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CONTRACT RENEGOTIATION AND ORGANIZATIONAL DESIGN

by

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ABSTRACT

This paper studies the implications of non-commitment for organizational design. An organizational form must trade-off between the coordination benefits associated with the centralization of information and its associated costs in terms of renegotiation. The analysis makes precise what these benefits and costs are. First, I characterize renegotiation-proof allocations for organizational forms that differ in the amount of decentralization that they support. Second, I compare these different organizational forms. The analysis shows that (1) complete decentralization of decision-making is always weakly dominated by a more centralized structures when information is dispersed in the organization; (2) the player with the most important or relevant information should be the decision-maker.

1 Introduction

It is an ongoing preoccupation of business managers to find the optimal decision-making structure for their firm. For example, suppose a new project comes up in a firm. The first important decision that must be made regarding the management of this project is how to design the relationship between the firm and the manager of this new project. One aspect of this important decision is how much autonomy should be given to the project's manager as opposed to the firm's owners or managers, namely, should decision-making for this project be centralized to the firm's top decision-makers, or should it be decentralized to the manager of the relevant project.

Milgrom and Roberts (1992) provide some examples in which the internal organization of the firm has played a central role in achieving success and high profitability. One striking example is that of General Motors. The internal reorganization of General Motors undertaken by Alfred Sloane in the early 1920's was motivated by a much needed change in its marketing strategy which in turn had to be implemented by a modification of its decision-making structure. Of concern was the feeling that some decisions had to be decentralized to the different divisions of the company, but at the same time, some coordination of decisions had to be maintained to ensure that the different divisions would not compete against each other. This reorganization was critical to the fact that within the next twenty years General Motors became the clear leader of the industry surpassing Ford and its highly centralized organization. Milgrom and Roberts also give the example of the early rivalry between the North West company and the Hudson's Bay company to capture the North American market for animal furs. Again, in this example, organizational design was a clear determinant of the success or failure of these rivals.

Although the problem of organizational design is central to business managers, economists still do not understand all facets of the problem. With a complete set of contingent markets and no market imperfections, the First Theorem of Welfare states that the Walrasian equilibrium is Pareto optimal. Organizational design then plays no role. Organizational design matters when markets are incomplete. For example, in the presence of asymmetric information, there cannot exist markets contingent on the private information detained by one or a group of agents. An organization can then arise as a substitute to these missing markets by allowing agents to write contingent contracts. Private information is then a sufficient condition for the emergence of firms.

Even if one admits that asymmetric information is a sufficient condition for the existence of organizations, economists do not know much about how such organizations should be internally structured, namely, should decision making be centralized or decentralized. In fact, the Revelation Principle (Myerson, 1979) states that any allocation attained by a complex decentralized organization can always be replicated by a simple centralized organization in which all agents report (truthfully) their private information to some central authority which then recommends, based on these reports, actions to be undertaken by the agents. This principle states that centralization is always (weakly) preferred to decentralization. This seems to be at odds with casual empirical observation. In most organizations, be they public or private, players seem to recognize the benefits of some decentralization of decision making. It is therefore a challenge for economists to understand rigorously the relative benefits and costs of decentralization.

An important aspect of the Revelation Principle is that it holds in environments in which players are committed not to renegotiate the initial contract once their private information has been reported. A centralized organization is based on an extensive communication network between players that produces the optimal decision as the result of a complete coordination of the available information. Such centralization may not be feasible if players can renegotiate the initial contract following communication of their private information, thus invalidating the Revelation Principle (see Holmström and Myerson (1983) and Beaudry and Poitevin (1995) for a discussion of this basic point).

The approach taken in this paper is to suppose that organizations act as substitute for incomplete markets because of the presence of asymmetric information. Within the organization, players cannot commit not to renegotiate past agreements every time communication occurs. For example, a contract signed between two players in the presence of asymmetric information may trade off between the efficiency of the allocation and the costs of providing players with incentives for revealing their private information. This trade-off generally involves incorporating in the contract some distortions (ex post inefficiencies) to elicit the players to reveal their private information. The problem is that, in general, these distortions are time-inconsistent, that is, once the players have reported their private information there is no reason to maintain allocative distortions. Thus, if players are not committed not to renegotiate the contract they will effectively renegotiate it. These observations have lead economists to study "renegotiation-proof" contracts.[1]

[1]For example, Fudenberg and Tirole (1990), Laffont and Tirole (1990), Dewatripont (1988, 1989), Hart

Renegotiation arises because players have an opportunity to communicate after the contract has been signed. Since renegotiation generally reduces their ex ante welfare, players may seek ways to commit not to communicate. The organizational design defines the communication channels that will govern the relationships between players. It is therefore natural to think that the design of communication channels takes into account the potential for harmful renegotiation. The organizational design then becomes a credible commitment towards the prevention of renegotiation.

Consider the following simple example. Two players form an organization. Player 1 is the principal and player 2, the agent. Suppose the two players sign a contract (setup the organization) at date 0. At date 1, the agent receives some private information that is payoff relevant to the two players. For example, the agent may be a production manager who learns about a new technology. The state of technology affects his utility cost of effort as well as the principal's value of production. Production occurs at date 2 after which payoffs for the two players are realized. It turns out that, even in this simple setting, organizational design can have a significant impact on the efficiency of the organization.

Consider an organization where the contract linking the two players is an incentive-compatible menu of production–wage pairs that are contingent on the agent's verifiable report of his private information. Such organization is quite vulnerable to renegotiation. The contract requires the agent to send a *verifiable* message to the principal on which production and transfer payments depend. Such communication modifies the set of alternatives that the two players can renegotiate, that is, once the agent has sent his verifiable message, the contract specifies which production–wage pair should be chosen among all those specified in the menu of the contract. The two players then have a fairly precise idea of their payoff if they do not renegotiate the contract. Consequently, if renegotiation occurs following the verifiable message it may be quite easy for the two players to agree to some new contract that improves on the chosen production–wage pair, and this even if such renegotiation potentially arises under asymmetric information. In this case, renegotiation may undo some of the incentives built in the contract, thus reducing the ex ante efficiency of the organization.

Consider now an organization where the contract is a mapping from production levels to transfer payments. The agent produces at a level of his choice, and his remuneration is contingent on the chosen production level as specified by the contracted mapping. Such

and Tirole (1988), Beaudry and Poitevin (1993, 1994), Maskin and Tirole (1992), all study the effect of renegotiation on contracts with asymmetric information.

organization is not as vulnerable to renegotiation as is the previous one. Even though some communication may take place, it is not verifiable as the contract specifies that the wage depends on the production level, not on the content of communication between the two players. Unverifiable communication does not change the set of alternatives that can occur if renegotiation is rejected. It is therefore almost impossible for the two players to agree on a Pareto improving contract, and renegotiation cannot be successful. Furthermore, renegotiation cannot succeed once the agent has produced since then only the wage needs to be paid, and the players cannot agree on whether to reduce it or increase it. Renegotiation then has very little effects on the ex ante efficiency of the organization.

The two types of organization just described differ in the nature of communication between the principal and the agent. By committing to some communication channels players can mitigate the effects of renegotiation. Such commitment can be interpreted as an assignment of rights to the players. When communication is verifiable, it is as if the principal retains the right to produce, therefore *centralizing* to herself the production decision. The contract then promises a given payoff to the agent contingent on the production level. This implies that communication must be verifiable for the agent to trust the principal into producing at the contracted level after learning his information. Verifiable communication then allows the principal to coordinate her production decision on the agent's information.

When no verifiable communication takes place, it is as if the principal gives her production rights to the agent, thus *decentralizing* the production decision to the agent. The contract then promises to sell the production to the principal at a pre-specified price. This implies that no communication is necessary to implement a production level. The agent has complete autonomy over production. He can use his information and the specification of payoffs in the initial contract to produce at the required level.

With this interpretation, the concepts of centralization and decentralization within an organization have the same interpretation as in an economy. Centralization means that the principal retains all rights and the agent has no autonomy over production decisions, while decentralization means that the principal relinquishes his right to produce to the agent who then has full autonomy over the production decision. The only difference between an organization and an economy is that, within an organization, payoffs are endogenously given through the initial bargained contract. In an economy, payoffs are given by exogenously determined market prices. Despite this difference, the similarity between the two environments justifies using the concepts of centralization and decentralization when discussing the design of communication channels and decision-making within the organization.

The assumption that players cannot commit not to renegotiate ex post has important consequences for our understanding of internal organizational design. If full commitment is possible, the two types of organizations are often equivalent (see Melumad and Reichelstein, 1987, for a characterization). When full commitment is not possible, however, organizational design matters. A decentralized organization limits the scope for ex post opportunism by limiting verifiable communication; a centralized organization cannot achieve such commitment, and is thus vulnerable to renegotiation. Ex ante, players should design a decentralized organizational form.

The superiority of decentralization over centralization within an organization may not, however, be robust to the presence of *bilateral* private information. Suppose both the principal and the agent possess some private information. For example, the principal may have some information about demand, while the agent knows better the state of technology. Optimal coordination requires that the production decision be based on the two players' information. The organizational form must be setup to coordinate the private information of the two players, while at the same time avoid costly (in terms of renegotiation) communication channels. There is a trade-off here between coordination and limited verifiable communication. The optimal organizational design is then represented by a contract which optimally achieves this trade-off.

With bilateral private information many different contracts are possible. A completely *centralized* organization is governed by a contract that specifies a menu (matrix) of production–wage pairs contingent on the verifiable reports of the two players. After learning their private information, both players make a report, and the executed production–wage pair depends on these reports. Such organization requires full verifiable communication, and hence yields maximal coordination of the available information. It also allows, however, for strong renegotiation possibilities since full verifiable communication reduces the set of implementable alternatives if renegotiation is rejected. It is then easy for the two players to agree to some Pareto improving contract.

A completely *decentralized* organization is governed by a contract that specifies a mapping from production levels into wages. After learning his private information the agent decides on a production level based on the contracted mapping between output and wage and his own private information (but not that of the principal). A completely decentralized organization eliminates all verifiable communication, and hence reduces the problem of renegotiation at the expense, however, of minimal coordination of information. The efficiency of the organization is then reduced because the production decision is based on very limited information.

With one-sided private information, only these two types of organization exist, that is, those with full verifiable communication (centralized) and those with no verifiable communication (decentralized). With bilateral private information, however, there exist hybrid types with partial verifiable communication. In a *hierarchical* organization, the principal may communicate her information to the agent who then makes the production decision based on this report and his own private information. It is governed by a contract that specifies a whole menu of different mappings of production levels into wages where the choice of a specific mapping is contingent on the principal's report. In a hierarchy, partial verifiable communication leaves some scope for renegotiation, but not as much as in a centralized organization since, following one-way communication, the set of implementable alternatives is still fairly large (a whole production–wage mapping). It may then be hard for the players to agree on what constitutes a Pareto improving allocation. A hierarchical organization allows some coordination through partial communication, but it also opens the door to some renegotiation which affects its ex ante efficiency.

The first objective of this paper is to characterize implemented allocations for all three types of organizational forms in environments with bilateral private information. The second objective is to compare these allocations to study (1) the determinants of decentralization in an organization and (2) the flow of information inside the organization.

There is a recent literature that studies the determinants of organizational form. Laffont and Martimort (1994) show how organizational design becomes a credible commitment against collusion. In a model with two regulators they show that separation of powers between these two regulators reduces their potential for discretionary behavior. The separation of powers limits the information each regulator can extract from the firm, which is shown to limit collusive behavior. This literature (see the citations in Laffont and Martimort) focuses on collusive behavior to invalidate the Revelation Principle and to explain decentralization. It is complementary to this paper which focuses on commitment problems.

The basic idea that organizational form can resolve commitment problems has been proposed by Milgrom (1988) in a model of moral hazard. Milgrom shows that, if ex post opportunism results in wasteful influence activities, decentralization of certain decisions to players that care about them may be an optimal response to prevent these activities. I focus on the design of communication channels as a means of coordinating and preventing renegotiation.

Melumad, Mookherjee, and Reichelstein (1990, 1991) compare the relative efficiency of different hierarchical structures when communication costs are exogenously imposed. For example, they show that decision-making should be decentralized to a better informed agent if he cannot communicate all of his information to the principal. In this paper, I endogenize or make precise what is the nature of these communication costs when full commitment is not possible.

The next section describes the economic environment. Section 3 presents the analysis for the one-sided private-information case. Section 4 provides a characterization of the implemented allocations for the different organization forms in the bilateral private-information case. Section 5 compares the different types of organizations. A conclusion follows.

2 The model

Two players form an organization to produce two actions a_1 and a_2. Player i physically executes action a_i. Actions are irreversible once executed. I denote by $a = (a_1, a_2)$ the vector of action-pairs. I assume that $a \in \mathcal{A}$ where $\mathcal{A}$ is a compact set. The environment in which the organization evolves is stochastic. The variables θ_1 and θ_2 parameterize the uncertainty. Each realization of the variable θ_i is drawn from a finite set $\Theta_i = \left\{\theta_i^L, \ldots, \theta_i^H\right\}$. The two variables are independently distributed. The probability of θ_1^x is $\pi_x > 0$, and the probability of θ_2^y is $p_y > 0$.

Player 1, the principal, has state-contingent preferences over an action-pair a defined by $U(\theta_1, \theta_2, a)$. The function U is monotonic, continuously differentiable, and concave in a for all θ_1 and θ_2. Player 2, called the agent, has state-contingent preferences over an action-pair a defined by $V(\theta_2, a)$. The function V is monotonic, continuously differentiable, and concave in a for all θ_2. Note that the agent's preferences do not depend on θ_1. The opposite would unnecessarily complicate the analysis. I assume that the principal and the agent have opposite preferences over a_1 and a_2, that is, $\text{sign}\, U_{a_i} = \text{sign} - V_{a_i}$ for $i = 1, 2$. The agent has reservation utility $\bar{v}$. These assumptions ensure that the contractual problem is well behaved.

In this environment, an allocation is a matrix of action-pairs where each entry is associated with a possible realization of the states of nature. Denote an allocation by $\mu = \{a^{xy}\}_{x,y=L}^{x,y=H}$, where a^{xy} is the executed action-pair in states θ_1^x and θ_2^y.

Consider the following example. An agent is hired to execute production. The variable θ_2 represents the productivity of the technology used to produce the units of output, and θ_1, the level of demand. The action a_2 represents the amount of units produced, while a_1 is a transfer from the principal to the agent. This transfer can be interpreted either as the agent's wage, or as the amount of resources that the central office transfers to the agent's division. The agent's preferences are $V(\theta_2, a) = v(a_1) - e(a_2, \theta_2)$ where $e(a_2, \theta_2)$ represents the agent's cost of producing a_2 units with the technology θ_2. The principal's preferences are $U(\theta_1, \theta_2, a) = P(\theta_1)a_2 - c(a_2, \theta_2) - a_1$ where $P(\theta_1)$ represents the price at which the units are sold, and $c(a_2, \theta_2)$, the cost of producing a_2 units with technology θ_2. With an appropriate choice of the functions v, e, P, and c, this example would satisfy all the above assumptions. Even though this is an interesting example, in what follows I stick with the more general formulation.

Events unfold as follows. Before the states of nature are revealed, the two players get together and agree to some organizational form. An organization is a commitment to some form of verifiable communication between the two players. Once the organization is in place, nature chooses states θ_1 and θ_2. The required verifiable communication takes place, thus inducing the execution of an action-pair a. Finally, payoffs are realized.[2]

The organizational form is implemented by a contract that the two players sign before the states of nature are realized. The form of the contract dictates the communication channels through which players coordinate on an action-pair, and thus the allocation that is implemented. This allocation depends on the type of contract that can be written and on the process by which the contract is chosen and carried out. A contract has the following general structure.

Definition 1 *A **contract** c (or mechanism) is defined by*

1. *A menu of actions $m(c) = \{a^{n_1,n_2}\}_{n_1,n_2=1}^{N_1,N_2}$ where $a^{n_1,n_2} \in \mathcal{A}$ for all n_1, n_2;*

[2]This framework is one of hidden information as the two players contract before the states of nature are realized.

2. *A verifiable communication structure through which the two players coordinate on an element of the menu.*

A contract has some important features. First, it allows for mechanisms other than direct revelation mechanisms since it is precisely the nature of the communication channels that is under investigation here. Second, the coordination on a given action-pair is achieved through the communication stage. The form of communication is derived endogenously and typically depends on the informational environment as well as on the commitment possibilities. Third, attention is restricted to contracts that only specify choices over deterministic outcomes. Finally, I assume that a contract is enforceable.

The first objective of the paper is to characterize the constraints that renegotiation imposes on implemented allocations and analyze how different contractual arrangements can alter these constraints. This is achieved by constructing a finite (renegotiation) game with the following features. I assume that players have already signed a (status quo) contract: after observing their private information, they communicate, possibly renegotiate; and finally, they execute the agreed-upon action-pair. Different organizational forms result in different communication and renegotiation outcomes in this renegotiation game. The resolution of this game can be used to derive conditions for an allocation to be robust to the possibility of renegotiation for a given organizational form. Such allocation is supported by a status quo contract that is not renegotiated along the equilibrium path of the renegotiation game.[3]

The second objective of the paper is to compare the welfare of the two players under different organizational forms. For each organizational form, there are typically many allocations that are robust to renegotiation. I therefore focus on the (constrained) efficient allocation that maximizes the ex ante expected utility of the principal subject to a participation constraint for the agent, and to conditions for it to be renegotiation-proof. The comparison is then made on the basis of these allocations.[4]

[3] This same approach has been used by Maskin and Tirole (1992).

[4] One reason why the renegotiation game is not extended to include an initial contract proposal stage that would endogenize the status quo contract is that an equilibrium renegotiation-proof allocation may fail to exist in such a game. This nonexistence result is, however, only caused by the fact that the game is finite. In a finite game, players can use the last stage of the game to commit to distortions which would be renegotiated away had the game one more renegotiation stage. The last stage may then allow players to implement the optimal full-commitment allocation. This approach is not satisfactory and is therefore discarded in favor of the one above.

Before proceeding with the analysis of private information, I will characterize the optimal allocation under symmetric information. Suppose first that the states of nature become common knowledge and verifiable after they are revealed. Consider the following game.

1. The principal offers a contract c_0.
2. The agent can accept or reject it. If he rejects it, the game ends, and both players receive their reservation utility.
3. In the third stage (if reached), the players publicly observe the states θ_1 and θ_2.
4. The executed action-pair is that prescribed by the element of the menu $m(c_0)$ corresponding to the observed states.

This game has a simple structure and the communication channels are trivial. The contract specifies a menu of action-pairs to be selected contingently on the realization of the states of nature. The players publicly observe the realized states of nature, and simply execute the action-pair from the contracted menu corresponding to the realized states.

For this game, the principal's strategy is to make a contract offer at the initial stage. The agent's strategy is to accept or reject any offer the principal may make. Throughout the paper, the equilibrium concept used is that of Perfect Bayesian Equilibrium (PBE) as defined in Fudenberg and Tirole (1991).

It is easy to show that any equilibrium allocation μ^{si} is a solution to the following maximization problem.[5]

$$(1) \qquad \begin{array}{ll} \max_{\{a^{xy}\}} & \sum_x \pi_x \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \\ \text{s.t.} & \sum_x \pi_x \sum_y p_y V(\theta_2^y, a^{xy}) \geq \bar{v} \end{array}$$

The equilibrium strategies are the following: the principal offers the contract c^{si} with associated menu $m(c^{si}) = \mu^{si}$; the agent accepts all contracts yielding an expected utility of at least $\bar{v}$.

[5]For simplicity I assume that the two players must stay in the organization following the realization of the states of nature. First, this a reasonable assumption when studying ongoing organizations, and second, the case where the agent could leave after the realization of θ_2 could also be studied using the technique of this paper.

The equilibrium allocation specifies an action-pair for each possible realization of θ_1 and θ_2. The contract helps players coordinate on an action-pair as well as providing them with some risk sharing. Organizational form is a matter of indifference in this framework. It is as if contingent markets were complete. The states of nature are verifiable and no communication is necessary. The players simply execute the action-pair corresponding to the realized states.

The equilibrium allocation is ex ante as well as ex post efficient. Ex post efficiency arises because the two players agree on which action-pair to execute following the realization of the states of nature. There is therefore no room for successful renegotiation. Such unanimity over which action-pair should be executed may be lost if the states of nature were privately observed. In the next section, I study the case in which θ_1 is single-valued and the realization of θ_2 is privately observed by the agent. Section 4 looks at the bilateral private-information case in which player i privately observes the realization of θ_i.

3 The one-sided private-information case

Results for the one-sided private-information case provides some intuition on the effect of renegotiation (or non-commitment) on optimal organizational design. Suppose that θ_1 is single-valued and $\theta_2 \in \Theta_2$. Organizational forms differ in the way players can communicate. Communication channels affect the incentives to reveal private information, and also the possibility for renegotiation at different stages. Two means of communication are considered. First, the players can communicate *verbally* and *verifiably*. The contract would then specify that, once the agent has observed θ_2, he must make a report to the principal. This report is verifiable and conditions which element of the contracted menu is to be implemented by the principal. Second, the agent can communicate *physically*. The contract then specifies that the agent executes a specific action level a_2 among all those specified by the different elements of the contracted menu. The principal then undertakes her own action a_1 based on the action selected by the agent and the contracted menu. In both cases, the contract specifies payoffs for each possible action-pair.

The presence of incentive constraints generally introduces ex post distortions in the allocation. Under full commitment, these distortions can be sustained ex post since no renegotiation is allowed. Under limited commitment, however, players cannot commit not to renegotiate. They may then try to use renegotiation to eliminate such distortions. I now characterize renegotiation-proof allocations under the two alternative communication structures when the two players cannot commit not to renegotiate.

Given an initial contract, renegotiation can occur at two instances. First, players can renegotiate after the agent has learned his private information, but before he selects an element of the menu. This is referred to as *interim renegotiation*. Second, renegotiation can occur after the agent has selected an element of the menu. This is *ex post renegotiation*. Beaudry and Poitevin (1995) show that interim renegotiation has no effect on the set of allocations implemented under full commitment.[6] I therefore focus on ex post renegotiation.

Ex post renegotiation is introduced by allowing one renegotiation round after the agent has communicated his private information to the principal. Consider the following renegotiation game in which players start out with an arbitrary status quo contract c_0.[7]

1. The agent observes the state of nature θ_2.

2. The agent selects an element $s_0 \in m(c_0)$.

2.1 The principal can offer a new contract c_1 to the agent.

2.2 The agent can then accept or reject this new offer.

2.3 If it is accepted, the agent selects an element $s_1 \in m(c_1)$.

3. The executed action-pair is that prescribed by the element s of the outstanding contract c.

For this game, a strategy for the principal consists in offering a renegotiation in stage 2.1 for every element $s_0 \in m(c_0)$ that the agent may have selected. The agent must communicate with the principal for every possible states of nature he might have observed by selecting an element in the menu of the status quo contract c_0; accept or reject the renegotiation offer after any history so far; and if he accepts the renegotiation c_1, he must communicate again with the principal by selecting an element in the menu of the accepted contract c_1.

The approach used here is to characterize those allocations that are supported by a status quo contract which is not renegotiated along the equilibrium path even though it is possible to do so. Allocations satisfying this property are called renegotiation-proof.

[6]This result is reminiscent of the "Groucho Marx" theorem proved in Milgrom and Stokey (1982).

[7]In this game, only the principal is allowed to make renegotiation offers. This is meant as a simplifying feature which has no bearing on the qualitative results.

Definition 2 *A **renegotiation-proof allocation for the renegotiation game** is an equilibrium allocation of the renegotiation game which is supported by a status quo contract that is not renegotiated in stage 2.1 along the equilibrium path.*

The characterization of renegotiation-proof allocations depends on whether communication from the agent to the principal is verbal or physical. Suppose the organizational form is such that all communication is verbal. The agent selects (verifiably) an element of the menu $m(c_0)$. This may communicate some information to the principal who may then try to renegotiate the contract. The following proposition provides a characterization of renegotiation-proof allocations when communication is verbal.[8]

Proposition 1 *Suppose communication is verbal. An allocation $\{a^{xy}\}_y$ is renegotiation-proof if and only if it satisfies the following conditions.*

$$(i)\quad V(\theta_2^y, a^y) \geq V(\theta_2^y, a^{y'}) \quad \forall y, y'$$

$$(ii)\quad \text{For all } y',\ \sum_{y\in\mathcal{Y}\left(a^{y'}\right)} p^y U(\theta_1, \theta_2^y, a^y) \geq$$

$$\left\{ \max_{\{\alpha^y\}_{y\in\mathcal{Y}\left(a^{y'}\right)}} \sum_{y\in\mathcal{Y}\left(a^{y'}\right)} p^y U(\theta_1, \theta_2^y, \alpha^y) \ s.t. \begin{array}{l} V(\theta_2^z, \alpha^z) \geq V(\theta_2^z, a^z)\, \forall z \in \mathcal{Y}\left(a^{y'}\right) \\ V(\theta_2^z, \alpha^z) \geq V(\theta_2^z, \alpha^{z'})\, \forall z, z' \in \mathcal{Y}\left(a^{y'}\right) \end{array} \right\}$$

where $\mathcal{Y}\left(a^{y'}\right) = \left\{y \text{ such that } \theta_2^y \in \Theta_2 \text{ and } a^y = a^{y'}\right\}$.

This proposition provides a characterization of renegotiation-proof allocations when communication is verbal. These allocations must satisfy standard incentive-compatibility constraints and a set of constraints imposed by the requirement of renegotiation-proofness. The conditions (ii) state that the equilibrium allocation must be such that, conditional on her updated information following the agent's selection in the menu $m(c_0)$, the principal cannot find it profitable to offer a new incentive-compatible contract to the agent. For example, if the equilibrium allocation is separating, the set $\mathcal{Y}\left(a^{y'}\right)$ is a singleton, and these constraints impose ex post efficiency.

Suppose now that communication is physical. The only difference with verbal communication is that the contract specifies that the agent must execute the action $\hat{a}_2$ associated with his preferred element in the menu $m(c_0)$. This implies that the principal's renegotiation

[8] This proposition corresponds to Beaudry and Poitevin's (1995) Proposition 5 and is therefore stated without proof.

offer consists of a contract for which every element of its associated menu includes the action $\dot{a}_2$ chosen by the agent. This effectively corresponds to the principal renegotiating only over action a_1. The following proposition characterizes renegotiation-proof allocations.[9]

Proposition 2 *Suppose communication is physical. An allocation is renegotiation-proof if and only if it satisfies the following conditions.*

$$V(\theta_2^y, a^y) \geq V(\theta_2^y, a^{y'}) \quad \forall y, y'$$

With physical communication, renegotiation-proofness does not impose any additional constraints on allocations beyond incentive-compatibility. It is important to point out that any attempt by the principal to renegotiate before the agent executes his action (interim renegotiation) does not affect allocations that are interim efficient. Since the implemented allocation would be interim efficient if c_0 was endogenous, interim renegotiation would not change the set of optimal renegotiation-proof allocations (Beaudry and Poitevin, 1995).

The comparison of the constraints in Propositions 1 and 2 indicates that, in general, verbal communication is more constraining than physical communication in the absence of full commitment. For example, with verbal communication, any separating renegotiation-proof allocation must be ex post efficient. This does not have to be the case with physical communication.

This result can be given the following interpretation. Verbal communication can be associated with a centralized organization where the principal retains the rights to actions a_1 and a_2, collects all relevant information from the agent, and then implements the action-pair dictated by the reported information and the initial agreement the players have. Alternatively, physical communication can be associated with a decentralized organization in which the principal confers the rights to action a_2 to the agent. The informed agent then chooses his preferred level of a_2 based on his private information and the payoffs specified in the contract. The result implies that decentralization of decision making is a credible means of avoiding the inefficiencies associated with renegotiation in environments where players cannot commit not to renegotiate.

In one-sided private-information environments, a decentralized organization is always preferred since only one player possesses private information. The organizational form then

[9]All proofs are relegated to the Appendix.

serves the only purpose of avoiding renegotiation. This is optimally achieved through decentralization. With bilateral private information, the organizational form must not only limit the scope for renegotiation, but also coordinate the actions on the information of the two players. The next section studies the trade-off between coordination (and centralization) and the prevention of renegotiation through decentralization.

4 The bilateral private-information case

In this section, I assume that $\theta_1 \in \Theta_1$ and $\theta_2 \in \Theta_2$, where the probabilities of θ_1^x and θ_2^y are $\pi_x > 0$ and $p_y > 0$ respectively.

With bilateral private information, there are three general classes of organizational forms. In the first class, all communication is verbal. The two players simultaneously make a report. Based on these reports, the contract prescribes an action-pair to be undertaken. In the second class, one player first makes a report, the second then communicates its information physically by executing its action, and finally the first player executes its action based on the communicated information. I shall consider in turn the two cases in which the principal or the agent first communicates verbally. In the third class, the two players communicate their information sequentially and physically. The two cases in which the principal or the agent communicates first are considered in turn.[10]

Before proceeding with the analysis, I present a benchmark case in which there is complete verbal communication and full commitment. Any given status quo contract c_0 would be executed according to the following game referred to as the FC game (for full commitment).

1. The principal observes the state θ_1, and the agent observes the state θ_2.
2. The principal selects a row $r_0 \in m(c_0)$, and the agent selects a column $n_0 \in m(c_0)$.
3. The executed action-pair is that prescribed by the intersection of the row r_0 and the column n_0.

[10]These three classes exhaust all interesting organizational forms. Players communicate either simultaneously, or sequentially. Simultaneous communication must be verbal. It is easy to show that simultaneous physical communication is (weakly) dominated by sequential physical communication. With sequential communication, the second stage of communication is always physical to avoid renegotiation (see Section 3). The first stage may be verbal or physical, corresponding respectively to the second and third classes.

For this commitment game, the principal's strategy is to select a row of the menu of the status quo contract contingently on the state θ_1. The agent's strategy is to select a column of the menu of the accepted contract contingently on the state θ_2.

Note that with bilateral private information, a menu is a matrix that associates an action-pair with each possible realization of θ_1 and θ_2. Therefore, by reporting its state of nature a player selects either a row (the principal) or a column (the agent) of the matrix. The executed action-pair is that at the intersection of the selected row and column. Also note that the two players report their information simultaneously. Simultaneous reports (weakly) dominate sequential reports since, in the former case, each player's incentive constraints only have to hold in expectation over the other player's types, while in the latter case, for one player they have to hold for every type of the other player.

Incentive-compatibility constraints for this commitment game are represented by the following conditions.

$$(i) \quad \sum_x \pi_x V(\theta_2^y, a^{xy}) \geq \sum_x \pi_x V(\theta_2^y, a^{xy'}) \quad \forall y, y'$$
$$(ii) \quad \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \geq \sum_y p_y U(\theta_1^x, \theta_2^y, a^{x'y}) \quad \forall x, x'$$

As with one-sided private information, the presence of incentive-compatibility constraints usually prevents players from achieving ex post efficiency. With full commitment not to renegotiate the contract, such distortions can be implemented. If, however, players cannot commit not to renegotiate, they have an incentive to eliminate such distortions once they learn their private information. Renegotiation can occur after the information has been learned, but before players communicate (interim renegotiation), or it can occur after the players have communicated (ex post renegotiation). For the same reasons as above I focus on ex post renegotiation.

The following subsections characterize the set of renegotiation-proof allocations for different communication structures or organizational forms. In each case, a renegotiation game is defined. For a given renegotiation game Γ, I define the set of renegotiation-proof allocations as follows.

Definition 3 *A* ***renegotiation-proof allocation for the*** Γ ***game*** *is an equilibrium allocation of the* Γ *game which is supported by a status quo contract that is not renegotiated in stage 2.1 along the equilibrium path.*

This generic definition is used throughout the analysis. Note that I delay the comparison of the different organizational structures to Section 5.

4.1 Centralized organization

I first examine the case in which the two players communicate their information simultaneously and verbally. She implements the action-pair dictated by the reported information and the initial contract. It is as if the principal was retaining the rights to actions a_1 and a_2 and centralizing all information.

For any outstanding contract c_0, the players play the following renegotiation game, referred to as the C game (for centralized communication).

1. The principal observes the state θ_1, and the agent observes the state θ_2.
2. The principal selects a row $r_0 \in m(c_0)$, and the agent selects a column $n_0 \in m(c_0)$.

2.1 The principal can offer a new contract c_1 to the agent.

2.2 The agent can then accept or reject this new offer.

2.3 If the contract c_1 is accepted, the agent selects a column $n_1 \in m(c_1)$.

3. The executed action-pair is that prescribed by the intersection of the row r and n of the outstanding contract c.

For the C game, the principal's strategy is to select a row of the menu of the status quo contract contingently on the state θ_1; and to offer a new contract c_1 to the agent contingently on the history of the game.[11] The agent's strategy is to select a column of the menu of the status quo contract contingently on the state θ_2: to accept or reject the renegotiation offer contingently on the history of the game: and to select a column in the menu of the contract c_1 (if it has been accepted) contingently on the history of the game.

The following proposition provides a characterization of renegotiation-proof allocations for the C game.

[11] Note that, without loss of generality, the principal can be constrained to offer a contract c_1 whose menu has only one row since the agent's preferences and the status quo outcome do not depend on θ_1.

Proposition 3 *An allocation is renegotiation-proof for the C game if and only if it satisfies the following constraints.*

$$(i) \quad \sum_x \pi_x V(\theta_2^y, a^{xy}) \geq \sum_x \pi_x V(\theta_2^y, a^{xy'}) \quad \forall y, y'$$

$$(ii) \quad \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \geq \sum_{y'} \left\{ \begin{array}{l} \max\limits_{\{\alpha^y\}_{y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)}} \sum_{y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, \alpha^y) \\ s.t. \\ V(\theta_2^y, \alpha^y) \geq V(\theta_2^y, a^{x'y'}) \quad \forall y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) \\ V(\theta_2^z, \alpha^z) \geq V(\theta_2^z, \alpha^{z'}) \quad \forall z, z' \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) \end{array} \right\} \quad \forall x, x'$$

$$(iii) \quad \sum_{y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, a^{xy'}) \geq \left\{ \begin{array}{l} \max\limits_{\{\alpha^y\}_{y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)}} \sum_{y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, \alpha^y) \\ s.t. \\ V(\theta_2^y, \alpha^y) \geq V(\theta_2^y, a^{xy'}) \quad \forall y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) \\ V(\theta_2^z, \alpha^z) \geq V(\theta_2^z, \alpha^{z'}) \quad \forall z, z' \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) \end{array} \right\} \quad \forall x, y'$$

where $\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) = \left\{y \text{ such that } \theta_2^y \in \Theta_2 \text{ and } \{a^{xy}\}_x = \left\{a^{xy'}\right\}_x\right\}$.

This proposition describes conditions that must be satisfied by any renegotiation-proof allocation of the C game. Conditions (i) represent standard incentive-compatibility constraints for the agent. The set $\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$ contains agent types for which the equilibrium allocation is $a^{xy'}$ when the principal's type is x. If the allocation is separating, this set reduces to a singleton. The third condition then states that, given that the principal and the agent have reported truthfully their private information, it is not possible for the principal to increase her expected utility (computed with her revised beliefs) by renegotiating to a surely acceptable contract by the agent, that is, an incentive-compatible contract that increases the agent's payoff regardless of his beliefs about the principal's type. For example, if the allocation is separating for a subset of types, conditions (iii) imply that it must be ex post efficient for all types in this subset. Conditions (ii) require that, given the expected renegotiation possibilities by the principal after reports are in, she reports her type truthfully. The set of conditions (ii) are more stringent than standard incentive-compatibility constraints because the prospect of renegotiation may increase the desirability of reporting falsely.[12]

The constraints in Proposition 3 are generally more stringent than those in the full-commitment case. Renegotiation allows the players to undo ex post some of the distortions

[12]Note that condition (ii) for $x' = x$ implies condition (iii). The latter are included for expositional purposes.

included ex ante to induce truth-telling. Consequently, the principal's incentive constraints become more stringent since she accounts for the possibility of renegotiating when evaluating different reports. The lack of commitment therefore reduces the set of implementable allocations compared with the full-commitment case.

Renegotiation has some effect because all verifiable communication is verbal. It is therefore easy to change the action-pair once communication has occurred. This may be partially avoided by having one of the players communicating verbally and the other physically. This is the object of the next subsection.

4.2 Hierarchical organization

In this section, I consider the case in which one player first communicates verbally its information to the other player, and then, the other player, on the basis of this report and its own information, undertakes its action. Finally, the first player undertakes its action. This organizational form is a mixed structure where some information is centralized through verbal communication, while some is being decentralized through physical communication. We can associate this organizational form with a hierarchical structure. Such organizational form is vulnerable to renegotiation after the first player verbally reports its information since no action has yet been undertaken. Once one of the actions has been undertaken, however, there is no room for further renegotiation.

There are two forms of hierarchical structure. First, the principal can communicate verbally with the agent who then executes his action, followed by that of the principal. Information is flowing down the hierarchy, from the principal to the agent. In this case, rights over the action-pair are conferred to the agent. The payoffs that he gets from exercizing these rights, however, are contingent on the report by the principal. Second, the agent can communicate verbally with the principal, who then executes her action followed by that of the agent. Information is flowing up the hierarchy, from the agent to the principal. The principal then retains the rights to the action-pair, with payoffs being contingent on the agent's report. These two cases are considered in turn.

4.2.1 Verbal communication by the principal

For any status quo contract c_0, the players play the following renegotiation game referred to as the HP game (for hierarchical communication initiated by the principal).

1. The principal observes the state θ_1, and the agent observes the state θ_2.

2. The principal selects a row $r_0 \in m(c_0)$.

2.1 The principal can offer a new contract c_1 to the agent.

2.2 The agent can then accept or reject this new offer.

3.1 The agent executes an action a_2 among all those available in the menu of the outstanding contract.

3.2 The principal executes the action a_1 associated with the choice of a_2 in the menu of the outstanding contract.

For the HP game, the principal's strategy is to select a row of the menu of the status quo contract contingently on the state θ_1, and to offer a new contract c_1 to the agent contingently on the history of the game. The agent's strategy is to accept or reject the renegotiation offer contingently on the history of the game, and to execute an action a_2 in the menu of the outstanding contract.

The HP game differs from the C game in that the agent can physically communicate his information to the principal after she has communicated verbally. Renegotiation can arise after the principal has verbally communicated when players have not yet physically committed to one action-pair. Following the agent's physical communication, no renegotiation can arise since only the principal's action can then be changed.

Proposition 4 *An allocation is renegotiation-proof for the HP game if and only if it satisfies the following constraints.*

$$(i) \quad \left\{ V(\theta_2^y, a^{xy}) \geq V(\theta_2^y, a^{xy'}) \quad \forall\, y, y' \right\} \quad \forall\, x$$

$$(ii) \quad \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \geq \left\{ \begin{array}{rl} \max_{\{\alpha^y\}} & \sum_y p_y U(\theta_1^x, \theta_2^y, \alpha^y) \\ s.t. & V(\theta_2^y, \alpha^y) \geq V(\theta_2^y, a^{x'y}) \quad \forall\, y \\ & V(\theta_2^y, \alpha^y) \geq V(\theta_2^y, \alpha^{y'}) \quad \forall\, y, y' \end{array} \right\} \quad \forall\, x, x'$$

Conditions (i) are simply the agent's incentive-compatibility constraints. These constraints are conditional on the principal's information since the agent executes his action after the principal has communicated her information. Conditions (ii) represent the principal's incentive-compatibility constraints taking into account the possibility for renegotiation. Following the principal's report x', the contract specifies that the executed action-pair must be part of the vector $\left\{a^{x'y}\right\}_y$. The right-hand-side of the equation then states that the principal can always successfully renegotiate to another allocation $\{\alpha^y\}$ that is incentive compatible for the agent (second set of constraints), and that he weakly prefers to this vector regardless of his private information and beliefs (first set of constraints). Any such offer is surely acceptable by the agent since it increases his payoffs regardless of his beliefs. Note that the renegotiated offer need not depend on θ_1 since the agent executes the action a_2 before the principal can communicate, and his preferences are independent of θ_1. Conditions (ii) then say that the principal must weakly prefer truthfully reporting her information to misreporting and renegotiating to a surely-acceptable offer. The principal's incentive constraints hold in expected terms over the agent's information since the principal reports before the agent communicates.

There are two differences between the constraints in Proposition 4 and those in the full-commitment case. First, renegotiation makes the principal's incentive constraints more stringent as she must take into account the possibility of renegotiating before reporting. Second, the sequentiality of communication implies that the agent's incentive-compatibility constraints must hold contingently on the principal's private information.

4.2.2 Verbal communication by the agent

I now consider the case in which the agent first communicates verbally his information to the principal, and then the principal physically communicates by executing her action.

Given a status quo contract c_0, the players play the following renegotiation game referred to as the HA game (for hierarchical communication initiated by the agent).

1. The principal observes the state θ_1, and the agent observes the state θ_2.

2. The agent selects a column $n_0 \in m(c_0)$.

2.1 The principal can offer a new contract c_1 to the agent.

2.2 The agent can then accept or reject this new offer.

3.1 The principal executes an action a_1 among all those available in the menu of the outstanding contract.

3.2 The agent executes the action a_2 associated with the choice of a_1 in the menu of the outstanding contract.

For the HA game, the principal's strategy is to offer a new contract c_1 to the agent contingently on the state θ_1 and the agent's choice of a column in the menu of the status quo contract, and to execute the action a_1 prescribed by the menu of the appropriate outstanding contract. The agent's strategy is to select a column in the menu of the initial contract contingently on his private information, and to accept or reject the renegotiation offer contingently on the history of the game.

Proposition 5 *An allocation is renegotiation-proof for the HA game if and only if it satisfies the following constraints.*

$$(i)\quad \sum_x \pi_x V(\theta_2^y, a^{xy}) \geq \sum_x \pi_x V(\theta_2^y, a^{xy'}) \quad \forall y, y'$$

$$(ii)\quad \sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, a^{xy}) \geq$$
$$\left\{\begin{array}{ll} \max_{\{\alpha^z\}} & \sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, \alpha^x) \\ s.t. & V(\theta_2^y, \alpha^z) \geq V(\theta_2^y, a^{zy'}) \quad \forall z, \forall y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) \\ & \sum\limits_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^z, \theta_2^y, \alpha^z) \geq \sum\limits_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^z, \theta_2^y, \alpha^{z'}) \quad \forall z, z' \end{array}\right\} \forall x, y'$$

$$(iii)\quad \left\{\sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, a^{xy}) \geq \sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, a^{x'y}) \quad \forall x, x'\right\} \forall y'$$

where $\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right) = \left\{y \text{ such that } \theta_2^y \in \Theta_2 \text{ and } \{a^{xy}\}_x = \left\{a^{xy'}\right\}_x\right\}$.

The conditions imposed by this communication scheme are different from those in the HP game because the two players move in reverse order and thus face different information structures before playing. The first conditions are the usual incentive-compatibility constraints for the agent which hold in expected terms over the principal's information since the agent reports before the principal communicates. The second conditions represent the principal's incentive-compatibility constraints. The principal executes her action after the agent has reported his information. The right-hand side of the inequality states that, from any allocation $\left\{a^{xy'}\right\}_x$ dictated by the agent's report, the principal can always successfully renegotiate to an allocation $\{\alpha^x\}$ that is incentive compatible for the principal and weakly preferred by the agent regardless of his private information and beliefs. Note that the renegotiated offer depends on θ_1 as the agent's perception of the status quo is contingent on it. It does not, however, depend on θ_2 as the principal selects a_1 before the agent can communicate again. The conditions (ii) then say that, conditional on his revised beliefs about the agent's type, the principal must weakly prefer to truthfully report her information and not renegotiate rather than renegotiate to a surely-acceptable offer. The conditions (iii) represent standard incentive-compatibility constraints for the principal where the principal evaluates each action-pair using her revised beliefs following the agent's report. In particular, if the allocation is separating for the agent types, these constraints reduce to standard ex post incentive-compatibility constraints.

Again, a simple examination of the constraints in Proposition 5 reveals that one-sided verbal communication and non-commitment reduce the set of implementable allocations compared with the full-commitment case.

4.3 Decentralized organization

Section 3 illustrates how physical communication becomes a means of avoiding renegotiation in the one-sided private-information case. I now investigate, for the bilateral private-information case, whether a decentralized organizational form in which communication is only physical and sequential can be helpful in reducing the losses associated with non-commitment and renegotiation. The only relevant case is that in which the two players take their action sequentially. The first player executes its action without any information from the other player. The second player then undertakes its own action thus coordinating somewhat on the information conveyed by the first player's choice of action. Clearly, such structure dominates a structure in which the two players would choose their respective action simultaneously, and thus would have no opportunity to communicate with each other. It should now be clear that such organizational form is not vulnerable to renegotiation because of the physical nature of communication.

There are two possible organizational forms. First, the principal can communicate physically by executing her action, and the agent then undertakes his action. Information is (physically) flowing down the hierarchy, from the principal to the agent. In this case, the principal retains all rights over the action-pair. Second, the agent can communicate physically by executing his action, and the principal then undertakes her action. Information is flowing up the hierarchy, from the agent to the principal. The agent then gets the rights over the action-pair.

The difference between the hierarchical and decentralized organizational forms is not in the assignment of rights per se, but rather in the fact that, in the first case, the menu can be contingent on one player's report, while it cannot in the second case. The extent of decentralization is therefore higher in the second case.

4.3.1 Physical communication by the principal

Given a status quo contract c_0, the players play the following renegotiation game referred to as the DP game (decentralized communication initiated by the principal).

1. The principal observes the state θ_1, and the agent observes the state θ_2.

2. The principal executes an action a_1 among all those available in the menu $m(c_0)$.

3. The agent executes the action a_2 associated with the choice of a_1 in the menu $m(c_0)$.

For the DP game, the principal's strategy is to select an action a_1 contingently on the state θ_1. The agent has no strategy since the contract is assumed to be enforceable, that is, the agent has no choice but to execute the action a_2 associated with the action a_1 in the menu of the outstanding contract.

The DP game differs from the previous games in that no verbal communication is required by the contract. The two players simply execute their respective action in turn. The implemented allocation can only depend on the principal's information, and therefore the menu of its associated contract only consists of a single column. Since renegotiation cannot arise after the principal has physically communicated, the offered contract will be renegotiation-proof. It is then clear that renegotiation-proof allocations satisfy the following incentive-compatibility conditions for the principal.

$$\sum_y p_y U(\theta_1^x, \theta_2^y, a^x) \geq \sum_y p_y U(\theta_1^x, \theta_2^y, a^{x'}) \quad \forall x, x'$$

The avoidance of renegotiation through physical communication is achieved at the expense of lower coordination of the information of the two players. The equilibrium allocation can only depend on the principal's private information and not on that of the agent.

4.3.2 Physical communication by the agent

I now consider the case in which the agent communicates physically with the principal by selecting his action first.

Given a status quo contract c_0, the players play the following renegotiation game referred to as the DA game (for decentralized communication initiated by the agent).

1. The principal observes the state θ_1, and the agent observes the state θ_2.

2. The agent executes an action a_2 all those available in the menu $m(c_0)$.

3. The principal executes the action a_1 associated with the choice of a_2 in the menu $m(c_0)$.

For the DA game, the agent's strategy is to select an action a_2 contingently on his information θ_2. For the same reasons as in the preceding section, the principal has no explicit strategy.

The implemented allocation can only depend on the agent's information since he selects his action before the principal has any opportunity to communicate. The menu of the contract consists of a single line. Again, renegotiation cannot arise after the agent has physically communicated. It is then clear that renegotiation-proof allocations satisfy the following incentive-compatibility conditions for the agent.

$$\sum_x \pi_x V(\theta_2^y, a^y) \geq \sum_x \pi_x V(\theta_2^y, a^{y'}) \quad \forall y, y'$$

Note that these conditions are equivalent to standard ex post incentive constraints since the allocation and the agent's preferences are independent of the principal's information. As before, renegotiation is avoided at the expense of lower coordination of the information of the two players. With one-sided private information, such coordination is not relevant, and decentralization is therefore the most preferred organizational form. With bilateral private information, coordination of information may be important. The next section compares the various organizational forms.

5 Comparisons of the different organizational forms

The different organizational forms can be compared by endogenizing the status quo contract with an initial proposal stage where the principal offers to the agent a contract which supports a renegotiation-proof allocation. For the Γ game, the optimal initial contract offer supports the following allocation.[13]

$$(2) \qquad \begin{array}{rl} \mu^{\Gamma} = \arg\max_{\{a^{xy}\}\in RP(\Gamma)} & \sum_x \pi_x \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \\ \text{s.t.} & \sum_x \pi_x \sum_y p_y V(\theta_2^y, a^{xy}) \geq \bar{v} \end{array}$$

where $RP(\Gamma)$ represents the set of renegotiation-proof allocations for the Γ game for some status quo contract c_0.

Before comparing the different organizational forms, I shall mention that existence of renegotiation-proof allocations is not a problem in well-behaved environments. For example, in single-crossing environments,[14] the set $RP(\Gamma)$ is closed and nonempty. Hence, for appropriate values of $\bar{v}$ there would exist a solution to problem (2).

I first analyze the extent of decentralization in organizations. Consider an optimal allocation under complete decentralization to the agent (DA renegotiation game), μ^{DA}. This allocation is independent of the principal's private information θ_1. Consider now the hierarchical organization in which the principal first communicates verbally (HP renegotiation game). In that game, the principal can always refrain from communicating any information about θ_1 by offering a contract consisting of a menu with identical rows. Her verbal communication is then uninformative to the agent, and the resulting allocation is independent of θ_1. There are two cases. First, suppose that the allocation μ^{DA} is renegotiation-proof under the HP organizational form, that is, $\mu^{DA} \in RP(HP)$. The allocation μ^{DA} is then weakly dominated by a solution to problem (2) for the HP game. Second, suppose that the allocation μ^{DA} is not renegotiation-proof under the HP organizational form, that is, $\mu^{DA} \notin RP(HP)$. It is then possible to show that there exists an allocation μ^{HP} that dominates μ^{DA}. Therefore, decentralization to the agent is weakly dominated by the hierarchical organization in which the principal communicates verbally.

A similar argument shows that an optimal allocation under complete decentralization to the principal (DP renegotiation game) is weakly dominated by that of the hierarchical form

[13] Note that a similar analysis could be performed with ex post individuality constraints for the agent.

[14] These environments are defined below.

in which the agent first communicates verbally (IIA renegotiation game). We can therefore state the following proposition.

Proposition 6 *A decentralized organization is always weakly dominated by an appropriate hierarchical organizational form.*

The intuition is that, if it is optimal for the principal to condition the allocation on only one player's private information, then this may be achieved equally well by a hierarchical organization as by a decentralized structure. If, to the contrary, it is not optimal to do so, then a hierarchical organization performs strictly better than a decentralized structure since it allows conditioning on the two players' private information.

This proposition implies that the solution to the one-sided private-information case is generally not robust to the introduction of bilateral private information. The trade-off between coordination and decentralization generally requires some coordination, making verbal communication an essential ingredient of an optimal organization.

A last remark on this result is in order. If one interprets the decentralization solution as a market solution with a nonlinear price schedule, then this result says that market arrangements can be optimal with one-sided private information, but may not be optimal with bilateral private information. In this case, a contractual solution with information exchange, that is, an organization weakly dominates the market solution.

It then remains to compare the relative efficiency of the different communication channels characterized in the previous section. To simplify the analysis, comparisons are made for the class of single-crossing games with only two types of principal and agent.

Assumption 1

- $\Theta_i = \left\{\theta_i^L, \theta_i^H\right\}$.
- $U(\theta_1, \theta_2, a_1, a_2) = u(\theta_1, \theta_2, a_2) - a_1$.
  $V(\theta_2, a_1, a_2) = v(a_1) - e(a_2, \theta_2)$.
- $U_{a_2} > 0$, $V_{a_2} < 0$, $V_{a_1} > 0$, $V_{a_1 a_1} < 0$.
- $-V_{a_2}/V_{a_1}$ *is decreasing in* θ_2.

- $-U_{a_2}/U_{a_1}$ *is increasing in* θ_1 *for each value of* θ_2*, and monotone in* θ_2 *for each value of* θ_1.

These assumptions impose a separable functional form between the action variable a_2 and the transfer a_1, risk neutrality for the principal, risk aversion for the agent, and single-crossing conditions on the players' preferences.

The characterization of optimal renegotiation-proof allocations depends on the relative size of the marginal trade-off for the principal and the agent. I consider two cases.[15]

Case P $$\frac{-V_{a_2}(\theta_2^L,\cdot)}{V_{a_1}(\theta_2^L,\cdot)} - \frac{-V_{a_2}(\theta_2^H,\cdot)}{V_{a_1}(\theta_2^H,\cdot)} \leq \frac{-U_{a_2}(\theta_1,\theta_2^L,\cdot)}{U_{a_1}(\theta_1,\theta_2^L,\cdot)} - \frac{-U_{a_2}(\theta_1,\theta_2^H,\cdot)}{U_{a_1}(\theta_1,\theta_2^H,\cdot)} \quad \text{for all } \theta_1.$$

Case S $$\frac{-V_{a_2}(\theta_2^L,\cdot)}{V_{a_1}(\theta_2^L,\cdot)} - \frac{-V_{a_2}(\theta_2^H,\cdot)}{V_{a_1}(\theta_2^H,\cdot)} > \frac{-U_{a_2}(\theta_1,\theta_2^L,\cdot)}{U_{a_1}(\theta_1,\theta_2^L,\cdot)} - \frac{-U_{a_2}(\theta_1,\theta_2^H,\cdot)}{U_{a_1}(\theta_1,\theta_2^H,\cdot)} \quad \text{for all } \theta_1.$$

I first characterize the optimal organizational form for Case P. Moreover, I make the following additional technical assumption.

Assumption 2 $U_{a_2\theta_1\theta_2} \leq 0$.

Proposition 7 *Assume that the preferences are depicted by Case* P*, and that Assumptions 1 and 2 are satisfied. The hierarchical structure HA is the preferred organizational form.*

In Case P, the full-commitment solution to problem (2) is independent of the agent's private information. Both types of principal are, however, separated. Type θ_1^L has an optimal pooling (over the agent's types) allocation, that is, an allocation at the tangency of $E_{\theta_2}U(\theta_1^L,\theta_2,\cdot)$ and $E_{\theta_2}V(\theta_2,\cdot)$. Type θ_1^H separates from type θ_1^L with a pooling (over the agent's types) allocation that is distorted towards overproduction. The intuition for this characterization is the following. Incentive compatibility and separation for the agent requires the higher type θ_2^H to get a higher wage a_1 and take a higher level of action a_2 than the lower type θ_2^L. This is, however, contrary to the principal's interest who, in Case P, values marginally more the action of the lower type θ_2^L. Separation is then too costly, and the resulting optimal allocation is pooling over the agent's type.[16]

[15] Beaudry and Poitevin (1993) show how these cases relate to familiar signalling or screening games. For example, Case S would include the Spence configuration, while Case P encompasses Rothschild and Stiglitz insurance framework, provided that these two games were generalized to bilateral private information.

[16] With one-sided private information and a continuum of types, a similar characterization obtained in Guesnerie and Laffont (1984) and Greenwood and McAfee (1991).

When the agent's types are pooled, the problem reduces to a one-sided private-information problem. It is then optimal to delegate decision-making to the player whose information affects the allocation, namely the principal. In the HA structure, the agent must first send a message. Since the allocation is independent of his type, his message is meaningless, and the principal follows by executing the action corresponding to her type. Note that in Case P, non-commitment puts no restriction in the HA game. The implemented allocation μ^{HA} is also a full-commitment optimal allocation.

I now consider Case S. Case S differs from Case P in that the optimal allocation is separating for the principal's and the agent's types in each organizational form.

Proposition 8 *Assume that preferences are depicted by Case S, and that Assumption 1 is satisfied.*
(i) For the C game, the optimal allocation is the solution to the following maximization problem.

$$
\begin{aligned}
\mu^C = \arg\max_{\{a^{xy}\}} \quad & \textstyle\sum_x \pi_x \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \\
s.t. \quad & \textstyle\sum_x \pi_x \sum_y p_y V(\theta_2^y, a^{xy}) \geq \bar{v} \\
& \textstyle\sum_x \pi_x V(\theta_2^y, a^{xy}) \geq \sum_x \pi_x V(\theta_2^y, a^{xy'}) \quad \forall y, y' \\
& \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \geq \sum_y p_y \left\{ \begin{array}{ll} \max_\alpha & U(\theta_1^x, \theta_2^y, \alpha) \\ s.t. & V(\theta_2^y, \alpha) \geq V(\theta_2^y, a^{x'y}) \end{array} \right\} \quad \forall x, x'
\end{aligned}
$$

(ii) For the HP game, the optimal allocation is the solution to the following maximization problems for all x.

$$
\begin{aligned}
\mu_x^{HP} = \arg\max_{\{a^y\}} \quad & \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, a^y) \\
s.t. \quad & \textstyle\sum_y p_y V(\theta_2^y, a^y) \geq \bar{v} - r_x \\
& V(\theta_2^y, a^y) \geq V(\theta_2^y, a^{y'}) \quad \forall y, y'
\end{aligned}
$$

where

$$
\begin{aligned}
\{r_x\} = \arg\max_{\{\rho_x\}} \quad & \textstyle\sum_x \pi_x U^x(\rho_x) \\
s.t. \quad & \textstyle\sum_x \pi_x \rho_x \leq 0 \\
& U^x(\rho_x) \geq U^x(\rho_{x'}) \quad \forall x, x'
\end{aligned}
$$

where $U^x(r_x)$ is the maximized value of the first maximization problem and the function $\hat{U}^x$ is implicitly defined by:

$$\hat{U}^x(r_{x'}) = \max_{\{a^y\}} \quad \sum_y p_y U(\theta_1^x, \theta_2^y, a^y)$$
$$\text{s.t.} \quad V(\theta_2^y, a^y) \geq V(\theta_2^y, \hat{a}^{x'y}(r_{x'})) \quad \forall y$$
$$V(\theta_2^y, a^y) \geq V(\theta_2^y, a^{y'}) \quad \forall y, y'$$

where $\{\hat{a}^{xy}(r_x)\}_y$ is the maximand of the first maximization problem.
(iii) For the HA game, the optimal allocation is the solution to the following maximization problems for all y.

$$\mu_y^{HA} = \arg\max_{\{a^x\}} \quad \sum_x \pi_x U(\theta_1^x, \theta_2^y, a^x)$$
$$\text{s.t.} \quad \sum_x p_x V(\theta_2^y, a^x) \geq \bar{v} - r_y$$
$$U(\theta_1^x, \theta_2^y, a^x) \geq U(\theta_1^x, \theta_2^y, a^{x'}) \quad \forall x, x'$$

where

$$\{r_y\} = \arg\max_{\{r_y\}} \quad \sum_y p_y U^y(r_y)$$
$$\text{s.t.} \quad \sum_y p_y r_y \leq 0$$
$$\bar{v} - r_y \geq \sum_x \pi_x V(\theta_2^y, \tilde{a}^{xy'}(r_{y'})) \quad \forall y, y'$$

where $U^y(r_y)$ is the maximized value of the first maximization problem, and $\{\tilde{a}^{xy}(r_y)\}_x$ is its maximand.

Hierarchical organizational forms differ from the centralized form by having sequential communication. The cost of sequential communication is that the incentive-compatibility constraints of the second player to move have to hold for every state of the private information of the other player. The benefit of sequential communication is that renegotiation takes place under asymmetric information, which allows to sustain ex post distortions. Proposition 8 illustrates precisely that trade-off.

Before discussing Proposition 8, it is useful to give some intuition about the full-commitment problem.[17] The full-commitment problem can be rewritten as the following two maximization problems. For each x,

$$\tilde{U}^x(r_x, c_x) = \max_{\{a^y\}} \quad \sum_y p_y U(\theta_1^x, \theta_2^y, a^y)$$
$$\text{s.t.} \quad \sum_y p_y V(\theta_2^y, a^y) \geq v - r_x$$
$$V(\theta_2^H, a^H) \geq V(\theta_2^H, a^L) - c_x$$

[17]This discussion is partly based on Maskin and Tirole (1990).

where the nonbinding type L's incentive constraint has been omitted.

$$\begin{aligned} \max_{r_x, c_x} \quad & \textstyle\sum_x \pi_x \tilde{U}^x(r_x, c_x) \\ \text{s.t.} \quad & \textstyle\sum_x \pi_x r_x \leq 0 \\ & \textstyle\sum_x \pi_x c_x \leq 0 \\ & \tilde{U}^x(r_x, c_x) \geq \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, \bar{a}^{x'y}(r_{x'}, c_{x'})) \quad \forall x, x' \end{aligned}$$

where $\{a^{xy}(r_x, c_x)\}_y$ is the maximand of the first maximization problem. The full-commitment contracting problem can be interpreted as a problem of trading slack in the participation (r_x) and incentive (c_x) constraints of the agent for different values of θ_1 subject to feasibility constraints on the amount traded and the principal's incentive constraints.[18]

The presence of renegotiation limits the amount of slack that can be traded. For example, any slack in incentive constraints is renegotiated away once communication has occurred. This is precisely the intuition behind the characterization of the optimal allocation of each hierarchical form.

In the HP game, because of renegotiation following the principal's communication, no slack is possible in the agent's incentive constraints, that is, $c_x = 0$ for all x. The optimal values for $\{r_x\}$ are then chosen subject to the agent's participation constraint and the principal's incentive constraint. These are the two constraints in the second maximization problem of the proposition. The principal's incentive constraints are different in the proposition since they must take into account the possibility for renegotiation. A type x principal reporting x' can obtain $\hat{U}^x(r_{x'})$ through renegotiation, where this is defined in the last maximization problem. Since renegotiation occurs after the agent learns his private information, one participation constraint for each y must hold. This implies that r_x can be chosen differently from $r_{x'}$ and still satisfy the principal's incentive constraints. There may therefore be partial insurance provided across the states θ_1. Some insurance is also provided against θ_2 since ex post distortions across the states θ_2 can be sustained because the principal does not know the agent's type when renegotiating.

Similarly, in the HA game, renegotiation following the agent's communication results in no slack being traded in the principal's incentive constraints, that is, $c_y = 0$ for all

[18] Contrary to Maskin and Tirole's analysis, the principal's incentive constraints may be binding here. They do not bind in Maskin and Tirole's model because the principal knows the state θ_1 before offering the contract. This limits, for insurance purposes, the cross-subsidization that can occur across the different types of principal, and thus relaxes the incentive constraints.

y.[19] The optimal values for $\{r_y\}$ are then chosen subject to the agent's participation and incentive constraints. These are the two constraints in the second maximization problem of the proposition. There may therefore be partial insurance provided across the states θ_2 depending on the interaction between the agent's incentive constraints and his demand for insurance. Some insurance is also provided against θ_1 since ex post distortions across the states θ_1 can be sustained because the agent does not know the principal's type when renegotiating.

In summary, both hierarchical forms are quite similar. Each one provides fairly good insurance against one state, but bad insurance against the other state, which is the state on which renegotiation is based.

The centralized form provides some insurance against both states as slack can be traded in the participation as well as incentive constraints of the two players. The incentive constraints are, however, modified by the requirement that all action-pairs must be ex post efficient. This eliminates the amount of implicit insurance provided by ex post distortions.

The trade-off between a hierarchy and a centralized structure can be represented by the trade-off between the different insurance possibilities. On the one hand, ex post distortions improve risk sharing. Such distortions can be sustained with a hierarchical structure but not with a centralized form. On the other hand, incentive-compatibility constraints which hold in expected terms (as in a centralized structure) provide a form of risk sharing that a hierarchical form cannot provide. The two forms of organizations present different possibilities for insurance, and the trade-off between the two depends on the preferences and the variance of the two players' private information. I now look at this trade-off for some limiting cases.

It is easy to see from Proposition 8 that, regardless of the uncertainty on θ_2, the allocation μ^{HP} can be arbitrarily close to the full-commitment allocation when θ_1^H is close enough to θ_1^L. Alternatively, regardless of the uncertainty on θ_1, the allocation μ^{HA} can be arbitrarily close to the full-commitment allocation when θ_2^H is close enough to θ_2^L. Furthermore, in each case, the allocation μ^C is bounded away from the full-commitment allocation. We therefore have the following proposition.

[19] The vector $\{r_y, c_y\}$ can be defined from the transformation of the full-commitment problem into two maximization problems where slack is traded in the participation constraint of the agent and the incentive constraints of the principal for different values of θ_2 subject to the agent's incentive constraints.

Proposition 9 *Assume that the preferences are depicted by Case S, and that Assumption 1 is satisfied. The hierarchical structure HP (HA) is the preferred organizational form if θ_1^H (θ_2^H) is close enough to θ_1^L (θ_2^L).*

In a hierarchy, information should be flowing from the player who has the "least important" information to the other player to minimize the costs associated with renegotiation. Decision making is decentralized to the player with the "most important" private information, where the information is important if it influences significantly the action to be taken. For example, if θ_i^H is significantly different from θ_i^L, presumably that the optimal action-pair is influenced significantly by the value of θ_i.

A centralized organization is always dominated by an appropriate hierarchical organization when θ_i^H is close to θ_i^L for some i. When, however, the private information of both players is important to the characterization of the optimal allocation, sequential communication becomes more costly in terms of lack of insurance against both states, and therefore the centralized form should be the preferred organizational structure. A centralized organization should then arise when all dimensions of private information are important to the efficiency of the organization.

6 Conclusion

This paper offers a framework for studying the trade-off between centralization and decentralization. Typically, one associates with centralization a better coordination of all relevant information in decision-making. It is also generally thought that centralization bears some costs. This paper makes precise what the costs and the benefits of centralization are. The costs of centralization come from the renegotiation of contracted allocations, while benefits stem from the coordination of the decision on all available information.

An optimal organization must setup formal communication channels through which information flows to the decision-maker. These channels offer the opportunity to renegotiate contracts, and such renegotiation has some ex ante efficiency costs. Organizational form then becomes a credible commitment to some communication channels that trade-off between coordination of information and its associated renegotiation costs.

Finally, this analysis suggests that it may be hard to derive a general approach to asymmetric-information problems with non-commitment. The results of this paper show that renegotiation-proof constraints depend on the details of the organizational form, and are likely to grow in complexity as the dimensions of the private information (and/or the size of the organization) increase. A "Renegotiation-Proof Revelation Principle" thus appears unreachable. The Revelation Principle is possible in a world with commitment because all organizational forms require the common property of incentive-compatibility. Such common property in renegotiation-proof environments has not been characterized yet. This explains why one must proceed with a case-by-case analysis.

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APPENDIX

Proof of Proposition 2 The necessity part of the proposition is straightforward: all renegotiation-proof allocations must be incentive-compatible.

The proof of the sufficiency part consists in constructing strategies and beliefs that support any incentive-compatible allocation as an equilibrium allocation that is not renegotiated along the equilibrium path of the renegotiation game. Consider the following strategies and beliefs.

Stage 2: The agent of type y selects his preferred action-pair in the menu, $a^y \in m(c_0)$, and execute the associated action a_2^y.

Stage 2.1: Regardless of her beliefs, the principal makes no contract offer. Her beliefs are simply the Bayesian revision of her prior concentrated on the set $\mathcal{Y}\left(a^{y'}\right)$, where $a^{y'}$ is the selected pair by the agent.

Stage 2.2: The agent of type y accepts all contract offers which are weakly preferred to the allocation $a^{y'}$, and rejects all other offers.

Stage 2.3: The agent of type y selects his preferred allocation in the menu $m(c_1)$, and execute the associated a_2 action.

It is clear that these strategies and beliefs form a PBE of the renegotiation game. In stage 2, the agent anticipates no renegotiation, and he therefore chooses his favored element in the menu of the outstanding contract by executing its associated action a_2. In stage 2.1, the principal can do no better than not making any offer, since she knows that the agent accepts only those contracts that are weakly worse off for her. Finally, in stages 2.2 and 2.3, the agent accepts all contracts that he weakly prefers to the status quo, and then selects his preferred element in the menu of the outstanding contract. *Q.E.D.*

Proof of Proposition 3 The first part of the proof shows that conditions (i)–(iii) must be satisfied by any renegotiation-proof allocation for the C game.
Conditions (i) are standard incentive-compatibility constraints for the agent which, without loss of generality, must be satisfied by any renegotiation-proof allocation.
Consider now the conditions (iii). Suppose one is not satisfied for a value of x and y' in a renegotiation-proof allocation. Renegotiation-proofness implies that, along the equilibrium

path, following the reports x (the principal) and y' (the agent), the action-pair $a^{xy'}$ must be executed without being renegotiated. Consider the principal's beliefs following the reports. The principal must (Bayesian) revise her prior in the set $\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$. Since the action-pair $a^{xy'}$ does not satisfy condition (iii), there must exist a vector of incentive-compatible action-pairs $\{\alpha^y\}$ for $y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$ such that

$$\sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, \alpha^y) > \sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, a^{xy'}),$$

and $V(\theta_2^y, \alpha^y) > V(\theta_2^y, a^{xy'})$ for all $y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$. Suppose that, in stage 2.1, the principal offers to the agent a contract c_1 with $m(c_1) = \{\alpha^y\}$ for $y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$. By construction, the agent should accept this contract regardless of his beliefs regarding the principal's type since rejection would implement the action-pair $a^{xy'}$ which is strictly worse than an appropriately chosen element of $\{\alpha^y\}$. Acceptance of c_1 by the agent effectively induces the principal in offering this contract, thus upsetting the equilibrium. Conditions (iii) must then be satisfied by a renegotiation-proof allocation.
Consider now the conditions (ii). Suppose that one is not satisfied for a value of x and x' in a renegotiation-proof allocation, and that the principal of type x reports x'. The interior of the right-hand-side of condition (ii) represents the maximum the principal of type x can get by reporting x' when the agent reports y'. The principal can attain it by renegotiating to an allocation that will surely be accepted by the agent regardless of his beliefs. (This is easily shown by the same argument as above.) Summing these terms over y' gives the expected utility the principal gets by reporting x' before she knows what the agent will report. If condition (ii) is not satisfied, the principal has an incentive to report x', and then renegotiate to an allocation that will surely be accepted by the agent. Hence, any renegotiation-proof allocation must satisfy the conditions (ii).

The next step in the proposition is to construct strategies and beliefs for the C game that support any allocation satisfying conditions (i)–(iii) as a renegotiation-proof allocation. Consider the following strategies and beliefs.

Stage 2: The principal of type x reports truthfully. The agent of type y reports truthfully.

Stage 2.1: If the principal has reported truthfully in stage 2, she makes no contract offer. If she has misreported, she offers a contract supporting the solution to the right-hand-side of condition (ii). Her beliefs are simply the Bayesian revision of her prior concentrated on the set $\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$.

Stage 2.2: Following the reports x' and y', the agent of type y accepts all contract offers which are weakly preferred to the allocation $a^{x'y'}$, and rejects all other offers. His beliefs are simply the Bayesian revision of his prior. Note that these beliefs are irrelevant for the acceptance decision since the agent's payoff is independent of θ_1.

Stage 2.3: The agent of type y selects his preferred allocation in the menu $m(c_1)$.

It is clear that these strategies and beliefs constitute a PBE of the C game. If the contract c_1 is accepted, the agent selects his preferred element in its associated menu. Given this selection strategy, it is rational for the agent to accept those contracts that he weakly prefers to the status quo action-pair $a^{x'y'}$. Given this acceptance strategy, a principal type that has reported truthfully can do no better than make no offer since the status quo allocation satisfies conditions (iii). A principal type that has misreported offers her preferred contract in the set of contracts that the agent weakly prefers to the status quo, that is, the solution to the right-hand-side of condition (ii). Finally, given the ensuing resolution of the game and given that the status quo allocation satisfies conditions (i) and (ii), it is optimal for the two players to report truthfully. *Q.E.D.*

Proof of Proposition 4 The first part of the proof shows that conditions (i)–(ii) must be satisfied by any renegotiation-proof allocation for the HP game.

Conditions (i) are standard incentive-compatibility constraints for the agent which reflect the sequentiality of decisions in the game. These constraints must naturally be satisfied by any renegotiation-proof allocation.

Consider now the conditions (ii). Suppose one is not satisfied for a value of x and x' in a renegotiation-proof allocation. Renegotiation-proofness implies that, along the equilibrium path, upon reporting x (the principal), every executed action-pair in the vector $\{a^{xy}\}_y$ is not renegotiated. Since condition (ii) is not satisfied for x and x', there exists an incentive-compatible vector of action-pairs $\{\alpha^y\}_y$ such that $\sum_y p_y U(\theta_1^x, \theta_2^y, \alpha^y) > \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy})$, and $V(\theta_2^y, \alpha^y) > V(\theta_2^y, a^{x'y})$ for all y. Suppose that the principal reports x' in stage 2, and offers in stage 2.1 a contract $\hat{c}$ with $m(\hat{c}) = \{\alpha^y\}_y$. In stage 2.2, it is a dominant strategy for the agent to accept the contract $\hat{c}$ because, by construction, this contract yields a strictly better allocation for the agent regardless of his beliefs about the principal's type. In stage 2.1, the principal then offers the contract $\hat{c}$, which is preferred to the status quo contract, given that she has reported x' in stage 2. In stage 2, the principal then has an incentive to report x' and renegotiate since, by construction, this yields her a strictly higher expected utility than reporting x. Hence, all conditions (ii) must be satisfied by a renegotiation-proof allocation for the HP game.

The next step in the proposition is to construct strategies and beliefs for the HP game that support any allocation satisfying conditions (i)–(ii) as a renegotiation-proof allocation. Consider the following strategies and beliefs.

Stage 2: Conditional on her type, the principal selects her preferred row in the menu $m(c_0)$.

Stage 2.1: Regardless of her type, the principal makes no contract offer if she has reported truthfully. Otherwise, she offers a contract supporting the solution to the right-hand-side of condition (ii).

Stage 2.2 Conditional on his type y and the principal's report x, the agent accepts all contract offers that are weakly preferred to a^{xy} and rejects all other offers. His beliefs are simply the Bayesian revision of his prior. They are irrelevant for his acceptance decision since his payoff is independent of θ_1.

Stage 3.1: The agent selects his preferred action-pair in the menu of the outstanding contract, and execute the associated action a_2.

It is clear that, if an allocation satisfies the conditions (i)–(ii), these strategies and beliefs form a PBE of the HP game. *Q.E.D.*

Proof of Proposition 5 The first part of the proof shows that conditions (i)–(ii) must be satisfied by any renegotiation-proof allocation for the HA game.
Conditions (i) represent the agent's incentive-compatibility constraints in expected terms over the principal's type since the agent selects a column of the menu before the principal has any chance of communicating her information to the agent. It is clear that these constraints must be satisfied by any renegotiation-proof allocation for the HA game.
Consider now conditions (ii). Suppose one is not satisfied for a value of x and y' in a renegotiation-proof allocation. Renegotiation-proofness implies that, along the equilibrium path, following the agent's report y', every executed action-pair in the vector $\left\{a^{xy'}\right\}_x$ is not renegotiated. In stage 2.1, the principal Bayesian updates her prior over the support

$\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$. Since condition (ii) is not satisfied for x and y', there exists a vector of action-pairs $\{\alpha^x\}_x$ such that

$$\sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, \alpha^x) > \sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^x, \theta_2^y, a^{xy}),$$

and $V(\theta_2^y, \alpha^x) > V(\theta_2^y, a^{xy'})$ for all x and $y \in \mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$. Furthermore, this vector is incentive compatible for the principal conditional on her revised beliefs, that is,

$$\sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^z, \theta_2^y, \alpha^z) > \sum_{y\in\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)} p_y U(\theta_1^z, \theta_2^y, \alpha^{z'})$$

for all z, z'. Suppose that the principal offers a contract $\hat{c}$ with $m(\hat{c}) = \{\alpha^x\}_x$ in stage 2.1. By construction, this new contract strictly dominates the outstanding contract for the agent, and he therefore accepts it regardless of his beliefs at stage 2.2. Given this, the principal indeed offers the contract $\hat{c}$ after the agent has reported y' at stage 2. Hence, all conditions (ii) must be satisfied by a renegotiation-proof allocation for the HA game.
I now consider the conditions (iii). These constraints state that, conditional on the principal's Bayesian updating of her prior following the agent's report, the principal has an incentive to report truthfully at stage 3.1. These constraints must be satisfied by any renegotiation-proof allocation.

The next step in the proposition is to construct strategies and beliefs for the HA game that support any allocation satisfying constraints (i)–(iii) as a renegotiation-proof allocation. Consider the following strategies and beliefs.

Stage 2: Conditional on his type, the agent selects his preferred column in the menu $m(c_0)$.

Stage 2.1: Regardless of her own type and the agent's selection, the principal makes no contract offer. Her beliefs are simply the Bayesian revision of her prior concentrated on the set $\mathcal{Y}\left(\left\{a^{xy'}\right\}_x\right)$.

Stage 2.2 Conditional on his type y and his report y', the agent accepts all contract offers that are weakly preferred to $\left\{a^{xy'}\right\}_x$ for all x, and rejects all other offers. The rejection of an offer $\{\alpha^x\}_x$ is supported by the beliefs that the principal has type $\hat{x}$ if $V(\theta_2^y, \alpha^{\hat{x}}) < V(\theta_2^y, a^{\hat{x}y'})$.

Stage 3.1: The principal selects her preferred action-pair in the column of the outstanding contract and execute the associated action a_1.

It is clear that, if an allocation satisfies the constraints (i)–(iii), these strategies and beliefs form a PBE of the HA game. *Q.E.D.*

Proof of Proposition 6 We first show that the allocation μ^{DA} is weakly dominated by the allocation μ^{HP} of the HP game. Since μ^{DA} is independent of θ_1, its conditions for renegotiation-proofness are equivalent to conditions (i) in Proposition 4. Suppose first that μ^{DA} satisfies conditions (ii) of Proposition 4. It would then be renegotiation-proof for the HP game, and the result would be proven. Now, suppose that μ^{DA} does not satisfy conditions (ii) of Proposition 4. This implies that at least one type of principal can increase its expected utility without decreasing that of the agent (and without violating the agent's incentive constraints). For each principal type x', compute the solution to the maximization problem of the right-hand-side of constraints (ii) in Proposition 4 with $a^{x'y} = \mu_y^{DA}$. Since the constraints of that maximization are independent of θ_1, these solutions themselves satisfy the principal's incentive compatibility constraints (ii) in Proposition 4. Furthermore, they satisfy the agent's incentive-compatibility constraints. This means that these solutions are renegotiation-proof for the HP game. Since this allocation is strictly better than μ^{DA}, the result is proven.

I now show that the allocation $\mu^{DP} = \{a^x\}_x$ of the DP game is weakly dominated by the allocation μ^{HA} of the HA game. Since μ^{DP} is independent of θ_2, its conditions for renegotiation-proofness are equivalent to conditions (iii) in Proposition 5. Second, conditions (i) of Proposition 5 are also satisfied for μ^{DP} since it is independent of θ_2. Finally, by definition we have:

$$\begin{aligned} \mu^{DP} = \arg\max_{\{a^x\}} \quad & \textstyle\sum_x \pi_x \sum_y p_y U(\theta_1^x, \theta_2^y, a^x) \\ \text{s.t.} \quad & \textstyle\sum_x \pi_x \sum_y p_y V(\theta_2^y, a^x) \geq \bar{v} \\ & \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, a^x) \geq \sum_y p_y U(\theta_1^x, \theta_2^y, a^{x'}) \quad \forall x, x'. \end{aligned}$$

Suppose that μ^{DP} does not satisfy condition (ii) for some x'. This implies that

$$\sum_y p_y U(\theta_1^{x'}, \theta_2^y, \alpha^{x'}) > \sum_y p_y U(\theta_1^{x'}, \theta_2^y, a^{x'})$$

where $\{\alpha_x\}_x$ solves the right-hand-side of condition (ii) for $x = x'$. This can only be possible if an incentive constraint is binding at $a^{x'}$ for a type x''. Otherwise, the principal cannot increase her expected payoff without decreasing that of the agent in some state y'. This implies that $\sum_y p_y U(\theta_1^{x''}, \theta_2^y, a^{x''}) > \sum_y p_y U(\theta_1^{x''}, \theta_2^y, a^{x''})$ for this incentive constraint to still be satisfied. If no incentive constraint is binding at $a^{x''}$, then this inequality cannot hold while at the same time maintaining agent 2 as well off in all states y. If an incentive constraint is binding at $a^{x''}$, then the previous argument is repeated until no incentive constraints are binding, at which point a contradiction is reached. This implies that μ^{DP} must satisfy conditions (ii). It is therefore renegotiation-proof for the HA game. Consequently, it is weakly dominated by the allocation μ^{HA} of the HA game. *Q.E.D.*

Proof of Proposition 7 (1) The first step in the proof is to compute the full-commitment allocation for a given value for θ_1. The next step is then to characterize the optimal full-commitment allocation. Finally, I show that the HA game supports this allocation.

Consider the following maximization problem.

$$(3)\qquad \begin{array}{rl} \max_{\{a^y\}} & \sum_y p_y U(\theta_1, \theta_2^y, a^y) \\ \text{s.t.} & \sum_y p_y V(\theta_2^y, a^y) \geq v \\ & V(\theta_2^L, a^L) \geq V(\theta_2^L, a^H) \\ & V(\theta_2^H, a^H) \geq V(\theta_2^H, a^L) \end{array}$$

The necessary first-order conditions are:

$a_1^L:\quad -p_L + \lambda p_L v'(a_1^L) + \psi_L v'(a_1^L) - \psi_H v'(a_1^L) = 0$

$a_2^L:\quad p_L u_{a_2}(\theta_1, \theta_2^L, a_2^L) - \lambda p_L e_{a_2}(a_2^L, \theta_2^L) - \psi_L e_{a_2}(a_2^L, \theta_2^L) + \psi_H e_{a_2}(a_2^L, \theta_2^H) = 0$

$a_1^H:\quad -(1-p_L) + \lambda(1-p_L)v'(a_1^H) - \psi_L v'(a_1^H) + \psi_H v'(a_1^H) = 0$

$a_2^H:\quad (1-p_L)u_{a_2}(\theta_1, \theta_2^H, a_2^H) - \lambda(1-p_L)e_{a_2}(a_2^H, \theta_2^H) + \psi_L e_{a_2}(a_2^H, \theta_2^L) - \psi_H e_{a_2}(a_2^H, \theta_2^H) = 0$

where λ, ψ_L, and ψ_H are the respective multipliers of the three constraints.

First, suppose that the allocation is separating. Incentive compatibility implies that $a_i^L < a_i^H$ for $i = 1, 2$. There are two cases. Either $\psi_L > 0$ and $\psi_H = 0$, or $\psi_L = 0$ and $\psi_H > 0$.

Suppose first that $\psi_L > 0$ and $\psi_H = 0$. The first and third first-order conditions, the concavity of v, and incentive compatibility imply that $p_L/(\lambda p_L + \psi_L) > (1-p_L)/(\lambda(1-p_L) - \psi_L)$. But this implies that $\psi_L < 0$, a contradiction.

Suppose now that $\psi_L = 0$ and $\psi_H > 0$. The last two first-order conditions imply that $u_{a_2}(\theta_1, \theta_2^H, a_2^H) - e_{a_2}(a_2^H, \theta_2^H)/v'(a_1^H) = 0$, which in turn means that type H is ex post efficient. Simple manipulations of first-order conditions yield: $\lambda p_L = (p_L + \psi_H v'(a_1^L))/v'(a_1^L)$ and $\psi_H = p_L(1-p_L)(v'(a_1^L) - v'(a_1^H))/(v'(a_1^H)v'(a_1^L))$. Substituting for these expressions in the first-order condition for a_2^L yields (after some manipulations):

$$u_{a_2}(\theta_1, \theta_2^L, a_2^L) - e_{a_2}(a_2^L, \theta_2^L)/v'(a_1^L) + (1-p_L)\left[\frac{1}{v'(a_1^H)} - \frac{1}{v'(a_1^L)}\right]\left(e_{a_2}(a_2^L, \theta_2^H) - e_{a_2}(a_2^L, \theta_2^L)\right) = 0.$$

Because $a_1^H > a_1^L$ and $V_{a_2\theta_2} < 0$ (the single-crossing assumption on V), the last term is negative. This implies that $u_{a_2}(\theta_1, \theta_2^L, a_2^L) - e_{a_2}(a_2^L, \theta_2^L)/v'(a_1^L) > 0$, which means that type L is underproducing compared to his ex post efficient locus. Further manipulations of the same equation yield:

$$u_{a_2}(\theta_1, \theta_2^L, a_2^L) - e_{a_2}(a_2^L, \theta_2^L)/v'(a_1^H) + \left[\frac{1}{v'(a_1^L)} - \frac{1}{v'(a_1^H)}\right]\left(-p_L e_{a_2}(a_2^L, \theta_2^L) - (1-p_L)e_{a_2}(a_2^L, \theta_2^H)\right) = 0.$$

Because $a_1^H > a_1^L$, the last term is positive. This implies that $u_{a_2}(\theta_1, \theta_2^L, a_2^L) - e_{a_2}(a_2^L, \theta_2^L)/v'(a_1^H) < 0$, which means that type L would be overproducing at $\left(a_1^H, a_2^L\right)$. Furthermore, the assumption for Case P implies that, for any given transfer a_1, the ex post efficient level of a_2 is always greater for type L than for type H. There is therefore a contradiction: given that type H is ex post efficient and type L is underproducing, type L cannot be overproducing at $\left(a_1^H, a_2^L\right)$. Hence, the optimal allocation cannot be separating. This pooling result is useful to characterize the full-commitment allocation when θ_1 is the principal's private information.

(2) The second step of the proof is to compute this full-commitment allocation. Consider the following maximization problem.

$$(4)\qquad \begin{aligned} \max_{\{a^{xy}\}} \quad & \textstyle\sum_x \pi_x \sum_y p_y U(\theta_1^x, \theta_2^y, a^{xy}) \\ \text{s.t.} \quad & \textstyle\sum_x \pi_x \sum_y p_y V(\theta_2^y, a^{xy}) \geq \bar{v} \\ & \textstyle\sum_x \pi_x V(\theta_2^L, a^{xL}) \geq \sum_x \pi_x V(\theta_2^L, a^{xH}) \\ & \textstyle\sum_x \pi_x V(\theta_2^H, a^{xH}) \geq \sum_x \pi_x V(\theta_2^H, a^{xL}) \\ & \textstyle\sum_y p_y U(\theta_1^L, \theta_2^y, a^{Ly}) \geq \sum_y p_y U(\theta_1^L, \theta_2^y, a^{Hy}) \\ & \textstyle\sum_y p_y U(\theta_1^H, \theta_2^y, a^{Hy}) \geq \sum_y p_y U(\theta_1^H, \theta_2^y, a^{Ly}) \end{aligned}$$

It is easy to show that the type H principal's incentive constraint is not binding. This is due to the fact that the principal is risk neutral, the agent, risk averse, and the type H principal values a_2 more than type L. These assumptions imply that, under symmetric information for θ_1, the transfer would be constant, and a_2 would be higher for θ_1^H than θ_1^L. Under asymmetric information for θ_1, the type L principal would therefore like to mimic type H. It follows that the type H's allocation must be distorted to satisfy type L's incentive constraint. This implies that type L's allocation is not distorted because of the presence of asymmetric information about θ_1. It is therefore independent of the agent's type as shown in the first step of the proof. Now, consider the necessary first-order conditions to problem (4) for a^{HL} and a^{HH}.

$$
\begin{aligned}
a_1^{HL}: &\quad -p_L\pi_H + \lambda p_L\pi_H v'(a_1^{HL}) + \psi_L\pi_H v'(a_1^{HL}) - \psi_H\pi_H v'(a_1^{HL}) + \phi\pi_H p_L = 0\\
a_2^{HL}: &\quad p_L\pi_H u_{a_2}(\theta_1^H, \theta_2^L, a_2^{HL}) - \lambda p_L\pi_H e_{a_2}(a_2^{HL}, \theta_2^L) - \psi_L\pi_H e_{a_2}(a_2^{HL}, \theta_2^L)\\
&\qquad + \psi_H\pi_H e_{a_2}(a_2^{HL}, \theta_2^H) - \phi\pi_H p_L u_{a_2}(\theta_1^L, \theta_2^L, a_2^{HL}) = 0\\
a_1^{HH}: &\quad -(1-p_L)\pi_H + \lambda(1-p_L)\pi_H v'(a_1^{HH}) - \psi_L\pi_H v'(a_1^{HH})\\
&\qquad + \psi_H\pi_H v'(a_1^{HH}) + \phi\pi_H(1-p_L) = 0\\
a_2^{HH}: &\quad (1-p_L)\pi_H u_{a_2}(\theta_1^H, \theta_2^H, a_2^{HH}) - \lambda(1-p_L)\pi_H e_{a_2}(a_2^{HH}, \theta_2^H) + \psi_L\pi_H e_{a_2}(a_2^{HH}, \theta_2^L)\\
&\qquad - \psi_H\pi_H e_{a_2}(a_2^{HH}, \theta_2^H) - \phi\pi_H(1-p_L)u_{a_2}(\theta_1^L, \theta_2^H, a_2^{HH}) = 0
\end{aligned}
$$

where λ, ψ_L, ψ_H, and $\pi_H\phi$ are the respective multipliers of the first four constraints, the last not being binding by the above argument. These first-order conditions are similar to those of problem (3) when U is replaced by $U(\theta_1^H, \cdot) - \phi U(\theta_1^L, \cdot)$. Furthermore, it is easy to show that the first-order conditions imply $0 < \phi < 1$.

Under Assumption 2, the function $U(\theta_1^H, \cdot) - \phi U(\theta_1^L, \cdot)$ inherits the same single-crossing property as U, as well as preserving the characterization of Case P. Applying step one of the proof then implies that the type H principal's allocation must be independent of the agent's type. To separate itself from type L, type H distorts her allocation by pooling the agent's types rather than separating them. The full-commitment allocation is then independent of the agent's type.

(3) The last step is to argue that the communication structure HA can implement the full-commitment allocation. The first two steps of the proof have shown that the problem is reduced to a one-sided asymmetric-information environment. The results of Section 3 show that it is optimal to delegate decision making to the informed agent. The HA structure achieves this by having the principal executing her action before the agent. The agent's prior message is essentially meaningless given that the allocation is independent of his type. *Q.E.D.*

Proof of Proposition 8 (i) It is easy to show that the allocation μ^C is separating. Any pooling of a subset of types of the principal or agent is renegotiated. This results directly from the single-crossing assumptions and the Case S assumption. Given full separation, the incentive constraints in the maximization problem of the proposition simply corresponds to the conditions in Proposition 3.

(ii) I first provide an upper bound on the expected utility of the principal in the HP game by imposing on the full-commitment problem necessary conditions for HP renegotiation-proofness. The full-commitment problem can be rewritten as the following sequence of maximization problems. For each x,

$$\begin{aligned} \tilde{U}^x(r_x, c_x) = \max_{\{a^y\}} \;& \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, a^y) \\ \text{s.t. } & \textstyle\sum_y p_y V(\theta_2^y, a^y) \geq \bar{v} - r_x \\ & V(\theta_2^H, a^H) \geq V(\theta_2^H, a^L) - c_x \end{aligned}$$

where the nonbinding incentive constraint has been omitted.[20]

$$\begin{aligned} \max_{r_x, c_x} \;& \textstyle\sum_x \pi_x \tilde{U}^x(r_x, c_x) \\ \text{s.t. } & \textstyle\sum_x \pi_x r_x \leq 0 \\ & \textstyle\sum_x \pi_x c_x \leq 0 \\ & \tilde{U}^x(r_x, c_x) \geq \textstyle\sum_y p_y U(\theta_1^x, \theta_2^y, \tilde{a}^{x'y}(r_{x'}, c_{x'})) \quad \forall x, x' \end{aligned}$$

where $\{\tilde{a}^{xy}(r_x, c_x)\}_y$ is the maximand of the first maximization problem. For similar reasons as above, the optimal allocation μ^{HP} is separating. Renegotiation proofness in the HP game implies that $c_x = 0$ for all x. Suppose that there exists a type x' such that $c_{x'} < 0$. Following her report, the type x' principal could always successfully renegotiate such slack until the incentive constraint becomes strictly binding. This implies that $c_x \geq 0$ for all x. Since the feasibility constraint says that $\sum_x \pi_x c_x \leq 0$, it follows that $c_x = 0$ for all x. The next step is to show that the principal's incentive-compatibility constraints are modified by renegotiation and should be expressed as in the statement of the proposition. Suppose the type x principal mimics type x'. Type x knows she can renegotiate from the type x' allocation. As shown in Proposition 4, such renegotiation yields $\acute{U}^x(r_{x'})$, where $\acute{U}^x$ is defined in Proposition * and replicates condition (ii) of Proposition 4. The principal's incentive constraint must then be $\tilde{U}^x(r_x, 0) = U^x(r^x) \geq \acute{U}^x(r_{x'})$. This shows that the maximization problems in Proposition 8 give an upper bound to the principal's expected utility in the HP game.

I now argue that this upper bound is renegotiation-proof in the HP game. Consider the conditions in Proposition 4. Conditions (i) are trivially satisfied by the characterization in the proposition. Conditions (ii) are also satisfied. First, conditions (ii) for $x = x'$ are satisfied by the first maximization problem. Second, for $x \neq x'$, a mimicking principal can obtain $\acute{U}^x(r_{x'})$. The constraint $U^x(r_x) \geq \acute{U}^x(r_{x'})$ then corresponds to condition (ii). Conditions

[20]It is straightforward to show that type L's incentive constraint is not binding.

(ii) are then satisfied by the solution defined in the proposition. The upper bound is HP renegotiation-proof. This completes this part of the proof.

(iii) I first provide an upper bound on the expected utility of the principal in the HA game by imposing on the full-commitment problem necessary conditions for HA renegotiation-proofness. The full-commitment problem can be rewritten as the following sequence of maximization problems. For each y,

$$\begin{aligned} \tilde{U}^y(r_y, c_y) = \max_{\{a^x\}} \quad & \textstyle\sum_x \pi_x U(\theta_1^x, \theta_2^y, a^x) \\ \text{s.t.} \quad & \textstyle\sum_x p_x V(\theta_2^y, a^x) \geq \bar{v} - r_y \\ & U(\theta_1^L, \theta_2^y, a^L) \geq U(\theta_1^L, \theta_2^y, a^H) - c_y \end{aligned}$$

where the nonbinding type H's incentive constraint has been omitted.

$$\begin{aligned} \max_{r_y, c_y} \quad & \textstyle\sum_y p_y \tilde{U}^y(r_y, c_y) \\ \text{s.t.} \quad & \textstyle\sum_y p_y r_y \leq 0 \\ & \textstyle\sum_y p_y c_y \leq 0 \\ & \bar{v} - r_y \geq \textstyle\sum_x \pi_x V(\theta_2^y, \check{a}^{xy'}(r_{y'}, c_{y'})) \quad \forall y, y' \end{aligned}$$

where $\{\check{a}^{xy}(r_y, c_y)\}_x$ is the maximand of the first maximization problem. For similar reasons as above, the optimal allocation μ^{HA} is separating. I now show that renegotiation proofness in the HA form implies that $c_y = 0$ for all y. Suppose that there exists a type y' such that $c_{y'} < 0$. Following the agent's report y', the principal could always successfully renegotiate such slack until her incentive constraint becomes strictly binding. This implies that $c_y \geq 0$ for all y. Since the feasibility constraint says that $\sum_y p_y c_y \leq 0$, it follows that $c_y = 0$ for all y. These restrictions imply that the full-commitment problem reduces to the maximization in the proposition, which then provides an upper bound on the expected utility of the principal in the HA game.

I now argue that this upper bound is renegotiation-proof in the HA game. Consider the conditions in Proposition 5. Conditions (i) and (iii) are incentive constraints which are satisfied by the characterization in the proposition. Conditions (ii) are also satisfied. This can be shown using a similar argument as that employed in the last part of the proof of Proposition 6. The upper bound is HA renegotiation-proof. *Q.E.D.*