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(forthcoming, REVUE D'ECONOMIE INDUSTRIELLE, APRIL 2000)

Olin Working Paper No. 00-1

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Complexity and Contract*

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January 2000

Abstract

It is well known that contract incompleteness can arise from the impossibility of planning for all future contingencies in a relationship (e.g. Williamson (1975)). In this paper it is shown that whether or not such incompleteness constrains the efficiency of the contract is very sensitive to assumptions concerning the timing of the resolution of uncertainty. It is shown that when agents must respond to an unforeseen contingency before being able to renegotiate the contract, then contract complexity is a binding constraint, a case that is called *ex post hold-up*. Secondly, it is suggested that the amount of multi-tasking can provide a measure of contract complexity. When complexity is low, contingent contracting is efficient, while subjective performance evaluation is more efficient when complexity is high. In this case the optimal contract for *ex post* hold-up is based upon the ability of humans to make subjective judgements that are in some cases more informative than explicit performance measures. Moreover, the efficiency of the contract is not sensitive to human error per se, but is an increasing function of the correlation in judgements between the contracting parties.

*Forthcoming in a special contracts issue of *Revue d'Economie Industrielle,* April 2000.

†I very much appreciate the comments of the referees, Sherwin Rosen, Alan Schwartz, and Oliver Williamson on this work, as well as seminar participants at the University of California Davis, Stockholm School of Economics, University of Oslo, University of Bergen, and the Yale Law School. I am also grateful to Mehdi Farsi for able research assistance. The financial support of National Science Foundation grant SBR-9709333 is gratefully acknowledged.

"The time is not here yet, but I hope it is coming when judges realize that the people who draft...contracts cannot envisage all the things that the future will bring."[1]

1 Introduction

Building upon the work of Simon (1957), Williamson (1975) observes that a fundamental reason for transaction costs is the impossibility of planning for all future contingencies in a relationship.[2] The purpose of this paper is explore the conditions under which such complexity can constrain the set of feasible contracts, and help us better understand the contracts observed in practice. Specifically, situations where agents are asked to make decisions when unforeseen events occur, but cannot renegotiate the contract is one I call *ex post* hold-up. In these cases, complexity can have an important impact upon the form of the optimal contract. The paper begins by comparing the structure of the *ex post* hold-up problem to other contracting problems in the literature and suggests that a key ingredient in understanding the form of the optimal contract is the timing of information and actions in a relationship. Secondly, a way to measure contract complexity is suggested that has empirical implications. Finally, the optimal governance of contracts facing *ex post* holdup when complexity is high depends upon the superior pattern recognition abilities of humans. In this case the optimal contract depends upon the degree of correlation in beliefs between the contracting parties.

Beginning Simon (1951), there is a large literature that takes as given contract incompleteness due to transaction costs and then explores the implications of this for efficient governance. Simon argues that giving one agent authority over another economizes on transaction costs by allowing one to delay decision making until after uncertainty has been resolved. In a similar vein, the recent property rights literature, beginning with Grossman and Hart (1986), argues that problems of contract incompleteness are resolved by an appropriate reallocation of bargaining power in a relationship through ownership rights. Agency theory, beginning with Ross (1973), Mirrlees (1999) and Holmström (1979), focuses upon how asymmetric information can explain observed contracting arrangements. Holmström and Milgrom (1991) show that in an multi-tasking context when signals concerning one task are not available, then the optimal contract may ignore information regarding performance on other tasks.

While contract incompleteness and asymmetric information are central theme in this literature, the role of human cognition is not. One reason, as observed by Oliver Hart (1990), is both agency theory and the property rights literature assume that agents select their actions immediately after the contract is signed. The contract is designed to provide the appropriate incentives for performance at this stage, and hence if *ex post* unanticipated events occur these cannot affect actions that are sunk. In other words, there is no role for anticipated events in the structuring of the optimal contract. Agents may anticipate events that cannot be described *ex ante,* but this is a different problem, and one for which Maskin and Tirole (1999b) demonstrate that under the appropriate conditions does not affect the ability of individuals to optimally regulate their relationship.

How then do we reconcile these results in contract theory demonstrating the irrelevance of human cognition for contract formation with Williamson (1985)'s view that bounded rationality is central to the theory of transaction costs?[3] My first point is that we can usefully categorize different contracting

[1] A. Denning, The Discipline of Law 56 (1979). As quoted in Farnsworth (1990), page 543.
[2] In particular the discussion in section 2.1 of Williamson (1975).
[3] See chapter 1.

problems as a function of *when* information is revealed. In the next section the sequence of moves for the agency model, the hold-up model and Simon's authority model are reviewed. While these are important classes of problems that correspond to many interesting contracting situations, there are not all inclusive. In many principal-agent situations the agent is called upon to respond to unexpected events in a way that is personally costly, but for which there is not sufficient time to renegotiate the outstanding contract with the principal. I call this contracting hazard *ex post* hold-up, and show in section 3 that the nature of human cognition may play an important role in the optimal regulation of the relationship.

Many employment relationships have exactly this characteristic. For example, fireman may have to respond quickly to events while a building is burning, and cannot renegotiate the contract with the city in mid-blaze. Emergency room doctors must deal with a variety of unexpected events, some of which are dangerous to the physician, especially when the patient has a communicable disease. In these situations hold-up can take one of two forms. First the agent after taking an action may not receive the compensation that he or she feels is appropriate. Secondly, the principal may worry that the agent may not have the correct incentives to take the appropriate action *ex post.*

Section 3 continues with a discussion of why contracting in these situations is difficult. If each event that an agent faces could be described beforehand, along with the appropriate response, then *ex post* hold-up would be solved with a complete state contingent contract. However when the services to be provided entail multi-tasking with random benefits and costs, the number of contract contingencies grows exponentially with the number of tasks. This implies that even with a moderate number of tasks, complete state contingent contracting is impossible. It is worth emphasizing that contract incompleteness in this case is *not* exclusively due to the bounded cognitive abilities of the contracting parties: when complexity grows exponentially with a variable of interest, the problem quickly becomes intractable for any finite computation device for even modest values of this variable.[4] This is an empirically useful result because it suggests that the number of tasks in a relationship is a measure of transaction costs that is independent of individual characteristics.

Anderlini and Felli (1994) take a complementary approach to contract incompleteness. They use the notion of a *computable* contract, namely any complete contract must have the property that it is possible to determine the terms and conditions using a finite number of computations. They give examples of contracts that are not computable, and hence are incomplete. Though this condition is a *necessary* condition, it is not *sufficient* to ensure the existence of a complete contract. All the state contingent contracts considered in this paper satisfy Anderlini and Felli's necessary condition, however like $NP - hard$ problems in computer science, they are not complete in practice due to bounds on computational complexity.

If contingent contracting is impossible, then the contract must first solve the determination of what constitutes appropriate performance *ex post*, and secondly assure the agent is rewarded for taking the appropriate action. This issue is addressed in section 4, where it is shown that the problem of performance evaluation is formally a problem in pattern recognition where the goal is to characterize event-action pairs into the sets acceptable or not acceptable. In cognitive science it is widely recognized that while humans are quite poor at thinking logically, they have very powerful pattern recognition abilities.[5] For example, the reason that humans are good at chess is not because of their ability to reason about the game, a skill for which computers are far more skilled, but rather their ability to recognize board patterns that represent

[4] A point that is well appreciated in the computor science literature. See for example Garey and Johnson (1979). Williamson (1975) makes a similar point on page 23 in reference to the game of chess.

[5] See Churchland and Sejnowski (1993) for an excellent introduction to these issues.

strong positions.[6] This ability is so difficult to program that only recently have computers been consistently better than humans at chess, and only with programs that are highly specialized. This implies that human judgment of performance is in many situations superior to any mechanical measuring system, and hence optimal contracts should be designed to incorporate this ability.

Incentives can be provided in these cases by observing that both the principal and agent have subjective evaluations of an agent's performance. As long as these evaluations are sufficiently correlated, then it is possible to construct a mechanism that ensures efficient performance. The optimal contract in this case takes the form of a bonus payment by the principal to the agent when the principal has judged performance to be acceptable. Given that third parties, such as the courts, are at a disadvantage in determining if performance is acceptable, then the optimal contract depends upon the agent's self assessment of performance. Should the principal not reward the agent when the agent believes he or she is deserving then the optimal contract requires the principal to pay a penalty to a third party.

The difficulty with such payments is that they are subject to the hazard of renegotiation. In the event of a disagreement, the principal and agent have a strong incentive to renegotiation to avoid paying the third party. Two well known solutions to this problem are discussed in section 5: enforcement with repeated interaction combined with the threat of termination and the use of rank order tournaments. This is a useful exercise because it answers an open question in the legal theory of relational contract raised by Goetz and Scott (1981). They observe that the right to unilateral termination, while part of many bilateral relational contracts, is not a usual condition for collective agreements, and hence they question the efficacy of such termination rights. The results here show that unilateral termination clauses may be a necessary condition for efficiency when bargaining is restricted to two individuals, and can only be modified when there are three or more individuals in a relationship.

2 Contracting Scenarios

Consider the following generic exchange problem between an agent (he) who produces a good or service for a principal (her) in exchange for compensation:

1. The agent is expected to choose an action $\mathbf{y}$ from a set of possible actions $\mathbf{Y}$ (in general multi-dimensional) at a cost $C(\mathbf{y}, \beta)$, where β is a random parameter chosen by Nature.

2. The benefit to the principal from this action is $qB(\mathbf{y}, q, \alpha)$, where α is random parameter chosen by Nature, and q is the quantity of trade, which is normalized to represent trade (1) or no-trade (0), or the probability of trade if $q \in (0, 1)$.

3. The principal and agent write a binding contract at the beginning of the relationship conditional upon their expectations and information available. I assume that the principal has all the bargaining power at each stage.[7] The payoffs to the principal and agent are respectively given by:

$$U_P = qB(\mathbf{y}, \alpha) - W, \tag{1}$$

$$U_A = W - C(\mathbf{y}, q, \beta). \tag{2}$$

[6] This was shown in a wonderful paper by Newell, Shaw, and Simon (1963).

[7] For simplicity, I follow the recent literature (Hart and Moore (1999) and Maskin and Tirole (1999a)) and assume that the principal has all the bargaining power in any *ex post* negotiation. This assumption can be dropped, but at the cost of unnecessarily complicating the argument.

The principal is assumed to offer a contract that maximizes her payoff subject to the agent receiving his reserve payoff from the relationship. The term "contract" is used in the economist's sense rather than in the more restrictive legal sense. That is the contract specifies a mechanism or game between the principal and agent, including expected actions and beliefs, even when these cannot be verified in court. In contrast the legal notion of contract refers to promises enforced by the threat of court awarded damages in the case of default. In particular for the economist these damage awards are an explicit part of the agreement between the two parties, as are actions that follow events that only the contracting parties can observe.

An important element of this broader notion of contract is the potential for one party (the principal) to reallocate bargaining power to the other party (the agent). This reallocation of bargaining power is central to the property rights literature beginning with Grossman and Hart (1986). The purpose of this section is to illustrate how the form of the optimal contract and the nature of property rights are sensitive to the *timing* of information revelation. I briefly outline the three important classes of contracting problems that have been considered in the literature, agency theory and the hold-up problem of Williamson (1975) and Grossman and Hart (1986), and Simon (1951)'s authority model, and discuss the relevance of theories of bounded rationality for each of these contracting problems. I then introduce the hazard of *ex post hold-up*, that is more appropriate for addressing the role of human cognition in contract formation.

2.1 Agency Theory

Agency theory, beginning with Ross (1973) and Holmström (1979) is the starting point for the modern theory of contract. It is possible to view all of the economic theory of contract as applications of agency theory: namely observed contracts are the result of negotiations between a principal and agent, who choose optimal contracts as a function of the available information. In this paper I follow Hart and Holmström (1987), and adopt a narrower definition of agency theory corresponding to the class of models that focus upon how to structure contracts as a function of mutually observed (and enforceable) signals of performance. In the context of our simple model let us fix β, and set $q = 1$. The timing of decisions are as illustrated in figure 1. At date 0 the contract is signed, then the agent chooses y, which is assumed to be a real number representing effort or some personally costly action: $\partial C/\partial y > 0$. The choice of effort affects the underlying distribution of α in such a way that more effort is beneficial to the principal: $\partial E\left(B\left(y,\alpha\right)\right)/\partial y > 0$ for all α. The principal then pays the agent a wage that is a function of the observed benefit, or $W = f\left(B\right)$.

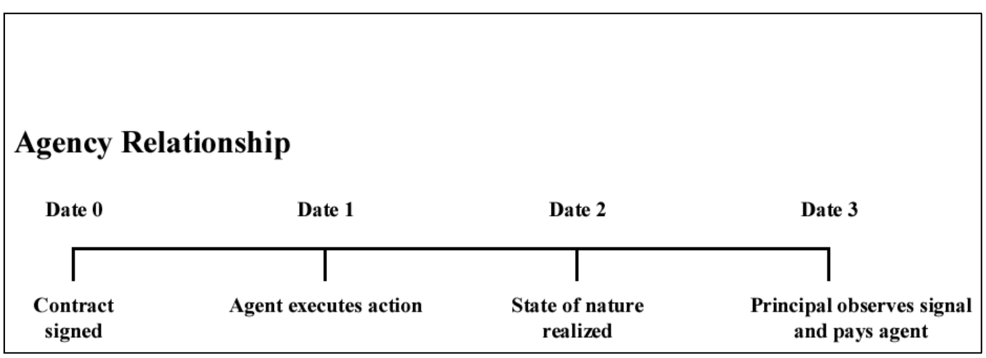

Figure 1: Time Line for Agency Relationship

In agency theory it is typically assumed that the agent is risk averse, and hence he would prefer a wage W that is independent of the random shock α. In that case the agent has no incentive to work and would select y to minimize the personal cost of effort. The major implication of the literature, as discussed in Hart and Holmström (1987), is in order to avoid this moral hazard problem the optimal contract should be a function of *any* signal of worker effort.

There is a great deal of evidence to suggest that the basic hypothesis of agency theory is correct, namely individuals do respond to incentives. Hence, if workers are paid a wage that is independent of income one expects to observe some shirking. Despite this fact, explicit pay for performance systems, while common, are far from being ubiquitous. The theory does predict that if an individual is infinitely risk averse, then it is optimal to set a fixed wage. However, the fact that some pay for performance is observed leads many experts, such as Gibbons (1997) and Prendergast (1999), to conclude that agency theory alone cannot explain all the variation observed in the data.

One solution, provided by Holmström and Milgrom (1991), begins with the observation that while effort is often multi-dimensional, performance measures may not be sufficiently rich to capture this variation. For example suppose that a homeowner is contracting for the services of a contractor who must allocate effort between speedy completion of the project and quality, whose actions are represented by the vector $y = \{y_s, y_q\}$, where y_s represents speed and y_q represents quality. In the absence of explicit contract terms, the cost minimizing effort is strictly positive: $\left\{y_s^o, y_q^o\right\} = \arg\min_{y_s, y_q \geq 0} C\left(y_s, y_q\right) > 0$. It is also reasonable to suppose that quality and speed are substitutes, and hence $C_{sq} > 0$.

In this simple example the benefit to the homeowner is assumed to have no uncertainty and is given by $B\left(y\right)$. Given that the payoff represents the subjective preferences of the homeowner, then one cannot write a contract conditional upon an explicit measure of B or for that matter quality y_q, also a subjective variable. Rather the only variable that is contractible is y_s, speed. In this case, assuming that the problem is convex, it follows that under the optimal contract $\left\{y_s^*, y_q^*\right\}$ solves:

$$C_{y_q}\left(y_s^*, y_q^*\right) = 0, \tag{3}$$

$$B_{y_s}\left(y_s^*, y_q^*\right) = C_{y_s} + B_{y_q}\left(y_s^*, y_q^*\right)\left(\frac{C_{y_s y_q}}{C_{y_q y_q}}\right) \tag{4}$$

The first term is the consequence of the contractor minimizing costs in the quality dimension, while the second term is the first order condition for speed. Since speed and quality are substitutes ($C_{sq} > 0$) then it follows that y_s^* is less than the first best.[8] Under Holmström and Milgrom (1991)'s assumption, if the substitution effect is sufficiently strong, or C_{qq} sufficiently small, then $y_s^* < y_s^o$. In other words the optimal contract may entail providing either no incentive or negative incentives for speed.

Hence incomplete contracts in agency theory arise from a paucity of information regarding performance. Notice that the hypothesis of rational expectations is central to the theory. The principal structures the incentive contract as a function of her expectations regarding future performance by the agent. The introduction of bounded rationality regarding the formation of expectations would imply that we may sometimes observe incentive contracts with unintended consequences (a possibility that is often observed in practice, as the examples in Kerr (1975)'s seminal article demonstrate). However, aside from the potential for error, agency theory provides little guidance regarding the implications of bounded rationality for observed contract form.

[8] A similar equation is derived in Baker (1992) who works out the optimal contract when the contractible variable is not perfectly aligned with benefits.

Also Holmström and Milgrom (1991)'s explanation for the lack of high power incentives for quality performance ignores the potential for incentives based upon non-contractible signals. In the case of the contractor, their model suggests that in a one period relationship the contractor would simply choose his most preferred quality, yet disputes over quality are quite common during construction. In many cases contracts are structured so that in areas that the quality is lacking, the builder may ask the contractor to take corrective actions, even though some aspects of quality were not explicitly contracted upon *ex ante*. This type of *ex post* renegotiation over non-contractibles is central to the hold-up model considered next.

2.2 Hold-up

Suppose now that the contractor is producing a house built to order. Given that time of completion is contractible, we focus only upon the provision of non-contractible quality. The main difference with respect to the agency model is the existence of a physical asset whose ownership rights can be transferred. Uncertainty plays a role in that *ex post* it may be more efficient to allocate the good to another buyer in the market. Suppose that the value of the house to the principal and the market are respectively given by $B(y_q,\omega)$ and $B^o(y_q,\omega)$, where it is assumed that $B(y_q,\omega) - B^o(y_q,\omega) = k(\omega)$, and $k(\omega)$ is an uncertain amount of relationship specific rent that depends upon the state of nature ω, (which may be positive or negative). Suppose that $\bar{k} = E(\max\{0, k(\omega)\}) > 0$, and hence *ex ante* there exists a positive level of idiosyncratic rent between the principal and the contractor. The time line for the contract is illustrated in figure 2.

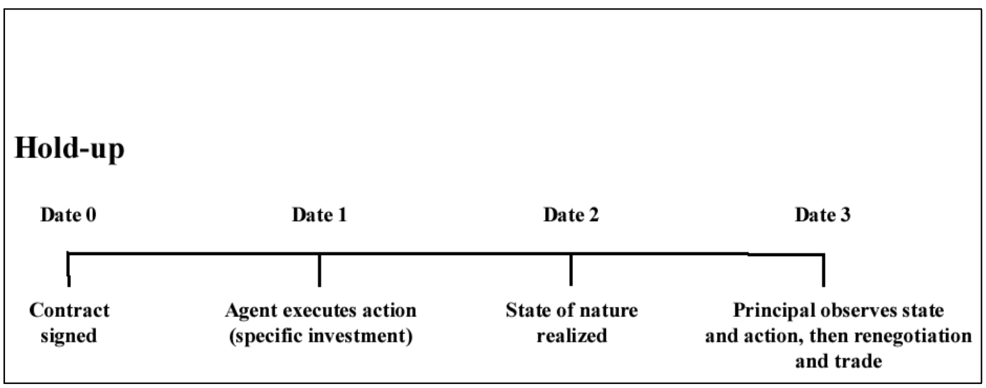

Figure 2: Time Line for Hold-up Model

The insight of the property rights literature, beginning with Williamson (1975) and Grossman and Hart (1986), is that the *ex post* distribution of bargaining power is an important determinant of the efficiency of the relationship, and that this bargaining power can be reallocated via ownership rights. Consider first the case in which the principal owns the house. Given that the principal has all the *ex post* bargaining power we obtain exactly the same solution as in the agency model above: the contractor selects his preferred quality, y_q^o, and agrees to a fixed price contract $p = C(y_q^o)$. In this case if *ex post* efficiency requires that the building be owned by another person, then the principal would simply sell the building to that person. Though this contract ensures *ex post* allocative efficiency, the lack of performance incentives implies that the contractor does not supply an efficient level of quality.

An alternative contract is for the principal to sell her right to the project to the contractor at a price $p = \max_{y_q} E\{B^o(y_q,\omega)\} - C(y_q)$, with the provision that she must be given the chance to match any offer that the contractor might receive from the market. This is a contract that provides the principal with the *right of first refusal,* a contract that was common in Hollywood for some actors and producers.[9] Under this contract the payoff of the contractor is:

$$
\begin{aligned}
U_A(y_q) &= E\{B^o(y_q,\omega)\} - C(y_q) - p, \\
&= E\{\max\{B^o(y_q,\omega), B(y_q,\omega)\}\} - \bar{k} - C(y_q) - p. \qquad (5)
\end{aligned}
$$

This contact provides first best incentives for quality, while ensuring that the principal receives all the rents.

There is a literature that explores how the complexity of the *ex post* environment makes it impossible to write an efficient contract (Segal (1999) and Hart and Moore (1999)). In these papers it is assumed that *ex post* there are a large number of potential goods that may be traded, but it is optimal to trade only one of these. When the nature of this good cannot be specified *ex ante*, then when the number of possible goods approaches infinity the optimal contract is a fixed price contract, which implies that the level of investment in the relationship is inefficient. This result demonstrates how environmental complexity can cause individuals to optimally choose an incomplete contract. However, this result is not an implication of bounded rationality and cognition *per se.* Both papers assume that contracting parties anticipate correctly the consequences of any mechanism they choose, and hence are not an exploration of the implications of unforeseen contingencies, rather they are concerned with "indescribable contingencies" (see Maskin and Tirole (1999b) for a further discussion of these points).

In fact Hart (1990) argues that hold-up models provide an inadequate foundation for the study of the implications of human cognition for organization and contract design. For example, suppose there is an unforeseen event ω' for which it is efficient that the asset be sold to the market. *Ex post* renegotiation ensures that this indeed will be the outcome, however given that specific investments have been sunk at the time individuals learn about ω', the occurrence of this event plays no role in setting *ex ante* incentives. Structuring relationships to efficiently deal with unforeseen contingencies is one of the motivations for Simon (1951)'s original model of the employment relationship.

2.3 Authority

Simon (1951)'s model of employment is concerned with the role played by authority. His idea is that in a complex world, rather than planning for all future events, one might gain by delaying decision making until after an event occurs. The formal timing for his model is illustrated in figure 3. After the contract is signed the principal is able to observe the state of nature, denoted by $\omega = \{\alpha, \beta\} \in \Omega$, where Ω is the set of possible states, and can direct the agent to perform a task y as a function of this information (without loss of generality we set $q = 1$). In Simon's model giving the principal authority imposes costs on the agent *ex post* since he may be asked to carry out tasks with large private costs, $C(y, \beta)$. Simon supposes that the authority relationship is characterized by a wage, W, and a set of tasks $\mathbf{Y}^o \subset \mathbf{Y}$ from which the principal may choose. Giving the principal more authority corresponds to choosing a larger set of tasks, $\mathbf{Y}^o$, that the

[9] In personal correspondence relating his discussions with Ben Klein and Earl Thompson, Alchian (1998) observes that many Hollywood contracts for shows were exactly of this form. An actor or producer on a long term contract could entertain outside offers, however if the studio matched the offer, the individual had an obligation to stay with his or her studio. Alchian argues informally that the right of first refusal served the purpose of providing incentives for efficient specific investment.

employee may be asked to carry out in exchange for a higher wage. Notice that since control is specified in terms of $\mathbf{Y}^o$, and not states, then the model automatically incorporates a protocol to be followed when an unforeseen event occurs.

If this set is a single action, i.e. $\mathbf{Y}^o = y$, then Simon calls this a sales contract and the concept of authority has no relevance. Simon shows that the optimal contract gives the principal some authority over the agent when the benefits of flexibility outweigh the costs. The potential for renegotiation changes this result. Suppose that the agent accepts any sales contract $\{W^*, y^*\}$ satisfying $W^* - E\{C(y^*,\beta)\} \geq 0$, then it will follow that the expected utility of the agent is at least zero. After the event $\omega = \{\alpha, \beta\}$ occurs, then under the sales contract the agent receives $U_A^*(\beta) = W^* - C(y^*, \beta)$ *ex post.* Suppose that the principal has all the bargaining power, then she can offer a new *efficient* contract that would be accepted by the employee as long as the utility is at least $U_A^*(\beta)$. Hence we have the following result:

Proposition 1 *If renegotiation before the agent chooses his action is possible, then the sales contract results in the first best.*

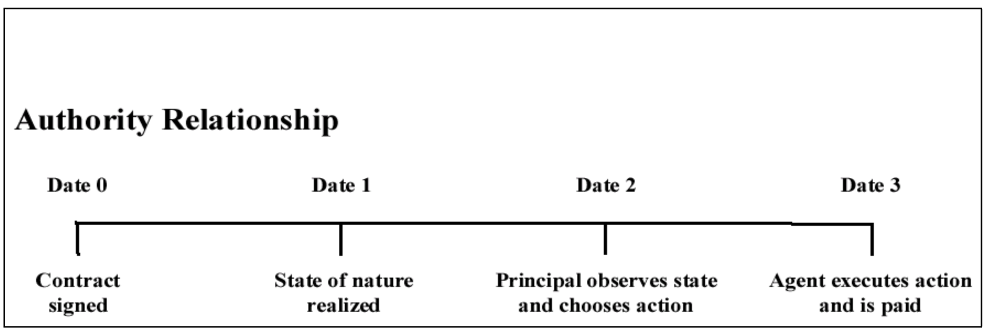

Figure 3: Time Line for Authority Relationship

In this contracting situation the allocation of bargaining power is not important, rather the key ingredient is the hypothesis that renegotiation can occur between the time the state is observed and the agent selects her action. What is interesting, is in contrast to the hold-up problem, the addition of renegotiation increases, rather than decreases efficiency. However, there are a number of situations for which the hypothesis that renegotiation is not possible is reasonable. For example firemen must make second by second decisions on how to respond to a burning building, teachers need to be able to deal with new and unexpected questions and events in the class, surgeons must be able to deal with unexpected events during an operation. Moreover, for the same reasons that renegotiation is not possible, the exercise of authority may also be impossible.

Alchian and Demsetz (1972) make this point when they argue that in employment relationships there is typically no real authority. The agent follows the principal's directives because he believes that he will be rewarded in the future. If the agent is dissatisfied then he is free to leave for another employment relationship. Alchian and Demsetz argue that the key point is the ability to *monitor* the agent's actions in order to be able to choose the appropriate level of compensation. The motivation for delaying decision making is based upon the possibility of unforeseen contingencies that make it impossible to have a complete plan. However, if the agent is unable to renegotiate her contract, she faces the prospect of taking a personally costly action, without any assurance that she will be rewarded. *Ex post* the principal can always claim that existing compensation is sufficient. This leads to a contracting hazard that I call *ex post hold-up.*

3 Ex Post Hold-up

In the contracting problems we have considered thus far, either the principal can observe the state of nature before the agent takes an action (authority) or the state of nature is revealed after the agent selects her action (agency and hold-up). A case that has not been considered, but is ubiquitous in many employment relationships, is one where the agent is expected to respond to uncertainty before the principal has knowledge of this event or can guide the agent in the selection of the appropriate action. I have already mentioned the case of fire fighters and surgeons, but this case also includes many employment situations where the employee is expected to internalize the objectives of the principal, and then make decisions on the principal's behalf.

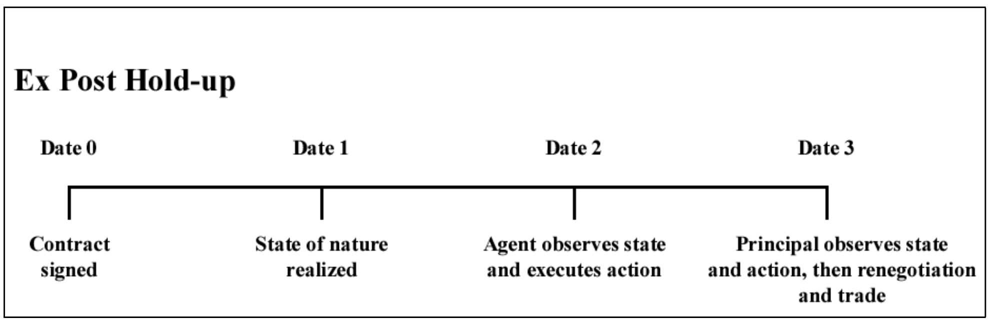

Figure 4: Time Line for Ex Post Hold-up

The hazard of *ex post holdup* arises from the need to have an agent respond appropriately to events as they occur without the intervention or guidance of the principal. The time line for this contracting problem is illustrated in figure 4. A defining feature of employment relations facing *ex post* hold-up is the need for the agent to carry out a number of different tasks in response to the costs and benefits of the different tasks. More formally, suppose that the agent is facing a multi-tasking problem parameterized as follows:

1. There are k tasks: $\mathbf{y} \in \mathbf{Y} = \left\{ \left\{ y^1, y^2, ..., y^k \right\} | y^1 + y^2 + ... + y^k \leq T \right\}$, where T is the agent's total time available to allocate between tasks.

2. The cost function takes the form: $C(\mathbf{y}, \beta) = \sum_{i=1}^{k} c\left(y^i, \beta^i\right)$, where $c\left(y^i, \beta^i\right)$ is the cost of allocating effort to task i. If y^i is zero, then this cost is zero, otherwise it is $\beta^i y_i^2 + f$. The cost parameter β^i is a random variable that can take on one of m discrete values $\{d_1, ..., d_m\}$.

3. The benefit function is assumed to take the form: $B(\mathbf{y}, \alpha) = \alpha^T \mathbf{y}$, where $\alpha^T \mathbf{y} = \alpha^1 y^1 + \alpha^2 y^2 + ... + \alpha^k y^k$ is the benefit to the firm from the agent's effort. The marginal benefit of task y^i is α^i, a random variable that can take on at most n values: $\{a_1, ..., a_n\}$.

In this parameterization, the state space is given by the possible benefit and cost parameters:

$\Omega = \{\{a_1, ..., a_n\} \times \{d_1, ..., d_m\}\}^k$. For each $\omega \in \Omega$, the optimal response is defined by:

$$\mathbf{y}^*(\omega) = \arg\max_{\mathbf{y}\in\mathbf{Y}} B(\mathbf{y}, \alpha) - C(\mathbf{y}, \beta). \tag{6}$$

An important assumption I make for the rest of the paper is that both the benefit and cost measures are themselves non-contractible. In the case of the benefits, consider for example a secretary in a large firm. His or her typing output is important to the firm, but there is no way to attach relative values to say typing versus filing. Similarly, the dollar value of a research paper written by a professor, or an hour devoted to seeing students is not known in practice. If the benefits were contractible, then the provision of an incentive contract would be straightforward. Similarly costs represent dis-utility to the agent, and hence are also difficult/impossible to verify accurately in practice.

3.1 State Contingent Contracts and Complexity

Though a single measure of performance may not be available, it may be reasonable to suppose that the principal can observe, or put into place a system that evaluates an agent's response to a specified state in a verifiable way. This is one way to avoid the potential for opportunistic behavior when an agent is simply told vaguely to do a good job is to outline explicitly what is expected for certain contingencies. For example, one may require a secretary to explicitly stop what he or she is doing if a client comes in and needs attention. Such an explicit condition may be necessary when an employee faces conflicting goals. For example the secretary may be asked to complete a typing task immediately, and hence might choose to ignore a client.

Thus for each ω suppose there is an appropriate response, denoted $\mathbf{y}^*(\omega)$. Given that the agent is risk neutral, then one may use a forcing contract that rewards the agent if and only if he achieves a satisfactory performance. This can be formally represented by the *judgement* function:

$$A : \Omega \times \mathbf{Y} \to [0, 1], \tag{7}$$

where $A(\omega, \mathbf{y})$ is interpreted as the probability that the choice $\mathbf{y}$ given ω is satisfactory. In the case of complete contingent contracting the principal defines the judgement function by $A^*(\omega, \mathbf{y}) = 1$ if $\mathbf{y} \geq \mathbf{y}^*(\omega)$, and zero otherwise. The contract takes the form $\{w, bA^*(\omega, \mathbf{y}^*(\omega))\}$, where w is a fixed payment and $bA(\omega, \mathbf{y}^*(\omega))$ is the bonus as a function of effort. This forms an optimal contract if it satisfies the individual rationality constraints and the incentive compatibility constraints:

$$w + b - E\{C(\mathbf{y}^*(\omega), \beta)\} = 0, \tag{8}$$

$$w + b - C(\mathbf{y}^*(\omega), \beta) \geq w - \min_{\mathbf{y}\in\mathbf{Y}} C(\mathbf{y}, \beta). \tag{9}$$

With no restrictions on the sign of w, as long as costs are bounded then there always exists a contract satisfying these conditions.

The issue now is the ability of the principal to write down and commit to such a contract. Notice that what is required is for every event ω to specify *ex ante* the expectations for the agent, and to reward the agent if these expectations are met. In this simple model the number of tasks is k, and the number of productivity and cost levels are m and n respectively The *complexity* of the contract is a measure of the cost of designing, writing and implementing the contract as a function of the data describing the relationship. The contract is *complete* if it describes the actions that are to be taken for each state of nature. As Williamson (1975) emphasizes, there are costs to writing and agreeing to a contract. For purposes of discussion suppose that the cost of agreeing upon a contingency ω is γ, then since the number of possible events is $n^k m^k$, the transaction cost for a complete contingent contract is $n^k m^k \gamma$. Suppose that $\gamma = 1$ cent, and that the number of cost and performance levels is the same ($n = m$), then the following table presents the cost of a complete contract as a function of the number of tasks and effort levels.

Number of Cost and	Number of Tasks			
Performance Levels	2	5	10	15
2	\$0.16	\$10	\$10,000	\$10 million
3	\$0.81	\$600	\$35 million	\$2 trillion
4	\$2.56	\$10,000	\$11 billion	\$11,000 trillion
5	\$6.25	\$100,000	\$1000 billion	\$10 million trillion
Cost of considering a contingency:	1 cent			

Table 1: Cost of a Complete State Contingent Contract

As one can see from table 1, when there are several tasks, even with a small number of performance levels, the cost of even thinking about a complete state contingent contract would be astronomical. Observe that it is the multi-tasking that increases the complexity costs, and not the number of cost and performance levels (the discreteness of the state space). In other words if the benefits and costs vary in a number of dimensions, then it is simply impossible to create a contingency plan for every possibility. What is worth emphasizing at this point is that thinking in terms of human bounds on rationality is not helpful in this case. The costs of writing a state contingent contract is so large, that even with sophisticated technology it would be impossible.

3.2 The Sales Contract Revisited: Ex ante governance

Even though the contracting parties cannot consider every possibility, they can still write a complete contingent contract, of which Simon (1951)'s sales contract is an extreme case. The sales contract is a form of *ex ante governance* requiring the agent to perform $\bar{\mathbf{y}}$, *regardless* of the state of nature. More generally, we can follow Dye (1985), and suppose that the contract specifies actions for a limited set of events. By an event we mean a subset of the set of possible states, Ω. For example the event might be that a secretary is required to type a paper, to which is associated the action 'type the paper today'. This event and response may not be efficient because demanding the paper be typed immediately may lead to mistakes. Also there may be other more pressing tasks. However in some cases, particularly when a relationship is not repeated, such a contingent contract may be preferred.

More formally, let $\Pi_N = \{E_1, E_2, ..., E_N\}$ be a partition of the state space Ω, and let $\mathbf{Y}_N = \{\mathbf{y}_1, \mathbf{y}_2, ..., \mathbf{y}_N\}$ be the associated actions. This defines a contract of complexity N, under which the agent in exchange for a wage W agrees to carry out the following actions:

$$c(\omega|\Pi_N, \mathbf{Y}_N) = \mathbf{y}_i, \text{ if and only if } \omega \in E_i, \tag{10}$$

Though this contract is complete in the sense that it defines an action for every state, it is not efficient. This is because all states in a single event E_i are associated with the same action, which many not necessarily be efficient.

For purposes of this example suppose that for each N the principal and agent agree upon a particular partition Π_N. Further suppose that if $N' > N$, then for every $E' \in \Pi_{N'}$, there is an $E \in \Pi_N$ such that $E' \subset E$. That is if we agree upon a more complex contract, it refines the events of less complex contracts. Let $c_N^*(\omega)$ denote the optimal contract relative to Π_N defined by:

$$c_N^*(\omega) = \arg\max_{\mathbf{y}\in\mathbf{Y}} E\left\{B(\mathbf{y}, \alpha) - C(\mathbf{y},\beta)\,|E_\omega\right\}, \tag{11}$$

where $E_\omega \in \Pi_N$ is the unique event such that $\omega \in E_\omega$. Under these assumptions we have the following proposition, whose proof is straightforward.

Proposition 2 *The* ex ante *surplus generated by* $c_N^*(\omega)$,

$$S_N^* = E\left\{B(c_N^*(\omega), \alpha) - C(c_N^*(\omega),\beta)\right\}, \tag{12}$$

is an increasing function of N.

The surplus *net* of transaction costs from the optimal contract of complexity N is $S_N^* - \gamma N$, where γ is the cost of adding a contract contingency. As illustrated in table 1, even if γ is very small, transaction costs for a complete state contingent contract may be very large, and hence we are unlikely to observe such a contract. Suppose that the agents choose the complexity of the contract to solve

$$\max_{N\geq 1} S_N^* - \gamma N, \tag{13}$$

then we have the following result:

Proposition 3 *Suppose that* $\gamma \times \#\Omega > S^*$ *where* $\#\Omega$ *is the number of states and* S^* *is the maximum surplus under a complete contingent contract then:*

1. *The optimal contract complexity is decreasing with contracting costs* γ.
2. *Keeping the transaction cost* γ *fixed, then proportional increase in the value of trade:* ζS_N, $\zeta > 1$, *increases the optimal complexity of the contract.*

This result highlights the fact that increasing transaction costs lowers the complexity of a state contingent contract. Secondly, as the value of trade rises, then so does the complexity of the contract, a result that is consistent with Macauley (1963)'s observations regarding the commercial contracts. The benefit of *ex ante* governance is that the agent knows and understands exactly what is expected in every event E_i. Moreover, if event E_i occurs, and the agent selects action $\mathbf{y}_i$, then since the agent has fulfilled the terms of the contract he receives payment in return.

However it is precisely the fact that the contract is well defined and binding that the principal faces the hazard of opportunism. Consider the following well known example from the Lincoln Electric Case where the firm attempted to expand its system of piece rates to secretarial staff. Let ω denote the correspondence to be typed in a particular day, and suppose that task i is the number of times that one strikes a particular letter. To improve productivity the company decided to reward individuals as a function of the number of keystrokes hit or $\sum y^i$. Clearly the intent is that the secretary type a particular text at a higher speed, but what occurred in one case is that the secretary during her lunch break hit repeatedly the same key to earn an above average income.[10]

This is a rather stark example of Williamson (1975)'s concept of opportunism. The difficulty here is that the secretary is simply responding to the incentives provided in the contract. Moreover, if the terms of employment simply specify the payment as a function of the number of keystrokes without mention of the quality of output, then even if the output is useless, the explicit terms call for payment to the secretary. The firm would argue (probably successfully) that the intent in this case is that the secretary produce useful documents, however the secretary could argue that this sophisticated firm had written an explicit contract and should be held responsible for its decisions. Unfortunately, organizations often make this kind of mistake, as highlighted in the famous article by Kerr (1975) who outlines several examples of workers responding to incentives in undesirable ways. As Kerr points out, many organizations are "rewarding A while hoping for B".

Propositions 2 and 3 suggest that in principle a sufficiently contingent contract would be close to the first best, a view point that has led many economists to promote the increased use of pay for performance contracts (see for example Milkovich and Wigdor (1991)). But table 1 illustrates that the complexity of jobs involving multi-tasking is such that even very sophisticated firms may not be able to anticipate all the consequences of a contract. Moreover, as Kerr observes, an explicit contract creates an incentive for the agent to discover ways to improve measured performance rather than a firm's performance, a behavior that is reinforced by the legal presumption that explicit contracts are legally binding.

This point is illustrated in the case of Wakefield v. Northern Telecom (1985). In this case a salesperson, Wakefield, was employed on an explicitly at will basis, but was also paid commissions for sales in his office. After several years of employment, he was dismissed just before he was to receive a commission payment from a significant sale. Northern Telecom did not pay this commission, arguing that the at will nature of employment relieved it of this obligation. However, the court ruled that employment at will did not absolve the firm from its explicit obligation to pay a commission, and established the protection of explicit performance pay, highlighting the risk that a firm faces when using a poorly constructed contract. Thus we conclude that contingent contracts face two related hazards. First they are likely not to be sufficiently sensitive to the possible states of the world, and hence may require the agent to respond inappropriately. Secondly, explicit contracts reward agents using well defined performance measures, creating an incentive for opportunistic behavior to manipulate the performance measure at the expense of the principal. The next section discusses how subjective evaluation may solve this problem.

4 Judgement and Subjective Performance Evaluation

An important insight of Simon (1951)'s model is the idea that actions should be decided upon *after* the state of nature is revealed. Even when the determination of the appropriate action, given ω, is of low cost, the large number of potential states make such contingent planning impossible. However, delaying decision making until after the state is revealed requires deciding what to do for a single state, dramatically reducing complexity. The difficulty is that now we face the problem of the agent being held up. If he takes an appropriate, but costly, action how can he be sure that the principal will reward him appropriately?

Secondly, given that our maintained hypothesis is that there is no univariate measure of performance,

[10] See Irrgang (1972), page 13.

then in the absence of an *ex ante* agreement how is the agent going to know what is appropriate performance, and how is the principal going to judge such performance? As Prendergast (1999) observes, in many cases both the principal and agent engage in subjective evaluations based upon *human* capabilities that cannot be replicated by any mechanical system. For example, the owner of a restaurant judges the performance of a chef by tasting the food. At the moment there is no known device that can automate such a process. When deciding upon whether to accept a paper for publication in a journal, once the referee has decided that the results are correct then the final decision must depend upon that vague criteria of "importance".

In these examples we are not facing the problem of bounded rationality. Rather governance depends upon the *superior* performance of human versus mechanical evaluations of performance. From the cognitive science literature we know that humans have remarkable pattern recognition abilities that we are only just beginning to understand and model. The formal link of incentives to pattern recognition can be seen using the judgement function $A(\omega, \mathbf{y})$, defined in section 3.2. Formally this function is a *classifier* that divides the set $\Omega \times \mathbf{Y}$ into two sets:

$$A = \{(\omega, \mathbf{y}) \in \Omega \times \mathbf{Y} | A(\omega, \mathbf{y}) = 1\}, \text{ and} \tag{14}$$

$$U = \{(\omega, \mathbf{y}) \in \Omega \times \mathbf{Y} | A(\omega, \mathbf{y}) = 0\}, \tag{15}$$

where A denotes 'acceptable performance' and U denotes 'unacceptable performance'. When there is multi-tasking, then the state space Ω is very large making a complete state contingent contract impossible. It might appear that this classification problem is much easier, however it turns out that constructing classifier functions is a generically difficult problem, as first shown in the work of Minsky and Papert (1988). While mathematically it is very difficult to construct good classifiers, it appears that the brain is specifically designed to be very good at such classification tasks.[11]

As Anderlini and Felli (1994) have shown, contracts can be viewed as a computer program. What we have learned from the cognitive science literature is when being called upon to decide if the response $\mathbf{y}$ to an event ω is acceptable, a human may simply be better at this than any alternative based upon an explicit contract.[12] Even though it is not possible to explicitly model this process of evaluation, one can assume that both the principal and agent have their own subjective evaluations of performance, and if they are both competent there should be a high degree of correlation in their evaluations.

4.1 Subjective Contracting

Suppose that the principal and agent both evaluate output and each have a subjective evaluation of acceptable or not. Given the complexity of decision making there are two sources of error. First the agent, even if competent, will sometimes make a mistake. The rate of error decreases as more effort is applied, and thus we model this by supposing the choice of the agent is given by the probability of success $\lambda \in [0, 1]$, produced at a cost $c(\lambda,)$, where $c(0) = 0$ (cost of no effort is zero), $c', c'' > 0$ (more effort costs increase at an increasing rate) and $c'(\lambda) \to \infty$ as $\lambda \to 1$ (perfection is impossible). When success occurs, then a

[11] Churchland and Sejnowski (1993) provide an accessible review of the relationship between human decision making and pattern recognition.

[12] In recent years enormous progress has been made on this problem. For example there are now computer programs that are good at handwriting recognition and speech recognition. However, these are recent developments, and of little significance for understanding the form that contracts have taken in the past.

reward B^* is produced, otherwise there is no return. Hence the net surplus of the relationship is given by:

$$S(\lambda) = \lambda B^* - c(\lambda), \tag{16}$$

with the first best level of effort, λ^{fb}, satisfying $B^* = c'\left(\lambda^{fb}\right)$.

Let us assume that these parameters are commonly known, and that if success does not occur, then this is commonly known by both parties (this assumption can be relaxed at the cost of greatly complicating the analysis). Subjective evaluation is modelled by supposing that when success does occur, then the principal and agent may or may not agree upon this. In the event of objective success, let λ_{ij}, $i, j \in \{A, U\}$, be the probability that the principal believes quality is i and the agent believes quality is j, where A and U denote "acceptable" and "unacceptable" respectively. Thus if the good outcome occurs, then λ_{AA} is the probability that both principal and agent agree on this. It is assumed that the signals are positively correlated, that is $\lambda_{AA}\lambda_{UU} - \lambda_{UA}\lambda_{AU} > 0$. If the beliefs of the principal and the agent are perfectly correlated then $\lambda_{AU} = \lambda_{UA} = 0$.

Due to the complexity of the relationship it is not possible to write a contract conditional upon the objective characteristics of output, nor can it be made binding upon the beliefs of the individuals. However the agents can agree to a contract that makes payments conditional upon messages sent by the principal and agent. Formally the contract between the principal and agent is given by:

$$c_{ij} = \{\pi_{ij}, w_{ij}\}, \tag{17}$$

where π_{ij}, w_{ij} are the payments to the principal and agent under the contract as a function of the message $i, j \in \{A, U\}$, satisfying the constraint $\pi_{ij} + w_{ij} \leq 0$.[13] This constraint allows the total payments to be less than zero, a possibility that will prove to be crucial. The *ex post* hold-up problem has the following sequence of moves:

1. The principal makes a take-it-or-leave-it contract offer to the agent, who accepts or rejects.
2. An event $\omega \in \Omega$ occurs.
3. The agent selects $\lambda \in [0, 1]$, which is his level of effort, in response to this event, to produce an observed response $\mathbf{y}$.
4. The principal and agent observe $\{\omega, \mathbf{y}\}$ and form subjective judgements regarding the success of the agent's action and simultaneously send messages from the set $\{A, U\}$ to the third party enforcing the contract.
5. The payoffs are determined.

I assume that the principal is able to select the most efficient incentive compatible contract. The payments under the contract to the principal and agent when they report k, but their true state is l are respectively:

$$\pi(k|l) = \pi_{kA}\lambda_{lA} + \pi_{kU}\lambda_{lU}, \tag{18}$$

$$w(k|l) = w_{Ak}\lambda_{Al} + w_{Uk}\lambda_{Ul}. \tag{19}$$

[13] From the revelation principal (e.g. Myerson (1979)) we know that without loss of generality we can identify the message space with the information that is private to each individual.

The principal's problem is to maximize expected payoff subject to the agent's individual rationality and incentive compatibility constraints:

$$\max_{\lambda,c} \lambda B^* + \lambda\pi(c) + (1-\lambda)\pi_{UU} \tag{20}$$

subject to

$$\lambda w(c) + (1-\lambda) w_{UU} - c(\lambda) \geq U^o \tag{21}$$

$$w(c) - w_{UU} = c'(\lambda) \tag{22}$$

$$\pi(l|l) \geq \pi(k|l), k, l \in \{A, U\} \tag{23}$$

$$w(l|l) \geq w(k|l), k, l \in \{A, U\} \tag{24}$$

$$\pi_{ij} + w_{ij} \leq 0,\ i, j \in \{A, U\} \tag{25}$$

where $\pi(c) = \sum_{i,j\in\{A,U\}} \pi_{ij}\lambda_{ij}$ and $w(c) = \sum_{i,j\in\{A,U\}} w_{ij}\lambda_{ij}$ are the expected transfers to the principal and agent respectively when the good outcome occurs. Constraint 21 requires the agent to earn at least his outside payoff, constraint 22 is the requirement that the agent select effort to maximize his payoff at stage 2. Constraints 23 and 24 are the stage 3 incentive compatibility constraints ensuring that the principal and agent truthfully report their subjective judgements to the third party enforcing the contract. The final constraint is the budget balancing constraint for the contract.

Notice that if the contract is budget balancing, $\pi_{ij} + w_{ij} = 0$ for all $i, j \in \{A, U\}$, then the contract defines a constant sum game at the message stage between the principal and agent. Such games have a unique value, and hence the payoff cannot depend upon subjective information. Thus in order that a subjective evaluation system induce positive effort on the part of the agent it is necessary that in some states there be a net loss to the relationship. The next result, due to MacLeod (1999), provides a complete characterization of the optimal contract when we relax the budget breaking requirement.

Proposition 4 *Suppose that $\lambda_{AA}\lambda_{UU} - \lambda_{AU}\lambda_{UA} > 0$ then optimal contract with subjective performance evaluation has the form:*

		Agent's Report A	Agent's Report U
Principal's Report	A	$(-b-w, b+w)$	$(-b-w, b+w)$
	U	$(-P-w, w)$	$(-w, w)$

Table 2: Contract Payoffs

where

- *The optimal effort λ^* solves $c'(\lambda^*) = B^* - \lambda^* c''(\lambda^*) \frac{\lambda_{UA}}{\lambda_{AA}\lambda_{A*}}$, where $\lambda_{A*} = \lambda_{AA} + \lambda_{AU}$ is the probability that the principal believes performance is acceptable.*
- *The bonus satisfies: $b^* = c'(\lambda^*)/\lambda_{A*}$.*
- *The fixed wage satisfies: $w = U^o + c(\lambda^*) - \lambda^* c'(\lambda^*)$.*
- *The penalty satisfies $P = c'(\lambda^*)/\lambda_{AA}\lambda_{A*}$.*

Under this contract the agent's payment is independent of his report, and hence he has no incentive to misrepresent his self-evaluation. The principal provides the agent with effort incentives by paying him a bonus whenever she believes that he has provided acceptable performance. If she reports unacceptable performance when the agent reports acceptable, then she must pay a penalty P. It is the prospect of paying a penalty when the reports from the agent and principal differ that provides the appropriate incentives for truthful revelation by the principal.

When correlation is imperfect and $\lambda_{UA} > 0$, there is a positive probability that the principal will pay the penalty. Given that the size of the penalty depends upon the size of the bonus promised, the lack of correlation increases the marginal cost of providing incentives. This is reflected in the term $\lambda^* c'' (\lambda^*) \frac{\lambda_{UA}}{\lambda_{AA}\lambda_{A*}}$, the amount by which the marginal benefit from effort is reduced in the optimal contract. Thus if the probability of the principal having an unacceptable evaluation while the agent has an acceptable self-evaluation is zero we obtain the first best. This result shows that the optimal contract is structured so that the principal's evaluation determines whether or not the agent receives a bonus, while the role of the agent's evaluation is to provide the necessary incentives for the principal to be truthful.

4.2 Implementing the Subjective Contract

Goetz and Scott (1981) define a relational contract as one for which "parties are incapable of reducing important terms of the arrangement to well-defined obligations". Contracts based upon subjective evaluation above certainly satisfy this criteria, and hence I shall call contracts addressing the problem of *ex post* holdup relational contracts. The term relational can also entail contracts that involve long term relationships. However attempts to characterize relational contracts in terms of their length have not been successful, as eloquently illustrated in Eisenberg (1995). What proposition 4 demonstrates is that the key ingredient for the enforcement of a relational contract is the creation of an economic institution that has the effect of imposing a penalty on one party, while ensuring that the other party is not made better off as a consequence.

Repeated relationships are one way to achieve this, but they are not the only institution to achieve this. When there are three parties to a contract, as in the case of rank-order tournaments, then one can simultaneously achieve efficient effort allocation and ensure that contract among the three parties satisfies the budget constraint. The analysis also resolves an open question posed by Goetz and Scott (1981), namely why is it that termination rights are important in bilateral contracts, but not important for collective agreements such as union contracts, where job security is often a stipulated condition.

4.2.1 The Termination Contract

As Becker (1975) and Williamson, Wachter, and Harris (1975) have observed, long term relationships often entail specific investments that would be lost upon termination. Hence, the threat of termination may create the penalty needed to enforce the relational contract. To see this consider an infinitely repeated principal-agent relationship where upon termination the principal and agent receive Π^o and U^o respectively, otherwise the payoffs per period are exactly as in the static case considered in the previous section. The size of the relationship specific investment is given by the difference between the value of trade and the value on the outside market:

$$S^* = \frac{\lambda^{fb} B^* - c\left(\lambda^{fb}\right)}{(1-\delta)} - (U^o + \Pi^o), \tag{26}$$

where λ^{fb} is the efficient effort level and δ is the one period discount rate.

For simplicity suppose that $\lambda_{UA} = 0$, that is when the principal believes performance is unacceptable, the agent agrees with this assessment. This implies that in equilibrium there are no separations, greatly simplifying the calculations. Given that the agent is indifferent to employment or not, then the compensation contract $\{w, b\}$ must satisfy:

$$U^o = w + \lambda\left(\lambda_{AA} + \lambda_{AU}\right) b - c(\lambda) + \delta U^o, \tag{27}$$

where δ is the discount rate, assumed to be the same for the principal and agent. Let $u^o = (1-\delta) U^o = w + \lambda\left(\lambda_{AA} + \lambda_{AU}\right) b - c(\lambda)$ denote the flow utility to the agent per period. Under this contract the agent chooses λ to satisfy:

$$c'(\lambda) = \left(\lambda_{AA} + \lambda_{AU}\right) b. \tag{28}$$

Given that $\lambda_{UA} = 0$, then termination never occurs in equilibrium and the principal's payoff satisfies::

$$\Pi^* = \lambda B^* - w + \lambda\left(\lambda_{AA} + \lambda_{AU}\right) b + \delta \Pi^*. \tag{29}$$

Ensuring that the firm pays the bonus (reports A truthfully) requires that her payoff be greater than in the case of misreporting conditional upon receiving a good signal:

$$-b + \delta \Pi^* \geq \delta \Pi^o. \tag{30}$$

That is the principal can pay the bonus and continue the relationship, or she does not pay b, and then the agent quits. Let λ^{fb} be the first best level of effort $\left(B^* = c'\left(\lambda^{fb}\right)\right)$, then the total value produced by the relationship is $S^* = \frac{\left(\lambda^{fb} B^* - c\left(\lambda^{fb}\right)\right)}{(1-\delta)}$, while the bonus needed to implement this effort is $b^{fb} = \frac{c'\left(\lambda^{fb}\right)}{\left(\lambda_{AA} + \lambda_{AU}\right)}$. For these parameters the optimal contract $\{w, b\}$ maximizing the principal's payoff, Π^*, subject to 27 to 30 is as follows:

Proposition 5 *If the value of the relationship specific investment is sufficiently large, that is* $S^* \geq \frac{b^{fb}}{\delta}$, *then there is an optimal relational contract with bonus pay* b^{fb}, *wage* $w = u^o - \lambda^{fb} c'\left(\lambda^{fb}\right) + c\left(\lambda^{fb}\right)$. *When* $S^* < \frac{b^{fb}}{\delta}$, *the optimal second best effort level,* λ^*, *decreases monotonically with* $(\Pi^o + U^o)$, *and is zero when* $S^* = (\Pi^o + U^o)$.

This result is an extension of MacLeod and Malcomson (1989) where it is shown that the value of a relationship must be strictly greater than the market alternative in order to generate positive effort from the relationship. Hence in a perfectly competitive market where there are no relation specific rents then $S^* = 0$ and it is not possible to implement any level of effort using a relational contract. Bull (1987) makes the additional interesting point that if the principal's behavior is public knowledge, then reputation effects can also generate a surplus sufficient to implement an efficient contract.

Notice that this creates an interesting problem for contract law. Reliance expenditures by the principal are normally protected under the law, even in the absence of an explicit contract. If the courts were to award damages to the principal should the agent decide to leave the relationship, then this would undermine the incentive needed for contract enforcement. One solution, recommended by Schwartz (1992), is for the courts to take a passive approach to contract enforcement. In the absence of explicit liquidation damages, if the contract permits the agent to leave at will, then the courts should support this right, not-withstanding significant investments on the part of the principal. Similarly, any explicit contingent contract terms should of course be enforced. As Baker, Gibbons, and Murphy (1994) show, contingent contracts can increase the size of the surplus and hence facilitate the enforcement of subjective performance clauses. Both of these principles appear to have been satisfied in the case of Wakefield v. Northern Telecom (1985) where the courts upheld the right of the firm to dismiss an employment while at the same time enforcing payments arising from an explicit commission contract.

4.2.2 The Tournament Contract

Goetz and Scott (1981) observe that unilateral termination clauses are very controversial.[14] In particular they question the need for such clauses based upon agency costs because these clauses are not found in contracts involving collective choice, particularly since many employment contracts guarantee job security. The labor contract literature in economics does however have an answer to this puzzle. When there are two or more agents, the termination contract is no longer the most efficient arrangement, rather the principal can improve efficiency through the use of a rank order tournament (Lazear and Rosen (1981)). Carmichael (1983) and Malcomson (1984) begin with the observation that employers can commit to having a limited number of high paying jobs. Under the assumption that these jobs must be filled, then the choice of who to put in a job does not affect the firm's budget constraint. Incentives are provided by promoting the individual to the high paying job that the firm judges to be the most able.

To see this consider a one period model with a principal and two agents. Suppose that the principal pre-commits an allocation of a fixed amount $2b$ to be divided between the two agents as a function of performance. As Carmichael (1983) and Malcomson (1984) observe, if this amount is fixed in advance then the principal has no incentive to misrepresent her subjective evaluations since they will not affect her total outlay. More precisely, suppose that the principal hires two identical agents indexed by $i \in \{1, 2\}$, to carry out identical, but independent tasks. Let $P_i \in \{A, U\}$ be the subjective evaluation of each agent *reported* by the principal, and let the payment to agent i is given by (j refers to the other agent):

$$w_i = \begin{cases} w + 2b, & \text{if } P_i = A, P_j = U, \\ w + b & \text{if } P_i = A, P_j = A, \\ w & \text{if } P_i = U, P_j = A. \end{cases} \tag{31}$$

Notice that $w_1 + w_2 = 2w + 2b$, and hence the total payment is independent of the report, and thus the principal has no incentive to misrepresent her reports.

Let λ_i be the effort of agent i, then his payoff given the effort of agent j is:

$$U_i = w + b\left(2\lambda_i \lambda_{A*}\left(1 - \lambda_j \lambda_{A*}\right) + \lambda_i \lambda_{A*} \lambda_j \lambda_{A*}\right) - c\left(\lambda_i\right). \tag{32}$$

Assume that the two agents are identical and hence they choose the same equilibrium effort as a function

[14] Page 1131.

of $b : \lambda_i(b) = \lambda_j(b) = \lambda(b)$ in equilibrium. These efforts satisfy the following first order condition:

$$\frac{c'(\lambda(b))}{\lambda_{A*}(1 - \lambda_{A*}\lambda(b))} = b, \tag{33}$$

from which we conclude that effort is an increasing function of b. The firm will choose the level of bonus pay b to solve:

$$\max_{w,b} \lambda(b) B^* - 2w - 2b, \tag{34}$$

subject to:

$$w + \lambda(b) \lambda_{A*}(1 - \lambda_{A*}\lambda(b)) - c(\lambda(b)) \geq U^0. \tag{35}$$

With this contract the principal is able to provide incentives for performance based upon a subjective evaluation of agent performance, while at the same time giving job security. However, as with the termination contract, the principal must have the right to allocate the bonus pay. Even with negotiated wages, it is possible to provide such incentives in a firm if the employer has the right to choose which employees are promoted, which in collective agreements is typically guaranteed under a right to manage clause. In other words, it is possible to have efficient relational contracts in the absence of a termination clause, but only if the principal is given some other unilateral right that affects an agent's compensation.

5 Discussion

The challenge of contract theory is to explain the myriad of contracting solutions that we observe in practice. This paper begins by delineating some different contracting problems as a function of the time at which individuals receive and must act upon information during the course of contract execution. The four cases I consider, agency, holdup, authority, and *ex post* holdup, are stylized descriptions of the actual contracting scenarios, but they do serve to highlight the sensitivity of optimal contracts to the temporal resolution of events in a relationship. For example in the case of the authority relationship *ex post* renegotiation ensures first best efficiency, where as in the hold-up model we get exactly the opposite result, as emphasized by Hart and Moore (1999). Hence the existence of gaps in a contract may or may not be indicative of failures of formation on the part of the contracting parties.

Moreover, the importance of contract incompleteness as a primitive of the model has recently received a critical evaluation by Jean Tirole (1999), who takes the view that many of the insights of this literature can be achieved within a complete contracting framework. In work with Eric Maskin (Maskin and Tirole (1999a)), he shows that contract incompleteness by itself does not necessarily constrain the set of feasible allocations, and hence we must conclude that contract incompleteness is not a sufficient basis on which to build an empirical theory of contract form. In other words we cannot take contract incompleteness as an observed exogenous parameter from which we draw testable implications regarding contract form.

Each of the four scenarios models explored in this paper give rise to contracts that are incomplete under the appropriate conditions, in the sense of not being sensitive to all available information. Hence, one can conclude that not only is contract incompleteness ubiquitous, but that it can arise for a variety of reasons. This suggests that we are unlikely to find a single, all encompassing theory of incomplete contracts. The optimal contract is very sensitive to context, which includes both the information available, the complexity of the environment and the timing of the resolution of uncertainty. This claim is consistent with current legal practice where we observe that the case law has developed a large set of doctrines to deal with specific situations.

One new insight from this analysis is that in some situations the fact that individuals have superior pattern recognition abilities implies that efficient incentive contracts are possible, even though a standard agency contract cannot achieve the first best. This can arise in situations where there is not sufficient time for contract renegotiation after an unforeseen event occurs. I have called this hazard *ex post* holdup, and argue that it is very common, especially in employment situations.

Contract scholars appear to have overlooked the fact that humans have extra-ordinary pattern recognition abilities, abilities that cognitive scientists are only just beginning to understand and model. Thus leading scholars such as Milgrom and Roberts (1992), pages 404-407, highlight the various problems with subjective evaluation systems without explaining why organizations continue to depend almost exclusively upon such systems (less than 20% of US workers are rewarded using explicit pay for performance systems). In a transaction characterized by *ex post* holdup, the human evaluation of performance in response to an unexpected event or emergency may simply be more accurate than a mechanical measurement of performance.

When complete state contingent contracting is possible, then *ex post* holdup entails no inefficiencies. When exchange is concerned with goods or services involving multi-tasking such complete contracting is impossible. This contracting incompleteness has little to do with bounds on human rationality, because the complexity of the contingent contract grows exponentially with the number of tasks, and hence efficient contingent contracting is *not* feasible with any known technology. This fact implies that the amount of multi-tasking may be used as an independent measure of transaction costs, and may be used to explain different observed contracting arrangements (as is done in Masten (1984) and MacLeod and Parent (1999)).

An interesting implication of this result is that the efficiency of the contract does not depend upon errors in judgement, as long as they are correlated with performance. However the efficiency is very sensitive to the correlation in the judgements between the principal and agents, and achieves the first best when there is perfect correlation. This result is very much consistent with the anecdotal evidence from the management literature that emphasizes the importance of trust and good working relationships between employees and their superiors. When employees no longer trust the evaluations of their superiors this leads, according to Milgrom and Roberts (1992) (page 406) to decreases in organizational effectiveness.[15] The crucial point is that firms use subjective evaluations despite the costs associated with the lack of correlation in judgements precisely because they are more efficient than the alternatives in the face of *ex post* holdup.

The final section of the paper addresses the problem of contract implementation. The optimal contract calls for the principal to bear a cost whenever she and the agent disagree. Since payments are made at the *ex post* stage, the use of a third party faces the hazard of renegotiation between the principal and agent to avoid making such payments. One mechanism to circumvent this, suggested in the literature on relational contracts, is the threat of termination. When there is sufficient value in a relationship then the threat of termination should the principal not pay a deserved bonus can ensure efficient performance. As is known from the mechanism design literature (see Moore (1992)) the problem of third party payments arises only in two person exchange. When there are three or more individuals then rank-order tournaments, as discussed in section 5.2, can ensure efficient performance using a budget balanced mechanism.

A difficulty with all these incentive mechanisms is that they depend upon the creation and

[15] See also Prendergast and Topel (1996) for an insightful analysis of the implications of favoritism for subjective pay systems.

redistribution of rents, which, as Williamson (1975) has emphasized, can in themselves lead to opportunism. This arises from individuals who attempt to discover ways to redistribute rents in ways that were not anticipated by the principal. This is a difficult problem that potentially give rise to an infinite regress as each mechanism that solves one form of opportunism creates the potential for more opportunistic behavior. One solution, discussed in Carmichael and MacLeod (1999), is that norms of fairness and fair division backed by the threat of some form or retribution, may provide a solution to problem of opportunism once it is sufficiently small. A full integration of such behavioral theories with contract theory must await further research.

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