Bounded Rationality and Incomplete Contracts

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April 25, 2007

Abstract

Thinking about contingencies, designing covenants and seeing through their implications is costly. Parties to a contract accordingly use heuristics and leave it incomplete. The paper develops a model of bounded rationality and examines its consequences for contractual design.

It is argued that cognition is a natural source of adverse selection in contractual relationships, that contracts may be too complete, and that relational contracting, vertical integration and short-term contracts generate (are not only responses to) contract incompleteness.

JEL numbers: D23, D82, D86, L22.
Keywords: Bounded rationality, incomplete contracts, cognition, transaction costs, heuristics, letter and spirit of contract.

1 Introduction

In mainstream contract theory, thinking about contingencies, designing covenants and seeing through their implications is costless. Contracts written by parties accordingly are efficient subject to explicit informational and participation constraints (complete contract theory) or within some given contracting set (incomplete contract theory). Contracts are never too detailed or too long.[1] Stylized facts such as the benefits of economizing on contract completeness under relationship interactions (Macaulay 1963) or vertical integration

*University of Toulouse and MIT. I am grateful to Patrick Bolton, Mathias Dewatripont, Antoine Faure-Grimaud, David Martimort, Eric Maskin, Patrick Rey, participants at the Melbourne Information Economics Revolution conference (March 2007), and especially Florian Ederer and Johannes Spinnewijn for helpful discussions and comments.

[1]In certain circumstances, optimal complete contracts take the form of "simple contracts" (e.g., Che-Hausch 1999, Hart-Moore 1999, Maskin-Tirole 1999a, Nöldeke-Schmidt 1995, Segal 1999). Similarly, short-term contracts may duplicate the outcome of optimal long-term contracts (e.g., Aghion-Bolton 1987, Diamond 1991, Hermalin 2002 and Rey-Salanié 1990, 1996).

(Williamson 1985), or the higher cost of negotiating long-term contracts (Välilä 2005) live in a theoretical vacuum.

By contrast, the less formal bounded rationality approach (Simon 1957, Williamson 1975, 1985) recognizes the cost of gathering and processing information and emphasizes the use of heuristics in contract design. This paper aims at bringing these two strands together. Like mainstream theory, it takes a rational choice approach to contracting; it however follows the bounded rationality approach by taking into account cognitive limitations.

Its general thrust goes as follows: The parties to a contract (buyer, seller) initially avail themselves of an industry heuristic, namely the best (most natural) contract under existing knowledge. The parties however are unaware of the contract's implications. Being unaware does not mean irrational, as parties realize that something may go wrong with this contract; indeed they may exert cognitive effort in order to find out about what may go wrong and how to draft the contract accordingly. Note that I here eschew the (in my view partly semantic) distinction between foreseen and unforeseen contingencies by assuming that every contingency is foreseeable (perhaps at a prohibitively high cost), but not necessarily foreseen. For example, the event that the oil price may increase, implying that the contract should be indexed on it, is perfectly foreseeable, but this does not imply that parties will think about this possibility and index the contract price accordingly.

This approach delivers two immediate implications that contrast with traditional contract theory: First, there are transaction costs of negotiating deals. Second, complete contracts may be wasteful contracts. Individual interests lead parties to fine-tune the contract whenever contract incompleteness could put them in a situation of being held up ex post. Completing contracts thus involves rent-seeking.

In this paper an incomplete contract is a contract specifying the available-heuristic[2] design and is renegotiated whenever this design turns out not to be appropriate. To derive predictions as to when contracts are likely to follow the availability heuristic and later be renegotiated, I develop a specific illustration of this broader theme. A buyer and a seller can contract for delivery of a known good or design A. This specification may or may not be what will suit the buyer's need. In the latter case, a different specification A' delivers more surplus to the buyer provided that the seller collaborates. At the initial stage, though, the parties are unaware of any other specification (they just know that A may not be the right design). Each may, before contracting, incur a cognitive cost to think about alternatives to A. A party who finds out that design A' is the appropriate one chooses whether to disclose the existence of (to describe) this design to the other party.

Second, and following Arrow 's (1962) insight about the difficulty of licensing trade secrets and that of Gabaix and Laibson (2006) about shrouded attributes, I posit that the enunciation of A' is an "eye-opener"; the very description of A' reveals that the state of nature is indeed such that A' rather than A is optimal. Put differently, a party's

[2] An availability heuristic refers to a rule of thumb or heuristic. Its determinants (such as vividness, salience and representativeness) were first investigated by Kahneman and Tversky (1973). For the purpose of this paper, it suffices to assume the existence of such a heuristic without going into the process through which this heuristic arose.

suggestion of contracting on A' gives the information away and prevents the knowledgeable party from fully benefiting from it, in the same way that Arrow's licensor cannot extract any royalties from the prospective licensee or Gabaix and Laibson's supplier prefers to keep some contract attributes shrouded rather than mentioning the likely add-on and committing to its price.

Such "awareness-inducing information" is related to, but distinct from the familiar concept of "hard information". In a standard hard-information model, the parties would be fully aware of the existence of designs A and A', but would be uncertain as to their respective payoffs (which one is appropriate); the contract can then be made contingent on one of the parties' bringing hard information that A' is appropriate. No such contract is feasible here since the description of A' simultaneously reveals the state of nature.

If the parties fail to identify (or strategically do not contract on) design A' when relevant, the contract is incomplete in the sense that it requires ex post renegotiation. In the absence of adjustment costs, ex ante transaction costs could be economized by waiting for the state of nature to unravel and relying on renegotiation; by contrast, adjustment costs vindicate some cognitive investments from a social point of view. Yet, even in the absence of adjustment costs, transaction costs are incurred, as it is in the parties' individual interest to know whether they are vulnerable to (or will benefit from) renegotiation.

The paper is an inquiry into what drives equilibrium transaction costs. Its main insights can be summarized in the following way. As we already pointed out:

1. Cognition is a natural source of adverse selection in contractual relationships.
2. Contracts may be too complete, that is, there may be too little, not too much, renegotiation. Rent-seeking, and not only the avoidance of ex post contract adjustments, drives individual incentives for cognition.

   We further show that:

3. Contracts are predicted to be *strictly* less complete under relational contracting or under vertical integration. Furthermore long-term contracting may be *strictly* suboptimal. Thus, relational contracting, vertical integration and short-term contracting generate (are not only responses to) contract incompleteness; this reverse causality has obvious implications for empirical work.
4. Parties to a contract tend to specialize in identifying potential bad news for themselves/good news for the other party.
5. Ex ante competition need not reduce transaction costs.

The paper is organized as follows. Section 2 relates the paper to the literature. Section 3 develops the framework, and analyzes its implications when only one party can engage in cognitive effort (section 3.1 on one-sided cognition) and when both parties can (section

3.2 on two-sided cognition). Section 4 shows that contract incompleteness is implied by (and, as noted earlier, is not only a driver of) repeated relationships, the possibility of vertical integration and short-term contracting. Section 5 extends the analysis to multiple sellers and section 6 concludes.

2 Relationship to the literature

The paper borrows unrestrainedly from and brings together several strands of the contract literature.

With Spier (1992) and Gabaix-Laibson (2006), it shares the view that contract incompleteness is related to asymmetric information. In Spier,[3] an informed party may not want to make the outcome contingent on certain adverse contingencies by fear of signaling to the other party that these contingencies have high likelihood. Gabaix and Laibson's emphasis on the hold-up associated with add-ons that the buyer is unaware of is closely connected to the problematic considered here. On the other hand, none of these two papers has cognitive costs, and contracts are too incomplete, not too complete.[4] Relatedly, the cost of asymmetric information need not be an inefficient contract (see Proposition 1 below), but rather the opportunity cost or delay incurred in preparing this contract.

Dye (1985) modeled contract incompleteness by introducing a fixed cost per contingency included in the contract. This approach was criticized on the grounds that a well-formulated contingency may be cheap to include in a contract and that it is unclear why writing costs should be proportional to the number of contingencies (Hart-Holmström 1987). In a sense, this paper follows Dye's impetus and attempts at opening Dye's black box of costs of writing complete contracts.[5] And to use Klein (2002)'s terminology, it focuses on "search costs" (the costs of thinking through the contracts' implications) while Dye analyzes "ink costs" (the costs of actually writing contracts).

In Crémer, Khalil and Rochet (1998a,b), a party engages in rent-seeking information acquisition before contracting. The focus of the paper however is quite different, as contracts in Crémer et al. involve no incompleteness. Similarly, the paper shares with Hirshleifer (1971) the insight that contracts may suffer from an excess provision of information.

The paper borrows from the classic contributions of Grossman-Hart (1986), Hart-Moore (1990) and Williamson (1985) and from the subsequent literature on investment

[3]See also Aghion-Hermalin (1990) and Allen-Gale (1992). Anderlini et al (2007) extend this approach by letting a court rule out certain forms of contract in order to maximize ex ante welfare.

[4]Contracts are incomplete in Martimort-Piccolo (2007) for a different reason: There, the parties to the contract are engaged in a game with another vertical structure. Committing to an incomplete contract modifies the latter's behavior and may turn out to be beneficial (see also Ellison 2005). That paper has no cognitive costs either.

Another factor of contract renegotiation is their imperfect enforcement by courts: see Guasch, Laffont and Straub (2006) for a model and empirical evidence.

[5]Other papers that have built and improved on Dye's approach are Anderlini-Felli (1994, 1999) and Battigalli-Maggi (2002), which take a rather different approach from that followed here.

specificity the idea that contractual choices impact the extent of ex post hold-ups. The paper considers pre-contractual investments, while the literature focuses on post-contractual ones.

Finally, the paper is most closely related to interesting and independent work by Bolton and Faure-Grimaud (2007) on the relationship between information acquisition and contracts. That paper builds on their 2005 paper, in which a single decision-maker may choose to incur delay costs (the counterparts of our cognitive costs) in order to take better decisions. The 2005 paper depicts individual decision-making as a bandit problem, in which thinking ahead to define a complete action -plan enables the individual to react more promptly to a new event, but delays initial decisions. There is no direct transaction cost, but delay is incurred while waiting for information to accrue. The 2007 paper applies these ideas to two-party contracting. Actions are known from the start but parties are initially uncertain about the payoffs attached to a risky action and must choose between this action and a safe one with known consequences. The parties may have a disagreement as to when to select an action (even if they happen to rank the actions similarly). Due to non-transferable utility, the more impatient party cannot compensate the other for acting quickly. Interestingly, Bolton and Faure-Grimaud show that the impatient party may deliberately transfer control to the more patient/cautious one. Their paper and this one share the view that the pursuit of individual interests may make contracts too complete;[6] the two papers are complementary as they use different modeling techniques and stress rather different themes.

3 Cognitive limitations and equilibrium contracts

Let us first describe the model.

Designs. A buyer (B) and a seller (S) contract on the delivery of a good. Initially they can avail themselves of (common-knowledge) design A. This design costs c for the seller to produce.

With probability $1-\rho$, design A is the appropriate design and delivers utility $v > c$ to the buyer.

With probability ρ, however, some other, initially undescribable,[7] design A' delivers utility v to the buyer while A delivers only $v - \Delta$, where $\Delta > 0$. Converting A into A' requires the seller's collaboration; the seller's supplemental cost of this conversion or "adjustment cost" is equal to $a \in [0, \Delta)$. That is, gains from renegotiation are $\Delta - a$. By contrast, if design A' is identified at the contracting stage, the total cost of production is c (there is obviously no adjustment cost).[8]

[6] In Bolton-Faure-Grimaud, the contract is incomplete if it does not specify which action is taken once investment is sunk and the state of nature is revealed; that is, there is scope for further learning before the actual decision is selected.

[7] The model is thus in the spirit of Maskin-Tirole (1999b), in that the von Neumann-Morgenstern utilities are known, but actions or contingencies may not be describable (they are just "numbers").

[8] We locate the uncertainty on the buyer's value. Symmetrically, one could assume that the value is

We assume that the availability-heuristic design A generates gains from trade even in the absence of cognition:

$$v - c - \rho a > 0.$$

Transaction costs. Before contracting, the buyer and the seller can incur thinking or cognitive costs $T_B(b)$ and $T_S(s)$, respectively.[9] If A is the appropriate design, they learn nothing from their investigation; if A' is the appropriate design, they learn A' with probability b and s, respectively; they learn nothing with probability $1-b$ and $1-s$. The choices b and s are unobserved by the other party and are individually rational. The functions T_i (for $i \in \{B, S\}$) are smooth, increasing and convex functions such that $T_i(0) = 0$, $T_i'(0) = 0$ and $T_i(1) = +\infty$. To guarantee that the solution of (4) below is unique and thereby shorten the analysis, we further make the following, maintained assumption:

Assumption 1. $T_B''(b) > \dfrac{\rho^2(1-\rho)\sigma\Delta}{(1-\rho b)^2}$ *in the relevant range.*

Furthermore, and as discussed in the introduction, the enunciation of A' by i fully reveals to $j \neq i$ that the proper design is A'.

Cognitive costs have a broad range of interpretations, including the managers' psychic cost of focusing on issues they are unfamiliar with, their opportunity cost of not devoting time to other important activities, or the fees paid to lawyers and consultants for advice on contracting.[10] The magnitude of cognitive costs is also revealed indirectly by the substantial incompleteness of many contracts and by the costs of this incompleteness.

Contract renegotiation. If the contract specifies the trade of design A' at some price p, then it is implemented without any renegotiation: The seller incurs cost c, delivers the good and the buyer obtains utility v.

By contrast, when the contract specifies design A, the seller delivers A, and the buyer takes possession of it. The buyer then learns whether the design is appropriate. If not, he renegotiates with the seller in order to obtain the adjustment to A'.

We will assume that the buyer and the seller have bargaining power β and σ, respectively ($\beta + \sigma = 1$), where a party's bargaining power measures the share of the gains from trade that the party can secure in a negotiation. That is, we apply the generalized Nash bargaining solution with weights β and σ. For notational simplicity, the bargaining powers are the same ex ante and ex post. Obviously, this assumption can no longer be sustained when we consider ex ante competition.

Because we will in most of the paper make assumptions that guarantee the existence of a pure-strategy equilibrium and therefore symmetric information on the equilibrium

always v, and that the seller's cost of producing is c if A is appropriate and $c + \Delta$ (which can be reduced back to c at cost a for the buyer by switching to design A' if A is not appropriate). The roles of the seller and the buyer would then be reversed. Section 3.2 combines the two forms of hold-up.

[9] As in Dewatripont-Tirole (2005) for example, the cost of cognition is depicted as a sampling cost. The idea is that, through a combination of cognitive attention and the usual cognitive mechanisms (inference, associativeness, etc.), the agents may stumble on (become aware of) implications of the current design and an alternative to it.

[10] For example, a water concession contract may be a few thousand page long.

path,[11] the Nash bargaining solution will always be well-defined. When we occasionally confront asymmetric-information bargaining, we can assume that the buyer (seller) makes a take-it-or-leave-it offer to the seller (buyer) with probability β (respectively σ).

The timing is summarized in Figure 1.

Figure 1 : Timeline

The assumption that the buyer takes possession of the good (and therefore gets v if A is appropriate and $v - \Delta$ if it is not and the contract is not renegotiated) shortens the analysis; it can be justified either by assuming that the buyer appropriates the know-how when consuming the good or by supposing that the buyer at that stage really needs the good and cannot credibly dispense with it.

We will say that the contract is *more incomplete* if the ex ante probability that it specifies the available design A, and therefore that it later is renegotiated, is higher.

Let us conclude this description of the model with a few remarks:

Efficient cognition. When the adjustment from A to A' is costless ($a = 0$), then any investment in cognition is pure rent-seeking in this model; that is, the socially optimal levels of cognitive efforts are equal to 0. We will more generally investigate whether the provision of cognitive effort is subject to free riding (has a public good flavor).

Interpretations. In the *technology licensing* interpretation, the seller licenses a technology to the buyer. To implement the technology to full functionality for his own use, though, the buyer may or may not need a license to another patent owned by the seller that he was not aware of. In the *procurement* interpretation, the authority may discover later on that the specified design does not fit his need and that further work may be demanded from the contractor. Finally, the model has an interpretation in terms of the *implications of a given contract*. Suppose that the contract describes a course of action, but that there may be a way for the seller to achieve the same contractual requirement in a way that is both cheaper for her and less attractive to the buyer. Assuming that the seller's cost savings associated with perfunctory provision of the output is smaller than the buyer's loss in surplus, the buyer then will have to renegotiate with the seller to adhere to the spirit, if not the letter of the contract.

[11] As we will see, deviations from equilibrium behavior do not create any problem with the bargaining solution either.

Cost of renegotiation: The renegotiation cost is here captured by the cost a of redesigning the product or redrafting the contract; alternatively, we could have formalized it as the risk of breakdown of renegotiation.

3.1 One-sided cognition

Let us assume in a first step that only the buyer has the ability to learn about the appropriate design. For example, the buyer may have an easier access to information about what he really needs. More fundamentally, we will later observe that there is a fundamental asymmetry between the buyer's and the seller's incentives to engage in cognitive activities prior to contracting.

The *socially efficient* level of cognition $\widehat{b}$ equalizes the marginal cost of thinking and its marginal benefit (the avoidance of the adjustment cost a when A' is the appropriate design):

$$T'_B(\widehat{b}) = \rho a.$$

(a) *Deterministic cognition region*

Let us first look for a pure-strategy equilibrium. Let b^* denote the equilibrium probability that the buyer discovers that A is not appropriate when this is indeed the case.

If the buyer finds out that A' is appropriate, then he will rationally insist that the contract specify the delivery of A' as he knows that under design A he will be held up with probability 1. Gross of cognitive costs, the payoffs are

$$\beta(v-c) \text{ for the buyer and } \sigma(v-c) \text{ for the seller.}$$

Suppose, next, that the buyer learns nothing. The contract then specifies delivery of design A. Let

$$\widehat{\rho}(b) \equiv \frac{\rho(1-b)}{1-\rho b}$$

denote the posterior probability that A is not appropriate conditional on cognitive intensity b and unawareness. If A' is the appropriate design, the seller captures a fraction σ of the renegotiation gain, creating a hold-up

$$h \equiv \sigma(\Delta - a).$$

Thus, everything is as if the buyer were able to make the adjustment himself, and so receive $v-a$, but had to pay a "tax" h to the seller.

On the *equilibrium path*, $b = b^*$ and the buyer and the seller both expect a hold-up benefit (for the seller) or cost (for the buyer) $\widehat{\rho}(b^*)h$. The ex ante price $p(b^*)$ for design A accounts for the possible hold-up, and so[12]

$$\sigma\big[v-c-\widehat{\rho}(b^*)a\big] = p(b^*) - \big[c-\widehat{\rho}(b^*)h\big], \tag{1}$$

[12]The analogous (and equivalent) condition for the buyer is:

$$\beta[v-c-\widehat{\rho}(b^*)a] = [v-\widehat{\rho}(b^*)(a+h)] - p(b^*).$$

or

$$p(b^*) = c + \sigma\big[v - c - \widehat{\rho}(b^*)\Delta\big].$$

The left-hand side of (1) is the share, accruing to the seller, of the total surplus as perceived when bargaining over design A, that is $v - c - \widehat{\rho}(b^*)a$. The right-hand side of (1) is the seller's profit. Her opportunity cost is $c - \widehat{\rho}(b^*)h$, since with conditional probability $\widehat{\rho}(b^*)$, she will have the opportunity to hold the buyer up for an amount h. The price $p(b^*)$ is such that the seller indeed obtains a fraction σ of the ex ante total surplus. The term $\widehat{\rho}(b^*)h$ can be interpreted as a *hold-up discount*.[13]

Finally, consider the buyer's choice of cognitive effort b. Assuming for the moment that the buyer trades even when having learned nothing, the latter solves:

$$\max_{\{b\}}\Big\{ - T_B(b) + \rho b\beta(v-c) + \rho(1-b)\big[v - a - h - p(b^*)\big] + (1-\rho)\big[v - p(b^*)\big]\Big\} \qquad (2)$$

$$\Longleftrightarrow \max_{\{b\}}\Big\{ - T_B(b) + \beta(v-c) + (1-\rho b)\widehat{\rho}(b^*)\sigma\Delta - \rho(1-b)(a+h)\Big\}.$$

To obtain (2), note that with probability ρb, the buyer proposes design A' and obtains share β of the joint surplus $v-c$. With probability $1-\rho b$, the two parties contract on design A at price $p(b^*)$. With probability $\rho(1-b)$, the appropriate design is not identified and the buyer must bear the adjustment cost a augmented by the hold-up h. Differentiating (2) (together with (1) and the equilibrium condition $b = b^*$) yields first-order condition:

$$T_B'(b^*) = \rho a + \rho[h - \widehat{\rho}(b^*)\sigma\Delta] \qquad (3)$$

The LHS of (3) is the buyer's *marginal cost of cognition.* His marginal benefit, the RHS of (3), is composed of three terms. The first, ρa, is the *social benefit.* The second ρh, is the *buyer's marginal benefit of avoiding a hold-up.* The third, $-\rho\widehat{\rho}(b^*)\sigma\Delta$, corresponds to the *change in the bargained price* when specifying design A' rather than design A (the bargained price for design A accounts for the possibility of hold-up and is therefore lower than that for design A').

Using the Bayesian updating condition,

$$T_B'(b^*) = \rho a + \rho\Big[h - \frac{\rho(1-b^*)}{1-\rho b^*}\,\sigma\Delta\Big]. \qquad (4)$$

In particular, in the absence of adjustment cost ($a = 0$, i.e., $h = \sigma\Delta$), the equilibrium level of effort is given by

$$T_B'(b^*) = \frac{\rho(1-\rho)}{1-\rho b^*}h.$$

[13] The generalized Nash bargaining solution allows us to abstract from the issue of inferences that are drawn by the seller in a sequential bargaining game when the buyer makes an off-the-equilibrium-path price offer. Consider an alternating-move bargaining game delivering fraction (β, σ) of the surplus in a complete information set-up. Then the solution $p(b^*)$ still prevails under (potentially) asymmetric information as long as the seller's beliefs are passive (that is, the seller still believes that the buyer has chosen $b = b^*$ when the buyer makes an off-the-equilibrium path offer). This issue of course does not arise if the seller makes a take-it-or-leave-it offer ($\sigma = 1$).

Under Assumption 1, condition (4) has a unique solution. One can interpret Assumption 1 in terms of an interesting *strategic complementarity* between the buyer's cognitive choice, b, and the seller's anticipation thereof, b^*. A seller who anticipates a high level of cognition will accept only a low hold-up discount for design A. In turn, a high price for design A makes design A' relatively more attractive and therefore encourages the buyer to engage in more cognition. Assumption 1 puts a bound on this strategic complementarity so as to ensure uniqueness of the deterministic cognition equilibrium.

Condition (4) implies that b^*, and therefore the equilibrium transaction costs increase with the adjustment cost a and with the utility loss Δ.[14]

To check that the cognitive intensity b^* given by (4) is indeed an equilibrium, we need to check that the buyer does not want to deviate and not trade when remaining unaware (the maximand in (2) implicitly assumes that trade always occurs). This is indeed the case if $b \geq b^*$ (as the buyer is then at least as confident as the seller about the absence of hold-up opportunity) or for b a bit below b^*. But for b much lower than b^*, the buyer puts much more weight than the seller on the design not being appropriate, and a bargaining breakdown may occur at the ex ante stage.

Expression (2) indeed describes the buyer's payoff as long as the buyer's expected utility when contracting on A (i.e., when being unaware) is positive.[15] Let b' denote the buyer's optimal cognitive intensity when planning not to write a contract when unaware:

$$b' = \underset{\{b\}}{\operatorname{argmax}} \ \Big\{ - T_B(b) + \rho b \beta (v-c) \Big\}.$$

A necessary and sufficient condition for b^* to be the equilibrium cognitive strategy is thus:

$$\beta\big[v - c - \rho(1-b^*)a\big] - T_B(b^*) \geq \rho b' \beta (v-c) - T_B(b'), \tag{5}$$

where we make use of the fact that parties are symmetrically informed on the equilibrium path and share the gains from trade $v - c - \rho(1-b^*)a$ in proportions (β, σ).

Appendix 1 shows that

(5) is satisfied if and only if $\beta \geq \beta_0$ for some $\beta_0 \in (0,1)$.

[14] b^* also increases with the seller's bargaining power σ as long as the transaction costs exceed the socially optimal level $\big(b^* > \widehat{b}\big)$; see below for the corresponding comparison.

[15] That is, $v - p(b^*) - \widehat{\rho}(b)(a+h) \geq 0$, or

$$\beta(v-c) \geq \widehat{\rho}(b)(h+a) - \widehat{\rho}(b^*)(h+\sigma a).$$

Because $\widehat{\rho}(b) \leq \rho$, a sufficient condition for this condition to be satisfied for all b when $a = 0$ is that the buyer's bargaining power be sufficiently large in relation to the relative hold-up stake:

$$\frac{\beta}{1-\beta} \geq \frac{\rho\Delta}{v-c}.$$

Are transaction costs too high or too low? From (3), we see that transaction costs are excessive if and only if the buyer's benefit of avoiding a hold-up exceeds the change in bargained price:

$$h > \widehat{\rho}(b^*)\sigma\Delta,$$

which, after some manipulations, can be rewritten as:

$$[\frac{1-\rho}{1-\rho b^*}]\Delta > a. \tag{6}$$

Fixing a, condition (6) is satisfied[16] if and only if $\Delta \geq \Delta^*(a)$ for some $\Delta^*(a) \in [0, a)$. Note that $\Delta^*(0) = 0$: In the absence of adjustment cost, the contract is always too complete. Conversely, (6) is violated and so the contract is too incomplete when there is no gain to renegotiation ($\Delta \equiv a$).

These results fit with our earlier intuition. Cognition is socially excessive if it is just meant to avoid hold-ups. By contrast, for large adjustment costs, which end up being shared between the two parties, free riding is paramount and cognition is socially suboptimal.

Does it pay to be bright/experienced? One may wonder whether brightness or experience benefits the contracting parties.[17] Intelligence or experience with this type of contract can be described in this framework as a reduction in the marginal cost of cognition, $T_B(b;\nu)$; that a higher ν corresponds to a higher intelligence or experience corresponds to the condition $\partial\big(T_B'(b;\nu)\big)/\partial\nu > 0$. Condition (4) implies that a brighter buyer is more likely to find out a contractual shortcoming ($\partial b^*/\partial\nu > 0$). This implies that with positive adjustment costs, a bright buyer is a more attractive trading partner for the seller (who receives $\sigma[v-c-\rho(1-b^*)a]$). As for the buyer, condition (2) implies that being perceived as stupid/inexperienced, by increasing the hold-up discount, benefits the buyer. The ideal situation for the buyer is therefore to be bright and not to be perceived so.

(b) *Randomized-cognition region*

Conversely, if $\beta < \beta_0$, the buyer necessarily randomizes over his cognition choice. Furthermore, the ex ante contract negotiation necessarily breaks down with strictly positive probability; for, in the absence of breakdown, the equilibrium price for design A must be independent of the value b chosen by the buyer (since the buyer prefers the lowest possible price among those consistent with a deterministic agreement regardless of his cognitive choice). Consequently, (2) and (4) must hold, a contradiction.

Appendix 2 provides an explicit solution when the seller has full bargaining power ($\beta = 0$) and adjustments are costless ($a = 0$). The equilibrium involves the buyer randomizing over some interval $[0, \bar{b}]$ and the seller randomizing over the price interval $[v - \rho\Delta, v - \hat{\rho}(\bar{b})\Delta]$ for design A (the seller charges v for design A'). The buyer has a zero expected utility, as one would expect given that the seller has full bargaining power. The lower bound $\underline{b}$ on the buyer's cognitive intensity is necessarily equal to 0 since the seller will never charge

[16] Recall that b^* is an increasing function of Δ and a.

[17] I am grateful to Joel Sobel for suggesting this question.

less than the willingness to pay, $v - \hat{\rho}(\underline{b})\Delta$, of the most pessimistic "type" $\underline{b}$. Thus the buyer's utility is $-T_B(\underline{b})$, and so $\underline{b} = 0$ for this utility to be non-negative.

To illustrate this randomization in a simpler manner, let us restrict the analysis to the case of two feasible levels of cognition:

Two levels of cognition. Suppose that the buyer chooses between cognition levels 0 (at no cost) and b (at cost T_B: we omit the argument for notational simplicity). Let ρ and $\hat{\rho} < \rho$ denote the corresponding posteriors, and $p_0 \equiv v - \rho\Delta$ and $p_b \equiv v - \hat{\rho}\Delta$ the buyer's associated willingnesses to pay for design A.

Let the buyer choose cognition level 0 (respectively b) with probability g (respectively $1-g$). Given that it is suboptimal for the seller to charge prices differing from p_0 and p_b, let the seller charge p_0 (respectively p_b) with probability f (respectively $1-f$).

To make things interesting, assume that

$$(1 - \rho b)(\rho - \hat{\rho})\Delta > T_B.$$

This condition ensures that the deterministic choice of no cognition is not an equilibrium;[18] for, if it were, then $f = 1$ and by deviating to cognition level b, the buyer would receive[19]

$$(1 - \rho b)(v - p_0 - \hat{\rho}\Delta) - T_B = (1 - \rho b)(\rho - \hat{\rho})\Delta - T_b > 0.$$

The buyer cannot choose cognition level b for sure either, since if he did the seller would charge p_b for sure ($f = 0$) and so the buyer's utility would be equal to $-T_B < 0$. In equilibrium therefore, the buyer must play a mixed strategy and be indifferent between the two cognitive choices:

$$f(1 - \rho b)(\rho - \hat{\rho})\Delta - T_B = 0.$$

Similarly, the seller must be indifferent between p_0 and p_b:[20]

$$p_0 - c + \frac{g\rho + (1-g)(1-\rho b)\hat{\rho}}{g + (1-g)(1-\rho b)}\Delta = \frac{(1-g)(1-\rho b)}{g + (1-g)(1-\rho b)}[p_b - c + \hat{\rho}\Delta],$$

or, after some manipulations:[21]

$$\frac{g}{1-g} = (1 - \rho b)\frac{(\rho - \hat{\rho})\Delta}{v - c}.$$

[18] In the continuous-cognition analysis of Appendix 2, this is ensured by the assumption that $T_B'(0) = 0$.

[19] The buyer is charged v and has a zero gross utility when bargaining over design A'. Yet the buyer prefers to disclose design A' when aware of it since he receives a negative utility of design A even for the lower price p_0:

$$v - p_0 - \Delta = -(1 - \rho)\Delta < 0.$$

[20] Note that the probability of "type" 0 *conditional* on design A is higher than g and is equal to $g/[g + (1-g)(1-\rho b)]$.

[21] To interpret this condition, rewrite it as:

$$g(v - c) = \big[(1-g)(1-\rho b)\big](\rho - \widehat{\rho})\Delta.$$

The LHS is the expected loss of charging p_b rather than p_0 (with probability g the buyer chooses no cognition and would have accepted p_0, yielding surplus $v - c$ to the seller). The RHS is the expected gain associated with rent extraction when the buyer engages in cognition b.

Note that when the gains from trade, $v - c$, increase, the seller's pricing behavior (f) remains unchanged (the prices p_0 and p_b increase with v, of course). By contrast, the buyer exerts more cognition (g decreases); otherwise the seller would be too eager to guarantee a sure agreement, i.e. to charge the lower price p_0.

Proposition 1. ***(one-sided cognition)***
(i) When $\beta \geq \beta_0$, the buyer incurs cognitive cost $T_B(b^*)$ where b^* is given by

$$T'_B(b^*) = \rho a + \rho[h - \widehat{\rho}(b^*)\sigma\Delta].$$

The buyer's cognitive cost increases with the severity of the hold-up problem (increases with Δ) and with the adjustment cost a.

The buyer fully bears the deadweight loss associated with cognition and has utility $\beta[v - c - \rho(1 - b^*)a] - T_B(b^*)$, while the seller has utility $\sigma[v - c - \rho(1 - b^*)a]$. The contract is too complete (there is too little renegotiation, i.e., $b^* > \widehat{b}$) if and only if

$$[\frac{1-\rho}{1-\rho b^*}]\Delta > a.$$

(ii) When $\beta < \beta_0$, contract negotiations break down with positive probability.

Remark: Condition (4) still holds even if A' is not necessarily the final design when A is not the appropriate one. Namely, suppose that when the buyer learns A' ex ante, there is probability ν that the appropriate design is some A'' rather than A'. As long as the buyer cannot further investigate whether A' or A'' obtains, then assuming there is no adjustment cost from A' to A'', condition (4) holds: The buyer under design A' receives expected gross payoff $\beta(v - c)$ *on and off* the equilibrium path (i.e., for any b, and not only for $b = b^*$). Put differently, the important feature behind (4) is that the identification of A' creates symmetric information, not that it is the final design. By contrast, if when finding A', the buyer could inquire whether A' or A'' is the right design, then b^* would be smaller than the value given by (4): The second cognitive cost would have to be subtracted from the buyer's gain from the first information acquisition.[22]

[22] Namely, suppose for simplicity that $a = 0$ and that the potential hold-up when adjusting from A' to A'' is Δ as well and that there is no breakdown of negotiation when the design is A' (β is sufficiently large). Cognition occurs in two stages, both of which are prior to contract design. First, the buyer investigates whether design A is appropriate. There is no second stage in the absence of awareness of A'. By contrast, when aware of A', the seller investigates whether A' is appropriate in the second cognition stage. Let $\mathcal{T}_B(z)$ denote the cognitive cost of finding A'' with probability z when knowing A'. Then, with obvious notation,

$$\mathcal{T}'_B(z^*) = \mu\big[1 - \widehat{\mu}(z^*)\big]h$$

and

$$T'_B(b^*) = \rho\big[[1 - \widehat{\rho}(b^*)]h - \mathcal{T}_B(z^*)\big].$$

3.2 Two-sided cognition

Suppose that the seller's cognition is no longer "prohibitively" expensive. The seller can learn about design A' (when relevant) with probability s at cost $T_S(s)$. We look for conditions under which the one-sided cognition equilibrium ($b = b^*$, $s = 0$) is also a two-sided cognition equilibrium. To this purpose, we investigate two questions: First, does the seller have an incentive to disclose the existence of design A' when she becomes aware of it? Second, does the seller refuse to trade when not learning about a potential hold-up? If the answers to these two questions are both negative, then the seller gains nothing from becoming informed and, a fortiori, does not want to incur costs to become informed.[23]

Disclosure of design A'. Suppose that the buyer selects b^*. If the buyer finds out that the design should be A', then any cognitive effort by the seller is wasted. Suppose therefore that the seller, but not the buyer, becomes aware that design A' is the appropriate one. The seller obtains

$$\sigma(v - c)$$

by revealing A'. By concealing A', she obtains instead:

$$p(b^*) - c + h = \sigma(v - c) + [h - \widehat{\rho}(b^*)\sigma\Delta].$$

Concealing design A' therefore dominates disclosure if and only if

$$h \geq \widehat{\rho}(b^*)\sigma\Delta \iff \Delta - a \geq \widehat{\rho}(b^*)\Delta.$$

This is nothing but the condition (condition (6)) under which transaction costs are too high. Put differently, the excessive incentive for the buyer to engage in cognition is deeply linked to the seller's incentive not to disclose. Here the seller has to weigh the hold-up benefit h that she will enjoy ex post by not disclosing and the hold-up discount, $\widehat{\rho}(b^*)\sigma\Delta$, on the bargained price under design A.

Incentive for not trading. If the seller does not benefit from disclosing design A', the only potential incentive for the seller to invest in cognition is to avoid trade when she does not discover an opportunity for a hold-up. If $p(b^*) \geq c$, or

$$v - c \geq \widehat{\rho}(b^*)\Delta, \tag{7}$$

however, the seller always wants to trade.

Proposition 2. ***(two-sided cognition.)*** *The one-sided cognition equilibrium for $\beta \geq \beta_0$ is also a two-sided-cognition equilibrium ($b = b^*$, $s = 0$) provided that:*
(i) contracts are too complete in the one-sided cognition equilibrium:

$$\Delta - a \geq \widehat{\rho}(b^*)\Delta, \tag{8}$$

and

(ii)

$$v - c \geq \widehat{\rho}(b^*)\Delta. \tag{9}$$

[23] This holds regardless of the degree of correlation between the two cognitive activities.

Proposition 2 captures a basic asymmetry between the buyer's and the seller's gains from cognition. The buyer gains from being informed about the probability of a hold-up as this enables him to avoid it. By contrast, if aware of an opportunity for a hold-up, the seller may not want to disclose it; her only potential use of this information is then to refuse to trade when she is pessimistic about the possibility of an additional income ex post. If the scope for hold-up is however limited (note that a sufficient condition for (9) to be satisfied is that $v - c \geq \rho\Delta$), then it is not worth forgoing gains from trade in order to economize on the hold-up discount.[24]

When does the seller engage in cognitive effort?

While Proposition 2 captures a fundamental asymmetry in the incentives to engage in cognition, more generally the seller may exert cognitive effort for one of three reasons:

(1) *Severe hold-up discount.* First, if the hold-up discount ($\widehat{\rho}(b^*)\sigma\Delta$) is large (either (8) or (9) fails), the seller may want to learn about the inappropriateness of design A, either to avoid the adjustment cost or to not trade when unaware of a hold-up opportunity.

(2) *Good news for the buyer.* We have so far assumed that cognition may unveil *bad news* (a hold-up opportunity) for the buyer. We could more symmetrically assume that cognition may also unveil *good news* for the buyer (some unexpected benefit delivered by the seller's technology). We then have a natural *specialization principle*: The buyer exerts cognitive effort in order to identify potential hold-ups while the seller tries to push the price up by finding reasons why her technology delivers value to the buyer.

(3) *Bad news for the seller.* The seller may attempt to learn about bad news for herself. Indeed, consider the more symmetric model with three states of nature. With probability ρ, the appropriate design is A', which delivers v at cost c, while A delivers $v - \Delta$ at the same cost. With probability μ, the appropriate design is A'', which delivers v at cost c, while A delivers v at cost $c + \Delta$ for the seller. For example, contract A fails to identify a loophole in a non-compete clause; due to Bertrand competition in an adjacent market, this loophole brings little or no revenue to the buyer, but costs Δ to the seller. Alternatively, design or contract A may fail to specify some marketing, technological or standardization

[24] Condition (9) is stronger than needed for the property that the seller does not incur any cognitive cost. For example, suppose that (i) the seller chooses cognitive cost $T_S(s)$ after being offered to negotiate on design A (so the seller knows that the buyer is unaware of an alternative design) and (ii) the probabilities of discovering A' if appropriate are independent for the buyer and the seller. Then the seller exerts no cognitive effort when bargaining over A if

$$\sigma(v - c) \geq \max_{\{s\}} \left\{\widehat{\rho}(b^*)s\big[p(b^*) + h - c\big] - T_S(s)\right\}.$$

In the extreme case of free cognition ($T_S \equiv 0$ and so $s = 1$), this condition boils down to

$$v - c \geq \widehat{\rho}(b^*)\Delta,$$

that is to (9); but it is in general weaker than (9).

effort by the buyer, costing Δ to the seller. When the appropriate design is A' or A'', but the initial contract specifies A, adjustment cost $a \in [0, \Delta)$ needs to be incurred (by the party who does not lose Δ) to move to the appropriate design.

Finally, with probability $1 - \rho - \mu$, A is the appropriate design and delivers value v at cost c.

Suppose that the two parties have a comparative advantage in investigating their own payoff, i.e., here in searching for bad news for themselves: the buyer can learn design A' (if relevant) with probability b at cost $T_B(b)$, and the seller can learn design A'' (if relevant) with probability z at cost $\mathcal{T}_S(z)$. The symmetry of the situation suggests that the seller indeed engages in cognition so as to identify bad news for herself. Appendix 3 checks that this is indeed the case and provides the equilibrium conditions for the cognitive efforts.

3.3 Discussion

We have focused on contracts that specify a design and a price. However, the fact that other designs (in the current model, A') are not initially describable may not prevent parties from writing contracts that elicit these designs when they later enter the parties' awareness; what can be achieved then depends on the specification of the stochastic structure for von Neumann-Morgenstern payoff functions.[25]

On the other hand, the robustness of the cognitive rent-seeking point and the implications derived in this paper hinge only on the fact that any mechanism is characterized by the shares $\widehat{\beta}$ and $\widehat{\sigma}$ of the gains from trade $\Delta - a$ realized when a design is adjusted with gain Δ for the buyer and cost a to the seller.[26] Because $\widehat{\beta} + \widehat{\sigma} = 1$, it may not be feasible to make both parties choose efficient levels of cognition.

Furthermore, even under one-sided cognition, discouraging cognitive investments will generally entail other costs. Consider for example the buyer's cognitive investment. From (8) and the fact that b^* increases with $\widehat{\sigma}$, reducing excess cognition requires lowering $\widehat{\sigma}$. It is easy to think of reasons why the seller must receive a minimum fraction of the surplus when the design is adjusted. Let us depict two such set-ups.

Degradation. In the first, when A is the right design, the buyer can degrade it, thereby appropriating some private benefit ξ and creating a cost d to the seller (for example the buyer may fail to invest in the technology, and thereby to generate spillovers for the seller); the value of A to the buyer is then only $v - \Delta$. Assume a cost $a \in (\xi, \Delta)$ of adjusting it back to A; then the states of nature in which A must be adjusted to A' because of degradation and because A was inappropriate to start with are indistinguishable from a von Neumann-Morgenstern perspective, and so any mechanism must deliver the same surpluses to the buyer and the seller. To avoid a degradation (which is undesirable if $a + d > \xi$), the share of the ex post surplus, $\widehat{\sigma}(\Delta - a)$, received by the seller in case of renegotiation must be sufficiently large. This puts a lower bound on the seller's hold-up, and therefore on the buyer's incentive to engage in cognitive rent-seeking.

[25] On this, see Maskin-Tirole (1999b).

[26] See Maskin-Moore (1999) and Segal-Whinston (2002).

Seller investment. Another standard reason why the seller must get some ex post surplus is that some specific investment by the seller must be encouraged. Suppose for example costless adjustments ($a = 0$) and that, conditional on A being the appropriate design, a post-contractual investment by the seller raises its utility by Δ after some adjustment. Again the adjustments from A to A', whether justified by an inappropriate initial design or by seller investment, are payoff-equivalent (they raise the buyer's utility by Δ). Encouraging specific investment by the seller requires providing her with enough surplus from adjustments, thus creating incentives for cognition.

Appendix 4 goes into the analysis of this section more formally and shows that cognitive rent seeking is robust.

4 Determinants of contract incompleteness and reverse causality

This section applies well-known ideas on reputational concerns, control rights and specific investments in order to derive their impact on the extent on contract incompleteness.

To shorten the analysis and simplify the notation, we will, for the rest of the paper, put ourselves in the benchmark of Proposition 1(i), and assume that adjustments are costless (and so cognition is always socially wasteful):

Assumption 2. *Adjustments are costless: $a = 0$. Furthermore, only the buyer can exert cognitive effort, and $\beta \geq \beta_0$.*

4.1 Relational contracting and incompleteness

Recall Macaulay (1963) and others' observation that contract incompleteness is related to relational contracting. We point out that the causality runs in both directions; while the literature has emphasized that firms will search for repeated relationships when contracts are necessarily incomplete, we here argue that repeated interactions *make* contracts more incomplete.

Let us embed the model of section 3 in a repeated context. There are continua of mass 1 of buyers and sellers, and time is discrete: $t = 0, 1, \cdots$. The discount factor is denoted by δ. Each period, a fraction $1 - \lambda \geq 0$ of sellers learn that they will exit in the following period. A fraction $1 - \lambda$ of new sellers arrives each period, and so the number of sellers remains equal to the number of buyers over time.

Each period, each buyer is matched with one seller, and conversely. The designs are new each period (an interesting extension of the current model would allow for industry learning about the proper design). He learns the seller's past behavior (see below) and decides whether to consider a project with this seller; considering per se, involves cost f for the buyer (on top of the cognitive cost $T_B(b)$ incurred after the buyer has sunk f); the introduction of this cost will be motivated later on. f can be interpreted either as an opportunity cost or as a preliminary-study cost.

A fraction θ of the sellers is "opportunistic" (i.e., their payoff function is that of section 3). The remaining fraction $1-\theta$ corresponds to "honest" sellers. Honest sellers abide by the *spirit* of the contract rather than the *letter*: If A' is the appropriate design, and A has been contracted for, an honest seller adjusts the design to A' for free (recall that there is no cost in doing so). And so a seller who holds up a buyer reveals that she is opportunistic.

The timing is summarized in Figure 2.

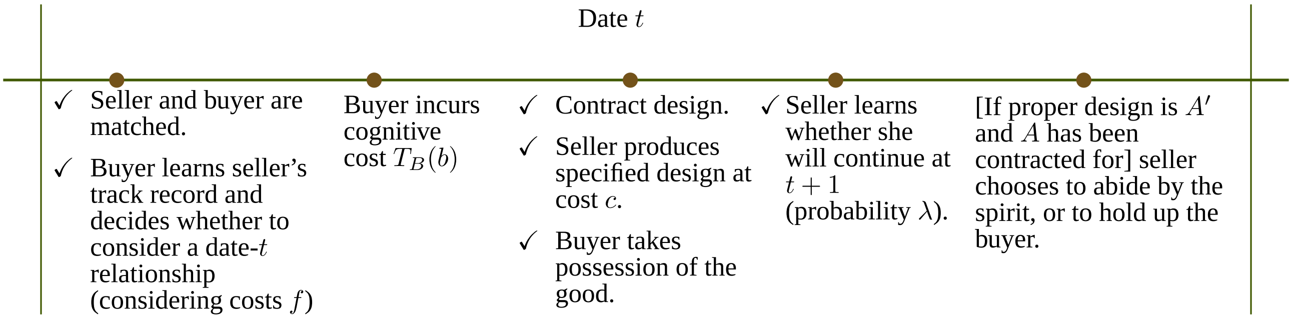

Figure 2 : Timeline

Special case: $\lambda = 1$.

Let us look for an equilibrium in which:

• all sellers, even opportunistic ones, comply with the spirit of the contract (no hold-up);

• buyers consider entering a relationship only with sellers who have not committed hold-ups in the past;

• contracts are always incomplete ($b = 0$, and so design A is always specified).

Note that the sellers' behavior allows buyers to economize on cognitive costs, and so $b = 0$ is indeed optimal when $\lambda = 1$. By contrast, when meeting with a seller who has a spotty track record, the buyer knows that the seller (who will not receive contracts in the future) will exploit any opportunity for hold-up. And so assuming that $\beta \geq \beta_0$, the buyer exerts cognitive effort b^* (given by condition (4)). The buyer contracts only with sellers with a clean track record if:

$$\beta(v-c) - T_B(b^*) < f < \beta(v-c) \tag{10}$$

Reputation can emerge only in the presence of an opportunity or preliminary-study cost f for the buyer: The cognitive cost $T_B(b^*)$ is sunk when bargaining and so, in equilibrium, is fully borne by the buyer. The seller does not suffer from the suspicion of hold-up associated with a spotty record unless somehow she becomes persona non grata (or more generally that the buyer reacts in a way that reduces the seller's rent). An opportunistic seller does not want to exploit an opportunity for a hold-up if

$$h \leq \frac{\delta}{1-\delta}\sigma(v-c),$$

or

$$\Delta \leq \frac{\delta}{1-\delta}(v-c). \tag{11}$$

Condition (11) captures the idea that future interactions loom large enough for the seller to abide by the spirit of the contract.

As Macaulay (1963) noted long ago:[27]

> "*There is a hesitancy to speak of legal rights or to threaten to sue in these negotiations.*"

General case.

The sole focus on the availability heuristic (contract A) is of course an extreme implication of the special case just considered. When $\lambda < 1$, hold-up opportunities are exploited with probability $\theta(1-\lambda)$, even though opportunistic sellers build a reputation for being honest when they are not about to exit. As a consequence, the buyer exerts a positive cognitive effort. Furthermore, there is a cross-subsidy from honest to opportunistic sellers since the price for design A reflects the possibility that the latter hold up the buyer.

The buyer's cognitive effort b_* ($< b^*$) is then given by:[28]

$$T_B'(b_*) = \frac{\rho(1-\rho)}{1-\rho b_*}\theta(1-\lambda)h. \tag{12}$$

The generalization of condition (10) is:

$$\beta(v-c) - T_B(b^*) < f < \beta(v-c) - T_B(b_*) \tag{13}$$

and that of condition (11) is:[29]

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[27] Page 61. This view is based on interviews with businessmen and lawyers. Representative narratives are:

> "*If something comes up, you get the other man on the telephone and deal with the problem. You don't read legalistic contract clauses at each other if you ever want to do business again. One doesn't run to lawyers if he wants to stay in business because one must behave decently.*"

and

> "*You can settle any dispute if you keep the lawyers and accountants out of it. They just do not understand the give-and-take needed in business.*"

[28] ¿From (5), $\beta \geq \beta_0$ and $b_* < b^*$, the buyer indeed wants to trade even if he does not discover design A'.

[29] The current gross payoffs for the buyers, the honest sellers and the opportunistic sellers for design A' are

$$v - p - \theta\widehat{\rho}(b_*)(1-\lambda)h,$$
$$p - c, \text{ and}$$
$$p - c + (1-\lambda)\widehat{\rho}(b_*)h,$$

respectively. We assume that in the negotiation the opportunistic sellers masquerade as honest ones. In

$$h \leq \frac{\delta}{1-\delta\lambda}\left[\sigma(v-c)+\widehat{\rho}(b_*)(1-\lambda)(1-\theta\sigma)h\right], \tag{14}$$

or

$$\Delta \leq \frac{\delta}{1-\delta\lambda}\left[v-c+\widehat{\rho}(b_*)(1-\lambda)(1-\theta\sigma)\Delta\right]. \tag{15}$$

Proposition 3. *Under Assumptions 1 and 2, contracts are more incomplete, the more forward-looking the sellers are (the higher δ and λ), the weaker the sellers' bargaining power (σ), and the smaller the fraction of opportunistic sellers (θ).*

It is well-known that reputation concerns may make up for the shortcomings of incomplete contracting. Proposition 3 goes further by stating that reputation and contract incompleteness are substitutes: Relationship contracting *generates* (is not only a response to) contract incompleteness.

4.2 Contract length

The relationship between transaction costs, incompleteness and contract length is illustrated for example by the contrast between traditional procurement contracts and public-private partnerships (PPPs) in which the conception and construction stage is bundled with longer-term operations and maintenance. PPPs (Private Finance Initiative, PFI, deals in the U.K.) are known to be prone to both contractual incompleteness and high transaction costs (Välilä 2005). The UK National Audit Office (2003) argues that "Private Finance Initiative deals remain very costly to negotiate and these costs need to be factored into the assessment." For example, the mere cost of negotiations for the London Underground deal was £180 million (and this number excludes bidders' transaction costs); the average cost of National Health Service PFI deals for external advisors only is about 3.7 percent of the capital value of the projects.

This section shows that a concern for economizing on transaction costs may lead the parties not to sign a long-term contract even it this entails standard underinvestment costs. The main idea is that if information accrues over time, waiting to sign a contract is a commitment not to incur wasteful cognitive expenses. Consider the timing in Figure 3.

the negotiation between the buyer and an honest buyer (otherwise the buyer refuses to trade), the honest buyer gets surplus

$$p-c=\sigma\left[v-c-\theta\widehat{\rho}(b_*)(1-\lambda)h\right].$$

Hence the opportunistic seller's instantaneous payoff is

$$\sigma(v-c)+(1-\theta\sigma)\widehat{\rho}(b_*)(1-\lambda)h.$$

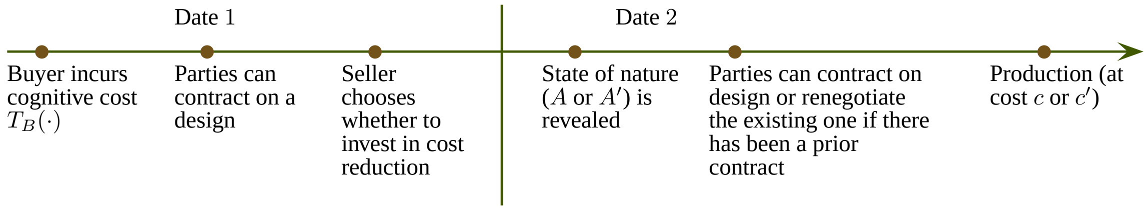

Figure 3 : Timeline

This timing embeds the standard rationale for long-term contracts. Here the seller may underinvest if there is no date-1 contract. For example suppose that the seller may reduce cost from c to $c' < c$ by investing $I_S < c - c'$. Assuming that the discount rate is equal to 0, this desirable investment is not sunk in the absence of date-1 contract provided that

$$\sigma(c - c') < I_S,$$

which we will assume. Agreeing on a design and a price at date 1 encourages this investment and generates gains from trade $c - c' - I_S$, that can be shared between the buyer and the seller. By contrast, agreeing on design A raises the prospect of a hold-up for the buyer.[30]

When the buyer learns about design A', he will want to disclose it and sign a long-term contract on A'. He thereby encourages specific investment by the seller and obtains $\beta(v - c' - I_S)$, gross of the cognitive cost.

When unaware about the existence of a hold-up, he can either refrain from contracting in order to prevent a hold-up, at the cost of discouraging investment by the seller. The buyer then obtains $\beta(v - c)$ by bargaining at date 2 once the state of nature is revealed. Alternatively, he can bargain over a long-term contract specifying design A and thereby encourage specific investment at the cost of a potential hold-up.

Let us first look for a *long-term contract equilibrium* in which the buyer chooses $b = b^*$ and offers a long-term contract (on design A, or A'). His payoff is:

$$\beta(v - c' - I_S) - T_B(b^*).$$

The buyer can deviate from this equilibrium by adopting a "short-term contracting" strategy, i.e., by choosing cognitive effort b'' and offering a long-term contract only if he becomes aware of design A', where

$$b'' = \underset{\{b\}}{\operatorname{argmax}} \Big\{ \rho b \big[\beta\big(v - c' - I_S\big)\big] + \big[1 - \rho b\big] \big[\beta(v - c)\big] - T_B(b) \Big\},$$

[30]Note that even if the adjustment cost a were positive, the particular timing presumed here would not capture another important cost of long-term contracts, namely the loss in flexibility associated with an inappropriate design.

or

$$T'_B(b') = \rho\beta\big(c - c' - I_S\big). \tag{16}$$

The long-term contract equilibrium exists if and only if:

$$\beta\big(v - c' - I_S\big) - T_B(b^*) \geq \beta(v - c) + \rho b''\beta\big(c - c' - I_S\big) - T_B(b''),$$

which can be written as:

$$\big(1 - \rho b''\big)\beta\big(c - c' - I_S\big) \geq T_B(b^*) - T_B(b''). \tag{17}$$

The left-hand side of condition (17) corresponds to the buyer's share of cost savings due to the seller' specific investment; that gain has probability $1-\rho b''$, the probability that the buyer does not offer to contract on design A in the short-term contracting strategy. The right-hand side of condition (17) corresponds to the transaction cost savings[31] under a short-term contracting strategy.

If (17) is violated (as is the case for β small), then short-term contracting occurs with positive probability. Note that, from the point of view of the seller, the buyer may not exert enough cognitive effort, making him too little confident to engage in a long-term contract.

Proposition 4. *Under Assumptions 1 and 2, the parties sign a long-term contract if condition* (17) *is satisfied. Otherwise short-term contracting emerges with positive probability.*

Short-term contracts can be shown to emerge when β is low, that is when specific investments are not jeopardized. This result fits well for example with Joskow (1987)'s empirical evidence on coal contracts, which shows that such contracts are much shorter when ex post competition makes the prospect of hold-up more remote.

4.3 Ownership

The endogeneity of the extent of completeness provides a rationale for the conventional wisdom that vertical integration economizes on contracting costs, i.e., that a key benefit of firms is that they allow less explicit contractual specifications.[32]

[31] When $c-c'-I_S$ is large, b'' exceeds b'. But then long-term contracting is trivially optimal (condition (17) is satisfied).

[32] For example, Klein (2002) argues:

> "*If [the pioneering Grossman and Hart model of integration] has the advantage of taking the incompleteness of contracts seriously, it does not consider the key aspect of the contractual arrangement we identify with the firm, namely that it involves less explicit contractual specification and more flexibility.*"

Note, though, that in recent interesting work, Hart and Moore (2007) do endogenize the degree of contractual incompleteness by introducing the behavioral feature of feelings of entitlement that make economic agents want to shade on performance when they feel shortchanged.

Suppose that the buyer ex post can "fix" (costlessly modify by himself) a wrong design A, provided that he acquires ownership of the seller's technology and not only of the seller's good.[33] Such "buyer ownership"[34] thus prevent ex post hold-ups.

The transfer of the seller's technology to the buyer however creates a deadweight loss. The literature has analyzed a number of reasons for why it may be so, and we will therefore not be interested in formalizing a particular cost; for example the transfer may create competition in the R&D or some downstream product market. Let $K > 0$ denote this cost.

To formalize the trade-offs in a simple manner, consider the following timing:
(i) The parties choose between seller- and buyer-ownership,
(ii) the buyer exerts cognitive effort b,
(ii) the buyer offers a design (A, or A' if available) and the two parties bargain over a price.

Seller ownership: the equilibrium (given that $\beta \geq \beta_0$) is as in section 3. The seller rationally anticipates cognitive effort b^*, and so the parties' total utility is

$$v - c - T_B(b^*).$$

Buyer ownership: Under buyer ownership, there is no hold-up and so $b = 0$. The design is always the available heuristic A. The parties' total utility is then[35]

$$v - c - K.$$

Buyer ownership arises if and only if:

$$T_B(b^*) \geq K. \tag{18}$$

Proposition 5. *Under Assumptions 1 and 2,*
(i) under vertical integration, the two parties contract on the available heuristics design A and incur no cognitive cost;
(ii) vertical integration (buyer ownership) arises if and only if

$$T_B(b^*) \geq K.$$

It is therefore more likely to emerge when the hold-up concern and the seller's bargaining power are substantial.

[33] This is one of many ways of apprehending the transfer of a control right from the seller to the buyer. For example, a transferable control model à la Aghion-Dewatripont-Rey (2004) could alternatively be envisioned.

[34] "Buyer ownership" may not be exclusive. For example, the seller may have granted a block license for her entire intellectual property, and still be able to use the intellectual property herself.

[35] Note that this contract is not renegotiation-proof, as the two parties could save the cost K by leaving ownership with the seller. Suppose, however, that the two parties expect to renegotiate to seller ownership. Then the buyer optimally exerts effort b^*. And, under condition (18) below, the buyer is better off insisting on buyer ownership. The equilibrium then necessarily involves mixed strategies.

Proposition 5 is consistent with available empirical evidence. Levin-Tadelis (2006) documents that local governments tend to provide public services in-house when contracting on these services is complex. To the extent that transaction costs increase with the complexity, it is natural that local governments use vertical integration to economize on them for highly complex or unknown operations. Novak-Stern (2006) investigates the relationship between make-or-buy choice and quality improvements over the life cycle in the automobile industry. They show that quality increases over time for in-house components and remains roughly constant for outsourced components. Proposition 5 provides one possible rationale for this observation. Flaws in design (the inappropriateness of A in our model) are unveiled and corrected only over time; thus the "adjustment cost" refers not only to the technical cost, but also to the buyer's lost time incurred in producing a lower-quality output.[36] Because the probability of adjustment, $\rho(1-b)$, is higher under vertical integration than under outsourcing, quality improvements are therefore more likely under vertical integration.[37]

5 Does competition reduce transaction costs?

This section provides some preliminary insights on the impact of *ex ante* competition among sellers. The bargaining weights β and σ (and relatedly the hold-up stake h) now refer exclusively to the *ex post* bargaining strengths. For the sake of simplicity and unless otherwise specified, we keep assuming (as in section 4) one-sided cognition and no adjustment cost. We generalize the analysis of section 3.1 to the case of Bertrand competition among (at least two) sellers.

Competition for design A' yields price equal to cost (c) and buyer gross surplus $v-c$. Suppose next that the proposed design is A and that the equilibrium level of cognition is b^* (as it turns out, this level will be the same as in section 3.1, so we do not introduce new notation). The competitive price is then

$$p = c - \widehat{\rho}(b^*)h.$$

Underpricing (low-ball bidding) thus reflects a hold-up discount.

And so the buyer solves

$$\max_{\{b\}} \Big\{ -T_B(b) + \rho b(v-c) + \rho(1-b)\big[v-c-\big[1-\widehat{\rho}(b^*)\big]h\big] + (1-\rho)\big[v-c+\widehat{\rho}(b^*)h\big]\Big\},$$

or, letting

$$H(b,b^*) \equiv \big[(1-\rho)\widehat{\rho}(b^*) - \rho(1-b)\big[1-\widehat{\rho}(b^*)\big]\big]h,$$

[36] To formalize this idea in the context of this paper's model, one can assume that the buyer's value is $v-\Delta$ for some time after the product is introduced and v once the seller has adjusted the design.

[37] An alternative explanation, noted by Novak and Stern, builds on Bajari-Tadelis (2001), which shows that adjustments are less likely to be made under high-powered incentive schemes (outsourcing here). The idea in Bajari and Tadelis is that accounting structures are permanently different under vertical integration and separation, and that fixed prices contracts are fraught with asymmetric information ex post, and therefore harder to renegotiate.

$$\max_{\{b\}} \Big\{ - T_B(b) + (v-c) + H(b,b^*) \Big\}.$$

By contrast, under bilateral monopoly (section 3.1), the buyer solved:

$$\max_{\{b\}} \Big\{ - T_B(b) + \beta(v-c) + H(b,b^*) \Big\}.$$

Thus competition allows the buyer to appropriate an extra $\sigma(v-c)$ (the seller's share of the total gross surplus), but does not impact his incentive to exert cognition.

Next consider the buyer's option not to contract on design A. The buyer then solves:

$$\max_{\{b\}} \Big\{ - T_B(b) + \rho b(v-c) \Big\}.$$

By comparison, under bilateral ex ante monopoly, he solved:

$$\max_{\{b\}} \Big\{ - T_B(b) + \rho b\beta(v-c) \Big\}.$$

This analysis yields:

Proposition 6. *Under Assumptions 1 and 2 and ex-ante seller competition, there exists $\beta_0^c < \beta_0$ such that a pure-strategy equilibrium exists if and only if $\beta \geq \beta_0^c$. The cognitive intensity x^* is then the same as under ex ante bilateral monopoly.*

Proposition 6 shows that competition in general does not reduce the buyer's transaction costs. Intuitively, the buyer is worried about the occurrence of an ex post hold-up, and this concern is the same regardless of the extent of ex ante competition.

By contrast, Proposition 2 suggests why the analysis of two-sided cognition (section 3.2) must be amended. We saw that in an ex-ante bilateral-monopoly situation, the seller may not want to sink cognitive effort because she may enjoy a positive surplus even when she is unaware of hold-up opportunity. Ex ante competition destroys this surplus. Indeed the seller loses $\widehat{\rho}(b^*)h$ in the absence of hold-up. Thus, provided that $T_S'(0) = 0$, the sellers sink cognitive effort. The situation then resembles one of common values, with positive affiliation among sellers, and negative affiliation between the sellers and the buyer. Interestingly, the winner's curse faced by the sellers depends not only on the auction's design, but also on the other sellers' and the buyer's cognitive investments. We leave the fascinating topic of auction design with transaction costs for future research.

6 Alleys for future research

The introduction listed the main insights. Rather than restating them, let us conclude with a couple of alleys for research.

The paper has stressed *pre-contractual* transaction costs. Similar techniques could be used to give content to transaction costs that are incurred at the *implementation* stage. For example, while in Maskin-Tirole (1999b) actions and contingencies may be undescribable at the contracting stage, they are costlessly describable ex post. Thinking through alternatives ex post however involves transaction costs that are similar to those formalized here. It is certainly worth considering ex post transaction costs.

Second, while the paper has stressed that a specialization in the cognitive investigations is natural, interesting patterns of strategic complementarities/substitutabilities may emerge. This would arise in particular if both parties' "thinking deeply enough about the issues" were needed for the realization of gains from trade.

Third, the standard designs (A) and the cognitive cost functions (T_i) are influenced by past contractual experimentation within and outside the industry. Familiarity with designs and their implications are path-dependent. The dynamics of contractual incompleteness and heterogeneity across relationships is a fascinating topic for research.

Fourth, we have assumed that the contract designers are residual claimants. In practice, they often are agents for their respective organizations. Their incentives to sink transaction costs (opportunity cost of their time, legal and consulting fees, etc.) depend on the design of their incentive package and on the internal monitoring set up. As observed to Macaulay (1963), managers are usually tempted to write incomplete contracts and count on relational contracting to discipline their counterpart. Their hierarchy and legal councils by contrast are advocates of more rigor and try to avoid the off-balance sheet liabilities associated with adjustment costs and hold-ups. Put differently, the extent of contract incompleteness depends on the firms' internal organizations.

Appendix 1: Existence of a cut-off β_0

Note, first, that for $\beta = 1$ and for any a, the buyer is better off always trading:

$$\max_{\{b\}} \Big\{ -T_B(b) + (v-c) - \rho(1-b)a \Big\} > \max_{\{b\}} \Big\{ -T_B(b) + \rho b(v-c) \Big\}$$
$$= \max_{\{b\}} \Big\{ -T_B(b) + v - c - (1-\rho b)(v-c) \Big\},$$

where we make use of the assumption that there are gains from trade even in the absence of cognition ($v - c - \rho a > 0$). Note also that for $\beta = 0$, the LHS of (5) is equal to $-T_B(b^*) < 0$ and the RHS to 0.
Let

$$U^T(\beta) \equiv -T_B\big(b^*(\beta)\big) + \rho b^*(\beta)\beta(v-c) + \big[1 - \rho b^*(\beta)\big]\beta\big[v - c - \widehat{\rho}\big(b^*(\beta)\big)a\big]$$

and

$$U^{NT}(\beta) \equiv -T_B\big(b'(\beta)\big) + \rho b'(\beta)\beta(v-c).$$

Consider a β such that the buyer wants to contract on design A when the seller expects $b^*(\beta)$ and:

$$U^T(\beta) = U^{NT}(\beta).$$

It must be the case that when choosing $b'(\beta)$ and the seller still expects $b^*(\beta)$, the buyer does not want to contract on design A. Furthermore, for the buyer not to be willing to trade at price $p\big(b^*(\beta)\big)$, it must be the case that

$$b'(\beta) < b^*(\beta).$$

And so:

$$\frac{dU^T}{d\beta} = v - c - \rho(1-b^*)a + (1-\rho b^*)\,\frac{d\widehat{\rho}}{db^*}\,\frac{\partial b^*}{\partial \beta}\sigma\Delta$$
$$> v - c - \rho(1-b^*)a$$
$$> \rho b'(v-c) = \frac{dU^{NT}}{d\beta}.$$

This establishes the existence of a cut-off β_0.

Appendix 2: Contract negotiation breakdown when the seller has full bargaining power

When the seller has full bargaining power, the buyer receives no surplus when unveiling design A'. The buyer's incentive to acquire information must then stem from a post-information-acquisition rent that he receives when having acquired information and being rather confident that there will be no hold-up. But such a rent can exist only if the seller is uncertain about how much information was acquired. Moreover, the lowest b on the equilibrium support must be equal to 0 since no rent can accrue to this "type". The lowest possible offer for design A is therefore $p = v - \rho\Delta$. Consider the following candidate mixed-strategy equilibrium:

- ✓ the seller's offer p follows cumulative distribution $F(p)$ on $[v - \rho\Delta, \overline{p}]$,
- ✓ the buyer's cognitive effort b follows cumulative distribution $G(b)$ on $[0, \overline{b}]$.

  The seller will never charge a price for design A that is refused with probability 1, and so $\bar{p} = v - \hat{\rho}(\bar{b})\Delta$, since "type" $\bar{b}$ is the type most optimistic about the absence of hold up.

When exerting cognitive effort b, the buyer accepts all offers satisfying $v - p - \widehat{\rho}(b)\Delta \geq 0$ and rejects others. His utility is then:

$$\begin{aligned} U(b) &= -T_B(b) + (1 - \rho b) \int_{v-\rho\Delta}^{v-\widehat{\rho}(b)\Delta} \big[v - p - \widehat{\rho}(b)\Delta\big] dF(p) \\ &\equiv -T_B(b) + (1 - \rho b)R(b). \end{aligned}$$

Note that $U(0) = 0$. For the buyer to play a mixed strategy, it must be the case that $U(b) = 0$ on $[0, \overline{b}]$; or

$$-T_B'(b) - \rho R(b) - (1 - \rho b) \frac{d\widehat{\rho}}{db} \Delta F\big(v - \widehat{\rho}(b)\Delta\big) = 0.$$

Using $\dfrac{d\widehat{\rho}}{db} \equiv -\dfrac{\rho(1-\rho)}{(1-\rho b)^2}$, and letting $B(p)$, an increasing function, be defined by

$$p \equiv v - \widehat{\rho}(B(p))\Delta,$$

and

$$K(b) = T_B'(b)(1 - \rho b) + T_B(b)\rho$$

(with $K' > 0$ and $K(0) = 0$),

$$F(p) = \frac{K(B(p))}{\rho(1-\rho)\Delta}. \tag{A.1}$$

Using $F(\bar{p}) = 1$, the upper bound of the support, $\overline{b}$, is given by

$$[1 - \rho\overline{b}]T_B'(\overline{b}) + \rho T_B(\overline{b}) = \rho(1 - \rho)\Delta. \tag{A.2}$$

Note that $\bar{b} < b^*$. We must further show that $U'(b) \leq 0$ for $b \geq \bar{b}$. For such values, the buyer always trades, at average price $p^e = E[p]$. Because for $b > \bar{b}$

$$U(b) = -T_B(b) + (1 - \rho b)[v - p^e - \widehat{\rho}(b)\Delta],$$
$$U'(b) = -T_B'(b) - \rho[v - p^e] + \rho = -T_B'(b) + T_B'(\bar{b}) < 0.$$

Let us now turn to the determination of $G(b)$. Let $\pi(p)$ denote the seller's expected profit, conditional on design A:

$$H_0\pi(p) = \int_{\widehat{\rho}^{-1}\left(\frac{v-p}{\Delta}\right)}^{\bar{b}} \left[p - c + \widehat{\rho}(b)\Delta\right](1 - \rho b)dG(b)$$

where $H_0 \equiv \displaystyle\int_0^{\bar{b}} (1 - \rho b)dG(b)$ is the probability of design A.

This can be rewritten as a function of the cut-off

$$\widetilde{b} \equiv \widehat{\rho}^{-1}\left(\frac{v-p}{\Delta}\right) :$$

$$H_0\pi(\widetilde{b}) = \int_{\widetilde{b}}^{\bar{b}} \left[v - c - \left[\widehat{\rho}(\widetilde{b}) - \widehat{\rho}(b)\right]\Delta\right](1 - \rho b)dG(b).$$

For π to be constant on $[0, \bar{b}]$, it must be the case that:

$$-\frac{d\widehat{\rho}}{d\widetilde{b}}\Delta\Big[\int_{\widetilde{b}}^{\bar{b}} (1 - \rho b)dG(b)\Big] - (v - c)(1 - \rho\widetilde{b})g(\widetilde{b}) = 0. \tag{A.3}$$

Let $H(\widetilde{b}) \equiv \displaystyle\int_{\widetilde{b}}^{\bar{b}} (1 - \rho b)dG(b)$, and $x \equiv \frac{(1-\rho)\Delta}{v-c}$

The distribution G admits an atom at $b = \bar{b}$. Let y denote this atom. Then

$$H_0 = (1 - \rho\bar{b})y + \int_0^{\bar{b}^-} (1 - \rho b)g(b)db = (1 - \rho\bar{b})y + x\int_0^{\bar{b}^-} \frac{\rho}{(1 - \rho b)^2}H(b)db,$$

or

$$H_0 = (1 - \rho\bar{b})y + x\Big[\frac{y}{1 - \rho\bar{b}} - H_0 + 1 - y\Big] \tag{A.4}$$

Furthermore:

$$ln\frac{H_0}{H(\tilde{b})} = x\Big[\frac{1}{1 - \rho\tilde{b}} - 1\Big] \tag{A.5}$$

yielding in particular (for $\tilde{b}$ converging to $\bar{b}$):

$$ln\frac{H_0}{y} = x\Big[\frac{1}{1 - \rho\bar{b}} - 1\Big]. \tag{A.6}$$

We thus obtain two equations (A4 and A6) with two unknowns (H_0 and y), yielding thereafter $H(\tilde{b})$ from (A5)) and then $g(\tilde{b})$ (from (A3)). Like in the two-cognition-level case studied in the text, the distribution of "net prices" $p - v$ is independent of the gains from trade parameters v and c. By contrast, gains from trade $v - c$ affect the distribution G of cognition levels through the parameter x.

Appendix 3: Symmetric hold-up

Let

$$h \equiv \sigma(\Delta - a) \text{ and } k \equiv \beta(\Delta - a)$$

denote the hold-up stakes,

$$\theta_B(b, z) \equiv \frac{\rho(1-b)}{\rho(1-b) + \mu(1-z) + (1-\rho-\mu)},$$

$$\theta_S(b, z) \equiv \frac{\mu(1-z)}{\rho(1-b) + \mu(1-z) + (1-\rho-\mu)},$$

denote the posterior probabilities and

$$\theta(b, z) \equiv \theta_B(b, z) + \theta_S(b, z).$$

In a pure-strategy equilibrium (b^*, z^*), the transaction price $p = p(b^*, z^*)$ for design A is given by:

$$\beta\big[v - c - \theta(b^*, z^*)a\big] = v - c - \theta_B(b^*, z^*)[a + h] + \theta_S(b^*, z^*)k. \tag{A.7}$$

and the transaction costs by:

$$T'_B(b^*) = \rho\big[a + h - \theta_B \sigma \Delta + \lambda_S \beta \Delta\big]$$

$$= \rho\big[\big(1 - \theta_B \sigma + \theta_S \beta\big)a + \big(1 - \theta_B\big)h + \theta_S k\big] \tag{A.8}$$

and

$$\mathcal{T}'_S(z^*) = \mu\big[\big(1 - \theta_S \beta + \theta_B \sigma\big)a + \big(1 - \theta_S\big)k + \theta_B h\big]. \tag{A.9}$$

Appendix 4: Formal analysis of section 3.3

This appendix makes the heuristic analysis of section 3.3 more formal.

Degradation. Section 3.3 argued that if the buyer can degrade the good delivered to him and later renegotiate to restore its full value, preventing degradation requires that the seller must get "enough" of the gains from renegotiation, thus inducing the buyer to engage in (possibly excessive) cognition.

Consider four *ex post* states of nature:

ω_1: the initial design A is appropriate and delivers the full utility v;

ω_2: design A is appropriate, but yields only $v-\Delta$ as the buyer has degraded it and thereby enjoyed private benefit ξ. The seller can at adjustment cost a restore the value to v;

ω_3: design A' is appropriate, but this was not identified ex ante. The seller can at adjustment cost a raise value from $v-\Delta$ to v;

ω_4: the appropriate design A' was contracted for ex ante and yields value v.

State ω_3 has probability $\rho(1-b)$, state ω_4 probability ρb, state ω_1 probability $1-\rho$ in the absence of degradation and 0 in case of degradation. Let $U_B(\omega)$ denote the buyer's *ex post* utility in state ω (the ex post utility is the utility obtained when the initial contract is implemented and perhaps renegotiated; it does not include (sunk) cognition costs and benefit from degradation).

What can be implemented in state of nature ω in general depends on the description of feasible actions and payoffs in that state of nature. We will just assume that the states of nature ω_2 and ω_3 are identical in terms of von Neuman-Morgenstern (VNM) utility functions. We now show that *even if* the contract can ex post induce any levels of utility $U_B(\omega_i)$ it wants (satisfying $U_B(\omega_2) = U_B(\omega_3)$ and consistent with the ex ante bargaining powers), controlling cognition is inconsistent with preventing degradation (inducing seller investment in the second illustration).

Note that for any mechanism that does not induce degradation:

$$U_B(\omega_1) \geq U_B(\omega_2) + \xi$$

(the buyer must be willing not to degrade design A when learning that it is appropriate),

$$U_B(\omega_4) = \beta(v-c)$$

(negotiation under symmetric awareness of A'),

$$U_B(\omega_2) = U_B(\omega_3)$$

(ex post VNM payoffs are the same in states ω_2 and ω_3, even though these states have different origins),

$$U_B(\omega_4) - U_B(\omega_3) = \frac{T_B'(b)}{\rho}$$

(buyer's incentive compatible cognition), and

$$\big[1-\widehat{\rho}(b)\big]U_B(\omega_1)+\widehat{\rho}(b)U_B(\omega_3)=\beta\big[v-c-\widehat{\rho}(b)a\big]$$

(ex ante bargaining over design A).

Combining these conditions, implementable levels of cognition consistent with the absence of degradation satisfy:

$$\frac{T_B'(b)}{\rho}=\big[1-\widehat{\rho}(b)\big]\xi+\widehat{\rho}(b)\beta a.$$

Let $\widehat{b}$ be the efficient level of cognition:

$$\frac{T_B'(\widehat{b})}{\rho}=a.$$

Cognition is necessarily excessive if

$$\big[1-\widehat{\rho}(\widehat{b})\big]\xi>\big[1-\widehat{\rho}(\widehat{b})\beta\big]a.$$

Finally, note that degradation is inefficient if $a+d>\xi$, where d is the negative externality on the seller (see the main text).

Seller investment. The analysis is very similar to that of degradation. For notational simplicity, we assume that $a=0$, so efficient cognition is $\widehat{b}=0$. States ω_3 and ω_4 are as before. The other two ex post states are described as follows:

ω_1: design A is the best design and yields $v-\Delta$ (there is nothing to be done);

ω_2: provided that the seller has already sunk private cost $K>0$, design A, which yields $v-\Delta$, can be turned (with the seller's complicity) into design A' and thereby deliver v to the buyer.

State ω_1 has probability μ and state ω_2 probability $1-\rho-\mu$ (if the state is ω_2 but the seller fails to invest, the ex post state reverts to ω_1). Again, ex post payoffs $U_B(\omega_i)$ do not include sunk cognition and investment costs.

One has:

$$U_B(\omega_2)=U_B(\omega_3),$$

(the VNM payoff functions are the same in states ω_2 and ω_3),

$$\frac{T_B'(b)}{\rho}=U_B(\omega_4)-U_B(\omega_3)$$

(privately optimal cognition, assuming $b\geq 0$).

$$U_B(\omega_4)=\beta(v-c),$$

(bargaining over design A'),

$$\left[\frac{1-\rho-\mu}{1-\rho b}\right]\Big[U_S(\omega_2) - U_S(\omega_1)\Big] \geq K$$

$$\iff \qquad \left[\frac{1-\rho-\mu}{1-\rho b}\right]\Big[U_B(\omega_1) - U_B(\omega_2) + \Delta\Big] \geq K$$

(seller investment is incentive compatible), and

$$\frac{\mu}{1-\rho b}\,U_B(\omega_1) + \frac{1-\rho-\mu}{1-\rho b}\,U_B(\omega_2) + \frac{\rho(1-b)}{1-\rho b}\,U_B(\omega_3) = \beta\Big(v - c - \frac{\mu}{1-\rho b}\,\Delta - K\Big)$$

(ex ante bargaining over design A).

Combining these conditions yields:

$$\frac{T_B'(b)}{\rho} = \left[\frac{\mu}{1-\rho-\mu} + \frac{\beta}{1-\rho b}\right]K - (1-\beta)\,\frac{\mu\Delta}{1-\rho b}.$$

In particular if μ is small, cognition is above the efficient level.

References

Aghion, P. and P. Bolton (1987) "Contracts as a Barrier to Entry," *American Economic Review*, 77(3): 388–401.

Aghion, P., and B. Hermalin (1990) "Legal Restrictions on Private Contracts Can Enhance Efficiency," *Journal of Law, Economics, and Organization*, 6: 381–409.

Aghion, P., Dewatripont, M., and P. Rey (2004) "Transferable Control," *Journal of the European Economic Association*, 2: 115–138.

Allen, F., and D. Gale (1992) "Measurement Distortion and Missing Contingencies in Optimal Contracts," *Economic Theory*, 2: 1–26.

Anderlini, L. and L. Felli (1994) "Incomplete Written Contracts: Undescribable States of Nature," *Quarterly Journal of Economics*, 109: 1085–1124.

———-(1999) "Incomplete Contracts and Complexity Costs," *Theory and Decision*, 46: 23–50.

Anderlini, L., L. Felli, and A. Postlewaite (2006) "Should Courts Always Enforce What Contracting Parties Write?," mimeo.

Arrow, K. (1962) "Economic Welfare and the Allocation of Resources for Invention," in R. Nelson, ed. *The Rate and Direction of Incentive Activity: Economic and Social Factors*. Princeton: Princeton University Press.

Bajari, P., and S. Tadelis (2001) "Incentives versus Transaction Costs: a Theory of Procurement Contracts," *Rand Journal of Economics*, 32: 387–407.

Battigalli, P., and G. Maggi (2002) "Rigidity, Discretion and the Costs of Writing Contracts," *American Economic Review*, 92(4): 798–817.

Bolton, P., and A. Faure-Grimaud (2005) "Thinking Ahead: The Decision Problem," NBER Working Paper No. W11867.

———- (2007) "Satisficing Contracts," mimeo.

Che, Y.K., and D. Hausch (1999) "Cooperative Investments and the Value of Contracting: Coase vs Williamson," *American Economic Review*, 89(1): 125–147.

Crémer, J., Khalil, F., and J.C. Rochet (1998a) "Strategic Information Gathering before a Contract is Offered," *Journal of Economic Theory*, 81: 163–200.

———- (1998b) "Contracts and Productive Information Gathering," *Games and Economic Behavior*, 25: 174–193.

Dewatripont, M., and J. Tirole (2005) "Modes of Communication," *Journal of Political Economy*, 113: 1217–1238.

Diamond, D. (1993) "Bank Loan Maturity and Priority when Borrowers Can Refinance," in C. Mayer and X. Vives, eds. *Capital Markets and Financial Intermediation*, Cambridge University Press, p12–35.

Dye, R. (1985) "Costly Contract Contingencies," *International Economic Review*, February: 233–250.

Ellison, G. (2005) "A Model of Add-On Pricing," *Quarterly Journal of Economics*, 120(2): 585–637.

Gabaix, X., and D. Laibson (2006) "Shrouded Attributes, Consumer Myopia, and Information Suppression in Competitive Markets," *Quarterly Journal of Economics*, 121(2): 505–540.

Guasch, J. L., Laffont, J.-J., and S. Straub (2006) "Renegotiation of Concession Contracts in Latin America," forthcoming, *International Journal of Industrial Organization*.

Hart, O., and B. Holmström (1987) "The Theory of Contracts," in T. Bewley, ed., *Advances in Economic Theory*, 5th World Congress of the Econometric Society. Cambridge University Press.

Hart, O., and J. Moore (1999) "Foundations of Incomplete Contracts," *Review of Economic Studies*, 66(1): 115–138.

———- (2007) "Contracts as Reference Points," forthcoming in the *Quarterly Journal of Economics*.

Hermalin, B. (2002) "Adverse Selection, Short-Term Contracting, and the Underprovision of On-the-Job Training," *Contributions to Economic Analysis & Policy*, 1(1), Article 5. http://www.bepress.com/bejeap/contributions/vol1/iss1/art5.

Hirshleifer, J. (1971) "The Private and Social Value of Information and the Reward to Inventive Activity," *American Economic Review*, 61: 561–574.

Joskow, P. (1987) "Contract Duration and Relationship Specific Investments: The Case of Coal," *American Economic Review*, 77: 168–185.

Kahneman, D., and A. Tversky (1973) "Availability: A Heuristic for Judging Frequency and Probability," *Cognitive Psychology*, 5: 207–232.

Klein, B. (2002) "The Role of Incomplete Contracts in Self-Enforcng Relationships," in E. Brousseau and J.M. Glachant, eds., *The Economics of Contracts*, Cambridge University Press, pp. 549–71.

Levin, J., and S. Tadelis (2006) "Contracting for Government Services: Theory and Evidence from U.S. Cities," mimeo.

Macaulay, S. (1963) "Non Contractual Relations in Business," *American Sociological Review*, 28: 55–70.

Martimort, D., and S. Piccolo (2007) "The Strategic Value of Incomplete Contracts for Competing Hierarchies," mimeo.

Maskin, E., and J. Moore (1999) "Implementation and Renegotiation," *Review of Economic Studies*, 66(1): 39–56.

Maskin, E., and J. Tirole (1999a) "Two Remarks on Property Rights," *Review of Economic Studies*, 66(1): 139–150.

———- (1999b) "Unforeseen Contingencies and Incomplete Contracts," *Review of Economic Studies*, 66(1): 83–114.

Nöldeke, G., and K. Schmidt (1995) "Option Contracts and Renegotiation: A Solution to the Hold Up Problem," *Rand Journal of Economics*, 26(2):163–179.

Novak, S., and S. Stern (2006) "How Does Outsourcing Affect Performance Dynamics? Evidence from the Automobile Industry," mimeo.

Rey, P. and B. Salanié (1990) "Long Term, Short Term and Renegotiation: On the Value of Commitment in Contracting," *Econometrica*, 58: 597–619.

———- (1996) "Long Term, Short Term, and Renegotiation: On the Value of Commitment with Asymmetric Information," *Econometrica*, 64(6): 1395–1414.

Segal, I. (1999) "Complexity and Renegotiation: A Foundation for Incomplete Contracts," *Review of Economic Studies*, 66(1): 57–82.

Segal, I., and M. Whinston (2002) "The Mirrlees Approach to Mechanism Design with Renegotiation: Theory and Application to Hold-Up and Risk Sharing," *Econometrica*, 70: 1–45.

Simon, H. (1957) "A Behavioral Model of Rational Choice," in *Models of Man*, New York: Wiley.

Spier, K. (1992) "Incomplete Contracts and Signaling," *Rand Journal of Economics*, 23: 432–443.

U.K. National Audit Office (2003) *Delivering Better Value For Money from the Private Finance Initiative*, June.

Välilä, T. (2005) "How Expensive are Cost Savings? On the Economics of Public-Private Partnerships," in *Innovative Financing of Infrastructure – The Role of Public-Private Partnerships*, *European Investment Bank Papers*, vol. 10(1): 95–119.

Williamson O. (1975) *Markets and Hierarchies: Analysis of Antitrust Implications*. New York: Free Press.

———- (1985) *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. New York: Free Press.