have an incentive to contract and communicate with the subcontractor *before* responding to the principal's offer, which may be difficult for the principal to prevent.

Yet another problem is that this approach cannot explain delegation to middlemen or managers that play no direct productive role. As explained above, it is generally strictly better for P to retain control and treat M as an information provider. This stems partly from the assumption of noncollusive behavior between supervisor and productive agents.

This motivates interest in literature which confronts these problems, by departing from the confines of the Revelation Principle.

4 Benefits of Delegation: Costly Communication and Contract Complexity

Reconsider the choice of DS versus C, where there are two productive agents. The question is whether the principal should delegate contracting with A_2 to A_1. A commonly alleged advantage of decentralization is that it utilizes the benefits of local information. This presumes that centralization is unable to take advantage of such local information. In the framework where the Revelation Principle applies, however, communication is costless and centralized decision-making can access the same information as any decentralized mode. Formalization of the 'local information' advantage of decentralization necessitates incorporation of constraints on what agents can report to the principal, or alternatively on the extent of information that can be processed by the principal.

Models of costly information processing in the mould of Radner (1993), Mount-Reiter (1995) or van Zandt (1996, 1997) are still in their infancy, and await extensions that incorporate incentive considerations. They model computations taking place in real time, and model advantages of decentralization in distributing information processing tasks throughout the organization, rather than concentrating it in one central authority. While this is undoubtedly an appealing idea, it requires modeling limits on information processing of the principal and agents. Modeling incentive compatibility constraints in such a context is difficult, since it requires modeling how agents divide their limited information processing capacity between attempting to game the principal for their own self-interest, and carrying out the computations they are authorized by their superiors.[10]

In order to avoid this foundational problem, an alternative approach is to introduce restrictions on communication between agents, rather than constrain their information processing capacities. Mechanisms are constructed under the assumption of 'unbounded rationality', but subject to these communication restrictions. MMR (1992) compare optimal centralized and decentralized mechanisms with an exogenous restriction on the size of the message space that can be used by any agent to communicate with others. In particular, if the upper bound on the size of the message space is not large enough to permit agents to communicate everything that they know, centralized decision-making cannot access all the information that delegation mechanisms utilize. For instance the mechanism DS allows production allocations between the two agents to be decided by A_1 on the basis of his

[10]Indeed, this decision itself is a higher order problem, quickly giving rise to an infinite regress of the form familiar in any model with 'decision costs'.

information about his personal cost θ_1, which he can only partially communicate to the principal. The restrictions on the size of the message space, however, are not explicitly modeled, and would likely require some underlying model of 'expertise' of suppliers not shared by P which restrict the vocabulary of communication between them, or the need to make decisions in real time where messages take time to be communicated.

The principal result in MMR (1992) is that: *DS strictly dominates C if (a) there is a finite message space for each agent, whereas costs lie on a continuum; (b) assumptions (3.1)–(3.3) of cost observability, top-down contracting and risk-neutrality hold; and (c) the cost function of agent A_i is multiplicatively separable between quantity produced q_i and the cost shock θ_i.* Note that this result applies irrespective of the size or nature of the message spaces, as long as they apply uniformly to both organizational regimes. Hence the comparison does not require any explicit model of communication costs. Note also this result pertains to DS and C with particular reporting structures (e.g., in C where agents either communicate simultaneously, or sequentially in two stages). So this does not establish the global optimality of delegation among the class of all possible mechanisms subject to the same message space restrictions. Part of the problem is that there is no general characterization so far available (analogous to the Revelation Principle) of the set of all possible feasible mechanisms in the presence of communication constraints.[11]

Nevertheless, the result captures the idea that delegated decision-making may be better able than most common versions of centralization to utilize 'local' information. Production assignments are selected by A_1 in DS on the basis of his information about own cost θ_1, which is finer than can be communicated to P. In general this 'flexibility' could be abused by A_1 to pursue his own interest at the expense of the principal: the restriction on communication also limits the ability of P to calibrate the outsourcing subsidy in DS precisely enough to ameliorate the problem of double marginalization of rents. Nevertheless MMR show that the added control loss is always outweighed by the advantage of better informed production decisions.

An alternative restriction which yields the same result concerns the number of contingencies in contracts. A contingency can be viewed as a statement of production targets and payments made to an agent, conditional on reports communicated by the agent. One measure of the complexity of a contract is the number of contingencies, since these have to written (often

[11] In particular the result described above does not exclude the possibility that a centralized mechanism with a more general multistage communication mechanism may be able to match the performance of DS. This is an open question for future research.

with the aid of lawyers) and read by third party enforcers (e.g., courts) at some cost. Accordingly contracts with more contingencies involve higher costs of writing and verification.

Of course in some situations this is not a good measure of complexity, e.g., when it is possible to express the contract in the form of a simple mathematical formula (the simplicity of which may be contrasted with the number of elements in the graph of the function, the complexity measure being considered here). A deeper analysis of complexity should be based on measures of complexity or computability of the mathematical formula that represents the contract.

The performance of DS and C can be compared with identical restrictions on the number of contingencies in contracts in either regime. Restricting contracts to finite complexity imposes limits not just on the size of message spaces of agents, but also of decisions (concerning production and payments) that can be taken on the basis of such reports. This further limits the flexibility advantage of DS over C, compared with the case where message space size is restricted. Despite this, it can be shown that *the superiority of DS over C still prevails under the same conditions as where message space sizes are restricted* (MMR (1997)). Production allocations can no longer be varied continuously by A_1; the contract can only specify a finite set of alternative production target configurations. Yet there is scope in DS for A_1 to choose flexibly among these different configurations based on his 'local' information which cannot be accessed by a centralized mechanism.

On the other hand if one or more of assumptions (3.1)–(3.3) do not hold then examples can be constructed whereby the ranking gets reversed, i.e., the exacerbation of the control loss outweighs the flexibility advantage, rendering C superior. Accordingly this theory succeeds in providing conditions when either of the systems (strictly) dominates the other. However there still remains the need to provide a deeper foundation of the notions of contractual complexity or communication costs employed in this branch of the literature.

5 Collusion Among Agents

We now describe a more recent and active strand of the literature evaluating delegation when agents collude, while all other traditional assumptions underlying the Revelation Principle are retained. Collusion affects the performance of both delegation and centralization. For instance we have already seen that the mechanisms constructed for DS that replicate outcomes of

the best centralized mechanism under conditions (3.1)–(3.3) are vulnerable to collusion among the agents. Optimal centralized mechanisms are also frequently vulnerable to collusion.[12] The question is how the two regimes compare in the presence of collusion.

One possible intuition for the virtues of delegation is that it already incorporates side-contracting among the agents, unlike centralization. However we shall see below that this intuition is difficult to make precise: when one models hidden side contracts in a particular way, a version of the Revelation Principle reappears, whereby centralization can replicate the outcomes of any delegation arrangement. Nevertheless, one can then explore the idea that delegation and centralization are equivalent under a broader set of circumstances when agents collude. In other words, delegation may be an optimal response to the presence of collusion among agents — if side contracting cannot be prevented, the principal may as well authorize it explicitly.

An additional reason to study collusion was mentioned previously: many instances of delegation are of the form DM, where authority is delegated to expert intermediaries or managers who play no role in actual production. In the absence of collusion P can costlessly obtain M's information and use this to design contracts for suppliers personally. Whereas delegation to M would not permit costless extraction of M's information, since it would form a source of information rents for M in contracting with the principal. However, the agents have a stake in bribing M to withhold his information under centralization. The presence of collusion would therefore prevent costless acquisition of M's information under centralization. In particular M would begin to earn rents under either regime in the presence of collusion, so the superiority of centralization is no longer obvious.

5.1 Modeling Collusion

Collusion is typically modeled as a side-contract between agents which is unobserved by P, and subject to asymmetric information within the coalition. Nevertheless many important details need to be specified concerning the nature of side-contracting game. How are these contracts negotiated, how does their timing relate to the proposal and acceptance stages of the contract offered by the principal? What is the range of decisions the agents

[12] Consider for instance a second price auction in which bidders can coordinate their bids and enter into hidden side-contracts that reallocate the good among themselves. There often exist such side contracts that are interim Pareto superior from the standpoint of the bidders.

can coordinate on, and what does the principal observe? How is the side-contract enforced?

The complexity of analysis of coalitional behavior under private information has motivated most authors to adopt assumptions that render the analysis as tractable as possible. Most of the literature follows the trend set by Tirole (1986) by ignoring all enforceability constraints by invoking role of long-term or other social relationships among agents. Only restrictions imposed by asymmetric information within the coalition (besides limited liability, if applicable) are imposed. At the same time their contractual relationship with the principal is short term and restricted to that defined by the formal contract.

It is also common to assume that side contract allows agents to coordinate reports to P, reallocate production assignments and payments between themselves. This corresponds to auction contexts where coordinated bid-rigging and hidden 'resale' of the good cannot be prevented by the seller. Since collusion occurs with asymmetric information, the Coase Theorem does not apply. Hence actual outcomes (e.g., production assignments) will depend on the allocation of bargaining power within the coalition. In turn this depends on who has the power to propose the side contract.

Laffont-Martimort (1998) assume that the organizational variant affects allocation of bargaining power: in DS A_1 makes a take-it-or-leave-it side contract offer to A_2, while in C a neutral third party designs the side contract for A_1 and A_2. This may seem natural in some ways: if the principal delegates authority for contracting with one of the agents to the other, it augments the bargaining power of the latter. Yet in the Laffont-Martimort (1998) formulation this is built in as an exogenous shift in bargaining power. An alternative would be to explain this shift endogenously. For instance, the reason that A_2 has more bargaining power *vis-a-vis* A_1 under centralization is that A_2 has the option of turning down the contract offered by A_1 and then playing the contract offered by the principal noncooperatively. Such an outside option is not available in DS – it is this that constitutes the source of A_1's monopsony power over A_2 under delegation.

The more recent literature models the endogenous effect of organizational structure on bargaining power within the coalition. Specifically, it is commonly assumed that one of the agents (denoted A^*, say) has the power to make a take-it-or-leave-it side-contract to the others. If the principal delegates subcontracting to A^*, then the other agents do not have the option of rejecting the subcontract and dealing with the principal on their own. Under centralization in contrast, they have the opportunity of rejecting the subcontract and playing the principal's game noncooperatively. This raises their outside option *vis-a-vis* A^*, effectively gaining bargaining power. The

extent to which they do so depends endogenously on the contract offered by the principal. The latter simultaneously defines the stakes of collusion for the agents, as well as their relative bargaining power.

A consequence of this formulation is that the difference between delegation and centralization boils down to this. If P delegates to A^* then all other agents have no alternative to the subcontract offered by A^*. Under centralization P offers a contract to all the agents, who now have the option of rejecting the side-contract offered by A^* and responding to P's offer non-cooperatively. Then centralization reduces to delegation if P offers a null contract to all agents but A^*. Therefore *a version of the Revelation Principle reappears: if the structure of the side contracting game is the same in different organizational variants (in the sense of who has the right to design the side-contract), then centralization is always weakly preferred to delegation.* Such a formulation cannot therefore permit delegation to dominate centralization. We are back to a question similar to that in the traditional first approach described above: is delegation costly relative to centralization?

5.2 Costs of Delegation with Collusion

In order to emphasize that centralization regime now incorporates collusion, we shall refer to the two variants of centralization (with and without M) by CMC and CC respectively. As before, we can phrase the key question either as comparison of CC and DS (should P delegate to one of two suppliers?), or of CMC and DM (should P delegate to a monitor/manager M?)

5.2.1 CC versus DS

This question is posed by Baliga-Sjostrom (BS, hereafter) (1998) in a model with moral hazard and limited liability. Two suppliers A_1, A_2 jointly produce an indivisible output for P. The probability of 'success' is increasing in the effort of each agent, which takes one of two possible values ('shirk' and 'work'). Production occurs sequentially, and the effort of one agent (A_1) is observed by the other (A_2) but not vice versa. The principal cannot observe efforts of either agent, and is constrained to pay them nonnegative wages (with zero as their respective outside options). The combination of moral hazard with limited liability gives rise to 'efficiency wage' information rents, and renders the Coase Theorem inapplicable. The stakes for collusion arise here whenever P tries to elicit A_2's information about A_1's effort: A_1 can bribe A_2 to withhold adverse information. BS do not model the actual process by which the side-contract is negotiated, using instead a notion of

an equilibrium side-contract as a Pareto-undominated side contract, given the principal's mechanism.

The main results of their paper are as follows: (i) In CC it is always optimal to use simple contracts with no communication, where P pays A_i a wage w_i in event of success and 0 otherwise; (ii) For a large range of parameter values, delegation is optimal (i.e., the best simple contract has either w_1 or $w_2 = 0$); and (iii) There exist other cases for which delegation is not optimal (e.g., if neither agent A_i is 'essential' enough that delegating to the other agent A_j would induce the latter to pay former a positive rent in event of success). The model thus captures the idea that in a large range of cases decentralization is an optimal response to collusion — the principal can implement the optimal centralized outcome under collusion by contracting with only one of the two agents and leaving that agent to subcontract with the other. The payment to the delegated agent is such that it motivates that agent to pay the other agent exactly the same efficiency wage as the principal desires, and leave the same amount for the delegated agent as well. However (iii) shows that such an implementation is not globally possible.

A similar comparison is carried out in an adverse selection framework of the kind described in previous sections by Mookherjee-Tsumagari (MT, hereafter) (2002). They find in contrast to the BS paper that delegation to a supplier is *always* strictly dominated by centralization. The essential reason is that the shift of bargaining power to A_2 that centralization allows the productive distortion inherent in DS to be reduced. Recall that this distortion took the form of 'insufficient outsourcing' from A_2. The need for A_1 to offer higher rents to A_2 in the centralized setting (where P offers a contract more favourable to A_2 than emerges in the solution to DS) forces A_1 to subcontract more to A_2, thus reducing the extent of the productive misallocation. In a sense, this is qualitatively similar to the cases studied by BS in which decentralization was not optimal: there centralization offers A_2 a positive efficiency wage which raises his effort, reducing the distortion arising in delegation when the delegated agent A_1 prefers to keep all the rents for himself and so does not pay any efficiency wage to A_2. The difference in results between the two papers could therefore reflect the fact that outputs and inputs are assumed to be divisible in the MT paper, enlarging the scope of distortions arising from A_1's monopsony power in delegation. Alternatively there are important distinctions between the moral hazard and adverse selection settings considered that drive their respective results.

5.2.2 DM versus CMC

Faure-Grimaud, Laffont and Martimort (FLM, hereafter)(2002) and Celik (2002) both consider the case of one productive agent A and one supervisor M. The former is privately informed about his own cost. The two papers adopt different assumptions about the nature of information available to M about this cost. FLM assume that the cost of the supplier takes two possible values, and M observes an informative signal which also takes two possible values. In contrast Celik assumes an arbitrary finite number of possible costs, with the information of M represented by a connected partition over the state space. Specifically, M can narrow down the agent's cost to a (connected) subset of possible cost levels, but cannot distinguish between different costs within this subset. Apart from the information structure, FLM allows for risk-aversion of M, whereas Celik assumes risk-neutrality, but this difference is less fundamental.

The results of these papers are strikingly different: *FLM find that delegation is always equivalent to centralization, whereas Celik finds that delegation is inferior in general (e.g., whenever the optimal contract for the agent in the absence of M is strictly monotone, and M is not perfectly informed about the agent's cost).* The intuition in Celik's paper seems similar to that in the MT paper: delegation to M is subject to a monopsony distortion, causing M to procure an insufficient amount from A that is not in the principal's interest. In particular, the optimal allocation involves incentive constraints that bind solely in the 'downward' direction, where more productive types of the agent are indifferent between underreporting and reporting truthfully. Centralization allows the principal to raise A's outside option in bargaining over the subcontract with M, reducing the extent of this monopsony distortion. In particular, since the agent's reservation utility with respect to the side-contract is strictly increasing in his productivity (owing to the agent's option of playing P's mechanism noncooperatively), it creates a set of 'countervailing' incentives for the agent to over- rather than underrepresent its productivity. This relaxation of the downward incentive constraints permits a reduction in the extent of underproduction. The pattern of incentive constraints and associated productive distortions in the FLM context are different, where 'upward' incentive constraints bind with delegation. In such a context creating countervaling incentives by raising the agent's outside option turn out not to be valuable for the principal.

Finally, MT (2002) compare CMC, DM and CC in the case of two productive agents A_1, A_2 and a perfectly informed M. Their motivation is to explore the idea that collusion may rationalize delegation to intermediaries uninvolved in production. This necessitates the presence of more than one

productive agent, since with M perfectly informed about the agents cost the principal gains nothing from M's presence.[13]

With M perfectly informed, there is effectively no asymmetric information within the coalition, so inducing changes in bargaining power within the coalition is not valuable for the principal and $DM = CMC$. Hence delegation is costless relative to the centralized alternative where P retains control and treats M as an information provider.

What is the value of hiring M when there are two productive agents? With M perfectly informed, DM reduces effectively to the case where the principal deals with a single consolidated agent that delivers both inputs at a cost equal to the sum of production costs of A_1 and A_2. Whereas if M is not hired, we have already explained that centralization (CC) is the better alternative than delegating to one of the suppliers (DS). So the value of hiring (and delegating to M) is effectively the same question as the effect of consolidating diverse suppliers, except that now we must consider the presence of collusion among the suppliers under centralization. MT show that exactly the same results concerning consolidation effects (discussed in Section 3.3 above) hold in the presence of collusion as well. Specifically, $DM < CC$ if the two agents produce substitutes, while $DM > CC$ if they produce complements and some additional distributional conditions are satisfied. In the latter case of supplier complementarity, therefore, DM is optimal among all the organizational modes considered: P is strictly better off hiring M, and then can delegate to him at no cost.[14] But in the substitutes case, it is strictly better for the principal to not hire M and contract personally with both suppliers.

6 Concluding Comments

In summary, most existing literature focuses on **costs** rather than the benefits of delegation. The latter are difficult to incorporate into traditional contract theory. Perhaps the most important benefit of delegation is the distribution of information processing tasks, but no progress has occurred in theories that marry information processing costs with incentives. Some progress has been possible with communication costs and simple measures of contract complexity, but these need better foundations.

[13]The coalition behaves the same way as the agent in the absence of M.

[14]However this result is driven by the assumption that M is perfectly informed about agents' costs. If M is imperfectly informed one expects delegation to M to be costly relative to CMC, but these costs ought to be small if M is 'sufficiently' well-informed.

The literature identifies a number of potential costs of delegation: moral hazard for intermediaries owing to noncoincidence of their own objectives with the principal's, and their monopsony power over subordinates. These can result in production distortions (insufficient sourcing from subordinates), cascading of information rents across vertical layers, and problems of coordinating different horizontal branches.

If agents do not collude, these agency costs of delegation can be avoided if the principal can monitor subcontract costs or quantitities, if contracts flow down the hierarchy, and agents are risk-neutral. If any one of these conditions do not hold then agency costs cannot be avoided. The only significant problem involves vertical control loss; if they can be avoided (under the above mentioned conditions) then incentive considerations do not complicate horizontal coordination across branches of the hierarchy.

If agents collude, centralization is also subject to unobserved side contracting among agents, creating similar distortions. However, centralization potentially allows greater control over side contracting outcomes by the principal offering outside options to subordinates that limit monopsony power of intermediaries. Depending on the precise distortions engendered, this added dimension of control may or may not be valuable. Overall, the presence of collusion among agents enlarges the range of circumstances where delegation implements optimal allocations.

There are numerous open questions and fruitful avenues for future research. I conclude by listing some of these.

First, a better understanding of effects of collusion is still needed. The few papers on this topic emerge with different results the intuitive basis for which is not very clear. One hopes a more unified perspective will emerge in due course. There is a need to explore implications of different formulations of side-contracting, e.g., more general assignment of bargaining power within coalitions, or alternative timing assumptions. Baron-Besanko (1999) provide an intriguing model in which agents themselves decide *ex ante* whether to consolidate themselves into a single entity, a decision which the principal observes and takes into account before offering a contract. In the models we described, the principal can anticipate a particular pattern of side contracting, but cannot observe whether or not the agents actually do side-contract. In contexts with more agents and vertical layers, the possibility of collusion-within-collusion further complicates the analysis.

Second, there needs to more effort in explaining the potential benefits of delegation. The need to insulate the organization from opportunistic *ex post* interventions by the principal is emphasized by the literature on incomplete commitment and contract renegotiation, issues we did not address

here. Alternatively, models integrating information processing or communication costs with incentive considerations would represent another promising research avenue.

A third possible avenue would consider applications and extensions to contexts involving more productive agents and a richer specification of the production technology. Questions concerning the optimal shape of hierarchies can then be addressed, e.g., trade-offs between span of control and number of vertical layers, how to group agents within departments, organizatonal diseconomies of scale, and the advantages of non-hierarchical organizations. Ultimately, one hopes that the theory can be used to deliver predictions that can be empirically tested, such as how optimal organizational form change with extent of product market competition or changes in information technology.

References

Aghion P. and J. Tirole (1997) "Formal and Real Authority in Organizations," *Journal of Political Economy* 105(1), 1-29.

Arrow K. (1974), *The Limits of Organization*, W.W. Norton, New York.

Baliga, S. and T. Sjostrom (1998), "Decentralization and Collusion," *Journal of Economic Theory,* 83:196-232.

Baron, D. P. and D. Besanko (1992), "Information, Control, and Organizational Structure," *Journal of Economics and Management Strategy,* 1:237-275.

Baron, D. P. and D. Besanko (1999), "Informational Alliances," *Review of Economic Studies,* 66:743-768.

Baron, David and David Besanko (1992) "Information, Control and Organizational Structure" *Journal of Economics and Management Strategy*, Vol 1(1), 367-384.

Beaudry P. and M. Poitevin (1995) "Contract Renegotiation: A Simple Framework and Implications for Organization Theory," *Canadian Journal of Economics*, 28, 302-335.

Bolton, Patrick and Mathias Dewatripoint (1994) "The Firm as a Communication Network", *Quarterly Journal of Economics*, 109, 4, 809-839.

Calvo, G. and S. Wellisz (1978) "Supervision, Loss of Control and the Optimal Size of the Firm" *Journal of Political Economy*, vol. 86, 943-952.

Cremer, J. and M. Riordan (1987) "On Governing Multilateral Transactions with Bilateral Contracts," *Rand Journal of Economics*, vol. 18, no. 3, 436-451.

Dessein, W. (2000), "Authority and Communication in Organizations", Graduate School of Business, University of Chicago. *Forthcoming in Review of Economic Studies.*

Faure-Grimaud, A. and D. Martimort (2001), "Some Agency Costs of Intermediated Contracting," *Economics Letters,* 71(1):75-82.

———————————- (1999), "Political Stabilization by an Independent Bureaucracy", mimeo, London School of Economics.

Faure-Grimaud, A., J.J. Laffont and D. Martimort (1998), "A Theory of Supervision with Endogenous Transaction Costs," mimeo, IDEI, University of Toulouse.

Faure-Grimaud, A., J-J. Laffont and D. Martimort (2002), "Collusion, Delegation and Supervision with Soft Information," University of Toulouse. *Forthcoming in Review of Economic Studies.*

Gilbert R. and M. Riordan (1995) "Regulating Complementary Products: A Comparative Institutional Analysis," *Rand Journal of Economics*, 26, 243-256.

Hammer M. and J. Champy (1993) *Reengineering the Corporation.* New York: Harper Collins.

Hart, O. (1995) *Firms, Contracts, and Financial Structure.* Oxford and New York: Oxford University Press, Clarendon Press, 1995.

Horngren, Charles and George Foster (1991) *Cost Accounting: A Managerial Emphasis, Seventh Edition*, Englewood Cliffs, NJ: Prentice-Hall Inc.

Laffont J. and D. Martimort (1998) "Collusion and Delegation," *Rand Journal of Economics* 29(2), 280-305.

Marschak T. and S. Reichelstein (1995) "Communication Requirements for Individual Agents in Networks and Hierarchies," *The Economics of Informational Decentralization: Complexity, Efficiency and Stability*, J. Ledyard (ed.), Boston: Kluwer Academic Publishers.

——————— (1999), "Network Mechanisms, Informational Efficiency

and Hierarchies," *Journal of Economic Theory.*

McAfee, Preston and John McMillan (1995) "Organizational Diseconomies of Scale" *Journal of Economics and Management Strategy*, 4(3), 399-426.

Melumad, Nahum, Dilip Mookherjee and Stefan Reichelstein (1995) "Hierarchical Decentralization of Incentive Contracts" *Rand Journal of Economics*, 26(4), 654-672.

———— (1992) "A Theory of Responsibility Centers" *Journal of Accounting and Economics* vol. 15, 445-484.

———— (1997) "Contract Complexity, Incentives and the Value of Delegation," *Journal of Economics and Management Strategy* 6(2), 257-289.

Mookherjee, D. and S. Reichelstein (1997), "Budgeting and Hierarchical Control," *Journal of Accounting Research,* 35(2): 129-55.

Mookherjee, D. and S. Reichelstein (2001), "Incentives and Coordination in Hierarchies," *Advances in Theoretical Economics,* 1(1).

Mookherjee, Dilip and Masatoshi Tsumagari (2002), "The Organization of Supply Networks: Effects of Delegation and Intermediation," mimeo, Department of Economics, Boston University.

Mount K. and S. Reiter (1995), "A Theory of Computing with Human Agents," working paper, Department of Economics, Northwestern University.

Myerson R. (1982), "Optimal Coordination Mechanisms in Generalized Principal Agent Problems," *Journal of Mathematical Economics.*

Poitevin, Michel (1995), "Contract Renegotiation and Organizational Design," mimeo, CIRANO Working Paper No. 95-3, Montreal.

Poitevin, M. (2000), "Can the Theory of Incentives Explain Decentralization?," *Canadian Journal of Economics,* 33(4):878-906.

Radner, Roy (1992) "Hierarchy: The Economics of Managing" *Journal of Economic Literature* vol. 30, 1382-1415.

———— (1993) "The Organization of Decentralized Information Processing," *Econometrica* vol. 61, no. 5, 1109-1146.

Segal, I. (2001), "Communication Complexity and Coordination by Authority," *mimeo,* Department of Economics, University of California, Berkeley.

Severinov, S. (1999), "Optimal Organization: Centralization, Decentraliza-

tion or Delegation?," *mimeo,* Department of Economics, University of Wisconsin, Madison.

Tirole, J. (1986), "Hierarchies and Bureaucracies: on the Role of Collusion in Organizations," *Journal of Law, Economics and Organization,* 2(2):181-214.

van Zandt, Timothy (1996) "Decentralized Information Processing in the Theory of Organizations," in *Contemporary Economic Development Reviewed, Volume 4: The Enterprise and its Environment*, Murat Sertel (Ed.), London: Macmillan Press.

———— (1997), "Real-Time Hierarchical Resource Allocation," mimeo, Department of Economics, Princeton University.

Williamson, Oliver (1967) "Hierarchical Control and Optimal Firm Size," *Journal of Political Economy* 123-138.

———— (1985) *The Economic Institutions of Capitalism* New York, Free Press.