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# Do we need handshakes to cooperate in buyer-supplier relationships?

José DE SOUSA, Xavier FAIRISE,

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## **Do we need handshakes to cooperate in buyer-supplier relationships?**

José DE SOUSA

*INRA, UMR1302 SMART, F-35000 Rennes, France  
CES, University of Paris, France*

Xavier FAIRISE

*Centre d'Études des politiques Économiques de l'Université d'Evry (EPEE et TEPP – FR  
CNRS no 3126), University of Evry, bd François Mitterand, 91025 Evry Cedex, France*

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### **Auteur pour la correspondance / Corresponding author**

**José DE SOUSA**

INRA, UMR SMART

4 allée Adolphe Bobierre, CS 61103

35011 Rennes cedex, France

Email: [jdesousa@univ-paris1.fr](mailto:jdesousa@univ-paris1.fr)

Téléphone / Phone: + 33 (0)1 44 07 81 92

Fax: + 33 (0)1 44 07 81 91

## **Do we need handshakes to cooperate in buyer-supplier relationships?**

### **Abstract**

Does formal contracting foster cooperation in a buyer-supplier relationship? In line with the literature, we find that a renegotiable contract with relationship-specific joint investments does not make it possible to reach the first-best. However, we show that a renegotiable contract may induce more cooperation than an informal arrangement. This result may help to understand how cooperation emerges in Japanese procurement practices, which typically involve relationship-specific joint investments and renegotiable contracts.

**Keywords:** Incomplete contracts, relationship-specific investments, cooperation

**JEL classifications:** K12, L22, C7

## **A-t-on besoin de la “poignée de main” pour coopérer dans les relations acheteur-vendeur?**

### **Résumé**

Les contrats formels favorisent-ils la coopération dans les relations acheteur-vendeur? En accord avec la littérature, nous trouvons qu'un contrat renégociable, avec des investissements joints spécifiques, ne permet pas d'atteindre la solution de premier rang. Cependant, nous montrons qu'un contrat renégociable peut induire une plus forte coopération qu'un arrangement informel. Ce résultat peut permettre de comprendre comment la coopération émerge dans les relations de sous-traitance au Japon. Ces relations intègrent typiquement des investissements joints spécifiques et des contrats renégociables.

**Mots-clefs :** Contrats incomplets, investissements spécifiques, coopération

**Classifications JEL :** K12, L22, C7

## **Do we need handshakes to cooperate in buyer-supplier relationships?**

### **1 Introduction**

Business research has opposed Western buyer-supplier arrangements against Japanese ones. Western arrangements, relying on detailed written contracts, have been considered to be more formal than Japanese ones. Moreover, “an emphasis has been placed on the idea of Japanese supplier relationships as ‘partnerships,’ or ‘cooperative’ arrangements, in contrast to ‘antagonistic’ supplier relations in the West” (McLaren, 1999: 122-23). McLaren (1999) shows that these international differences in buyer-supplier arrangements can emerge in a simple theoretical economic model without resorting to cultural or attitude differences. Based on differences in production costs, he demonstrates that an informal ‘handshake’ arrangement, contrary to a formal contract, fosters cooperation. Baker, Gibbons and Murphy (2002) develop repeated-game models to show that informal agreements and unwritten codes of conduct, defined as relational contracts, help circumvent difficulties in formal contracting. Moreover, Che and Chung (1999) and Che and Hausch (1999) consider cooperative investments in an incomplete contract setting and show that the contract has no value in fostering cooperation. In this paper, we study instead how formal contracting may promote cooperation.

McLaren (1999) models a procurement relationship, in which a buyer may commission a supplier to produce a tailor-made input. Two procurement arrangements

are specified. The first arrangement is formal. Parties sign an unbreakable fixed-price contract, which specifies a date of delivery of the input and a price. The second arrangement is informal and represents the so-called ‘handshake’ arrangement. Parties agree verbally, without signing a prior contract, that the supplier will produce the input, while the payment would be worked out later through bargaining. Before producing the input, that is, *ex ante*, the supplier can reduce the cost of the tailor-made input by making two types of process investments, called autonomous investments and joint investments. Some assumptions are made concerning these investments. Joint investments are relationship-specific and require an explicit cooperation between the buyer and the supplier. Autonomous investments, which the supplier can undertake on its own, are *not* relationship-specific. This implies that autonomous investment costs are *not* sunk *ex post*. Parties can pay an additional fee to recover the *ex ante* costs and adapt the tailor-made input to an alternative buyer. Under this assumption, the unbreakable fixed-price contract gives optimal incentives for a supplier’s autonomous investments. On the other hand, the externality of the joint investment is not internalized, and “the supplier will do virtually no joint investment because it knows that the buyer will have no incentive to do follow-up work” (McLaren, 1999). Consequently, the *contract has no value* to foster cooperation. In contrast, the informal arrangement provides suboptimal incentives to make autonomous investments, but it fosters cooperation, as the supplier can always get the buyer to share the costs *ex post*.

Assuming that autonomous investments are *not* relationship-specific allows McLaren to study how the market environment affects the arrangement prevailing in buyer-supplier relationships. Therefore, McLaren stresses the importance of the degree of vertical integration in an industry, which affects the fierceness of competition in the market for inputs, as the exogenous determinant of the choice between different arrangements. However, there is a huge literature in transaction cost economics documenting that autonomous investments are relationship-specific (e.g., Williamson, 1975, Klein, Crawford and Alchian, 1978, Joskow 1987). This specificity rules out the possibility of adapting the tailor-made input for an alternative buyer but does not necessarily lead to hold-up problems. When autonomous investments benefit only the investor, their specificity is not a source of inefficiency (e.g., Chung, 1991 or Edlin and Reichelstein, 1996). In contrast, an inefficiency result arises when the investor makes an autonomous investment that determines its partner's valuation, as in Che and Chung (1999) or Che and Hausch (1999). When the investments have such a 'cooperative' nature, the parties cannot do better than to abandon contracting altogether in favor of a simple informal arrangement (i.e., an ex-post negotiation without a prior fixed-price contract).<sup>1</sup> One restriction of this strand of literature lies in the cooperativeness of investments. They are autonomous, that is, done independently of the other party, and render direct benefits to the investor's partner without involving *joint* work.

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<sup>1</sup>The inefficiency result holds with sequential investments (Che, 2000) or with the introduction of private information (Hori, 2006).



We retain here the investment structure of McLaren (1999), who distinguishes autonomous from joint investments. However, we depart from his analysis by assuming first that autonomous investments are relationship-specific and second that the fixed-price contract is renegotiable. Both assumptions are quite common in the incomplete contract literature (e.g., Aghion *et al.*, 1994; Chung 1991 or Edlin and Reichelstein, 1996). The former assumption rules out the external market for the input and implies that investments are sunk ex post. The latter blurs the distinction between formal and informal arrangements in interesting ways, as presumed by McLaren (1999: 125).<sup>2</sup> In this framework, we find that contracting does not lead to the first-best. On the other hand, *contracting is valuable* compared to an informal arrangement. A renegotiable contract promotes some cooperation and is welfare improving. This result is not necessarily in conflict with that on the value of handshakes in McLaren (1999). In fact, in both settings, the possibility of bargaining ex post fosters cooperation: although the present setting underlines the value of contracting as partial commitment, contract incompleteness leaves room for informal arrangements.<sup>3</sup>

This result may help to understand how cooperation emerges in Japanese buyer-

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<sup>2</sup>It is worth noting that with relationship-specific investments an unbreakable fixed-price contract implies that the default point value is zero. Since specific investments are sunk, the break-up of the contract would generate a loss of value and give optimal incentives to invest. As a result, it can be demonstrated that if parties credibly commit not to renegotiate their initial fixed-price contract, optimal cooperation can be reached, by implementing a game of messages which discloses the relevant information to a third party. See supplementary material on <http://jose.desousa.univ.free.fr/research/sup.htm>.

<sup>3</sup>We are grateful to a referee for suggesting this interpretation.

supplier relationships. Our framework roughly fits some stylized facts about these relationships. First, parties trade in customized parts, which require autonomous and joint relationship-specific investments by the supplier (see among others Asanuma, 1985a,b, 1989; Aoki, 1988, Nishiguchi, 1994, Qiu and Spencer, 2002 and Spencer and Qiu, 2001). The Japanese automobile is a textbook example of both types of investments. As an example of joint investments, Japanese car manufacturers cooperate with suppliers to design parts of the final product.<sup>4</sup> They coordinate tasks, share information and meet each other. This cooperation is typically linked to joint investments, which are the source of productivity improvements over time. Second, Japanese practices tend to differ from American ones in key areas such as quality control and price determination. However, characterizing Japanese arrangements as informal and cooperative and Western arrangements as formal and antagonistic is a coarse generalization. In fact, the difference is blurred, as Western firms have adopted many Japanese practices (see e.g Cusumano and Takeishi, 1991), while Japanese firms contract with their partners (Asanuma, 1985a,b, Nishiguchi, 1989). Based on a survey of automobile manufacturers, Cusumano and Takeishi (1991) provide evidence of the contractual nature of the Japanese buyer-supplier relationships. They find that, for each new model of car, parties sign a new contract. “The most common contract (62 percent of the sample) is 4 years, corresponding to the average model life-cycle” (Cusumano and Takeishi, 1991). Given that the average total du-

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<sup>4</sup>For instance, with the introduction of the airbag systems car manufacturers initiated cooperations with plastic subcontractors to redesign the dashboard and bear the additional weight of the airbag.

ration of a Japanese buyer-supplier relationship is about ten years, this means that parties sign up to three different contracts by relationship. As a consequence, they do not rely simply on handshakes and ex post bargaining. Third, these contractual arrangements provide room for renegotiation. Parties write basic renegotiable contracts establishing basic rules covering a range of items including price determination, payment, delivery, property rights, the supply of materials and quality issues (Nishiguchi, 1989). Finally, these contractual arrangements also promote cooperation. The typical contract sets a target price for each input produced. Buyers then cooperate and help suppliers to reach their targets (Cusumano and Takeishi, 1991; see also Nishiguchi, 1989).

The rest of the paper is organized as follows. In the next section, we present the model, a simple two-stage game between a buyer and a supplier. This model departs from McLaren's model in two respects: we assume relationship-specific autonomous investment and the renegotiability of the contract. In section 3, we establish two benchmark outcomes to compare our results: the first-best and the ex post bargaining (without an initial contract). In section 4, we show that a formal fixed-price contract arrangement may foster cooperation. Finally, in section 5, we conclude.

## 2 Model

We consider a basic two-stage procurement model between a buyer ( $b$ ) and a supplier ( $s$ ). The buyer procures an input from the supplier. There are two simple ways of

procuring the input: a formal or an informal arrangement. The sequence of moves slightly differs according to the chosen arrangement.

In the formal arrangement, parties design a renegotiable fixed-price contract in the first stage and specify ex ante a fixed monetary transfer ( $\bar{t} \in \mathbb{R}$ ) of the buyer to the supplier for a fixed quantity of input ( $\bar{q} \in \mathbb{R}_+$ ). This initial allocation is enforceable by the court and ensures for the parties a *status quo* payoff. Contract terms are enforced in the second stage, unless they are renegotiated, in which case parties share ex post the surplus from renegotiation according to their bargaining strength.

In the informal arrangement, the sequence of events is slightly different. In the first stage, parties agree verbally on the quantity of input without signing an initial contract. In the second stage, they bargain the terms of trade and determine the payment.

Whatever the arrangement, autonomous and joint investments are not contractible and are made simultaneously in the first stage. They are relationship-specific, which rules out outside options and the possibility of adapting the input for an alternative buyer (see above).

### **Payoff functions and the nature of investments**

Let  $v(q, j_b, j_s)$  denote the buyer's gross value of procuring the good  $q \in \mathbb{R}_+$  and  $c(q, a, j_b, j_s)$  the supplier's gross monetary cost of producing  $q$ . Valuations are de-

terminated by relationship-specific investments. Let  $a \in \mathfrak{R}_+$  be the level (and cost) of autonomous investments made by the supplier. Let  $j_b \in \mathfrak{R}_+$  and  $j_s \in \mathfrak{R}_+$  be the level (and cost) of the joint investment contributions made by each party, respectively.<sup>5</sup>

Throughout this study, we make the following assumptions.

**Assumption 1**  $v$  and  $c$  are continuously differentiable in all arguments.

**Assumption 2**  $v(q, j_b, j_s) \geq 0$  is increasing in all arguments and strictly concave. For all  $q > 0$  and  $(j_b, j_s) \in \mathfrak{R}_+^2$ , it satisfies:

$$\begin{aligned} \lim_{q \rightarrow 0} v_1(q, j_b, j_s) = \infty, \quad \lim_{j_b \rightarrow 0} v_2(q, j_b, j_s) = \infty, \quad \lim_{j_s \rightarrow 0} v_3(q, j_b, j_s) = \infty; \\ \lim_{q \rightarrow \infty} v_1(q, j_b, j_s) = 0, \quad \lim_{j_b \rightarrow \infty} v_2(q, j_b, j_s) = 0, \quad \lim_{j_s \rightarrow \infty} v_3(q, j_b, j_s) = 0. \end{aligned}$$

**Assumption 3**  $c(q, a, j_b, j_s) \geq 0$  is increasing in  $q$ , decreasing in investments and strictly convex. For all  $q > 0$  and  $(a, j_b, j_s) \in \mathfrak{R}_+^3$ , it satisfies:

$$\begin{aligned} \lim_{q \rightarrow 0} c_1(q, a, j_b, j_s) = 0 \quad \lim_{a \rightarrow 0} c_2(q, a, j_b, j_s) = -\infty, \\ \lim_{j_b \rightarrow 0} c_3(q, a, j_b, j_s) = -\infty \quad \lim_{j_s \rightarrow 0} c_4(q, a, j_b, j_s) = -\infty. \\ \\ \lim_{q \rightarrow \infty} c_1(q, a, j_b, j_s) = \infty \quad \lim_{a \rightarrow \infty} c_2(q, a, j_b, j_s) = 0, \\ \lim_{j_b \rightarrow \infty} c_3(q, a, j_b, j_s) = 0 \quad \lim_{j_s \rightarrow \infty} c_4(q, a, j_b, j_s) = 0. \end{aligned}$$

Concavity and convexity of assumptions 2 and 3 imply decreasing returns for both parties.

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<sup>5</sup>Another way to model cooperation would be to assume that autonomous investments generate also direct externalities to the partner as in Che and Hausch (1999). A restriction however is that such autonomous investments render direct benefits to the investor's partner without involving a joint work.

**Assumption 4**

$$\forall (j_b, j_s) \in \mathbb{R}_+^2 \quad v(0, j_b, j_s) = 0, \quad \text{and} \quad \forall (a, j_b, j_s) \in \mathbb{R}_+^3 \quad c(0, a, j_b, j_s) = 0.$$

Assumption (4) says that when  $q = 0$  both valuations do not depend on the level of investments. Since there is no outside market for investments, this assumption suggests that investments are relationship-specific (Chung, 1991: 1034).

**Assumption 5** *The cross derivatives of  $v(q, j_b, j_s)$  and  $c(q, a, j_b, j_s)$  satisfy*

$$v_{i\ell}(q, j_b, j_s) > 0 \quad \text{and} \quad c_{i\ell}(q, a, j_b, j_s) < 0 \quad \text{for all } i \neq \ell.$$

Assumption (5) says that investments are complementary.

**Assumption 6**

$$v_2(q, j_b, 0) = 0, \quad \text{and} \quad c_3(q, a, 0, j_s) = 0.$$

Assumption (6) stipulates that the marginal return of the joint investment is null when only one party is contributing.

### 3 Benchmark outcomes

We establish two useful benchmarks, the first-best and the no-contracting outcome, with which later results about contracting may be compared.

#### 3.1 The first-best outcome

The first-best corresponds to the solution of the integrated firm program, which internalizes the effects of investment. The maximization program of the integrated

firm is separable. In a first step, we determine the optimal quantity ( $q^*$ ) given the investment levels. Then, we determine the investment levels given the optimal quantity.

Let  $\Pi$  denote the maximum gross joint surplus, such that:

$$\Pi(a, j_b, j_s) = \max_{q \geq 0} [v(q, j_b, j_s) - c(q, a, j_b, j_s)].$$

According to the optimality condition  $v_1 = c_1$ , we obtain

$$q^* = q^*(a, j_b, j_s) \tag{1}$$

the quantity equalizing the marginal benefit to the marginal cost, therefore

$$\Pi(a, j_b, j_s) = v(q^*, j_b, j_s) - c(q^*, a, j_b, j_s).$$

The net joint surplus of investments  $S(a, j_b, j_s)$  is given by:

$$S(a, j_b, j_s) = \Pi(a, j_b, j_s) - a - j_b - j_s,$$

with  $\Pi(a, j_b, j_s)$  strictly concave since  $v(\cdot)$  is concave and  $c(\cdot)$  convex. The efficient investments are such that  $(a^*, j_b^*, j_s^*) \in \arg \max_{a, j_b, j_s} \Pi(a, j_b, j_s) - a - j_b - j_s$ .

Given the assumptions on  $v$  and  $c$ ,  $(a^*, j_b^*, j_s^*)$  are unique and satisfy a system of first-order conditions (FOCs):

$$\Pi_1(a^*, j_b^*, j_s^*) - 1 = 0, \quad (2)$$

$$\Pi_2(a^*, j_b^*, j_s^*) - 1 = 0, \quad (3)$$

$$\Pi_3(a^*, j_b^*, j_s^*) - 1 = 0, \quad (4)$$

### 3.2 The (informal) no-contracting outcome

We now consider the no-contracting game. Let us recall the sequence of events. Ex ante, parties agree verbally, without a prior contract, that the supplier will produce the input. Ex post, parties share the surplus according to their exogenous bargaining positions.<sup>6</sup> Considering this sequence, we retain the subgame-perfect equilibrium as the equilibrium solution concept. The optimal quantity  $q^* \in \mathfrak{R}_+$  and the monetary transfer  $t \in \mathfrak{R}$  are determined in the second stage, while investments are realized in the first stage.

At the second stage, the negotiation outcome on  $q$  and  $t$  is solution of a Nash bargaining process, with  $\mu \in [0, 1]$  the supplier's bargaining strength:

$$\max_{t, q} [v(q, j_b, j_s) - t]^{1-\mu} [t - c(q, a, j_b, j_s)]^\mu.$$

Therefore  $q^* = q^*(a, j_b, j_s)$ , is implicitly determined by

$$v_1(q^*, j_b, j_s) = c_1(q^*, a, j_b, j_s),$$

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<sup>6</sup>In an incomplete contract framework, it does not seem reasonable to assume that bargaining positions may be endogenously determined ex ante and enforced.



and

$$t(a, j_b, j_s) = (1 - \mu)c(q^*, a, j_b, j_s) + \mu v(q^*, j_b, j_s).$$

At the first stage, the buyer and the supplier maximize their surplus:

- for the buyer:

$$U_b = v(q^*, j_b, j_s) - (1 - \mu)c(q^*, a, j_b, j_s) - \mu v(q^*, j_b, j_s) - j_b;$$

- for the supplier:

$$U_s = (1 - \mu)c(q^*, a, j_b, j_s) + \mu v(q^*, j_b, j_s) - c(q^*, a, j_b, j_s) - a - j_s.$$

Given the optimal produced quantity  $q^*$ , determined by equation (1) in both the first-best and the no-contracting outcome, we rewrite the above surplus using  $\Pi(a, j_b, j_s)$ . It follows that parties make the investment levels of the no-contracting outcome  $(\hat{a}, \hat{j}_b, \hat{j}_s)$  satisfying

$$(\hat{j}_b) \in \arg \max_{j_b} (1 - \mu)\Pi(a, j_b, j_s) - j_b,$$

$$(\hat{a}, \hat{j}_s) \in \arg \max_{a, j_s} \mu\Pi(a, j_b, j_s) - a - j_s,$$

and the following system of FOCs:

$$\frac{\partial U_b}{\partial j_b} = (1 - \mu)\Pi_2(\hat{a}, \hat{j}_b, \hat{j}_s) - 1 = 0, \quad (5)$$

$$\frac{\partial U_s}{\partial a} = \mu\Pi_1(\hat{a}, \hat{j}_b, \hat{j}_s) - 1 = 0, \quad (6)$$

$$\frac{\partial U_s}{\partial j_s} = \mu\Pi_3(\hat{a}, \hat{j}_b, \hat{j}_s) - 1 = 0. \quad (7)$$

Since  $\mu \in [0, 1]$ , efficiency cannot be achieved. This may be explained as follows. Investments are made ex ante, while the surplus is shared ex post according to the bargaining positions. The payment  $t$  is determined independently of the investments made; therefore, externalities cannot be internalized.

What are the consequences of such an inefficiency? Given the concavity of  $\Pi(a, j_b, j_s)$ , the parties will invest less than the socially optimal level.<sup>7</sup>

**Proposition 1** *Under assumptions (1) to (6), the absence of contracting prior to investing in specific assets induces under-investments, such that:  $\hat{a} < a^*$ ,  $\hat{j}_b < j_b^*$  and  $\hat{j}_s < j_s^*$ .*

**Proof** See appendix.

## 4 Contracting and cooperation

We have seen that parties do not reach efficiency by simply bargaining ex post the terms of trade without a prior contract. Now suppose that parties sign a simple renegotiable fixed-price contract that specifies a fixed monetary transfer ( $\bar{t} \in \mathbb{R}$ ) of the buyer to the supplier for a fixed quantity of goods ( $\bar{q} \in \mathbb{R}_+$ ). Two questions arise. First, does the signing of this simple renegotiable contract make it possible to achieve efficiency? Second, failing that, does contracting offer a better outcome than the no-contracting game? If not, the contract has no value, and the optimal contract is the ‘no contract.’

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<sup>7</sup>Note that overinvesting is also a possible and inefficient outcome.

## 4.1 The contracting outcome

With regard to the first question, we find in a simple way that contracting does not make it possible to reach the first-best. This is not very surprising and can be shown formally.

Let first define the (gross) renegotiation surplus ( $RS$ ), available ex post as:

$$RS = \Pi(a, j_b, j_s) - [v(\bar{q}, j_b, j_s) - c(\bar{q}, a, j_b, j_s)].$$

At the second stage, we assume a Nash bargaining process on  $q$  and  $t$ , solution of

$$\max_{t,q} [v(q, j_b, j_s) - t - v(\bar{q}, j_b, j_s) + \bar{t}]^{1-\mu} \times [t - c(q, a, j_b, j_s) - \bar{t} + c(\bar{q}, a, j_b, j_s)]^\mu.$$

We obtain  $q^* = q^*(a, j_b, j_s)$  implicitly determined by

$$v_1(q^*, j_b, j_s) = c_1(q^*, a, j_b, j_s),$$

and

$$t(a, j_b, j_s) = (1 - \mu) [c(q^*, a, j_b, j_s) - c(\bar{q}, a, j_b, j_s)] + \mu [v(q^*, j_b, j_s) - v(\bar{q}, j_b, j_s)] + \bar{t}.$$

The first stage objectives to be maximized are:

- for the buyer:

$$U_b = \underbrace{v(\bar{q}, j_b, j_s) - \bar{t}}_A + \underbrace{(1 - \mu)RS}_{B} - j_b.$$

(A) is the buyer's payoff given by the initial contract. It represents the buyer's *status quo* position. (B) is the payoff from the renegotiation process, depending on the buyer's bargaining strength  $(1 - \mu)$ .

- for the supplier:

$$U_s = \underbrace{\bar{t} - c(\bar{q}, a, j_b, j_s)}_C + \underbrace{\mu RS}_D - a - j_s.$$

(C) is the supplier's cost given by the initial contract. It represents the supplier's *status quo* position. (D) is the payoff from the renegotiation process, depending on the supplier's bargaining strength  $\mu$ .

Parties make the investment levels of the contracting outcome  $(\tilde{a}, \tilde{j}_b, \tilde{j}_s)$ , satisfying

$$(\tilde{j}_b) \in \arg \max_{j_b} v(\bar{q}, j_b, j_s) - \bar{t} + (1 - \mu)RS - j_b,$$

$$(\tilde{a}, \tilde{j}_s) \in \arg \max_{a, j_s} \bar{t} - c(\bar{q}, a, j_b, j_s) + \mu RS - a - j_s.$$

and the following system of first-order conditions:

$$\frac{\partial U_b}{\partial j_b} = \mu v_2(\bar{q}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu)c_3(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu)\Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - 1 = 0, \quad (8)$$

$$\frac{\partial U_s}{\partial a} = -(1 - \mu)c_2(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s) + \mu\Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - 1 = 0, \quad (9)$$

$$\frac{\partial U_s}{\partial j_s} = -\mu v_3(\bar{q}, \tilde{j}_b, \tilde{j}_s) - (1 - \mu)c_4(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s) + \mu\Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - 1 = 0. \quad (10)$$

Since  $\mu \in [0, 1]$ , it is not possible to implement the first-best outcome. This implies that contracting with renegotiation does not make it possible to achieve efficiency.

## 4.2 Contracting or no-contracting?

We fail to achieve efficiency with contracting. However, we wonder whether writing a contract is valuable, that is, if contracting offers a better outcome than no-contracting. A simple comparison of the no-contracting FOCs (5 - 7) with the contracting FOCs (8 - 10) shows that there is no obvious result regarding the improving effect of contracting.

The bargaining position ( $\mu$ ) plays an important role in deriving more precise results about the comparison between contracting and no-contracting outcomes. Before proceeding to the formal comparison, we consider some critical values of the parameter  $\mu$  and two useful lemmas. Then we work out the comparison.

Let first define the set  $\mathcal{A}$ :

$$\mathcal{A} = \{k \in [0, 1] / kv_3(q, j_b, j_s) + (1 - k)c_4(q, a, j_b, j_s) \leq 0, \forall q, a, j_b, j_s\}.$$

Let  $\bar{\mu} = \sup \mathcal{A}$ . This number exists; if  $k = 0$ , the above inequality, used to define  $\sup \mathcal{A}$ , reduces to  $c_4(q, a, j_b, j_s) \leq 0$ , which is satisfied  $\forall q, a, j_b, j_s$ . The following useful lemma can now be stated.

**Lemma 1** *If  $\mu < \bar{\mu}$ , then:  $\mu v_3(q, j_b, j_s) + (1 - \mu)c_4(q, a, j_b, j_s) \leq 0, \forall q, a, j_b, j_s$ .*

**Proof** See appendix.

We now define one other critical value of  $\mu$ . Consider the set  $\mathcal{C}$ :

$$\mathcal{C} = \{k \in [0, 1] / kv_2(q, j_b, j_s) + (1 - k)c_3(q, a, j_b, j_s) \geq 0, \forall q, a, j_b, j_s\}.$$

Let define  $\underline{\mu} = \inf \mathcal{C}$ . This number again exists; if  $k = 1$ , the inequality, used to define  $\mathcal{C}$ , becomes  $v_3(q, j_b, j_s) \geq 0$ , which is satisfied  $\forall q, j_b, j_s$ . A second useful lemma can now be stated.

**Lemma 2** *If  $\mu > \underline{\mu}$ , then:  $\mu v_2(q, j_b, j_s) + (1 - \mu)c_3(q, a, j_b, j_s) \geq 0$ ,  $\forall q, a, j_b, j_s$ .*

**Proof** The proof is the same as the one of Lemma 1.  $\parallel$

Using Lemmas 1 and 2, we now determine the value of the simple fixed-price contract in comparison with the no-contraction outcome:

**Proposition 2** *Suppose that assumptions (1) to (6) hold. If  $\underline{\mu} < \mu < \bar{\mu}$ , then the no-contracting outcome generates a general under-investment in comparison with the contracting outcome. It follows that  $\hat{a} < \tilde{a}$ ,  $\hat{j}_b < \tilde{j}_b$  and  $\hat{j}_s < \tilde{j}_s$ .*

**Proof** See appendix.

The results of propositions (1) and (2) state that no-contracting leads to under-investments compared to both the first-best and the contracting solutions. However, these propositions do not allow to discriminate between contracting and no-contracting outcomes in terms of welfare. Contracting would be welfare improving, if we could prove that (suboptimal) contracting investments are lower than the first-best ones, but over-investment is also a suboptimal solution. The comparison of the first-best and the contracting outcomes depends on the value of  $\bar{q}$  fixed in the contract. We have the following proposition.

**Proposition 3** *Suppose that assumptions (1) to (6) hold. If  $\bar{q}$  is such that  $\bar{q} < q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s)$ , then the contracting outcome generates a general under-investment in comparison with the first-best. It follows that  $\tilde{a} < a^*$ ,  $\tilde{j}_b < j_b^*$  and  $\tilde{j}_s < j_s^*$ .*

**Proof** See appendix.

The contracting investment levels  $(\tilde{a}, \tilde{j}_b, \tilde{j}_s)$  depend on the value of  $\bar{q}$  (see equations 8-10). It turns out that if  $\bar{q}$  is such that  $\bar{q} < q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s)$ , then investment levels in the contracting case are lower than in the first-best outcome.

### 4.3 Numerical investigations

The two preceding propositions suggest that parameters  $\mu$  and  $\bar{q}$  play a crucial role in the comparison of the different outcomes (in terms of investments, produced quantities and total surplus). However, it is not possible to provide precise analytical results enabling the discrimination between contracting and no-contracting outcomes. It is also impossible to perform surplus comparisons. To provide insight into the influence of parameters  $\mu$  and  $\bar{q}$  on the model outcomes, we conduct numerical investigations.

The buyer's value and the supplier's cost functions are defined as follows:

$$\begin{aligned} v(q, j_b, j_s) &= B_0 q^{b_0} \left[ (j_b^{\beta_2} j_s^{\beta_2})^\theta \right]^{b_1}, \\ c(q, a, j_b, j_s) &= A_0 q^{a_0} \left[ \left( \alpha_0 a^{-\frac{1-\sigma}{\sigma}} + \alpha_1 j_b^{-\frac{1-\sigma}{\sigma}} + \alpha_2 j_s^{-\frac{1-\sigma}{\sigma}} \right)^{-\nu \frac{\sigma}{1-\sigma}} \right]^{-a_1}, \end{aligned}$$

with  $B_0 > 0$ ,  $b_0, b_1 > 0$ ,  $b_0 + b_1 < 1$ ,  $\beta_1, \beta_2 > 0$ ,  $\beta_1 + \beta_2 = 1$ ,  $0 < \theta < 1$ ,  $A_0 > 0$ ,

$a_0 > 1, a_1 > 0, a_0 - a_1 > 1, \sigma > 0, 0 < \nu < 1, \alpha_0, \alpha_1, \alpha_2 > 0$  and  $\alpha_0 + \alpha_1 + \alpha_2 = 1$ .

Numerical investigations are made using the following benchmark calibration:

Under this parametrization, assumptions 1-6 are satisfied. Note that assumptions 5 and 6 concerning the supplier's cost function are satisfied if  $\nu a_1 - \frac{1-\sigma}{\sigma} < 0$ .

A graphical presentation of the results is given in Figures 1 - 6. We first study the impact of a variation of the supplier's bargaining strength  $\mu$  on the investment levels, the produced quantities and the total surplus. We consider our three cases, that is, first-best, no-contracting and contracting. Concerning the contracting case, several values of the fixed quantity  $\bar{q}$  are taken into account. It should be noted that the contracting case with  $\bar{q} = 0$  is similar to the no-contracting case.

The numerical experiments suggest that the investment levels  $(a, j_b, j_s)$  in the contracting case are sensitive to the value of the fixed quantity  $\bar{q}$  (see Figures 1 - 3). More precisely, they increase as  $\bar{q}$  grows. Moreover, the results show that the contracting investment levels are above the no-contracting ones and may be greater than the levels in the first best case. This latter case occurs for high values of  $\bar{q}$ , that is, when  $\bar{q}$  is about 1.5 times the value of the quantity produced in the first-best case (see table 3). There is a critical value of  $\bar{q}$ , which is roughly 0.24. If  $\bar{q}$  is less than 0.24, the supplier's contracting joint investments are increasing in  $\mu$  (the supplier's bargaining strength), whereas the buyer's contracting joint investments are decreasing in  $\mu$ . The converse applies if  $\bar{q} > 0.24$ . Finally, if  $\bar{q} = 0.24$ , the contracting investment levels are independent of the bargaining strength, higher



than the no-contracting case and lower than the first-best.

Figures 4 - 5 provide a representation in terms of produced quantities and total surplus. In the contracting case, the produced quantity increases as  $\bar{q}$  grows. Note that if  $\bar{q}$  is less than the critical value of 0.24, the contracting produced quantity is increasing in  $\mu$  and that the opposite is true if  $\bar{q}$  is greater than 0.24. Concerning the total surplus, our simulations show that the no-contracting case surplus is significantly smaller than the first-best one. The no-contracting surplus attains a maximum when  $\mu$  is approximatively equal to 0.5. However, contracting allows significant improvement in the total surplus. It increases as  $\bar{q}$  grows and attains a maximum. The total surplus decreases thereafter.

Figure 6 provides a three-dimensional representation of the relationship of the supplier's bargaining strength  $\mu$  to the fixed-quantity  $\bar{q}$  and the total surplus in the contracting case  $\tilde{S}$ . Note that for small values of  $\bar{q}$  and polar values of  $\mu$  ( $\mu$  close to 0 or 1), the contracting surplus tends to be very small. The surface of Figure 6 suggests there exists values of  $\mu$  and  $\bar{q}$  that maximize the contracting surplus. Solving a second-best problem<sup>8</sup>, we determine the values of  $\mu^*$  and  $\bar{q}^*$  maximizing the contracting total surplus. Results reported in table 4 suggest that contracting may significantly improve the allocation. If  $\mu$  and  $\bar{q}$  are appropriately set, the contracting surplus is very close to the first-best one (it is less by 1.44%).

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<sup>8</sup>We determine the values of  $\mu$  and  $\bar{q}$  maximizing the total surplus subject to the set of constraints constituted by equations (8)-(10).

## 5 Conclusion

In this paper, we analyze two simple ways in which the input could be procured: (1) a renegotiable fixed-price contract and (2) an ex post bargaining of the terms of trade without a prior contract. We found that arrangements fail both to achieve efficiency and to provide an incentive for optimal joint investments. A direct implication of this result is that a process of vertical integration, with a unified direction, provides optimal incentives to cooperate.

We also aimed to compare the contracting and the no-contracting solutions. We found that contracting induces larger autonomous and joint investments compared to not contracting. Moreover, our formal analysis suggests that the supplier's bargaining strength and the fixed quantity of input play a crucial role in the comparison of the different outcomes (in terms of investments, produced quantities and total surplus). Formally, contracting is welfare-improving for values of the fixed quantity lower than a given threshold. Numerically, we have shown that the contracting surplus is very close to the first-best one for appropriate values of the supplier's bargaining strength and the fixed quantity of input. Therefore, handshakes are not always needed to promote cooperation.

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## A Proof of proposition 1

It is worth noting that assumption (5) implies that  $\Pi_{il} > 0$  for all  $i \neq l$ .

Consider now the following problem:

$$\max_{a, j_b, j_s} \Pi(a, j_b, j_s) - \left( \lambda + \frac{1-\lambda}{\mu} \right) a - \left( \lambda + \frac{1-\lambda}{1-\mu} \right) j_b - \left( \lambda + \frac{1-\lambda}{\mu} \right) j_s. \quad (11)$$

with  $\lambda \in [0, 1]$ .

The first-order conditions are:

$$\begin{aligned} \Pi_1(a, j_b, j_s) &= \lambda + \frac{1-\lambda}{\mu}, \\ \Pi_2(a, j_b, j_s) &= \lambda + \frac{1-\lambda}{1-\mu}, \\ \Pi_3(a, j_b, j_s) &= \lambda + \frac{1-\lambda}{\mu}. \end{aligned}$$

The maximization problem (11) has a unique solution, that is,  $a(\lambda)$ ,  $j_b(\lambda)$  and  $j_s(\lambda)$ .

Note that  $a(1) = a^*$ ,  $j_b(1) = j_b^*$ ,  $j_s(1) = j_s^*$  and  $a(0) = \hat{a}$ ,  $j_b(0) = \hat{j}_b$ ,  $j_s(0) = \hat{j}_s$ .

Define

$$\begin{aligned} V(\lambda) &= \Pi(a(\lambda), j_b(\lambda), j_s(\lambda)) - \left( \lambda + \frac{1-\lambda}{\mu} \right) a(\lambda) \\ &\quad - \left( \lambda + \frac{1-\lambda}{1-\mu} \right) j_b(\lambda) - \left( \lambda + \frac{1-\lambda}{\mu} \right) j_s(\lambda), \end{aligned}$$

and

$$\begin{aligned} W(\lambda) &= \Pi(a(\lambda_0), j_b(\lambda_0), j_s(\lambda_0)) - \left( \lambda + \frac{1-\lambda}{\mu} \right) a(\lambda_0) \\ &\quad - \left( \lambda + \frac{1-\lambda}{1-\mu} \right) j_b(\lambda_0) - \left( \lambda + \frac{1-\lambda}{\mu} \right) j_s(\lambda_0) - V(\lambda). \end{aligned}$$

We necessarily have  $W(\lambda) \leq 0$  and  $W(\lambda_0) = 0$ . Thus, the function  $W(\lambda)$  attains a maximum at  $\lambda = \lambda_0$ . At this point, the first and second order optimality conditions are necessarily satisfied, we thus have  $W'(\lambda_0) = 0$  and  $W''(\lambda_0) < 0$ .

The first and second derivatives of  $W(\lambda)$  are:

$$\begin{aligned} W'(\lambda) &= - \left( 1 - \frac{1}{\mu} \right) a(\lambda_0) - \left( 1 - \frac{1}{1-\mu} \right) j_b(\lambda_0) \\ &\quad - \left( 1 - \frac{1}{\mu} \right) j_s(\lambda_0) - V'(\lambda), \\ W''(\lambda) &= -V''(\lambda). \end{aligned}$$

The first-order condition gives:

$$\begin{aligned} W'(\lambda_0) &= - \left( 1 - \frac{1}{\mu} \right) a(\lambda_0) - \left( 1 - \frac{1}{1-\mu} \right) j_b(\lambda_0) \\ &\quad - \left( 1 - \frac{1}{\mu} \right) j_s(\lambda_0) - V'(\lambda_0) = 0. \end{aligned}$$

The above expression holds for any  $\lambda_0$ . The first derivative of  $V(\lambda)$  is then:

$$V'(\lambda) = - \left( 1 - \frac{1}{\mu} \right) a(\lambda) - \left( 1 - \frac{1}{1-\mu} \right) j_b(\lambda) - \left( 1 - \frac{1}{\mu} \right) j_s(\lambda).$$

We deduce the expression of the second derivative of  $V(\lambda)$ :

$$V''(\lambda) = - \left( 1 - \frac{1}{\mu} \right) a'(\lambda) - \left( 1 - \frac{1}{1-\mu} \right) j'_b(\lambda) - \left( 1 - \frac{1}{\mu} \right) j'_s(\lambda).$$

The second order condition  $W''(\lambda_0) < 0$  also holds for any  $\lambda_0$ . We thus have  $W''(\lambda) < 0$  for all  $\lambda$ . Consequently:

$$W''(\lambda) = - \left( 1 - \frac{1}{\mu} \right) a'(\lambda) - \left( 1 - \frac{1}{1-\mu} \right) j'_b(\lambda) - \left( 1 - \frac{1}{\mu} \right) j'_s(\lambda) < 0.$$

Given that  $\mu \in ]0, 1[$ , we necessarily have  $a'(\lambda) > 0$  or  $j'_b(\lambda) > 0$  or  $j'_s(\lambda) > 0$ . Suppose for example

that  $a'(\lambda) > 0$  and differentiate the FOCs with respect to  $\lambda$  to obtain:

$$\begin{aligned} a'(\lambda)\Pi_{11} + j'_b(\lambda)\Pi_{12} + j'_s(\lambda)\Pi_{13} &= 1 - \frac{1}{\mu} < 0, \\ a'(\lambda)\Pi_{21} + j'_b(\lambda)\Pi_{22} + j'_s(\lambda)\Pi_{23} &= 1 - \frac{1}{1-\mu} < 0, \\ a'(\lambda)\Pi_{31} + j'_b(\lambda)\Pi_{32} + j'_s(\lambda)\Pi_{33} &= 1 - \frac{1}{\mu} < 0. \end{aligned}$$

The cross derivatives  $\Pi_{ij}$  being negative, we get:

$$\begin{aligned} j'_b(\lambda)\Pi_{22} + j'_s(\lambda)\Pi_{23} &= 1 - \frac{1}{1-\mu} - a'(\lambda)\Pi_{21} < 0, \\ j'_b(\lambda)\Pi_{32} + j'_s(\lambda)\Pi_{33} &= 1 - \frac{1}{\mu} - a'(\lambda)\Pi_{31} < 0. \end{aligned}$$

It immediately follows that:

$$\begin{aligned} &\begin{pmatrix} j'_b(\lambda) & j'_s(\lambda) \end{pmatrix} \begin{pmatrix} \Pi_{22} & \Pi_{23} \\ \Pi_{32} & \Pi_{33} \end{pmatrix} \begin{pmatrix} j'_b(\lambda) \\ j'_s(\lambda) \end{pmatrix} \\ &= j'_b(\lambda) \left( 1 - \frac{1}{1-\mu} - a'_b(\lambda)\Pi_{31} \right) + j'_s(\lambda) \left( 1 - \frac{1}{\mu} - a'_b(\lambda)\Pi_{41} \right) < 0. \end{aligned}$$

We necessarily have  $j'_b(\lambda) > 0$  or  $j'_s(\lambda) > 0$ . Suppose for example that  $j'_b(\lambda) > 0$ . The same argument shows that  $j'_s(\lambda) > 0$ .  $\parallel$

## B Proof of lemma 1

Consider any values of  $q, a, j_b, j_s$ . Define  $g(\mu) = \mu v_3(q, j_b, j_s) + (1 - \mu)c_4(q, a, j_b, j_s)$ .

We get  $g'(\mu) = v_3(q, j_b, j_s) - c_4(q, a, j_b, j_s) > 0$ .

It follows that  $g(\mu) < g(\bar{\mu}) \leq 0, \forall \mu \in [0, \bar{\mu}[$ .

## C Proof of proposition 2

Let  $(\tilde{a}, \tilde{j}_b, \tilde{j}_s) \in \mathbb{R}_+^3$  be the investment levels of the contracting outcome, solutions of the following first-order conditions:

$$\begin{aligned} (1 - \mu)\Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= 1 - \mu v_2(\bar{q}, \tilde{j}_b, \tilde{j}_s) - (1 - \mu)c_3(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s), \\ \mu\Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= 1 + (1 - \mu)c_2(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s), \\ \mu\Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= 1 + \mu v_3(\bar{q}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu)c_4(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s). \end{aligned}$$

$(\hat{a}, \hat{j}_b, \hat{j}_s) \in \mathbb{R}_+^3$  are the investment levels of the no-contacting solution:

$$(1 - \mu)\Pi_2(\hat{a}, \hat{j}_b, \hat{j}_s) = 1; \quad \mu\Pi_1(\hat{a}, \hat{j}_b, \hat{j}_s) = 1; \quad \mu\Pi_3(\hat{a}, \hat{j}_b, \hat{j}_s) = 1.$$

Using Lemmas 1 and 2, it can be easily shown that for all  $\mu \in [\underline{\mu}, \bar{\mu}]$

$$\begin{aligned} \Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - \Pi_1(\hat{a}, \hat{j}_b, \hat{j}_s) &= \frac{1 - \mu}{\mu} c_2(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s) < 0, \\ \Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - \Pi_2(\hat{a}, \hat{j}_b, \hat{j}_s) &= -\frac{1}{1 - \mu} [\mu v_2(\bar{q}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu)c_3(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s)] < 0, \\ \Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - \Pi_3(\hat{a}, \hat{j}_b, \hat{j}_s) &= \frac{1}{\mu} [\mu v_3(\bar{q}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu)c_4(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s)] < 0, \end{aligned}$$

The rest of the proof is similar to the one of the under-investment result in the no-contacting outcome (see proposition 1).  $\parallel$

## D Proof of proposition 3

Let  $(\tilde{a}, \tilde{j}_b, \tilde{j}_s) \in \mathbb{R}_+^3$  be the investment levels of the contracting outcome, solutions of the following first-order conditions:

$$\begin{aligned} (1 - \mu)\Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= 1 - \mu v_2(\bar{q}, \tilde{j}_b, \tilde{j}_s) - (1 - \mu)c_3(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s), \\ \mu\Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= 1 + (1 - \mu)c_2(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s), \\ \mu\Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= 1 + \mu v_3(\bar{q}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu)c_4(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s). \end{aligned}$$

The above conditions can be rewritten as follows:

$$\begin{aligned}
 1 - \Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= -\mu \Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) + \mu v_2(\bar{q}, \tilde{j}_b, \tilde{j}_s) + (1 - \mu) c_3(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s), \\
 1 - \Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= -(1 - \mu) \Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - (1 - \mu) c_2(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s), \\
 1 - \Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= -(1 - \mu) \Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) - \mu v_3(\bar{q}, \tilde{j}_b, \tilde{j}_s) - (1 - \mu) c_4(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s).
 \end{aligned}$$

$(a^*, j_b^*, j_s^*) \in \mathbb{R}_+^3$  are the investment levels of the first-best solution:

$$\Pi_2(a^*, j_b^*, j_s^*) = 1; \quad \Pi_1(a^*, j_b^*, j_s^*) = 1; \quad \Pi_3(a^*, j_b^*, j_s^*) = 1.$$

Assumption 5 implies  $c_2$  and  $c_4$  are decreasing in  $q$  and  $v_2$  is increasing in  $q$ . It is easily deduced that if  $\bar{q}$  satisfies  $\bar{q} < q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s)$ , one has:

$$\begin{aligned}
 \Pi_1(a^*, j_b^*, j_s^*) - \Pi_1(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= (1 - \mu) [c_2(q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s), \tilde{a}, \tilde{j}_b, \tilde{j}_s) - c_2(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s)] < 0, \\
 \Pi_2(a^*, j_b^*, j_s^*) - \Pi_2(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= \mu [v_2(\bar{q}, \tilde{j}_b, \tilde{j}_s) - v_2(q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s), \tilde{j}_b, \tilde{j}_s)] \\
 &\quad + \mu c_3(q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s), \tilde{j}_b, \tilde{j}_s) + (1 - \mu) c_3(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s) < 0, \\
 \Pi_3(a^*, j_b^*, j_s^*) - \Pi_3(\tilde{a}, \tilde{j}_b, \tilde{j}_s) &= (1 - \mu) [c_4(q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s), \tilde{a}, \tilde{j}_b, \tilde{j}_s) - c_4(\bar{q}, \tilde{a}, \tilde{j}_b, \tilde{j}_s)] \\
 &\quad - (1 - \mu) v_3(q^*(\tilde{a}, \tilde{j}_b, \tilde{j}_s), \tilde{j}_b, \tilde{j}_s) - \mu v_3(\bar{q}, \tilde{j}_b, \tilde{j}_s) < 0,
 \end{aligned}$$

The rest of the proof is similar to the one of the under-investment result in the no-contracting outcome (see proposition 1). ||

## E Graphics



Figure 1: Autonomous investment

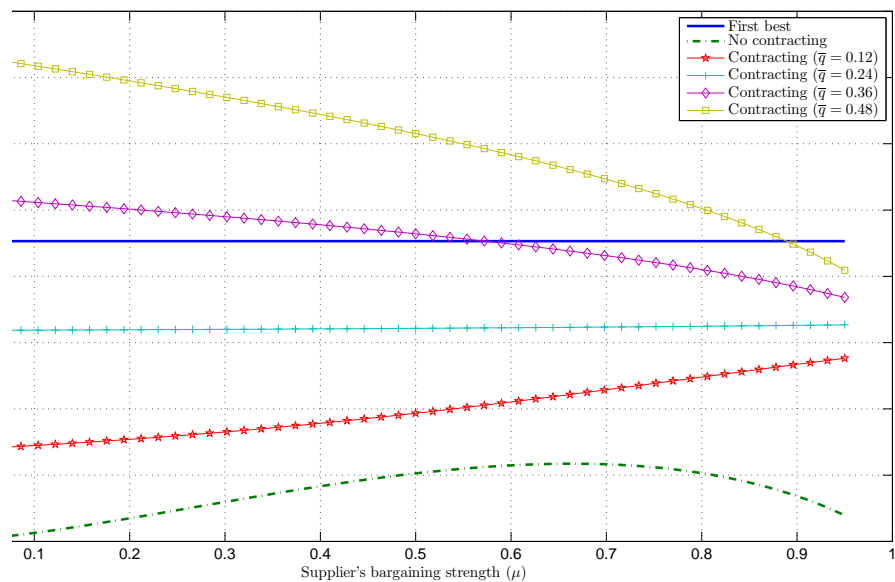


Figure 2: Buyer's joint investment

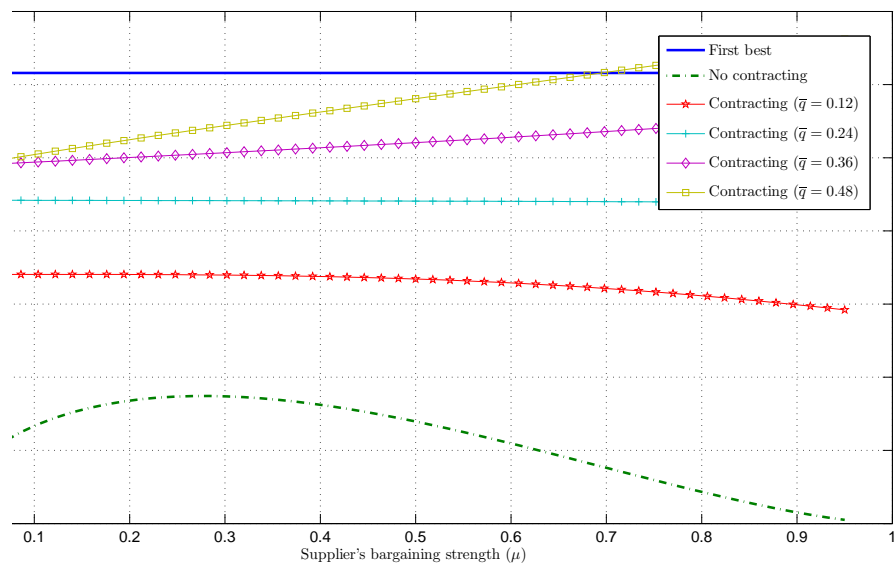


Figure 3: Supplier's joint investment

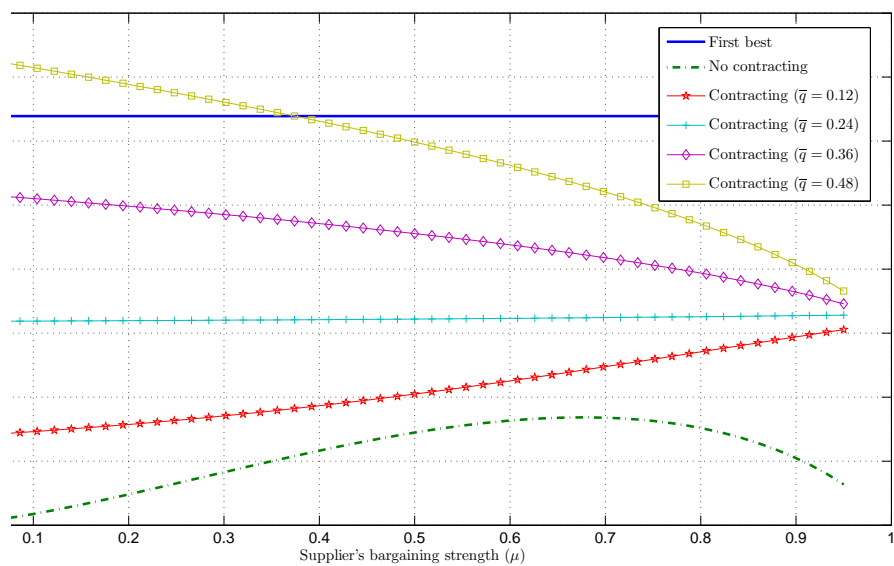


Figure 4: Produced quantities

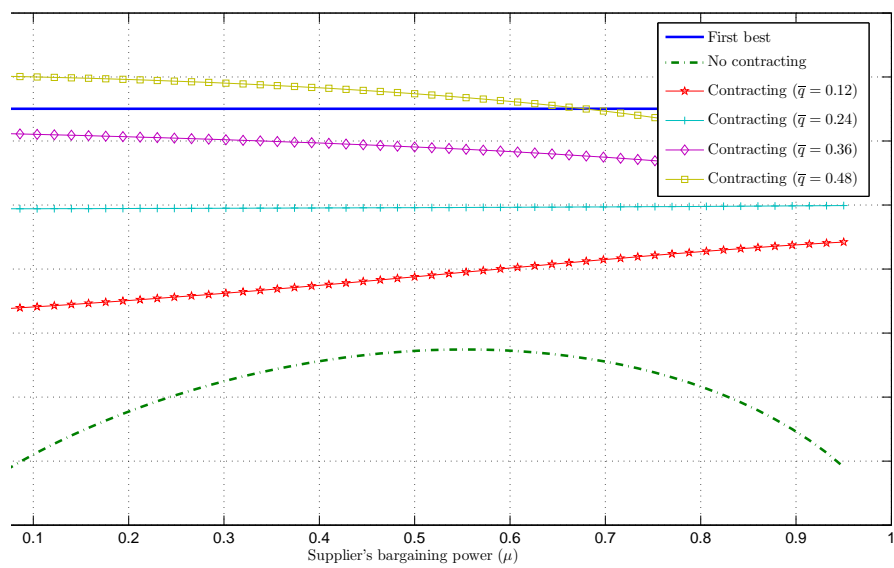


Figure 5: Total surplus

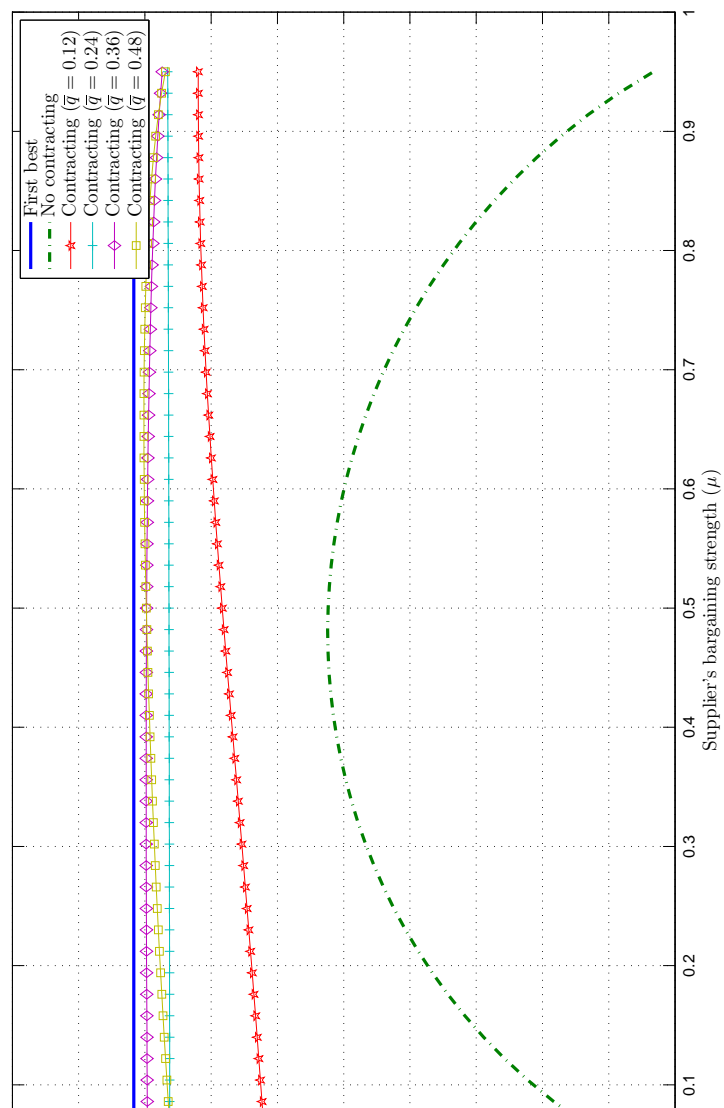


Figure 6: Contracting surplus

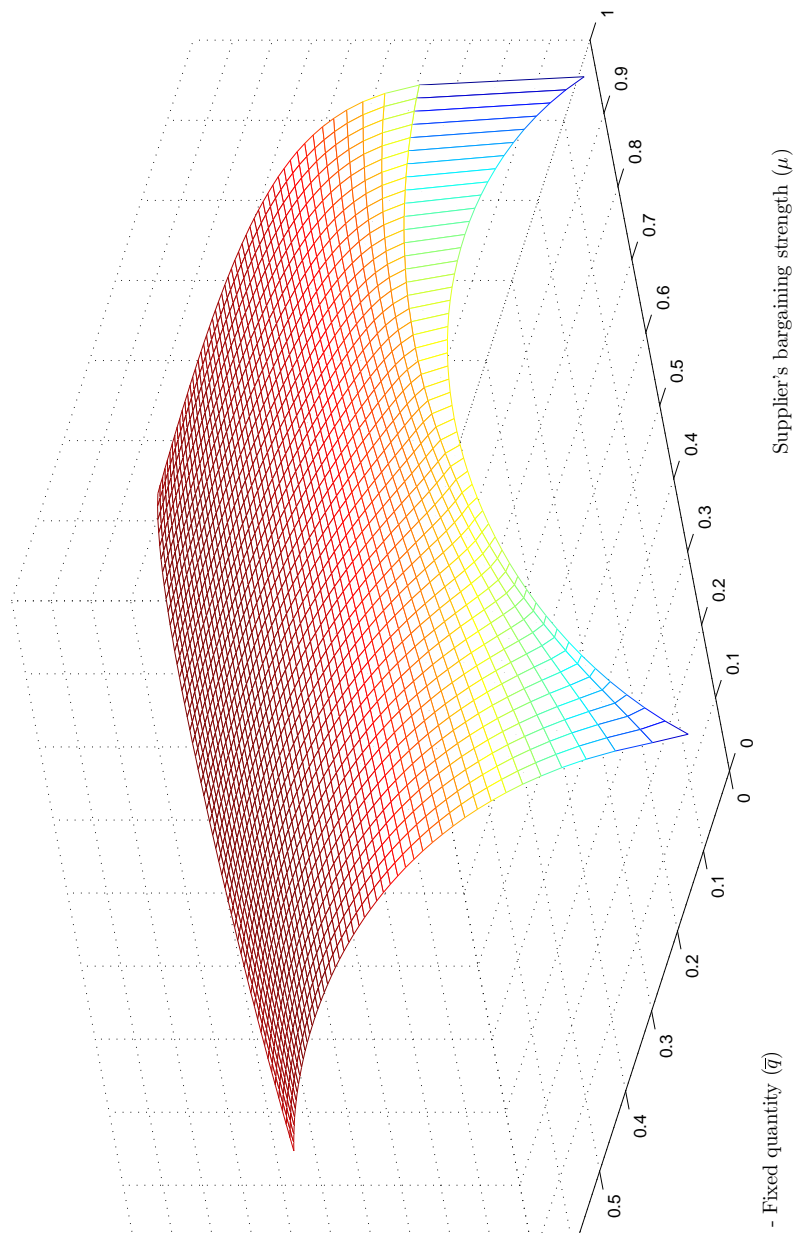


Table 1: Benchmark calibration: buyer's value

$B_0$	$b_0$	$b_1$	$\beta_1$	$\beta_2$	$\theta$
10	0.5	0.3	0.8	0.2	0.8

Table 2: Benchmark calibration: supplier's cost

$A_0$	$a_0$	$a_1$	$\alpha_0$	$\alpha_1$	$\alpha_2$	$\sigma$	$\nu$
10	2	0.8	0.4	0.2	0.4	0.6	0.8

Table 3: First best results

$q^*$	$a^*$	$j_b^*$	$j_s^*$	$S^*$
0.3252	0.4530	1.2317	0.6391	2.0334

Table 4: Contracting results ( $\bar{q}^* = 0.4571$  and  $\mu^* = 0.6144$ )

$\tilde{q}$	$\tilde{a}$	$\tilde{j}_b$	$\tilde{j}_s$	$\tilde{S}$
0.3206	0.5436	1.1694	0.5259	2.0042

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4 allée Adolphe Bobierre, CS 61103

35011 Rennes cedex, France

**Email :** [smart\\_lereco\\_wp@rennes.inra.fr](mailto:smart_lereco_wp@rennes.inra.fr)

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