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A Theory of Authority in Bilateral Contracting

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Abstract

ìTwo players are involved in a joint project during which a decision must be reached. Each player has private information about future profits. Authority gives one player the right to decide first in a pre-defined set of alternatives. In this framework, I show that (partial) authority should be assigned to the player who gets the highest share of the total surplus. This organizational architecture replicates the performance of an optimal revelation mechanism without the cost of hiring a third party acting as a principal.

Keywords: Contract, asymmetric information, control rights, limited liability, hidden information.

JEL Classification: D23, D82, G32, L22.

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1   Introduction

Authority or control rights defined as "the right to decide" is a major issue in organizations and, more generally, in contract relationships. It affects not only the distribution of benefits among contracting partners, but also the performance of the whole organization. As a result, it is one of the central issues raised during contractual negotiations.

Over 40 years ago, Herbert Simon defined authority as the right to select actions from a set of alternatives affecting part or the whole of an organization.[1] More recently, Aghion and Tirole (1997) added that authority may result from an implicit or explicit contract allocating the right to decide on specified matters to a member or a group of members in the organization. Beyond this definition, authority is a relative concept: there may be various degrees of authority leading to several levels of delegation. Decisions are more or less precise, leaving freedom and initiative to subordinates. In short, a hierarchical structure is determined by who has authority and on what.

Who should hold authority in organizations? The incomplete contract approach gives us a clear answer: when partners make non-contractible profit-enhancing investments, authority should be assigned to the partner who's investment yields the higher marginal benefit to the organization (Grossman and Hart, 1986). This approach relies on the assumption of non-contractible features such as specific investments and future outcomes. It mainly stresses the fact that control rights are allocated as a means of alleviating such contract incompleteness. The theory of Aghion and Tirole (1997) on formal and real authority has the same flavor. The partners' specific investments consist of information gathering on projects'returns.

With complete contracts and private information, the answer is less clear. The old saying that "knowledge is power" suggests that the distribution of information within the organization should matter. This is certainly the case when only one

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[1] "We will say that B [the "boss"] exercises authority over W [the "worker"] if W permits B to select x [an element in the set of specific actions W performs]. That is, W accepts authority when his behavior is determined by B's decision. In general, W will accept authority only if x_0, the x chosen by B, is restricted to some given subset (W's "area of acceptance") of all possible values. This is the definition of authority that is most generally employed in modern administrative theory." (Simon 1951, p. 294)

agent in an organization has private information. In standard principal-agent models, the informed player reveals his information by selecting an allocation in the menu of contracts via a message. In doing so, he exerts full authority. The principal is quite passive: he, at most, executes the action selected by the agent. With more than one informed player, for instance in bilateral asymmetric information, the picture is different. On the one hand, assigning full authority to one player might not be any more efficient since valuable information is lost when this player takes all decisions without referring to its partner. This case calls for partial authority, to some level of delegation. On the other hand, the *Revelation principle* tells us that any organizational architecture cannot beat centralization of authority in the hands of an uninformed third party. This third party collects all private information and then takes the best decision (see, for example, Myerson, 1982). However, this principle relies on the existence of such an uninformed and benevolent third party, immune to collusion, renegotiation or others manipulation of information. It also assumes unlimited and costless communication, as well as full commitment on messages.[2]

The aim of this paper is to propose a complete-contract theory of authority in a multi-private information organization. In a two-sided asymmetric information framework, I show that the bilateral organization can do as well as with an uninformed third party *via an appropriate hierarchical structure*. Hence, this third party is useless. Additional incentive problems and inefficiencies induced by collusion (e.g. Laffont and Martimort, 1997, Beliga and Sjöström, 1998) or costly communication (e.g. Memulad, Mookerjee and Reichelstein, 1997, Radner 1993) can be avoided. Moreover, I show that whoever has authority might matter. The optimal assignment of authority depends mainly on the partners' bargaining power or, more generally, on how the total surplus is divided.

The model considered here is one of hidden information with limited liability. After contracting, each partner has private information which affects future profits. The two partners subsequently coordinate on decisions. Contracts are written contingently on future events, all perfectly foresighted. The contract specifies who has authority and on what. It allows for various degrees of delegation.

More precisely, the partners agree on a menu of allocations (decisions and pay-

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[2]See Poitevin 2000 for a survey on other motives for non-trivial allocation of authority once some assumptions underlying the revelation principle are relaxed.

ments) contingent on future states of nature and on a hierarchical structure. The hierarchical structure stipulates who has authority (the leader) and on what set of alternatives. I define authority by *the right to choose first* in a set of alternatives. This set of alternatives is pre-defined in the contract. When making its choice (i.e. choosing amongst alternatives), the leader conveys some information to its partner. Then the other player (the subordinate) picks up an allocation in the selected set of alternatives. By doing so, it also reveals its own information along the equilibrium path. In this sense, authority defines a *sequence of communication*, with the leader communicating before the subordinate. This sequence of communication affects the incentives to reveal information truthfully in a perfect Bayesian equilibrium. Formally, it affects the incentive-compatible constraints.

In the paper, I first consider a message game in the traditional mechanism design sense as a benchmark. The two agents send messages to an uninformed and benevolent third party who then selects an allocation in the contract menu. The allocations implemented in a direct revelation mechanism of this game are second-best. They satisfy *interim* incentive-compatible constraints for each player (i.e. in expectation of its partner's information given its own information). According to the Revelation principle, the agents' second-best (expected) payoffs constitute upper bounds on what can be achieved in a Bayesian equilibrium. Then I allow only for sequential communication amongst the two agents, i.e. sequential mechanisms. The incentive-compatible constraints are still in their *interim* form for the leader but they must hold now *ex post* for the subordinate. These constraints are therefore more stringent, meaning that the performance of the organization (i.e. the expected total surplus to be shared amongst the agents) can be affected. It turns out that the second-best (expected) payoffs can be achieved in bilateral contracting by the right sequence of communication. This sequence assigns the first move to the player who gets the higher share of the whole surplus.

Our model describes many real interactions. In a supplier-retailer relationship or upstream-downstream relationship within a firm, the supplier/upstream production unit has private information about its production costs whereas the retailer/marketing unit has superior data about the state of the demand. They must coordinate on a production level, on the design and/or the quality of the product. In technological alliances between pharmaceutical companies and biotech start ups, these two firms coordinate on a project to develop a new drug. The

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first firm has better knowledge of the drug market value whereas the later has a better idea of its chemical properties. Another example is the implementation of a polluting production plant. The project involves the polluting firm which is well aware of its private benefit from producing the polluting goods, the victims of the pollution, and the environmental regulation agency which has better information on the environmental damage. The two partners must coordinate on emission levels.[3]

In the economic literature, the framework closest to the present one is Maskin and Tirole's (1990) principal-agent model with an informed principal, with private values. However, Maskin and Tirole assume that the players contract when they are already informed, whereas here they contract in a situation of symmetric information. Maskin and Tirole consider an adverse selection problem whereas our framework is one of hidden information with limited liability. They suppose that the principal has all bargaining power whereas I allow for any distribution of bargaining powers. Several papers address the issue of delegated contracting in a principal-two agents model (e.g. Melumad, Mookherjee and Reichelstein (1995), Laffont and Martimort, 1998 in adverse selection models; Baliga and Sjöström, 1998, Pérez-Castrillo and Macho-Stadler, 1998, in moral hazard models). They show that the performance of an optimal revelation mechanism can be replicated, or is dominated (in case of collusion), by a three-tier hierarchy, wherein the principal contracts with only one agent and delegates to that agent the authority to contract to the other agent. Here I focus on authority and delegation of decision-making in bilateral contracts *without* a principal.[4] Another branch of the literature analyzes delegation of authority as an alternative to communication when, due to contractual incompleteness, communication entails inefficiencies (e.g. Bester, 2003, Cremer, 1995, Dessein, 2002, Krähmer, 2002). Here authority determines the way information is communicated, one way being more efficient than another.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 studies the second-best allocations, that is, the allocations implemented in a direct mechanism with an uninformed third player as a benchmark. The

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[3]Note that, consistently with the model, in all these examples information has a private value. See Maskin and Tirole (1990) for other examples.

[4]Note that a principal is defined here as an uniformed player who collects message and then selects an allocation.

implementation of these second-best allocations in bilateral contracting under two hierarchical structures is analyzed in Section 4. Finally, Section 5 contains concluding remarks.

2 The model

Two agents, 1 and 2, undertake a joint project during which a decision x (e.g. production, quality, price) must be reached. I assume $x \in \mathbb{X}$ where $\mathbb{X}$ is a compact set. The relationship is initiated by a contract. After the contract is signed, each player i observes a random variable θ_i which represents i's private information. Assume $\theta_1 \in \{L, H\}$, and $\theta_2 \in \{l, h\}$.

Player i has state-contingent preferences over action x defined by $u_i(x, \theta_i)$. The function u_i is monotonic, continuously differentiable and concave on x. In Maskin-Tirole's terms, private information has private value. It is assumed that Player 1 prefers H to L in the precise sense that $u_1(x, H) > u_1(x, L)$ for any action $x > 0$. Symmetrically, Player 2 prefers h to l, that is $u_2(x, h) > u_2(x, l)$ for any $x > 0$. Let $\Delta u_1(x) = u_1(x, H) - u_1(x, L)$ and $\Delta u_2(x) = u_2(x, h) - u_2(x, l)$. Examples of such functions include profits, production costs, revenue from marketing a product, and utility functions.[5]

In this framework, a state of nature is a vector $\theta = (\theta_1, \theta_2)$, often simply denoted as $\theta_1 \theta_2$. There are four states of nature: Hh is the best state, Hl and Lh are two medium states, and Ll is the worst state. The set of states of nature is denoted $\Omega = \{Ll, Hl, Lh, Hh\}$. Denote $p(\theta)$ the probability of θ, $p(\theta_i)$ the probability of θ_i, and $p(\theta_i | \theta_j)$ the probability of θ_i given the realization of θ_j. I put no restriction on these probabilities except that they are all strictly positive.[6]

The organization surplus (or the project return) is denoted $\pi(x, \theta) = u_1(x, \theta_1) + u_2(x, \theta_2)$ for every state of nature $\theta \in \Omega$. I assume that it is strictly concave and non-negative over $\mathbb{X}$, and attains its maximum value at a single point x_θ^*. Players perform transfers amongst themselves. We denote t^i the transfer received by i.

An allocation is a vector $a = (x, t^1, t^2)$. An allocation rule $\mathcal{A}$ is a menu of

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[5]Note that they satisfy the single-crossing (often called Mirless-Spence) condition.

[6]In particular, I allow for some correlation of information (except, of course, full correlation). Note that Cremer and MacLean's full extraction of the result in case of correlated information (Cremer and McLean, 1988) does not hold here because I assume limited liability.

allocations $a_\theta = (x_\theta, t_\theta^1, t_\theta^2)$ contingent on each state of nature $\theta \in \Omega$. A contract $\mathcal{C}$ is defined by:

- an allocation rule $\mathcal{A} = \{a_\theta\}_{\theta \in \Omega}$;

- an assignment of authority $L \in \{1, 2\}$ on a set $\mathcal{P}(\mathcal{A})$ of alternatives A.

Formally, $\mathcal{P}(\mathcal{A})$ is a partition of $\mathcal{A}$. Authority gives to Player L, the "leader", the right to choose an alternative $A \in \mathcal{P}(\mathcal{A})$. The other player, the "subordinate", labelled S, selects an allocation $a \in \hat{A}$. We will say that L exerts *full authority* if the set of alternatives is the menu of actions: $\mathcal{P}(\mathcal{A}) = \{\{a\} \in \mathcal{A}\}$. In contrast, L exerts *partial authority* if $\mathcal{P}(\mathcal{A})$ is any coarsest partition of $\mathcal{A}$ (except, of course, $\mathcal{P}(\mathcal{A}) = \{\mathcal{A}\}$).

The sequence of actions is as follows.

1. The two players get together and agree to some contract $\mathcal{C}$.

2. Each agent i observes its private information θ_i.

3. The contract is carried out.

   3.1 The leader L chooses an alternative $\hat{A} \in \mathcal{P}(\mathcal{A})$.

   3.2 The subordinate S chooses an allocation $\hat{a} \in \hat{A}$.

   3.3 The decision is executed and transfers are paid as prescribed by the contract.

I do not explicitly model the bargaining process at Stage 1. I derive the equilibrium contract for any outcome of the bargaining process. Formally, denoting Player i's expected payoff $U_i = E_\theta[u_i(x_\theta, \theta_i) + t_\theta^i]$ for $i = 1, 2$, the agreement divides the total surplus $E_\theta[\pi(x_\theta, \theta)]$ into two shares U_1 and U_2 so that:

$$U_1 + U_2 = E_\theta[\pi(x_\theta, \theta)]. \tag{1}$$

I will analyze the equilibrium contract for any divide (U_1, U_2) of the surplus.[7]

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[7]The model thus encompasses all forms of bargaining solutions. For instance, in principal-agent models, the principal, say i, has all bargaining power up to the agent's reservation utility. In this case, U_j denotes the agent's reservation utility while the principal gets $U_i = E_\theta[\pi(x_\theta, \theta)] - U_j$. In bargaining games, $U_i = (E_\theta[\pi(x_\theta, \theta)] - \underline{U}_i)^\lambda$ and $U_j = (E_\theta[\pi(x_\theta, \theta)] - \underline{U}_j)^{1-\lambda}$ where $\lambda \in (0, 1)$ represents i's bargaining power and $\underline{U}_i$ and $\underline{U}_j$ represent the players' outside options.

I assume that both players are protected by limited liability: their payoff cannot be negative. This restriction on ex post payoff is endogenized by assuming that any agent can quit the relationship at any stage (or that they cannot commit ex ante not to do so ex post).[8]

3 Second-best decisions

In this section, I wish to characterize the best decisions that can be implemented in the above framework. For this purpose, I adopt a mechanism design approach. I consider a (fictitious) message game as a benchmark. I identify the allocation implemented by a direct revelation mechanism of this message game. In other words, I suppose that a benevolent and uninformed third party can centralize all information. Formally, I consider the following contractual execution subgame at Stage 3 in the above game:

3.1 Each player i sends a message $\hat{\theta}_i$ to a third party.

3.2 The third party selects the allocation $a_{\hat{\theta}_1 \hat{\theta}_2}$. It orders to execute $x_{\hat{\theta}_1 \hat{\theta}_2}$ and to pay $t_{\hat{\theta}_1 \hat{\theta}_2}$ as prescribed by the contract.

I focus on the optimal allocations implemented in Perfect Bayesian Equilibrium (PBE) of this message game in which all information is truthfully revealed to the Principal. These allocations are called the second-best allocations and denoted $\{a_\theta^{sb}\}_{\theta \in \Omega} = \{x_\theta^{sb}, t_\theta^{1sb}, t_\theta^{2sb}\}_{\theta \in \Omega}$. These second-best allocations maximize the organization surplus $E_\theta[\pi(x_\theta, \theta)]$ subject to the following constraints, for every $\theta \in \Omega, \theta_i, \theta_i', \theta_i \neq \theta_i', \theta_j, i = 1, 2, j = 1, 2$:

$$
\begin{aligned}
E_\theta[u_i(x_\theta, \theta_i) + t_\theta^i] &\geq U_i & IR^i \\
E_{\theta_j}[u_i(x_{\theta_i \theta_j}, \theta_i) + t_{\theta_i \theta_j}^i | \theta_i] &\geq E_{\theta_j}[u_i(x_{\theta_i' \theta_j}, \theta_i) + t_{\theta_i' \theta_j}^i | \theta_i] & IC_{\theta_i}^i \\
u_i(x_\theta, \theta_i) + t_\theta^i &\geq 0 & LL_\theta^i \\
t_\theta^1 + t_\theta^2 &= 0 & BB_\theta
\end{aligned}
$$

The first two constraints IR^1 and IR^2 are individual rational or participation constraints stipulating that each agent accepts the contract. The second set of

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[8]Another way to endogenize the limited liability constraint is to suppose that players can undertake an action $a = 0$ that gives 0 payoff. See Sappington (1993) for detailed justifications of this assumption.

constraints, $IC^i_{\theta_i}$ for $i = 1, 2$ are incentive-compatible constraints, stipulating that i has incentive to report truthfully her or his information for $i = 1, 2$. The third set of constraints, LL^i_θ for every $\theta \in \Omega$, and $i = 1, 2$ are limited liability constraints, stipulating that i gets a positive payoff in every state of nature. The last constraints BB_θ are budget balance constraints that make sure that transfers are balanced in each state of nature.

The revelation principle ensures that the second-best surplus $E_\theta[\pi(x^{sb}_\theta, \theta)]$ is the higher expected benefit that the two partner can achieve with a revelation mechanism. Hence, this game provides an upper bound on total surplus. For my purpose, I focus only on decisions $\{x^{sb}_\theta\}_{\theta \in \Omega}$ as part of any second-best allocation. I establish two propositions.

Proposition 1 *The second-best decisions are first-best only if*
$U_1 \geq p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$ *and* $U_2 \geq p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_1 l})|h]$.

Proof: I show that if $\{x^*_\theta\}_{\theta \in \Omega}$ is implemented then $U_1 \geq p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$. First, $LL^1_{L\theta_2}$ satisfied implies $t^1_{L\theta_2} \geq -u_1(x^*_{L\theta_2}, L)$ for $\theta_2 = l, h$. Together with IC^1_H satisfied, these two limited liability constraints imply:

$$E_{\theta_2}[u_1(x^*_{H\theta_2}, H) + t^1_{H\theta_2}|H] \geq E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]. \tag{2}$$

Moreover, $LL^1_{L\theta_2}$ satisfied for $\theta_2 = l, h$ imply:

$$E_{\theta_2}[u_1(x^*_{L\theta_2}, L) + t^1_{L\theta_2}|L] \geq 0. \tag{3}$$

Multiplying (2) by $p(H)$ and (3) by $p(L)$ and summing up the two equations yield:

$$E_\theta[u_1(x^*_\theta, \theta_1) + t^1_\theta] \geq p(H)E_{\theta_1}[\Delta u_1(x^*_{L\theta_2})|H]. \tag{4}$$

That is $U_1 \geq p(H)E_{\theta_1}[\Delta u_1(x^*_{L\theta_2})|H]$.

A symmetrical proof can be computed to show that if $\{x^*_\theta\}_{\theta \in \Omega}$ is implemented then $U_2 \geq p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_1 l})|h]$. $\square$

Proposition 1 implies that for the first-best decisions to be implemented, players' expected utility (or reservation utility) must be high enough but not too high.[9]

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[9]Recall that $U_1 \geq p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$ implies
$U_2 \leq E_\theta[\pi(x^*_\theta, \theta)] - p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$; and $U_2 \geq p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_1 l})|h]$ implies $U_1 \leq E_\theta[\pi(x^*_\theta, \theta)] - p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_1 l})|h]$ due to total surplus sharing as defined in Equation 1.

We assume that, when U_1 and U_2 satisfy Proposition 1 bounds, first-best decisions can be implemented. That is, there exist transfers $\{t_\theta^1, t_\theta^2\}_{\theta \in \Omega}$ satisfying all constraints with decisions $\{x_\theta^*\}_{\theta \in \Omega}$.

Before proceeding, we need to introduce new notation. For $\theta_1 = L, H$, define $x_{\theta_1 l}^{m2}$ as the (unique) decision satisfying

$$\pi'(x_{\theta_1 l}^{m2}, \theta_1 l) - \frac{p(h|\theta_1)}{p(l|\theta_1)} \Delta u_2'(x_{\theta_1 l}^{m2}) = 0,$$

and, for $\theta_2 = l, h$, define $x_{L\theta_2}^{m1}$ as the (unique) decision satisfying:

$$\pi'(x_{L\theta_2}^{m1}, L\theta_2) - \frac{p(H|\theta_2)}{p(L|\theta_2)} \Delta u_1'(x_{L\theta_2}^{m1}) = 0.$$

With this new piece of notation, I can now set out the following results.

Proposition 2 *The second-best decisions $\{x^{sb}(\theta)\}_{\theta \in \Omega}$ satisfy:*

- $x_{L\theta_2}^{m1} \leq x_{L\theta_2}^{sb} < x_{L\theta_2}^*$ *and* $x_{H\theta_2}^{sb} = x_{H\theta_2}^*$, *for any* $\theta_2 = l, h$, *when*
  $p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^{m1})|H] \leq U_1 < p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^*)|H]$.

- $x_{\theta_1 l}^{m2} \leq x_{\theta_1 l}^{sb} < x_{\theta_1 l}^*$ *and* $x_{\theta_1 h}^{sb} = x_{\theta_1 h}^*$, *for any* $\theta_1 = L, H$, *when*
  $p(h)E_{\theta_1}[\Delta u_2(x_{\theta_1 l}^{m2})|h] \leq U_2 < p(h)E_{\theta_1}[\Delta u_2(x_{\theta_1 l}^*)|h]$.

Proof: To satisfy Player 1's limited liability and incentive constraints when $U_1 < p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^*)|H]$, transfers must be set at $t_{L\theta_2}^1 = -u_1(x_{L\theta_2}, L)$ for $\theta_2 = l, h$. Then IC_H^1 implies $E_{\theta_2}[t_{H\theta_2}^1 - u_1(x_{H\theta_2})|H] = E_{\theta_2}[\Delta u_1(x_{L\theta_2})|H]$. Player 1's expected payoff is $U_1 = p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2})|H]$ while Player 2's is $U_2 = E_\theta[\pi(x_\theta, \theta)] - p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2})|H]$. The last expression takes its maximum value at $\{x_{Ll}^{m1}, x_{Lh}^{m1}, x_{Hl}^*, x_{Hh}^*\}$ and $U_1 = p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^{m1})|H]$. When U_1 increases (and therefore U_2 decreases), the total surplus $E_\theta[\pi(x_\theta, \theta)]$ is increased by an increase of x_{Ll} and x_{Lh} from bottom values x_{Ll}^{m1} and x_{Lh}^{m1} up to optimal values x_{Ll}^* and x_{Lh}^*. Hence, for any U_1 between $p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^{m1})|H]$ and $p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^*)|H]$, $x_{L\theta_2}^{sb}$ for $\theta_2 = h, l$ range between $x_{L\theta_2}^{m1}$ and $x_{L\theta_2}^*$. The proof is symmetric for the second part of Proposition 2. □

Proposition 2 contains two kinds of information. First, it identifies conditions on players's payoff values such that first-best decisions cannot be implemented

and, therefore, some second-best decisions are indeed implemented. Second, it characterizes these second-best decisions.

It is easy to understand Proposition 2 by referring to the seminal principal-agent model as a special case of our model. Recall that in standard principal-agent models, the principal retains all bargaining power up to the agent's reservation utility usually normalized to 0. However, in order to induce truth-telling, the contract assigns an informational rent to the agent.[10] This information rent corresponds to the supplementary (expected) payoff the agent can gain by pretending its utility is low when it is actually high (formally $p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2})|H]$ for 1 and $p(h)E_{\theta_1}[\Delta u_2(x_{\theta_2 l})|h]$ for 2). The distorted decisions solve a trade-off between maximizing the total surplus and minimizing the informational rent. They are lower than the first-best actions. The minimized informational rent gives a lower bound on the agent's payoff.

When the agent gets more bargaining power, that is U_j increases and becomes higher than the informational rent, then the distorted decisions increase and move closer to the first-best ones. Finally, the first-best decisions can be implemented once U_j is equal to or higher than the information rent with first best decisions, namely $p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$ for 1 and $p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_2 l})|h]$ for 2. When U_j becomes so high that U_i is lower than i's informational rents at first-best decision levels, first-best decisions cannot be implemented anymore. The general picture is illustrated in Figure 1 below.

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[10]Note that limited liability is the key assumption implying that, contrary to d'Aspremont and Gérard-Varet (1979), first-best decisions cannot be implemented for extreme bargaining powers. Moreover, this assumption deviates from Mookherjee and Reichelstein's (1992) framework in which Bayesian incentive-compatible decisions can be implemented in dominant strategies.
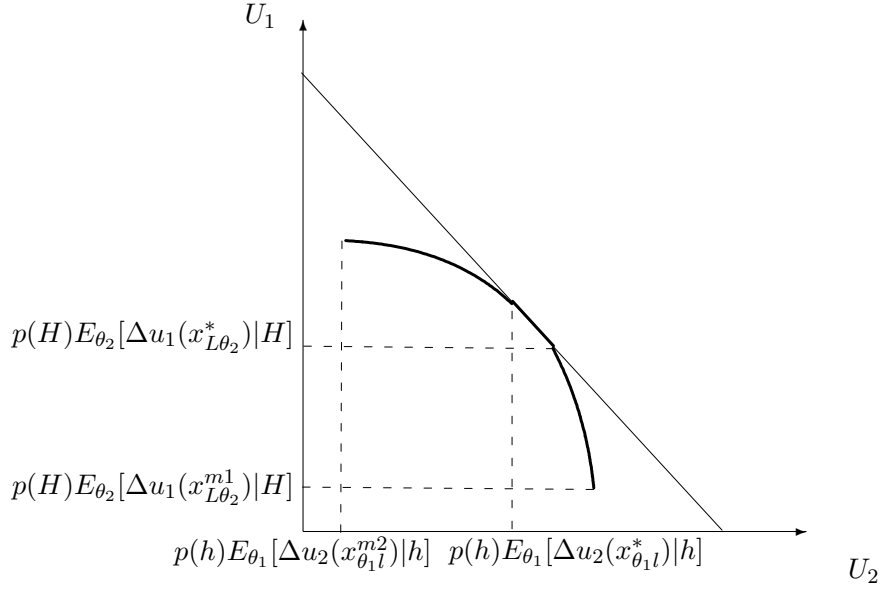
Figure 1

The thin line represents any split (U_1, U_2) of the full information expected profit $E_\theta[\pi(x_\theta^*, \theta)]$. The thick line represent any splits (U_1, U_2) of the second-best expected profit $E_\theta[\pi(x_\theta^{sb}, \theta)]$, that is the maximal utility levels that can be achieved with incentive-compatible contracts. First-best surplus is attained (with asymmetric information) when the thick line crosses the thin line. Otherwise, it is strictly below it. The distance between the two lines increases with the gap between U_1 and U_2. For extreme values of U_1 and U_2, no incentive-compatible contract can be designed.[11] We now turn to bilateral contracting.

4   Second-best implementation in bilateral contracting

In this section I focus on two specific allocations of partial authority. I consider the cases of 1 having partial authority on $\mathcal{P}(\mathcal{A}) = \{\{a_{Ll}, a_{Lh}\}, \{a_{Hl}, a_{Hh}\}\}$ and 2

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[11]This is mostly due to limited liability which forces the player who has bargaining power to allow its partner an informational rent.

having partial authority on $\mathcal{P}(\mathcal{A}) = \{\{a_{Ll}, a_{Hl}\}, \{a_{Lh}, a_{Hh}\}\}$. In the first case of 1's partial authority, the contract is carried out in this 1-partial authority subgame:

3.1 Player 1 chooses a subset $\hat{A} \in \{\{a_{Ll}, a_{Lh}\}, \{a_{Hl}, a_{Hh}\}\}$.

3.2 Player 2 chooses an allocation $\hat{a} \in \hat{A}$.

3.3 The decision is executed and transfers are paid as prescribed by the contract.

The second case is symmetric.

An allocation $\{a_\theta\}_{\theta \in \Omega}$ can be implemented as PBE of the i-partial authority game (for $i = 1, 2$) if it satisfies the following constraints, for any $\theta_i, \theta_i', \theta_i \neq \theta_i'; \theta_j, \theta_j', \theta_j \neq \theta_j'$,

$$
\begin{aligned}
E_\theta[u_i(x_\theta, \theta_i) + t_\theta^i] &\geq U_i & IR^i \\
E_\theta[u_j(x_\theta, \theta_j) + t_\theta^j] &\geq U_j & IR^j \\
E_{\theta_j}[u_i(x_{\theta_i \theta_j}, \theta_i) + t_{\theta_i \theta_j}^i | \theta_i] &\geq E_{\theta_j}[u_i(x_{\theta_i' \theta_j}, \theta_i) + t_{\theta_i' \theta_j}^i | \theta_i] & IC_{\theta_i}^i \\
u_j(x_{\theta_i \theta_j}, \theta_j) + t_{\theta_i \theta_j}^j &\geq u_j(x_{\theta_i \theta_j'}, \theta_j) + t_{\theta_i \theta_j'}^j & IC_{\theta_i \theta_j}^j \\
u_i(x_\theta, \theta_i) + t_\theta^i &\geq 0 & LL_\theta^i \\
u_j(x_\theta, \theta_j) + t_\theta^j &\geq 0 & LL_\theta^j \\
t_\theta^1 + t_\theta^2 &= 0 & BB_\theta
\end{aligned}
$$

This set of constraints includes the same individual rationality, limited liability and budget balance constraints as those in the benchmark game. Player i's incentive constraint are also unchanged. They still hold in expectation because i does not know j's information when making its decision. However, Player j's incentive constraint must now hold for each state of nature θ rather than only in expectation. To be precise, IC_θ^j tells us that, given that i has revealed its information by selecting a subset in its decision set, j has incentive to select the right decision, thereby revealing its own information. In other words, j takes the decision with full information but restricted alternatives.

Proposition 3 *A contract implements second-best decisions by assigning authority to:*

- *Player 1 when $U_1 \geq p(H) E_{\theta_2}[\Delta u_1(x_{L\theta_2}^*) | H]$,*

- *Player 2 when $U_2 \geq p(h) E_{\theta_1}[\Delta u_2(x_{\theta_1 l}^*) | h]$.*

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Other assignments of authority might not implement the second-best decisions.

Proof: The proof proceeds in two steps. First, I show that the second-best decisions can be implemented when Player 1 has authority for $U_1 \geq p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$. The second part (i.e. Player 2) is symmetric. Second, I provide an illustrative example in which the second-best decisions cannot be implemented when authority is assigned contrary to what Proposition 3 recommends.

Step 1: $\{x^{sb}_\theta\}_{\theta \in \Omega}$ can be implemented when Player 1 has authority for $U_1 \geq p(H)E_{\theta_2}[\Delta u_1(x^*_{L\theta_2})|H]$.

Suppose that $p(h)E_{\theta_1}[\Delta u_2(x^{m2}_{\theta_1 l})|h] \leq U_2 \leq p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_1 l})|h]$. Consider the second-best allocation $\{a^{sb}_\theta\}_{\theta \in \Omega}$ that satisfies $x^*_{\theta_1 h} = x^*_{\theta_1 h}$ for $\theta_1 = H, L$; $x^{sb}_{\theta_1 l} \in [x^{m2}_{\theta_1 l}, x^*_{\theta_1 l}]$ and $U_2 = p(h)E_{\theta_1}[\Delta u_2(x^{sb}_{\theta_1 l})|h]$ for $\theta_1 = H, L$; $t^2_{\theta_1 l} = -u_2(x^{sb}_{\theta_1 l}, l)$ and $t^2_{\theta_1 h} = -u_2(x^*_{\theta_1 h}, h) + \Delta u_2(x^{sb}_{\theta_1 l})$ for $\theta_1 = H, L$, $t^1_\theta = -t^2_\theta$ for every $\theta \in \Omega$. It is easy to show that this second-best allocation satisfies all the constraints associated with the 1-partial authority game. In particular, $LL^1_{\theta_1 h}$ for $\theta_1 = H, L$ writes $u_1(x^*_{\theta_1 h}, h) + t^1_{\theta_1 h} = \pi(x^*_{\theta_1 h}, \theta_1 h) - \Delta u_2(x^{sb}_{\theta_1 l})$. Adding and subtracting $u_1(x^{sb}_{\theta_1 l}, \theta_1)$ yields $\pi(x^*_{\theta_1 h}, \theta_1 h) - \pi(x^{sb}_{\theta_1 l}, \theta_1 h) + \pi(x^{sb}_{\theta_1 l}, \theta_1 l)$ which is strictly positive since $\pi(x^*_{\theta_1 h}, \theta_1 h) > \pi(x^{sb}_{\theta_1 l}, \theta_1 h)$ for $\theta_1 = H, L$. Hence, the two constraints LL^1_{Hh} and LL^1_{Lh} are satisfied. For higher U_2, transfers t^2_θ can be increased to satisfy the constraints associated with the 1-partial authority game.

Step 2: Example where $\{x^{sb}_\theta\}_{\theta \in \Omega}$ is not implemented when partial authority is assigned to 1 when $U_2 < p(h)E_{\theta_1}[\Delta u_2(x^*_{\theta_1 l}|h]$.

Consider a vertical relationship between a retailer/a marketing unit labelled 1 and a supplier/a production unit labelled 2. They contract/design an organization to produce x units. The production unit incurs production costs $\theta_2 x$ while the marketing unit enjoys a total receipt $(\theta_1 - x)x$. In this case, $\theta_2 \in \{l, h\}$ stands for (constant) unit production costs and $\theta_1 \in \{L, H\}$ represents the level of demand. Preferences are defined by the following functions:

- $u_1(x, \theta_1) = (\theta_1 - x)x$.

- $u_2(x, \theta_2) = -\theta_2 x$,

The profit is $\pi(x, \theta) = (\theta_1 - x)x - \theta_2 x$. Its is maximized at $x^*_\theta = \dfrac{\theta_1 - \theta_2}{2}$ for every $\theta \in \Omega$, and yields $\pi(x^*_\theta, \theta) = \dfrac{(\theta_1 - \theta_2)^2}{4}$.

To be consistent with the general framework, it is assumed that $H > L$ and $h < l$.[12] Suppose that θ_1 and θ_2 are independent and identically distributed with equal probability $\frac{1}{2}$ to be low or high. To guarantee interior solutions with these parameters, we impose $L - l > H - L$ and $L - l > l - h$.

Now suppose that U_2 is at its lower bound in Proposition 2, formally $U_2 = p(h)E_{\theta_1}[\Delta u_2(x_{\theta_1 l}^{m2})|h]$. For the functional forms assumed here, $x_{Ll}^{m2} = \frac{2L - H - l}{2}$ and $x_{Hl}^{m2} = \frac{L - l}{2}$. The second-best decisions $\{x_{Ll}^{m2}, x_{Hl}^{m2}, x_{Lh}^{*}, x_{Hh}^{*}\}$ can only be implemented with transfers $t_{\theta_1 l}^2 = -u_2(x_{\theta_1 l}^{m2}, l) = -t_{\theta_1 l}^1$ for $\theta_1 = H, L$ so that Player 2 is left on its limited liability or participation constraint ex-post in states Ll and Hl.

Suppose that, contrary to what Proposition 3 recommends, partial authority is assigned to Player 2. Assume that the state of nature is Ll. Then, after Player 2 has selected $\{a_{Hl}, a_{Ll}\}$, Player 1 prefers to select a_{Hl} rather than a_{Ll}. By doing so he gets $u_1(x_{Hl}^{m2}, L) + t_{Hl}^1 = \pi(x_{Hl}^{m2}, Ll)$ instead of $u_1(x_{Ll}^{m2}, L) + t_{Ll}^1 = \pi(x_{Ll}^{m2}, Ll)$. Since $x_{Hl}^{m2} = x_{Ll}^{*}$ in this example, then $\pi(x_{Hl}^{m2}, Ll) = \pi(x_{Ll}^{*}, Ll) > \pi(x_{Ll}^{m2}, Ll)$. This destroys incentive-compatibility. Of course, since the model is symmetric, the same exercise can be reproduced for Player 1 having authority when $U_1 = p(H)E_{\theta_2}[\Delta u_1(x_{L\theta_2}^{m1})|H]$.□

The above result is twofold. First, it tells us that a bilateral contract can achieve the second-best outcome. Therefore, players can avoid contracting with a third party. Second, it shows that authority or decision rights matter. For some realistic parameters, the second-best outcome can be achieved only with the appropriate assignment of authority. In the proof, I provide an example in which the second-best decisions cannot be implemented with an unsuitable assignment of authority. Hence, a wrong hierarchical structure might lead to Pareto dominated outcomes. Figure 2 below provides a graphic representation of Proposition 3.

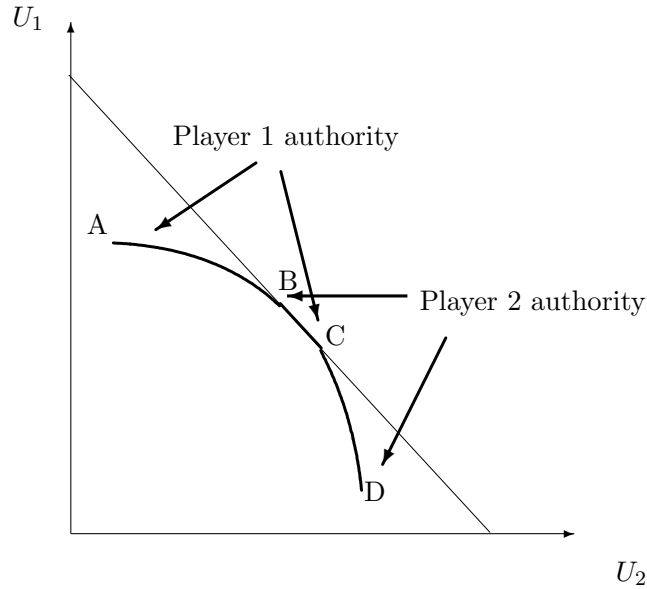[12]This ensures that $u_2(x, l) > u_2(x, h)$ for every $x > 0$.

Figure 2

The second best expected surplus in thick curve ABCD can be achieved i) with Player 1's authority but not necessarily with Player 2's authority on the part AB; ii) with either Player 1's or 2's authority on the part BC; iii) with Player 2's authority but not necessarily with Player 1's authority on the part CD. The result can be summarized as follow.

Theorem *Authority goes together with a higher share of the surplus.*

5   Concluding comments

I conclude with three brief comments. Firstly, the above theorem finds some empirical support in Lerner and Merges (1998). Lerner and Merges analyze an original data set on technological alliances between drug companies and biotech start-ups. As mentioned above, these alliances are contracts signed to develop, produce and sell new drugs. Pharmaceutical companies provide biotech firms with financial resources to cover their development costs. These deals explicitly specify

the allocation of control rights in several tasks (e.g. management of clinical trials, manufacture of final product, marketing, right to expand the alliance) which, according to interviewed managers, seems to be "a central issue" raised during the negotiations. The authors found strong evidence that the allocation of control rights depends mainly on the financial condition of the biotech firm. Biotech firms in bad financial condition tend to retain less control rights; suggesting that biotech firms' control is negatively correlated with drug companies' investment. This empirical result is consistent with our theorem: for higher investment levels, the drug company asks for a higher share of the total surplus and, therefore, is more likely to retain authority.

Secondly, the efficient hierarchical architectures stipulate partial and not full authority. This is because all private information has valuable for the organization. Some form of delegation is therefore needed to benefit from the subordinate's information. Full authority would naturally arise in a one-sided asymmetric information framework. In this case, the second-best allocation is implemented by letting the informed player choose a single decision in the contract menu, as in principal-agent models.

Lastly, the analysis is reduced to bilateral contracting among risk-neutral partners. An interesting extension would be to introduce risk aversion into agents' preferences. By moving incentive constraints from ex-ante to interim, the allocation of authority affects risk-sharing. The efficient assignment of authority would then trade-off risk-sharing and bargaining power. Another extension would be to generalize the model to more than two contracting partners. These extensions are, of course, beyond the scope of the present paper.

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