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Reputation and the Dynamics of Contractual Incompleteness.

Claudine Desrieux and Jean Beuve

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Reputation and the Dynamics of Contractual Incompleteness

Jean Beuve*
Claudine Desrieux†

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Abstract

This article examines why in some cases parties are willing to sign agreements that are left intentionally incomplete with regard to future contingencies, and why they prefer to choose more complete agreements in some other situations. More complete contracts allow avoiding ex-post renegotiations and the risk of hold-up, but also mean that parties have to expend more costs in ex-ante design. Another solution to avoid ex-post hold-up is to rely on relational contracting: one of the partner promises to renew the contract if the other does not holdup in case of renegotiations. This allows to save on the ex-ante costs, and by implication, to leave the contract incomplete, but the respect of the informal agreement is more uncertain. We build a model to show how parties to a contract choose between these two solutions to avoid hold-up, and how the degree of contractual (in)completeness evolves over time. *Keywords: Contractual Incompleteness, Reputation, Relational Contracts. JEL Codes: D23, L14, L22*

*IAE Sorbonne Business School, University of Paris I
†ERMES et Laboratoire d'Economie du Droit, University of Paris II

1 Introduction

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2 Introduction

Observed contracts are rarely complete in the Arrow Debreu sense. Parties intentionally sign incomplete agreements, mainly because writing complete formal agreements is costly, especially when a transaction is complex and many unforeseen events may arise. Then, there is a trade-off between these costs and the gains to avoid contractual incompleteness and potential *ex post* opportunism (Crocker and Reynolds [1993], Battigalli and Maggi [2008]). In this paper, we would like to investigate what happens to this trade-off when parties trade repeatedly (with an infinite horizon): Does repeated contracting diminish the fears of hold up in renegotiations, making a less complete (and a less costly) agreement more attractive? How does the impact of past interactions determine the willingness to draft complete agreements?

Empirical studies provide ambiguous answers. In the offshore drilling industry, Corts and Singh [2004] find that oil and gas companies are less likely to write complete agreements as the frequency of their interaction with a driller increases. Gulati [1995] studies the governance structures in interfirm alliances and finds that repeated alliances between partners are less likely than other alliances to be organized using formal equity-based contracts. Close interactions between firms over prolonged periods leads to increased trust making details equity-based contracts unnecessary. More recently, Kalnins and Mayer [2004] show that repeated contracting at a U.S. information technology services firm leads on average to less use of fixed price contracts (that are rather considered as *complete* agreements), although the effects of repeated contracting varies across client firms and sometimes leads to more use of fixed-price contracts. However, focusing on the Air Force engine procurement contracts, Crocker and Reynolds [1993] report that contracts become more and more complete over time.

These various empirical results seem to suggest that the degree of contractual incompleteness evolves over time when two partners trade repeatedly, but there is no general rule, as parties may turn to more complete or incomplete agreements.

We propose here to explain the evolution of contractual (in)completeness with a model showing that this evolution depends on the ability to sustain relational contracts in a dynamic setting. Relational contracts are informal commitments governing non-contractible actions and sustained by the value of future transactions (Bull [1987]; Baker et al. [2002]). When the discounted payoff

stream from commitment to this informal agreement is higher than the discounted payoff stream from deviation, a relational contract is sustainable and allows to avoid *ex post* opportunism. Our model shows that in this situation, there is no need to make formal contracts as complete as possible, so that investment in contractual completeness should be lower. However, such a strategy implies to know whether a relational contract can be sustained or not, *i.e.* whether the parties pay enough attention to the future of their relationship to be able to commit on informal agreements. The rate at which the parties discount the future payoffs indicates how they value future business: the higher this discount rate, the more they value future business, and then, the more able they are to sustain relational contracts.
In this paper, we explore two scenarii: *(i) symmetric information:* the parties know whether a relational contract is sustainable or not because the information about their discount rates is symmetric, *(ii) asymmetric information:* the parties do not know whether a relational contract can be sustained, because the value of the discount rate is private information.

Our results show that when the information is symmetric, the parties may save on the *ex ante* costs to write a complete contract. On the other hand, when the information about the sustainability of a relational contract is asymmetric, we show that this information can be acquired over time by observing the behavior of the co-contractor. The revelation of information determines the amount of *ex ante* costs spent to make a contract as complete as possible.

To address these issues, we propose to study a buyer/seller relationship in a dynamic framework. The buyer asks the seller to perform a task, and the seller executes the contract according to the buyer's specification. However, the contractual design may reveal to be inappropriate during its execution, and some additional costs are required to perform the tasks. This leads to the renegotiation of the contract, because of its incompleteness, and the seller may hold up the buyer during this renegotiation.
Before signing the initial contract, the buyer may exert some effort (cost) to find out what could go wrong and how to draft the contract accordingly. The more cost are spent *ex ante*, the more complete the contractual design is. This reduces the probability that the contract reveals to be incomplete *ex post*, and then the probability to be held up. The buyer can do this because a contingency is foreseeable (perhaps at a prohibitively high cost), but not necessarily foreseen. It is more likely to be foreseen if some *ex ante* efforts are made to learn about future states of the world. In our model, the buyer decides the level of *ex ante* contracting costs in completeness (at the first stage of each period) and the renewal (or not) of the contract (at the last stage of each period). As for the seller, he decides to hold up or not in case of renegotiation due to contractual incompleteness. The result shows that the level of *ex ante* contracting costs to complete the formal contract depends on the ability of the seller to sustain a relational contract.

Our paper can be related to the literature on contractual incompleteness.[1] Many papers take contractual incompleteness for granted and assume contractual incompleteness for exogenous reasons: bounded rationality (Williamson [1975, 1985]) or because the cost to make everything verifiable is too high (Hart [1995]). Some other papers try to explain endogenous contractual incompleteness. Parties voluntarily sign incomplete contracts by assessing the cost to write complete agreements and the benefits to avoid *ex post* opportunism. Shavell [1984] shows that when the *ex ante* cost of negotiating breach terms is greater than the benefit, parties prefer to leave the contract incomplete and delegate the damage decision to the court. Anderlini and

[1] For a more general description of the literature on incomplete contracts, see Kornhauser and MacLeod [2010].

Felli [1994] provide a theory of contract incompleteness based upon the computational cost of describing an event. Related to this work, Battigalli and Maggi [2002] discuss how contract complexity affect the choice of contract terms - whether they are rigid or flexible.

More recently, some contributions have tried to account for contractual incompleteness by formalizing bounded rationality. For instance, in Tirole [2009], parties have to spend *ex ante* costs to learn about future contingencies.[2] The theoretical framework of our paper is inspired by Tirole [2009]: contractual incompleteness is determined by the amount of resources ("transaction costs" in Tirole's paper) that are expended *ex ante* to identify the appropriate contractual design.[3] We derive the same proposition about the over-investment in contractual completeness under a static framework. However, the main concern of Tirole [2009] is to determine the factors (*ex ante* competition, *ex post* bargaining power, contract length) that drive equilibrium transaction costs. He suggests that relational contracting could also be one of these factors (Tirole [2009], p.283) but does not provide the dynamic model that allows to explore such a causality. To our knowledge, our model is the first contribution showing that contractual incompleteness is determined by the sustainability of relational contracts. Only Bernheim and Whinston [1998] have explored the links between incomplete contracts and relational contracts. They regard contractual incompleteness as a cause and not a consequence of relational contracts, since punishment strategies allowing a relational contract to be sustainable can be more easily elaborated when contracts are incomplete. Our contribution is to formally show the reverse causality: incomplete contracts are not a cause but a consequence of relational contracts.

Last, our paper is also related to the literature on relational contracting. This literature investigates the emergence of informal contracting when formal contracting may yield to suboptimal outcomes (Macaulay [1963]; Bull [1987]; Baker et al. [1994, 2002, 2008]). These papers focus on the consequences of the concern for reputation, while some other papers deal with how reputation builds over time (Watson [1999, 2002]; Halac [2011b]). The evolution of agency relationship is also under study in Halac [2011a]: this paper analyzes optimal relational contracts when the value of the outside option of the parties is their private information, which means that the value of the relationship between contracting parties is not commonly known. Information is revealed over time through default of the parties. In our paper, we inspire from this revelation mechanism, by showing how the decision to renege or not allows to learn about the private information of the co-contractor. This determines the level of costs spent to complete the contract at the subsequent periods.

The rest of the paper is organized as follows. Section 2 describes our theoretical framework. In section 3, we describe the result under a static framework. Section 4 describes the dynamic game. In section 5, we show how relational contracting leads to contractual incompleteness in a dynamic framework under symmetric information. Section 6 explores the case for asymmetric information. Section 7 concludes.

[2] Another contribution dealing with bounded rationality and contractual incompleteness is Bolton and Faure-Grimaud [2010]. The authors propose a model of equilibrium contracting between two agents who face time costs of deliberating current and future transactions. They show that equilibrium contracts may be incomplete and assign control rights: they may leave some enforceable future transactions unspecified and instead specify which agent has the right to decide these transactions.

[3] In other words, contractual incompleteness is measured by the probability that the design specified in the contract needs to be altered *ex post*.

3 The theoretical framework

3.1 Agents and contractual design

We consider an infinite repeated bilateral contractual relationship between a buyer (B, whom we refer as "he") and a seller (S, whom we refer as "she"). The buyer wishes a project or a service, and asks the seller to perform the work according to his specifications, *i.e.* according to the contractual design. The value of the project is K^+ for the buyer and the seller executes the contract at cost c.[4] The contract is a cost-plus contract[5], so that the seller is paid a price $P = c + F$ where F (> 0) is the additional compensation beyond the reimbursement of the cost. As in Bajari and Tadelis [2001], we focus here on problems of *ex post* adaptations in a context where the level of contractual incompleteness is endogenously determined. More precisely, we consider that both parties share uncertainty about contingencies that may arise once the contract is signed and the production begins.[6] Then, during the execution of the contract, some adaptations may be needed to reach K^+ because the contractual design proved to be inappropriate. In this situation, the contract is said to be incomplete because some actions to reach K^+ were not foreseen *ex ante*. The parties have then to renegotiate the contract.

3.2 Contingencies

Before proposing the contract, B may perform some costly non-observable efforts to learn about future contingencies, which allows him to propose a more or less appropriate contractual design. As in Tirole [2009], these additional costly efforts incurred before the signature of the contract allow the buyer to determine *ex ante* what may go wrong *ex post* and to draft the contract accordingly. Then, those costs determine the level of (in)completeness.

We denote $k(\in [0;1[)$ the intensity of the effort made by the buyer (at each period) to learn about future contingencies.[7] The higher the intensity of the effort, the more complete the proposed contract will be.[8] Then, by investing $k \in [0;1[$:

- **With probability** $\rho(k)$, the proposed design (called design A) is the appropriate design. Then, the contract is considered as "complete", because everything happens as foreseen *ex ante*. The contract delivers utility K^+ for B and costs the seller c to produce $(K^+ > c > 0)$. As a consequence, the utility of the buyer is $V = K^+ - P$, and that of the seller is $U = P - c = F$. Hence, the total surplus is $K^+ - c$.
- But, **with probability** $1 - \rho(k)$, the design is inappropriate and only delivers K^-, with $K^- = K^+ - \Delta$ where $\Delta > 0$. In this case, we consider the contract as incomplete because unforeseen contingencies prevent from reaching K^+, and parties need to renegotiate their

[4] Both K^+ and c are common knowledge.

[5] The contract could as well be a fixed price contract, allowing the seller to make a profit. We focus on cost-plus contract so that the level of the mark-up is more explicit.

[6] The seller has no private information about the occurrence of unforeseen contingencies that could arise. See Bajari and Tadelis [2001] to justify this concern for *ex post* adaptation in public procurement. An illustration of such *ex post* adaptation can also be found in MacLeod and Chakravarty [2009] about the construction of the Getty museum in Los Angeles.

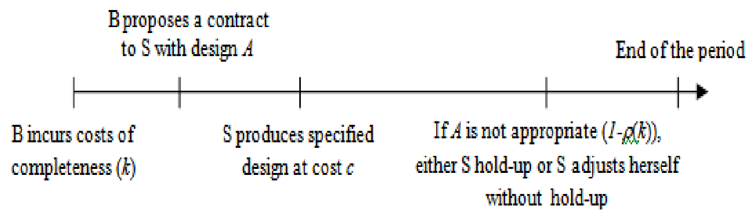
[7] Since only the buyer may suffer from hold-up in our setting, he is the only party to invest to make the contract more complete.

[8] We speak interchangeably of k as an effort or an investment in contractual completeness.

agreement. Indeed, some other, initially unknown, design A' delivers utility K^+ to B. Converting A into A' implies contract's modifications, that cost "a" to B. We assume that these costs are distributed over $[\underline{a}, \overline{a}]$ with $(0 < \underline{a} < \overline{a} < \Delta)$ according to a probability density function $z(a)$, and the average value of a is denoted $\tilde{a}$. The buyer knows this distribution.[9] Then, net gains from renegotiations are $\Delta - a$.[10] Moreover, the seller can decide to hold-up the buyer during the renegotiation process, *i.e.* she grabs a part h of the net gains of renegotiation. We assume that the seller has an *ex post* bargaining power $\sigma \in [0, 1]$, so that $h = \sigma(\Delta - a)$. As a consequence, the level of hold-up is distributed over $[\underline{h}, \overline{h}]$ (with $0 < \underline{h} < \overline{h} \leq (\Delta - \underline{a})$) according to the same probability distribution as a.

The function $\rho(k)$ is smooth, increasing, concave, and defined on $[0, 1[$ so that $\rho(0) = 0$, $\rho'(0) = 0$, $\rho'(k) > 0$, $\rho''(k) < 0$, $\lim_{k \to 1} \rho(k) = 1$.

Figure 1: Timing of the game for one contractual period



3.3 First-Best level of investments in contractual completeness

Let us determine here the optimal level of investments in contractual completeness k^* that maximizes the total surplus.

$$k^* \quad = \quad \arg\max_k [\rho(k)(K^+ - c) + (1 - \rho(k))(K^+ - c - \tilde{a}) - k] \Leftrightarrow \rho'(k^*) = \frac{1}{\tilde{a}} \qquad (1)$$

The optimal investment is that $\tilde{a}\rho'(k^*) = 1$: the marginal benefit of the investment equals its marginal expected cost.

4 The static game

Let us first suppose that B and S meet only once. Using backward induction, we can easily see that whenever *ex post* adaptations are needed, S decides to hold-up B. Then, the expected payoff of B is $E(V^{NE}) = K^+ - P - (1 - \rho(k))(\tilde{a} + \tilde{h}) - k$.[11]

$$k^{NE} \quad = \quad \arg\max_k [E(V^{NE})] \Leftrightarrow \rho'(k^{NE}) = \frac{1}{\tilde{a} + \tilde{h}} \qquad (2)$$

[9] We can assume that the seller also knows this distribution, even if it has no consequence, since she does not bear the cost of these costs of *ex post* adaptation.

[10] We assume that trade is efficient, i.e. $\forall k, a; K^+ - c - (1 - \rho(k))a > 0$.

[11] The superscript "NE" stands for "Nash Equilibrium".

By comparing the first-order conditions (1) and (2), and because of the concavity of the function $\rho(.)$, $\rho'(k^{NE}) < \rho'(k^*) \Rightarrow k^{NE} > k^*$: B over-invests in contractual completeness compared to the optimal level of investment.

Proposition 1. *Under a static game, the contract signed between a buyer and a seller is too complete compared to the socially efficient level of completeness.*

5 The repeated game

When the agents are in a long term relationship and care about reputation, some positive consequences on their behavior can be expected. For instance, Baker et al. [2002, 2008] show that some incentives to invest can be generated by concern for future relationships, and Bull [1987] and Klein [1988] suggest that reputation effects can limit hold-up problems. In our model, we show how future business may also prevent over-investments in contractual completeness, when it is possible, *i.e.* when relational contracts avoiding the hold-up problems can be implemented (subsection 4.2).

Relational contracts are informal commitments between the parties, and are sustained by the value of future relationships. They are sustainable (*i.e.* self-enforced) when the parties prefer to respect their informal agreements rather than renege and end the relationship.

To determine whether such relational contracts can be implemented, we first determine the participation and self-enforcement constraints of the buyer (subsection 4.3) and then those of the seller (subsection 4.4).

5.1 The dynamic environment

We now consider that the buyer and the seller trade repeatedly. The parties have different discount rates, $\delta_B \in (0,1)$ for the buyer, and $\delta_S \in (0,1)$ for the seller. These discount rates remain the same for all periods.

At each end of a period, the buyer can decide to renew the seller or not. We assume that there is no outside option for the seller if the relationship ends, while the buyer can pursuit the game with another seller but returns to the Nash Equilibrium level of investment in contractual completeness k^{NE}.

$\forall t \in \mathbb{N}^*$, we denote $k_t \in [0;1[$ the intensity of the effort made by the buyer to learn about future contingencies in period t. Since the environment changes over the periods, this effort is specific to each period. Then, at each period t, the design is appropriate with probability $\rho(k_t)$, and inappropriate with probability $1-\rho(k_t)$.

To sum up, at each period of the game, the buyer has to decide the level of effort k_t, while the seller has decide not to hold-up or to hold-up in case of *ex post* adaptations, where $d_t = \{0;1\}$ denotes this decision. The per-period payoff of the buyer is $E(V_t) = K^+ - P - (1-\rho(k_t))(a_t + d_t h_t) - k_t$ and that of the seller is $E(U_t) = P - c + (1-\rho(k_t))(d_t h_t)$.

5.2 The relational contract

We assume that B can propose an informal agreement (*i.e.* a relational contract) to S and asks her not to hold-up in the case of unforeseen *ex post* adjustments. This allows him to save on effort k_t. If S cooperates, B promises to renew her with probability 1 at time t+1. Conversely, if S deviates, B threatens to choose another seller at the next period. If the relational contract is sustainable by both parties, then no hold-up occurs at equilibrium. The level of investment in contractual completeness becomes:

$$k^{RC} = \arg\max_k [E(V^{RC})] = \max_k [K^+ - P - (1-\rho(k))\tilde{a} - k] \Leftrightarrow \rho'(k^{RC}) = \frac{1}{\tilde{a}} \tag{3}$$

In other words, at equilibrium, the level of investment is optimal: $k^{RC} = k^*$. This is a stationary equilibrium: $\forall t \geq 1$, $k_t = k^{RC}$. The expected payoff of the seller is $E(U^{RC}) = P - c = F$ since the seller never holds up. Let us now see whether such a relational contract can be implemented.

5.3 The participation and self-enforcement constraints of the buyer

The buyer proposes a relational contract only if his expected payoff under relational contracting is higher than under Nash Equilibrium, *i.e.* if $E(V^{RC}) > E(V^{NE})$:

$$\Leftrightarrow K^+ - P - (1-\rho(k^{RC}))\tilde{a} - k^{RC} > K^+ - P - (1-\rho(k^{NE}))(\tilde{a}+\tilde{h}) - k^{NE}$$

$$\Leftrightarrow k^{NE} - k^{RC} + (1-\rho(k^{NE}))\tilde{h} > (\rho(k^{NE}) - \rho(k^{RC}))\tilde{a} \tag{PCB}$$

The left-hand side of (PCB) represents the gains of the buyer thanks to the relational contracts: he saves on investments in contractual completeness ($k^{NE} - k^{RC}$) and on potential hold-up ($(1-\rho(k^{NE}))\tilde{h}$). The right-hand side of this equation represents the higher cost of contractual modification the buyer is likely to support: because contracts are more incomplete, he will have to finance more frequently the adaptation cost “a". Whenever (PCB) holds, the buyer has better propose a relational contract to the seller than choose to over-invest in contractual completeness. Let us now pinpoint the self-enforcement constraint of the buyer (SEB), *i.e.* the conditions under which he respects his informal commitment. As it is traditional from the literature on relational contracting, we use here the trigger strategy. In case of deviation, the buyer does not renew S and invests the Nash equilibrium level of investment (with another seller) forever. Then, B respects his informal commitment if:

$$E(V^{RC}) + E(V^{RC})\frac{\delta_B}{1-\delta_B} \geq E(V^{RC}) + E(V^{NE})\frac{\delta_B}{1-\delta_B} \tag{SEB}$$

When (PCB) binds so that $E(V^{RC}) \geq E(V^{NE})$, then equation (SEB) holds: the buyer commits to his informal promise.

Lemma 1. *When the participation constraint of the buyer holds, a relational contract threatening not to renew the seller in case of hold-up is sustainable by the buyer and allows him to invest k^*, whatever his discount rate $\delta_B \in (0,1)$.*

5.4 The self-enforcement constraint of the seller

The self-enforcement constraint of the seller (SES) implies that her payoff stream is higher under cooperation than deviation (*i.e.* hold-up and no more trade):

$$E(U^{RC}) + \frac{\delta_S}{1-\delta_S} E(U^{RC}) > E(U^{RC}) + h \Leftrightarrow \frac{F\delta_S}{1-\delta_S} > h \Leftrightarrow \frac{h}{F+h} < \delta_S \tag{SES}$$

Her discount rate has to be high enough for the relational contract to be sustainable.

Definition 1. We define $\overline{\delta} = \frac{\overline{h}}{F+\overline{h}}$ as the discount rate above which the relational contract is sustainable for the seller even for the highest value of hold-up ($\overline{h}$) and $\underline{\delta} = \frac{\underline{h}}{F+\underline{h}}$ as the discount rate below which the relational contract is never sustainable, *i.e.* deviation is more profitable even for $\underline{h}$.

Following definition 1 and (SES), we can distinguish three seller types:

- H when $\delta_S > \overline{\delta}$
- L when $\delta_S < \underline{\delta}$
- M when $\delta_S \in [\underline{\delta}, \overline{\delta}]$

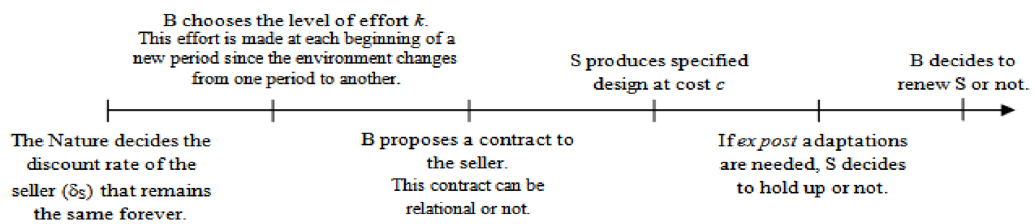
Lemma 2.

- *The type H seller never deviates since her self-enforcement constraint (SES) always holds. The relational contract is sustainable.*
- *The type L seller always deviates, since deviation is preferable for her even when the smallest amount of hold-up occurs. The (SES) never holds, so that no relational contract can be sustained.*
- *There is a level of hold-up $h_d^M \in [\underline{h}, \overline{h}]$ above which the type M seller prefers to deviate. Following definition 1 and (SES), we can define $h_d^M = \frac{\delta_S^M}{1-\delta_S^M} F$. The (SES) only holds on $[\underline{h}; h_d^M]$, which implies that the relational contract can be sustained only for low amounts of hold-up.*

5.5 Timing of the game

Under repeated game, the timing is as follows:

Figure 2: Timing of one period in the repeated game



6 Repeated Games under symmetric information

In this section, we consider that the information about the discount rates of the parties (δ_S and δ_B) is symmetric. We determine how relational contracting may explain the investment in contractual completeness made by the buyer at the beginning of each period. In subsection 5.1., we show that the optimal level of investment in contractual completeness can be reached when the seller is of type H, but that this level of investment is still k^{NE} with type L sellers. In subsection 5.2, we detail how a second-best relational contract can be implemented with some type M sellers, so that the buyer still over-invests in contractual completeness, but less than with type L sellers.

6.1 Contractual completeness and the sustainability of relational contracts

From lemma (1) and lemma (2):

- With a type H seller, the relational contract is self-enforced for both the buyer and the seller. The investment in contractual completeness is optimal since $k^{RC} = k^*$.
- With a type L seller, the (SES) never binds. No relational contract can be implemented, and the buyer has to invest k^{NE} if he trades with this seller.
- If the seller is of type M, the self-enforcement constraint only binds up to a value $h_d^M \in [\underline{h}, \overline{h}]$. As a consequence, the relational contract is not sustainable for all the values of h, *i.e.* for all value of a.

Since the relational contract does not allow to prevent the type M seller's opportunism for all the value of a, the optimal level of investment in contractual incompleteness cannot be reached. However, under some conditions, the buyer may propose a "second-best relational contract" to the type M seller that allows him to save on the investment in contractual completeness (compared to the Nash equilibrium level), even if he still over-invests. Let us detail below such a second-best relational contract.

6.2 The second-best relational contract

A type M seller holds up whenever $h \geq h_d^M$. Since $h = \sigma(\Delta - a)$, we denote a^M the level of the modification cost a corresponding to h_d^M, so that $a^M = \Delta - \frac{h_d^M}{\sigma}$. Then, whenever $a \in [\underline{a}, a^M]$, the relational contract is no longer sustainable for the type M seller. However, the buyer may still ask the seller not to hold-up and promises him to get an extra bonus when $a \in [\underline{a}, a^M]$ if no hold-up occurs. This bonus is an *ex ante* predetermined payment that depends on the level of a in case of inappropriate contractual design.[12] We denote $b(a) \geq 0$ this bonus. Under such a

[12] Recall that a is observable by both parties, even if it is non-contractible.

second-best relational contract, the payoffs of the buyer and the type M seller are respectively:

$$E(V^{SRC}) = K^+ - P - (1-\rho(k^{SRC}))(\tilde{a} + [\int_{\underline{a}}^{a^M} b(a)z(a)da]) - k^{SRC}$$

$$E(U^{SRC}) = P + (1-\rho(k^{SRC}))[\int_{\underline{a}}^{a^M} b(a)z(a)da]$$

Where k^{SRC} denotes the level of investment in contractual completeness when the second-best relational contract holds.

6.2.1 The level of investment under the second-best relational contract

Under a second-best relational contract, the payoff of the buyer when he trades with a type M seller is:

$$E(V^{SRC}) = K^+ - P - (1-\rho(k))[\tilde{a} + (\int_{\underline{a}}^{a^M} b(a)z(a)da)] - k$$

Then, the buyer invests k^{SRC} in contractual completeness such that:

$$\begin{aligned} k^{SRC} &= \arg\max_k [E(V^{SRC})] = \max_k K^+ - P - (1-\rho(k))[\tilde{a} + (\int_{\underline{a}}^{a^M} b(a)z(a)da)] - k \\ \Leftrightarrow k^{SRC} & \quad \text{such that } \rho'(k^{SRC}) = \frac{1}{\tilde{a} + (\int_{\underline{a}}^{a^M} b(a)z(a)da)} \end{aligned}$$

If the second-best relational contract is sustainable, the payoff of the seller is $E(U^{RC}) = P - c + (1-\rho(k^{SRC}))(\int_{\underline{a}}^{a^M} b(a)z(a)da)$. By comparing with (1) and (2), we obtain $k^{RC} = k^* \leq k^{SRC} \leq k^{NE}$.

6.2.2 The sustainability conditions

The participation constraint of the buyer: For the buyer to propose a second-best relational contract, his payoff has to be higher under this informal agreement than under Nash equilibrium. His participation constraint (PCB2) is:

$$E(V^{SRC}) \geq E(V^{NE}) \Rightarrow E(V^{SRC}) - E(V^{NE}) \geq 0 \tag{PCB2}$$

The self-enforcement constraint of the buyer: The buyer commits to this second-best relational contract when he has better give the bonus b(a) (when $a \in [\underline{a}, a^M]$) than renege and then invests k^{NE} in the following periods. Then, his self-enforcement constraint (SEB2) is $\forall a \in [\underline{a}; a^M]$:

$$K^+ - P - a - b(a) + \frac{\delta_B}{1-\delta_B}E(V^{SRC}) \geq K^+ - P - a + \frac{\delta_B}{1-\delta_B}E(V^{NE})$$

$$\Leftrightarrow (E(V^{SRC}) - E(V^{NE}))\frac{\delta_B}{1-\delta_B} \geq b(a) \tag{SEB2}$$

Let us note that whenever (SEB2) holds, the participation constraint of the buyer (PCB2) binds since:

$$\begin{aligned} \text{(SEB2)} &\Rightarrow E(V^{SRC}) - E(V^{NE}) \geq b(a)\frac{1-\delta_B}{\delta_B} \\ &\Rightarrow E(V^{SRC}) - E(V^{NE}) \geq 0 \Leftrightarrow \text{(PCB2)} \end{aligned}$$

To sum up, the buyer can propose a second-best relational contract to a type M seller. This informal agreement foresees to give an extra bonus $b(a)$ when $a \in [\underline{a}, a^M]$ if the seller does not hold up. The buyer proposes and commits to this informal agreement if the bonus $b(a)$ never exceeds $b^{max} = (E(V^{SRC}) - E(V^{NE}))\frac{\delta_B}{1-\delta_B}$.

The highest bonus he has to give occurs when $a = \underline{a}$, since it implies $h = \bar{h}$.[13]. In other words, a second best relational contract is sustainable for the buyer if $b(\underline{a}) \leq (E(V^{SRC}) - E(V^{NE}))\frac{\delta_B}{1-\delta_B}$.

The self-enforcement constraint of the type M seller (SES2): $\forall a \in [\underline{a}; a^M]$,

$$\begin{aligned} & P - c + b(a) + E(U^{SRC})\frac{\delta_S}{1-\delta_S} \geq P - c + h \\ \Leftrightarrow\ & P - c + b(a) + E(U^{SRC})\frac{\delta_S}{1-\delta_S} \geq P - c + \sigma(\Delta - a) \\ \Leftrightarrow\ & b(a) \geq \sigma(\Delta - a) - E(U^{SRC})\frac{\delta_S}{1-\delta_S} \end{aligned} \tag{SES2}$$

A type-M seller committs to the second-best relational contract if he gets a minimal extra bonus $b(a) = \sigma(\Delta - a) - E(U^{SRC})\frac{\delta_S}{1-\delta_S}$ whenever $a \in [\underline{a}; a^M]$. To sum up, a second-best relational contract that foresees to give to the seller an extra bonus $b(a)$[14] whenever $a \in [\underline{a}, a^M]$ can be sustained between a buyer and a type M seller if:

$$\begin{aligned} b(a) &= \sigma(\Delta - a) - E(U^{SRC})\frac{\delta_B}{1-\delta_B} \\ s.t.\ \ b(\underline{a}) &\leq b^{max} = (E(V^{SRC}) - E(V^{NE}))\frac{\delta_B}{1-\delta_B} \end{aligned}$$

Proposition 2.

- *With a type H seller, the buyer's investment in contractual completeness is at the optimal level k^* since a relational contract threatening not to renew the seller in case of hold-up is sustainable by both parties.*
- *With a type L seller, no relational contract is sustainable and the buyer still over-invests in contractual completeness (k^{NE}) if he trades with the seller.*
- *Under some conditions, a second-best relational contract can be implemented between the buyer and a type M seller. It allows the buyer to invest k^{SRC} so that $k^* < k^{SRC} \leq k^{NE}$.*

7 Repeated games under asymmetric Information

In this section, we consider that only the sellers know their discount rates (δ_S) so that the information is asymmetric. For simplicity and to focus on only one particular information asymmetry, we assume that δ_B is known by all the agents. We detail in this section the information structure of the parties (subsection 6.1), the equilibrium concept we use (subsection 6.2), and why there is no separating equilibrium through the choice of contracts (subsection 6.3.). Last, we show how the separation of types may occur over time through the observation of the behavior of the seller (subsection 6.4.).

[13] Recall that $\forall a,\ h = \sigma(\Delta - a)$

[14] This bonus can be rewritten as $b(a) + \frac{\delta_S}{1-\delta_S}(\int_{\underline{a}}^{a^M} b(a)z(a)da) = \sigma(\Delta - a) - \frac{\delta_S}{1-\delta_S}(P - c)$.

7.1 The information structure

7.1.1 Basic assumptions

Let us now assume that the buyer does not know δ_S. However, to simplify our analysis, we do no longer consider continuous types of sellers. Then, the buyer does not know the seller's type but he knows that there are three possible discount rates for the seller: $\{\delta_H; \delta_M; \delta_L\}$.

- δ_H is such that $\delta_H \geq \bar{\delta}$: if the seller has a discount rate of δ_H, she represents a type H seller, with whom a relational contract allowing to reach the optimal level of investment in contractual completeness is sustainable.
- δ_L is such that $\delta_L \leq \underline{\delta}$: if the seller has a discount rate of δ_L, she represents a type L seller, with whom any relational contract is sustainable and the buyer has to over-invest in contractual completeness (k^{NE}).
- δ_M is such that $\delta_M \in [\underline{\delta}, \bar{\delta}]$: if the seller has a discount rate of δ_M, she represents a type M seller. This type M seller deviates from $h_m \in [\underline{h}, \bar{h}]$. To simplify our analysis, we assume that a second-best relational contract (as described above) can be implemented with this type M seller: the participation and self-enforcement constraints of this type M seller and the buyer are fulfilled.

The buyer also knows the probability density function z. At each period t, the buyer also gets some information from the past plays, and more specifically he knows : (i) his own past investment in contractual completeness, (ii) whether *ex post* adaptations occurred, (iii) the decisions of the seller to hold-up or not. Only the investments in contractual completeness is private information of the buyer. In other words, the set of histories of the buyer (g_t^B) and of the seller (g_t^S) are defined as follows:

- $g_t^B = \{k_0, h_0, d_0, ..., k_{t-1}, h_{t-1}, d_{t-1}\}$
- $g_t^S = \{h_0, d_0, ..., h_{t-1}, d_{t-1}, h_t\}$

7.1.2 Beliefs

At the beginning of each period t, the buyer assigns the following probabilities:

- $\alpha_t \in (0, 1)$ is the probability that the discount rate of the seller is δ_H.
- $m_t \in (0, 1)$ is the probability that her discount rate is δ_M.
- $\ell_t \in (0, 1)$ is the probability that her discount rate is δ_L.

As a consequence, at each period t, $\alpha_t + \ell_t + m_t = 1$.

7.1.3 Revisions of beliefs

At the end of each period t, the buyer observes whether *ex post* adaptations were needed and he observes d_t, *i.e.* whether the seller held up or not. We denote $r_t^\theta(g_t^S, h_t)$ the probability that the seller with the discount rate δ_θ does not hold up at period t, given the amount of potential hold-up h_t and given the history of play g_t^S. From the previous definitions, $r_t^H = 1$ and $r_t^L = 0$ but $r_t^M \in \{0, 1\}$. More precisely, $r_t^M = 0$ when $h \geq h_m$ and $r_t^M = 1$ when $h < h_m$. At the end of each period t, the buyer can revise his beliefs using the Bayes'rule:

- $\alpha_{t+1} = \mu(\alpha_t/d_t) = \frac{\alpha_t}{\alpha_t + (m_t) r_t^M (g_t, h_t)}$. More precisely:
  - If $h \geq h_m$, this implies that $r_t^M = 0$ and $\alpha_{t+1} = 1$.
    This means that if the seller does not hold up for high values ($h > h_m$), the buyer realizes that the seller is of type H since type L and type M sellers would have held up in these conditions (as shown in lemma 2).
  - If $h < h_m$, then $r_t^M = 1$ and $\alpha_{t+1} = \frac{\alpha_t}{\alpha_t + m_t}$. The buyer has observed no hold-up so that the seller is not a type L seller. However, since both type M and type H sellers do not hold up when $h < h_m$, the buyer cannot distinguish between these two types.
- $\ell_{t+1} = \mu(l_t/d_t) = \frac{\ell_t}{\ell_t + m_t(1 - r_t^M(g_t, h_t))}$
  en, $\ell_{t+1} = 1$ if $h < h_m$ because $r_t^M = 1$.
  - If $h < h_m$, this implies that $r_t^M = 1$ and $\ell_{t+1} = 1$.
    This means that if the seller holds up for low values ($h < h_m$), the buyer realizes that the seller is of type L since type H and type M sellers would not have held up in these conditions (as shown in lemma 2).
  - If $h > h_m$, then $r_t^M = 0$ and $\ell_{t+1} = \frac{\ell_t}{\ell_t + m_t}$. The buyer has observed hold-up so that the seller is not a type H seller. However, since both type M and type L sellers hold up when $h > h_m$, the buyer cannot distinguish between these two types.
- $m_{t+1} = 1 - \ell_{t+1} - \alpha_{t+1}$

Moreover, we assume that:

- If $\alpha_t = 0$ or $\alpha_t = 1$ at period t, it remains the same for all subsequent histories.
- If $\ell_t = 0$ or $l_t = 1$ at period t, it remains the same for all subsequent histories.
- If $m_t = 0$ or $m_t = 1$ at period t, it remains the same for all subsequent histories.

Under asymmetric information, in period t, the payoff of the buyer is denoted $V(\alpha_t, m_t, \ell_t, k_t)$ since his payoff will depend on his investment in contractual completeness k_t, and his beliefs about the seller's type (inducing the realization of hold-up or not).

7.2 Strategies and Equilibrium concept

The solution concept used in this paper is perfect Bayesian equilibrium in pure strategies, and we focus on Pareto-efficient equilibria. A strategy for the buyer is defined as the choice of effort level $k \in (0,1)$ at date t given history g_t^B, so that $s_{B,t} = (g_t^B, k)$. A pure public strategy for the seller of type θ is $s_{S,t}^\theta = (r_t^\theta(g_t^S, h_t))$, where $r_t^\theta(g_t^S, h_t)$ is the probability that the seller of type θ decides not to hold up at date t, given history g_t^S (and then including the observed amount of potential hold-up h_t).

As a consequence, in this paper, a PBE is triple (s_B, s_S, μ) such that:

1. s_B and s_S^θ are mutual best responses for all t and sets of histories g_t^B, and g_t^S.
2. $\alpha_{t+1} = \mu(\alpha_t/d_t) = \frac{\alpha_t r_t^H(g_t^S,h_t)}{\alpha_t r_t^H(g_t^S,h_t)+(1-\alpha_t)r_t^M(g_t^S,h_t)} = \frac{\alpha_t}{\alpha_t+(1-\alpha_t)r_t^M(g_t^S,h_t)}$
3. $\ell_{t+1} = \mu(\alpha_t/d_t) = \frac{\ell_t}{\ell_t+(1-r_t^M(g_t^S,h_t))m_t}$

Let us first show that there is no separating equilibrium where the information about the seller's type is revealed through the contract that the seller accepts (subsection (7.3)). Since there is no means to determine the type of the seller before entering in the contractual relationship, we next show that the types can only be separated by observing reneging from the informal agreement (subsection (7.4)).

7.3 The absence of separating equilibrium through the choice of contract

In our dynamic setting, only contract-pooling equilibria exist in pure strategies. The buyer has no means to force the sellers to reveal truthfully their type by proposing different contracts.

Proposition 3. *Only contract-pooling equilibria exist in pure strategies when the seller's type is private information.*

Proof. If there were a separating equilibrium through the choice of the contract, the buyer would propose different contracts to the seller, and the chosen contract would be different according to the seller's type. If the equilibrium is pooling, the sellers always choose the same contract among the proposals, regardless of type. A separating equilibrium also implies that the payoff streams of each player are maximized subject to participation constraints (no losses for the players) and incentive constraints (each type of seller is not attracted to the contract of the other types of sellers). Let us consider three contracts: C_1 is designed for the type H seller, C_2 for the M type, and C_3 for the L type. For these contracts to be self-enforced by each type of seller, they are designed as follows:

- C_1: The buyer asks the seller not to hold up in case of unforeseen *ex post* adaptation. He informally promises the seller to renew her with probability one at the following period. There is no additional fee proposed to the seller in case of *ex post* adaptation.
- C_2: The buyer proposes the same agreement than in C_1 and also commits to give an additional bonus $b = b^M$ to the seller in case of *ex post* adaptation. The additional bonus b^M solves the self-enforcement constraint of the type M seller.
- C_3: The buyer does not propose any relational contract. There is no commitment on the seller's renewal, so that the contractual relationship is only defined on one period.

From proposition 2, each seller's type has enough incentives to respect its corresponding contract, and no hold up occurs at equilibrium for type M and type H sellers (and the relationship ends if a party reneges). If there were a separating equilibrium, then:

- By choosing C_1, the seller reveals to be of type H, and the buyer invests k^{RC}. The per-period payoffs of the seller and of the buyer are respectively $E(U^{RC})$ and $E(V^{RC})$.
  By denoting $\mathcal{U}_H^{C_1}$ the payoff stream of the type H seller under C_1, then $\mathcal{U}_H^{C_1} = E(U^{RC}) + \frac{\delta_H}{1-\delta_H}E(U^{RC})$.
- By choosing C_2, the seller reveals to be of type M. The buyer invests k^{SRC}, and the per-period payoffs become $E(U^{SRC})$ and $E(V^{SRC})$.
  By denoting $\mathcal{U}_M^{C_2}$ the payoff stream of the type M seller under C_2, then $\mathcal{U}_M^{C_2} = E(U^{SRC}) + \frac{\delta_M}{1-\delta_M}E(U^{SRC})$.
- By choosing C_3, the seller reveals to be of type L. The buyer invests k^{NE} and the seller gets $E(U^{NE})$, while the buyer's payoff is $E(V^{NE})$.
  The contractual relationship is only defined on one period, so that $\mathcal{U}_L^{C_3} = E(U^{NE})$.

A separating equilibrium exists if each type of seller picks the desired contract and has no incentives to masquerade as another type. The incentive compatibility constraints become:

$$\mathcal{U}_H^{C_1} > U_H^{C_2} \text{ and } \mathcal{U}_H^{C_1} > \mathcal{U}_H^{C_3} \tag{IC1}$$

$$\mathcal{U}_M^{C_2} > \mathcal{U}_M^{C_1} \text{ and } \mathcal{U}_M^{C_2} > \mathcal{U}_M^{C_3} \tag{IC2}$$

$$\mathcal{U}_L^{C_3} > \mathcal{U}_L^{C_1} \text{ and } \mathcal{U}_L^{C_3} > \mathcal{U}_L^{C_2} \tag{IC3}$$

(IC1) means that the type H seller has better choose C_1 than C_2 or C_3, (IC2) shows that the type M seller has better choose C_2 than any other contract, and (IC3) means that the type L prefers C_3 to C_1 and C_2. Let us now show that at least one of the incentive compatibility constraint does not hold. Assume that the type L seller deviates to C_1. Then, the buyer invests k^{RC} (believing that the seller is of type H), and the type L seller chooses to hold-up whenever *ex post* adaptations occur (as demonstrated in lemma 2). She obtains:

$$\mathcal{U}_L^{C_1} = P - c + (1-\rho(k^{RC}))\tilde{h} + \rho(k^{RC})\delta_L \mathcal{U}_L^{C_1}$$

$$\mathcal{U}_L^{C_1} = \frac{P - c + (1-\rho(k^{RC}))\tilde{h}}{1-\rho(k^{RC})\delta_L}$$

We can now prove that $\mathcal{U}_L^{C_1} > \mathcal{U}_L^{C_3}$, *i.e.* that the type L seller has better mispresent as a type H seller and chooses C_1 rather than C_3. Remember that $\mathcal{U}_L^{C_3}$ represents the payoff of the type L seller when he chooses C_3, and thus gets $E(U^{NE})$ since C_3 is only defined on one period ($\mathcal{U}_L^{C_3} = E(U^{NE}) = F + (1-\rho(k^{NE}))\tilde{h}$).
Since $k^{NE} > k^{RC}$,

$$F + (1-\rho(k^{NE}))\tilde{h} < F + (1-\rho(k^{RC}))\tilde{h}$$

Moreover, $\frac{1}{1-\rho(k^{RC})\delta_L} > 1$, which implies:

$$F + (1-\rho(k^{NE}))\tilde{h} < F + (1-\rho(k^{RC}))\tilde{h} < \frac{F + (1-\rho(k^{RC}))\tilde{h}}{1-\rho(k^{RC})\delta_L}$$

By transitivity,

$$
\begin{aligned}
&F + (1 - \rho(k^{NE}))\tilde{h} < \frac{F + (1 - \rho(k^{RC}))\tilde{h}}{1 - \rho(k^{RC})\delta_L} \\
&\Leftrightarrow \mathcal{U}_L^{C_1} < \mathcal{U}_L^{C_3}
\end{aligned}
$$

Since $\mathcal{U}_L^{C_1} < \mathcal{U}_L^{C_3}$, the type L seller gains from masquerading as a type H seller.
The intuition behind this result is that the choice of the C_1 contract by the seller leads to an investment k^{RC} from the seller, which is a low investment in contractual completeness. The occurrence of hold-up then becomes higher than under C_3, so that the type L seller has better choose C_1 and cheats in case of *ex post* adaptation.
In the same way, we can show that a type L seller is always better under C_2 than C_3 since the occurrence of hold-up is higher under C_2 than C_3 (because of the intermediate level in contractual completeness k^{SRC}). Since the type L seller is always better off by masquerading as a type H or a type M seller, (IC3) is always violated, and there is no separating equilibrium through the choice of the contract.

7.4 Revelation through reneging

Even if no separating equilibrium can be implemented at the first stage of the period, the buyer may acquire some information at the end of each period and full separation of types can occur over time. The buyer proposes the seller a relational contract, promising to renew her with probability one at period $t+1$ if the seller does not hold-up in case of *ex post* adaptation.
The seller will progressively reveal her type through her behavior, *i.e.* through her decision to cooperate or to renege from the relational contract: in case of *ex post* adaptations, a type L seller always reneges, a type M seller reneges from the amount h_m of hold-up, and a type H seller never reneges.
We first describe how the beliefs of the buyer evolve over time (subsection 6.4.1), and then how much he invests at each period t (subsection 6.4.2).

7.4.1 Evolution of the beliefs under asymmetric information

At any period t:

- **If no ex-post adaptation occurs**, the buyer cannot observe whether the seller reneges from her informal commitment or not. Then, he has no additional information about the seller's type. At the following period, he renews him and invests $k_{t+1} = k_t$.
- **If ex-post adaptations occurs**, the buyer can observe the behavior of the seller (*i.e.* whether she commits to her informal promise or not). As shown in subsection 6.1.3, the buyer can then revise his beliefs.
  - *If no hold up is observed* The seller is not a type L seller, but can be either a type M or H. By denoting h_t the potential hold up the seller could have made because of this *ex post* adaptation, the beliefs evolve as follows:

* If $h_t \geq h_m$, then the seller is of type H since he did not hold up for the large amounts of hold up. In other words, $\alpha_{t+1} = 1$ and the game goes back to symmetric information.
* If $h_t < h_m$, then the seller can be either a type M or a type H seller. The probabilities are revised as follows: $\ell_{t+1} = 0$; $\alpha_{t+1} = \frac{\alpha_t}{\alpha_t+(m_t)r^M(h_t)} = \frac{\alpha_t}{\alpha_t+m_t}$; and $m_{t+1} = 1 - \alpha_{t+1} = \frac{m_t}{\alpha_t+m_t}$.

– *If hold-up is observed*: The seller is either a type L or a type M, but cannot be a type H since hold up was observed. The beliefs of the buyer evolve as follows:

* If the potential hold up h_t was such that $h_t \geq h_m$, then $\ell_{t+1} = 1$ and the game turns to symmetric information.
* If $h_t < h_m$, then the seller is a type M or a type L and probabilities are revised as follows:
$\alpha_{t+1} = 0$; $\ell_{t+1} = \frac{\ell_t}{\ell_t+(1-r^M(h_t))m_t} = \frac{\ell_t}{\ell_t+m_t}$, and $m_{t+1} = 1 - \ell_{t+1} = \frac{m_t}{\ell_t+m_t}$.

However, for such a revelation of type to appear over time, the sellers have not to deviate from their types. In the appendix, we show that the incentives compatibility constraints hold (ensuring that there is no seller misrepresents as another type).

7.4.2 The investment in contractual completeness at each period t

At each period t, given his beliefs, the buyer maximizes his payoff stream that depends on his beliefs and his investment in contractual completeness.

$$k_t = \arg\max_{k_t}\{\mathcal{V}(\alpha_t, m_t, \ell_t, k_t)\}$$

$$= \arg\max_{k_t} \qquad \{V(\alpha_t, m_t, \ell_t, k_t)$$

$$+\delta_B[(\int_{h_m}^{\overline{h}} h \times z(h)dh)[\alpha_t \mathcal{V}(1,0,0,k^{RC}) + (m_t+\ell_t)(\mathcal{V}(0, m_{t+1}, \ell_{t+1}, k_{t+1}))]]$$

$$+\delta_B[(\int_{\underline{h}}^{h_m} h \times z(h)dh)[(\alpha_t+m_t)\mathcal{V}(\alpha_{t+1}, m_{t+1}, 0, k_{t+1}) + \ell_t \mathcal{V}(0,0,1,k^{NE})]]\}$$

subject to $\mathcal{V}(k_t) > \mathcal{V}^{NE}$ (since $\mathcal{V}^{NE}$ is the payoff stream of the buyer when he uses his outside option and always invests k^{NE}.) The first line of this maximization program represents the payoff of the buyer in period t, $V(\alpha_t, m_t, \ell_t, k_t)$, that depends on the investment k_t and the beliefs $(\alpha_t; m_t; \ell_t)$.[15] The second line represents the payoff stream of the buyer at the following period when high values of hold up ($h > h_m$) occur in period t. If no hold-up occurs (which means that the seller is of type H so that this situation occurs with a probability α_t), the buyer knows that the seller is of type H. The payoff stream becomes $\mathcal{V}(1,0,0,k^{RC})$ since $\alpha_{t+1} = 1$ and the buyer invests k^{RC} forever. However, if hold-up occurs, the buyer cannot distinguish between type M and type L seller, so that he revises his beliefs as described in subsection 6.4.1 and his payoff stream becomes $(\mathcal{V}(0, m_{t+1}, \ell_{t+1}, k_{t+1}))$.

[15] $V(\alpha_t, m_t, \ell_t, k_t) = K^+ - P - (1-\rho(k))(\tilde{a} + \ell_t \times \tilde{h} + m_t(\int_{h_m}^{\overline{h}} hz(h)dh))$

The third line describes the payoff stream of the buyer in period $(t+1)$ if low values of hold-up occurs in period t. If the buyer observes hold-up, he revises his beliefs so that $\ell_{t+1} = 1$ and he invests k^{NE} forever. If he does not observe hold-up, he cannot distinguish between type H and type M sellers, so that his payoff stream becomes $\mathcal{V}(\alpha_{t+1}, m_{t+1}, 0, k_{t+1})$.

Since under asymmetric information, the buyer has to take into account the potential hold up that occurs when the seller is of type L (with probability ℓ_t) or of type M (with probability $(\int_{h_m}^{\overline{h}} h \times z(h)dh) \times m_t$), then he invests more in contractual completeness than k^{RC}, i.e. the level of investment when he is certain that the seller is of type H and does not hold-up: $k_t \geq k^{RC}$. Moreover, the previous maximization program shows that whenever *ex post* adaptation occurs with $h > h_m$, and no hold-up is observed, then the buyer realizes that the seller is of type H, and invests k^{RC} afterwards. The level of investment then goes from k_t to k^{RC} which means that this level decreases as the buyer does not need to invest in contractual completeness any more to protect himself from hold-up. This describes the situation where contracts become more incomplete over time (as reported in the empirical studies of Corts and Singh [2004] and Kalnins and Mayer [2004]).
On the other hand, whenever hold-up occurs for low values of h (such that $h \leq h_m$), then the buyer understands that the seller is of type L and invests k^{NE} afterwards. The level of investment in contractual completeness increases from k_t to k^{NE} because the buyer is now certain that the seller always holds up in case of *ex post* adaptation. This describes the situation where contracts become more complete over time (as illustrated in the air force engine sector studied by Crocker and Reynolds [1993]). Quite interestingly, in the empirical analysis of Crocker and Reynolds [1993], the explicative variable "conflicts" (that accounts for the existence of past contractual conflicts between the partners) is positive and significant to explain the high level of contractual completeness. This seems consistent with our theoretical work: when past conflicts have emerged between a seller and a buyer, this may explain why parties look for more complete contracts afterwards.

Proposition 4. *When the information is asymmetric about the discount rate of the seller (i.e. the buyer does not know whether the seller pays enough attention to future business), the level of contractual completeness evolves according to the past behavior of the seller. When the seller never holds up, contracts become more incomplete over time.*

8 Conclusion

In this article, we examine what happens to the trade-off between costs and benefits defining contractual completeness, when parties have perspective of future business. We show that under symmetric information about the discount rates of the parties (that account for how they valorize future business), the level of contractual completeness is determined by the ability to sustain a relational contract. Such a contract is an informal agreement between the parties to prevent opportunistic behavior. In our paper, the co-contractor informally commits not to hold up during the execution of the contract and he is renewed at the following period in case of cooperation. When the co-contractor has a high discount rate, the relational contract is sustainable, and there is no need to invest in costly complete agreements, since opportunistic behavior is avoided thanks to the relational contract. However, when the co-contractor has a low discount rate, then he may renege from the informal commitment, and the buyer has better invest in complete formal agreements to prevent opportunism caused by contractual incompleteness. When the information about the discount rate of the co-contractor is asymmetric, the level of contractual completeness evolves over time, and is determined by the past behavior (cooperation or deviation) of the co-contractor. When the seller never holds up, contracts become more incomplete, but when he holds up even for small values, contracts become more complete over time. Then, our results identify a new source of endogenous contractual completeness: the ability of the parties to sustain a relational agreement. Moreover, we show that reputation building helps to understand the evolution towards more and more incomplete formal contracts. Last, our results also suggest that the identity of the parties matters when they contract, so that an identical transaction can entail different contracting costs (in completeness) depending on the contracting parties involved. This may shed a new light on some management practices, and on the choices of contractual partners, when the opportunistic behavior of a partner is feared.

This paper also calls for several extensions. In future works, we would like to explore what happens when parties adopt different strategies in case of reneging from an informal commitment. In our model, we use the trigger strategy so that once a party reneges, she never trusts any more. However, alternative strategies (as “tit-for-tat”) could be implemented, and maybe lead to different results. A second extension would be to model multilateral relationships, in which a seller could trade with different buyers and his opportunistic behavior could impact on several transactions (or not), whether the communication between the different buyers is efficient or not. Last, another work would be to give some empirical contents to our propositions and to organize lab experiments, with different treatments making relational contracts more or less sustainable, and to see whether endogenous contractual completeness change in these different contexts.

9 Appendix

The incentives compatibility constraints: For the observation of the seller's behavior to allow to separate the types, we have to check that no seller has some interest to masquerade as another type. Let us now demonstrate that:

- a type L seller prefers to hold up whenever *ex post* adaptation occurs than not to hold up to misrepresent as a type M or type H seller *(I1)*

- a type M seller prefers *(i)* to hold up when $h \in [h_m, \bar{h}]$ than to misrepresent as a type H seller, and *(ii)* not to hold up when $h \in [\underline{h}, h_m]$ rather than misrepresent as a type L seller *(I2)*

- a type H seller always chooses not to hold up rather than to misrepresent as a type M or type L seller. *(I3)*

- To show that *(I1)* is true, let us assume that L misrepresents as a type H seller. This strategy induces that L does not hold up when *ex post* adaptation occurs (whatever $h \in [\underline{h}, \bar{h}]$).
  - When the potential hold up is $h \geq h_m$, the buyer then believes that the seller is of type H and invests k^{RC} in contractual completeness. The consequence is that the

seller benefits from a higher expected hold up at the following period: the amount of hold up does not change[16] but the probability of occurrence is now higher since *ex post* adaptation occurs with probability $(1-\rho(k^{RC})) \geq (1-\rho(k_t))$. The seller L's optimal strategy is then to hold up at the following period as soon as *ex post* adaptation occurs. If no *ex post* adaptation occurs (with probability $\rho(k^{RC})$), she is renewed. Then, when the type L seller misrepresents as a type H seller, her payoff stream becomes U_H^L:

$$\begin{aligned} &U_H^L = F + h(1-\rho(k^{RC})) + \delta_L \rho(k^{RC}) U_H^L \\ &\Leftrightarrow U_H^L = \frac{F + h(1-\rho(k^{RC}))}{1-\delta_L \rho(k^{RC})} \end{aligned}$$

When *ex post* adaptation occurs, the type L seller has no interest to masquerade as a type H seller whenever her gain by holding up $(F+h)$ is larger than her gain by misrepresenting as a type H seller, *i.e.* when

$$\begin{aligned} &F + h \geq F + \delta_L U_H^L \\ &\Leftrightarrow h \geq \delta_L \frac{F + h(1-\rho(k^{RC}))}{1-\rho(k^{RC})\delta_L} \\ &\Leftrightarrow h(1-\rho(k^{RC})\delta_L) \geq \delta_L(F + h(1-\rho(k^{RC}))) \\ &\Leftrightarrow h > \delta_L(F + h(1-\rho(k^{RC})) + h\rho(k^{RC})) \end{aligned}$$

$$\Leftrightarrow \frac{h}{F+h} \geq \delta_L \tag{4}$$

From lemma 2, the discount rate of the type L seller is such that $\delta_L > \frac{h}{F+h}$. Then, (4) is always true, then the type L seller has no incentive to misrepresent as a type H seller.

- When *ex post* adaptation occurs and the potential hold up is $h < h_m$, the type L seller still prefers to hold up rather than masquerade as a type M or type H seller. Indeed, given the structure of beliefs, the buyer invests $k_{t+1} < k_t$ when he observes that the seller did not hold up $h \in [\underline{h}, h_m]$ at period t. The seller benefits from a higher expected hold-up in the following period: $(1-\rho(k_{t+1}))h$. The optimal strategy for the buyer is then to hold up whenever *ex post* adaptation occurs. Her expected payoff stream becomes:

$$\begin{aligned} U_L^M &= F + (1-\rho(k_{t+1}))h + U_L^M \delta_L \rho(k_{t+1}) \\ \Leftrightarrow U_L^M &= \frac{F + (1-\rho(k_{t+1}))h}{(1-\delta_L \rho(k_{t+1}))} \end{aligned}$$

The type L seller does not misrepresent as a type M or L (when $h \leq h_m$) if her gain is higher by holding up than by misrepresenting, *i.e.* when:

$$F + h > F + \delta_L U_L^M \tag{5}$$

$$(5) \Leftrightarrow \frac{h}{h+F} \geq \delta_L$$

Then, the type L seller always prefers to renege when $h < h_m$ than to misrepresent as a type M or type H, and *(I1)* is true.

[16] Whatever the investment in contractual completeness, the amount of hold up h is distributed over $[\underline{h}, \bar{h}]$ through the probability density function z.

- Let us now show that a type M seller does not masquerade as a type H or a type L seller.
  - First, a type M seller always prefers to hold up when $h > h_m$ than to misrepresent as a type H seller to benefit from a higher expected hold up in the following period. In case of misrepresentation, given the structure of the beliefs, the payoff stream of the seller becomes:

$$\begin{aligned} U_M^H &= F + (1-\rho(k^{RC}))(\int_{h_m}^{\overline{h}} hz(h)dh) + \delta_M((\rho(k^{RC})) \\ &\quad +(1-\rho(k^{RC}))(\int_{\underline{h}}^{h_m} z(h)dh))U_M^H \\ \Leftrightarrow U_M^H &= \frac{F + (1-\rho(k^{RC}))(\int_{h_m}^{\overline{h}} hz(h)dh)}{1-\delta_M((\rho(k^{RC})) + (1-\rho(k^{RC}))(\int_{\underline{h}}^{h_m} z(h)dh))} \end{aligned}$$

    Then, a type M seller does not masquerade as a type H seller when $h \geq h_m$ if:

$$h > \delta_M U_M^H \Leftrightarrow \frac{h}{F+h} > \delta_M \tag{6}$$

    From (SES), (6) is true.
  - Second, a type M seller does not misrepresent as a type L, *i.e.* does not hold up when $h \geq h_m$.
    Let us show that her payoff stream is higher when she does not hold up than when she holds up: in case of hold up, she gets $h \in [\underline{h}, h_m]$ and then will no longer be renewed. On the contrary, if she does not hold up, she is renewed, and the buyer invests $k_{t+1} > k_t$. Then, her expected payoff without holding up is

$$\begin{aligned} U_M^M &= F + (1-\rho(k_{t+1}))(\int_{h_m}^{\overline{h}} hz(h)dh) + \delta_M U_M^M(\rho(k_{t+1}) + (1-\rho(k_{t+1}))) \\ &= \frac{F + (1-\rho(k_{t+1}))(\int_{h_m}^{\overline{h}} hz(h)dh)}{1-\delta_M(\rho(k_{t+1}) + (1-\rho(k_{t+1})))} \end{aligned}$$

    Then, the type M seller decides not to masquerade as a type L (by holding up when $h < h_m$) if:

$$h < \delta_M U_M^M \Leftrightarrow \delta_M > \frac{h}{h+F} \tag{7}$$

    From (SES), with $h \in [\underline{h}, h_m]$, (7) is always true.

  As a consequence, a type M seller never misrepresents as a type H or a type L.

- Last, let us now demonstrate *(I3)*.
  A type H seller has no incentive to masquerade as a type L or a type M seller, *i.e.* to hold up for $h \in [\underline{h}, \overline{h}]$. Indeed, her payoff stream is higher when she does not hold up and is renewed, than when she decides to hold up. When she does not hold up, she gains $E(U^{RC})$ at each period forever, while if she holds up she gets h and then is not renewed. As a consequence, the type H seller prefers not to hold up whenever:

$$h < \frac{\delta_H \times E(U^{RC})}{1-\delta_H} \Leftrightarrow \delta_H \geq \frac{h}{h+F} \tag{8}$$

Then, from (SES), *(I3)* is always true.

A type H seller has no incentive to misrepresent as a type H or a type M seller. Moreover, a type M seller has never interest to deviate and to misrepresent as a type L. Let us assume that a type M seller chooses to hold up when $h \leq h_m$, then the buyer believes in the next rounds that he is a type L seller and no longer renews him. Instead, if the type M seller does not hold up and

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