U**A**B

Universitat Autònoma de Barcelona

Multiple-Sourcing and Specific Investments

Miguel A. García-Cestona

Working Paper # 95/3

A Working Paper in the *documents de treball d'economia de l'empresa* series is intended as a mean whereby a faculty researcher's thoughts and findings may be communicated to interested readers for their comments. Nevertheless, the ideas put forwards are responsibility of the author. Accordingly a Working Paper should not be quoted nor the data referred to without the written consent of the author. Please, direct your comments and suggestions to the author, which address shows up in the next page.

Abstract

When should firms rely on multiple suppliers? I address here the issue of vertical market structure. In my model, the two-vendor policy plays a "stopper" role in the main manufacturer's hands who can induce competition among suppliers in future periods and, doing so, effectively curtails the single supplier's advantages. At the same time, suppliers have incentives to make a first-period effort. The main result of this paper is to show that, under certain conditions (the a-priori distribution of supplier costs), a multiple-source system is optimal and it can beat a single-source system in adopting new technologies.

1 Introduction

When should a manufacturing firm rely on multiple sourcing? In what follows I shall take the existence of manufacturing firms and independent suppliers for granted[1], and search for reasons why firms do not purchase from one big supplier.

When asked about the rationale behind the extended practice of contracting a single engine-supplier, many commercial airlines offer an explanation based on the presece of economies of scale in workshop tooling and training to justify their strategy. Certainly there are industries and environments (e.g., natural monopoly) where single-sourcing is observed.

Nevertheless, several reports (Piore (1989) and MIT Commission on Industrial Productivity (1989) among others) confirm a trend towards higher reliance on suppliers: a larger share of a product's final added value comes from parts and components purchased by the manufacturer to suppliers. It is for this reason that the way in which firms structure relations with their suppliers is becoming a crucial issue. I address here the issue of vertical market structure and in particular, the optimality of multiple sourcing under certain scenarios.

As background to my argument, I present the situation in the car manufacturing industry[2]. Several reasons sustain this choice. First, the Automobile Industry represents the single largest industrial sector in the world economy. Furthermore, today's car production generates a complex web of relations and interchanges among different firms, industries and economic sectors. Second, car manufacturing companies have traditionally been forerunners in the design and adoption of new production systems and organizational forms (e.g., Ford and mass production, General Motors and the multidivisional organization, Toyota and lean production, etc.). Systems and forms which have later being adopted by other manufacturing activities.

---

[1]In his influential work "The Nature of the Firm" (1937), Ronald Coase analyzed the questions of why firms do exist at all, and why is not all production carried out by one big firm, starting the transaction costs literature.

[2]Government procurement also provides numerous examples. At the time of deciding about a new jet manufacturing project, the Department of Defense was pushing for a dual-source approach, even though the companies involved, General Electric and Pratt&Whitney, both claimed (ex-ante) the unfeasability of such a solution due to market size considerations.

Third, even nowadays the Automobile industry offers significantly different responses to the issue of how to handle suppliers.

Asanuma's series of papers (1988,1989) on the Japanese and American Automobile Industry offers the most detailed factual analysis of the Manufacturer-Supplier relationship in Japan and its comparison with the American situation. Two features are of special relevance for this analysis:

- Contracts: American firms use a competitive bidding system, while in Japan, contracts are assigned to existing suppliers through a rating system.

- Two-vendor policy: The "core-firm"[3] tries to establish (and makes use of) alternative sources, with more than one supplier for the same or similar components.

The following analysis is an attempt to explain the rationale behind a multiple-sourcing market structure and supplier rankings, as opposed to the single supplier approach.

Asanuma's description of the competitive bidding system may be summarized as follows. When a car manufacturer goes through the process of developing a new component, it determines first a detailed specification of the desired characteristics. Only then, a bidding process follows among the suppliers able to satisfy those standards. Competitive bidding serves the firm in selecting the most efficient supplier (in terms of current cost) and allows suppliers to enjoy their cost advantage over competitors. No communication exists between suppliers and the core firm at the time of designing the product. The reason underlying the success of competitive bidding is the assumption that a prime manufacturer is able to design every manufacturing specification by itself. Suppliers, knowing the specific product characteristics and his own technological constraints, submit their bids.

I want to focus on a different set-up. Now manufacturers assign contracts to suppliers based on their past performance. A new relationship arises, in which firms expect from their suppliers to accumulate knowledge (through specific investments) for future use in improving products and costs.

Clearly, this approach is not appropriate in all cases. One should disregard situations in which the market already offers the components, and

---

[3]Asanuma's equivalents to dual-sourcing and prime manufacturer.

examples in which core firms provide the blue-prints for parts manufacture. As we will show later, the bidding system seems to work properly there. This new approach becomes relevant when, under some level of uncertainty, suppliers are players with actions beyond the mere execution of manufacturing designs. Situations where only coordinated actions allow the firm to achieve its optimum.

1.1 Existing Literature.

Vertical integration has inspired an abundant literature. The following review is limited to papers on supplier involvement and vertical integration.

Grossman and Hart [1986] developed a new framework with their asset ownership definition in terms of "residual rights of control" over production decisions. For them, vertical integration means the transfer of rights to one of the parties. Their notion has come under criticism from other authors, like Tirole [1988] who prefers the term "authority" to denote this power allocation to fill unspecified contingencies. In any case, those residual rights serve the purpose of moving the status-quo point in the bargaining problem. While this may help to achieve efficiency in the production decisions, it does not directly affect investment decisions, in sharp contrast with the transaction cost literature.

Milgrom and Roberts [1990] provide a detailed enumeration of the modern manufacturing firm's characterizing factors. Flexible equipment, reduced inventories, emphasis on quality, quick adaptation to consumer's needs are, among others, some of the visible features of their "production manufacturer cluster". Changes in technology and demand have generated an increasing trend of shorter life products and extensive product differentation which, in turn, calls for renewed efforts to accomodate existing theory to these new realities. They also mention the manufacturer's increased reliance on independent suppliers and subcontractors as part of the "cluster" in their motivation. But being their model a price-theoretic one, with a multiproduct monopolistic firm, the emphasis is set on flexible production and responses to changes in demand. In contrast, the suppliers' approach and its influence on organizational structure constitutes the driving force behind my analysis.

A specific treatment of the prime manufacturer-supplier relationship is given in Riordan [1991]. There, he deals with a particular kind of vertical

integration: backward integration. A large downstream firm may acquire claims on small upstream firm's residual claims. Riordan's main result is to show the optimality of a certain degree of backward integration under "normal" circumstances. Backward integration operates as an incentive device, mitigating the opportunistic exercise of monopsonist power by the downstream firm. Two remarks are in order. First, my approach plays a role in situations where suppliers are important players, not mere specialized and small units as in Riordan's. Coordination of both, downstream and upstream is needed to achieve results. Second, even though equity holdings are a reality in industries like the car-manufacturing in Japan, and Riordan's paper successfully motivates their presence, I favor a different factor, which in my opinion plays a more decisive role: the existence of supplier rankings[4].

Seshadri et al [1991] view multiple sourcing as a way of preventing a variety of procurement problems. In their paper, they emphasize the bidding aspects of procurement and investigate the effects of multiple sourcing on competitive behavior prior to supplier selection. That is, they treat the number of bidders as an endogenous variable and explore ways in which the buyer can avoid the possibility of stock-out. They also provide an interesting list of arguments in favor of multiple sourcing that I proceed to describe.

1. Reduction of the non-selection risk: multiple sourcing implies that more potential suppliers may succeed in the bidding process. That itself can increase the number of companies(suppliers) interested in participating.

2. A buyer's insurance argument. The more suppliers participate the less likely stock-outs are.

3. Multiple sourcing gives the buyer the opportunity to affect suppliers' behavior over time, once the first-period contract has been awarded[5].

In their paper, Seshadri et al focus on the first two points. This paper deals briefly with the second point and concentrates on the third one: the possibility for the buyer to induce competition among suppliers over time.

---

[4]The fact that those shareholdings interlocks remain mostly unchanged through time, supports the views of those who consider them a tool to smooth communication and facilitate informational exchanges. Supplier rankings could play a more direct incentive role instead.

[5]Tirole's point: long-run buyer-seller relationships may lead to collusion between personnel across firms.

Farrell and Gallini (1988) view second-sourcing as a seller's commitment not to gouge buyers in future periods. In their two-period environment, buyers are the ones to incur specific set-up costs at the time of adopting a new technology. Key elements to their analysis are: a) the seller is a monopolist and b) there is a link between the (first period) set-up cost and the second-period demand. When price commitment is not feasible, the monopolist may be willing to give her technology away (i.e., invite competitors to enter in the second period). In my formulation, the sellers conduct specific investments. There is no monopolist in the first period, or if there is one remains a monopolists for both periods. The larger the specific cost is, the easier the adoption of a single-sourcing, in contrast with Farrell and Gallini's result where the larger the set-up cost, the more probable second-sourcing becomes.

Concerning the empirical literature, I concentrate on the automobile industry, which is where these supplier-manufacturer relations are most developed. I referred before to Asanuma's series of papers on the Japanese Automobile Industry.

The complexity behind this supplier-prime manufacturer relationship is very rich and Asanuma lists many features: long-term contracts, existence of rankings, two-vendor policy, price reductions, earlier supplier involvement in the design of components, flexibility, supplier categories..., but only the ones mentioned above are explicitly incorporated into my analysis.

On the definition of vertical integration, I follow Aoki [1990] and consider this manufacturer-suppliers relation a type of integration. He coins the term "Quasi-Integration" to describe the supplier relation in the Japanese firm. Prime manufacturers maintain a low level of operating integration through bigger reliance on subcontractors and subsidiaries. In his analysis, the subcontracting group becomes a crucial institution, described as a stratified, quasi permanent group of suppliers working for a major manufacturing company. What purposes does it serve? Rejecting the traditional explanations of being a prime manufacturer's device to extract a monopsonic rent from suppliers, or a response to the lack of capital in the emerging Japan of the '60s, Aoki [1988] suggests a more positive explanation. Productivity and informational efficiency are the reasons underlying the subcontracting group. For the time being, I do not address formally the existence of subcontracting groups. Nevertheless, this issue deserves analysis in future extensions of the model.

I present a two-vendor policy and a detailed use of a supplier ranking system. In my model, the ranking operates as a discipline device: suppliers will have an incentive to make an additional effort during the first period if this entitles them to future gains. At the same time, the two-vendor policy plays a "stopper" role in the main manufacturer's hands who has then a "guaranteed" price in the second supplier and therefore, can effectively curtail the primary supplier's advantages. I assume specific investments from both sides, facing then a double hold-up situation. On one hand, we observe the usual suppliers' underinvestment problem due to the model's uncertainty. On the other hand, we have a situation where the prime-manufacturer underinvests too, afraid of giving too much away to the supplier. The prime-manufacturer implements a two-vendor policy to limit supplier's power, shifting the manufacturer's status-quo point to a more favourable position, at a cost.[6]

The main result of this paper is to show that, depending on the a-priori distribution of supplier costs, a multiple-source system is optimal and it can beat a single-source system in terms of quickness in adopting new technologies and development of new products.

The rest of the paper is organized as follows: Section 2 develops a two-period model of the prime maufacturer-supplier relationship. Section 3 characterizes the optimal supplier structure and shows that a two-vendor policy is optimal. Finally, in Section 4 I turn to some examples and conclusions.

---

[6]Similarly, it is my view that supplier associations in the automobile-manufacturing industry prevent companies from exploiting their power due to reputational losses within the group (i.e., a big number of future contracts are on stake). Interestingly enough, supplier organization is associated with the existence of specific investments.

2 Model

In this section, I present a model with two sets of risk-neutral actors: a buyer or prime manufacturer (henceforth referred to as PM) and two potential sellers or suppliers, who provide the company with a necessary component for the production of a unit of output. Computer chips, car batteries and jet engines would be valid examples of these components. In this framework, the buyer exercises discretion over the organizational structure while suppliers may invest in cutting production costs. Furthermore, these investments are specific to the buyer.

PM has three organizational alternatives,

- Single-sourcing procurement: a long-term contract where she chooses only one supplier at the beginning and keeps him over time.

- Multiple sourcing: two suppliers are kept over time.[7]

- Competitive bidding: a system which allows, in every period, to employ the most efficient outside supplier at a competitive price.

There are two periods (see Figure 1). Production costs remain unknown until the end of each period when investments have been taken and production is on its way. Supplier $i's$ production cost in the period t is a random variable represented by $\tilde{c}_{i,t}$, where

$$\tilde{c}_{it} = c_{t-1} - e_{i,t} + \tilde{\varepsilon}_{i,t}, \quad t = 1, 2 \tag{1}$$

where c_{t-1} is the previous production cost and c_0 has a given value. $e_{i,t}$ denotes the t-period supplier's private information which, together with the initial cost, generates the actual production cost by some noise $\tilde{\varepsilon}$, with $E(\tilde{\varepsilon}_{i,t}) = 0$, $E(\tilde{\varepsilon}_{i,t}^2) = \sigma_t^2$. Furthermore, $\tilde{\varepsilon}_i$ is independent of any other variable, included other $\tilde{\varepsilon}_j, j \neq i$. Both sides, buyer and suppliers, know the distributions of ε and e. The goal of both actors, suppliers and PM, is the maximization of their respective individual expected profits.

---

[7]For simplicity, I only deal with dual sourcing. More than two suppliers would introduce the issue of diversity between the number of potential suppliers and the number of vendors employed by the manufacturer with multiple sourcing. Although interesting, that would obscure the current analysis.

One important assumption is made concerning previous production costs: At time t, c_{t-1} is common to both suppliers. I will justify this later on the basis of some transfer of knowledge favored by PM.

The following sequence of events unfold over time: First, PM offers a contract specifying the market structure to be implemented (i.e., single or multiple sourcing) and also announces the division of the second-period production volume among the suppliers according to their rank[8]. If PM selects multiple sourcing, suppliers will split the first period production in equal parts and proceed to invest in an independent and simultaneous way. The buyer cannot observe the level of suppliers' investments. Third, production follows and the cost realization, $c_{i,1}$, is publicly observed and used to elaborate a suppliers' ranking and determine the payments. The sequence of events is quite similar for the second period, with the exception of two important features: a) now production is divided according to the rank rather than to the number of suppliers, and b) *PM* makes a fixed payment to the supplier with the lowest second-period production cost.

Suppliers make investment decisions[9] to reduce production costs. These investment levels are non-verifiable and for that matter non-contractable. The idea of having investments in both periods responds to the need of continuous improvements and upgradings of the products. Automobile manufacturers usually conduct major changes in a car model every four years. During the four years the product keeps receiving smaller variations, nevertheless. Our continuous investment approach fits both situations: the step-by-step improvements carried out between major changes, and the investments for the new, uplifted versions, whose costs build up in the costs of existent models.

If the parties choose to trade, the traded good has a value for the buyer and a production cost to the supplier. Ex-ante, the buyer's value is known while the cost is not. In the absence of trade, the surplus is nil for both parties. Bargaining over the surplus generates an underinvestment situation, a usual result in the specific investments literature.

---

[8]Ex-ante, both suppliers are symmetric but after the first period, they can be ranked in terms of their previous, publicly observed, production costs.

[9]I start with 'suppliers only' making specific investments. A more appealing scenario would be one where both, suppliers and the buyer, get involved in specific investments. I intend to tackle this approach in the future, as an extension of the current model.

3 Solving the problem

I proceed now to solve the problem in a backward induction fashion. First, I calculate the gains corresponding to multiple sourcing in the last period, and compare them later with the efficiency losses derived from the initial production.

3.1 Last period

Here, I assume PM equates suppliers' production costs after one period. That is, even though suppliers have different realization costs in the first period, the buyer intervenes (spreading the information maybe or facilitating suppliers interaction) in such a way that only one common initial cost, $c_1 = min(c_{11}, c_{12})$, will be used at the time of calculating the second period production costs. In practice, this translates into the fact that the-less-eficient supplier can learn from (and catch up with) the best supplier with a one-period delay. This 'transfer of knowledge' from the best supplier to the worse does indeed occur in the so-called 'real world'. As I mentioned earlier, it is not unusual for Toyota to pass blueprints designed by one supplier to one other provider if it is the case that they are splitting Toyota's business. Recent moves by General Motors handing blueprints drawn by one supplier to other (several) suppliers have also occurred but would not fit our description: GM is simply revealing some previously private information to the general population of suppliers. Unfortunately, they seem to respond more to a non-conventional (and probably myopic) GM's strategy: sever the present contracts for all parts and open new bids in an attempt to cut present costs without considering the future implications.

Assumption 1 *The buyer is able to transfer knowledge and make her suppliers' initial costs equal in the second period.*

The justification for this assumption is the following: over time, PM is able to learn more about her suppliers and she can pass that specific knowledge to the whole supplier body, with some delay. Suppliers are aware of the process (PM absorbing, expropriating their comparative advantage) and they endogenize it at the time of making specific investments in the first

period. The winner receives a compensation for disclosing this information. The compensation comes determined by the allocated production share for the second period. In our two-vendor, two-period approach, this assumption translates into the disappearance of the cost differences between suppliers after the first period. Assumption 1 facilitates the analysis of the problem but may be relaxed without creating fundamental changes[10].

Next I assume the use of a proportional sharing rule between PM and the suppliers.

Assumption 2 *At the time of sharing production gains, the parties split the gains in accordance to some bargaining parameter, exogenously given in our framework.*

I want to focus in the organizational structure of suppliers rather than focusing in the bargaining problem and consequently, I will not model the later explicitely. I just want to note that this parameter α embodies the notion of technological strength. Suppliers with a higher technological lead over competitors enjoy higher levels of α. As we will show later on the paper, those scenarios where suppliers present higher values of α will favor the use of single-sourcing.

3.1.1   Case 1: a two-vendor approach

At the beginning of the second period, we have two suppliers ranked in terms of their production cost and indexed by t and b, *top* and *bottom* respectively. Unlike the first period, suppliers are no longer symmetric: they start with the different production allocations assigned to their rank. However, and by virtue of Assumption 1, the catching-up process has been completed and both suppliers enjoy the same initial cost c_1. The following notation is used,

- α is an exogenous bargaining parameter and denotes the supplier's share in the trade gains, $0 < \alpha < 1$.

- λ stands for the second-period production allocated to the top-ranked supplier, with[11] $\frac{1}{2} \leq \lambda \leq 1$.

---

[10] As long as the level of improvement (e.g., 85%, 95%...) was known in advance, the results would remain.

[11] We start with $0 \leq \lambda \leq 1$, but values of λ in the interval $[0, \frac{1}{2})$ would only provide perverse incentives to suppliers.

- v_t is the buyer's output value in period t. For convenience, I will use $\tilde{v}, \tilde{\tilde{v}}$ later in the paper, to denote the trade value net of second-period effort and all effort respectively. While v_t are known parameters, $\tilde{v}, \tilde{\tilde{v}}$ are random variables and include the noise. That is,
$$\tilde{v}_2 = v_2 - \tilde{c}_{2t} - e_t = v_2 - c_1 - \tilde{\varepsilon}_t.$$

- $P(e_2)$ is the probability that supplier t gets the lowest second-period cost and, therefore, wins the prize. It is a function of both suppliers' second-period efforts.

- Y is the prize offered by the buyer to the supplier with the lower second-period production cost.

- ψ denotes the effort cost function, which I will assume quadratic $\psi(e) = \frac{e^2}{2}$

At this time, suppliers face an investment decision and solve, in an independent and simultaneous way, the following problem

$$\max_{e_t} \quad E_\epsilon \left\{ \alpha\lambda(\quad v_2 - \tilde{c}_{2t}) + P(e_2)Y - \psi(e_t) \right\} \tag{2}$$

$$s.t. \quad e_t \geq 0 \tag{3}$$

$$e_t \leq \gamma c_1 \tag{4}$$

$$\max_{e_b} \quad E_\epsilon \left\{ \alpha(1- \quad \lambda)(v_2 - \tilde{c}_{2b}) + (1 - P(e_2))Y - \psi(e_b) \right\} \tag{5}$$

$$s.t. \quad e_b \geq 0 \tag{6}$$

$$e_b \leq \gamma c_1 \tag{7}$$

where the expressions (2) and (5) refer to the top-ranked and the second-ranked supplier's problem respectively[12].

The probability of supplier t getting the lowest second-period cost, P, is given by

$$P(e) \equiv Prob(c_t \leq c_b) = Prob(\varepsilon_t - \varepsilon_b \leq e_t - e_b) = G(e_t - e_b) \tag{8}$$

---

[12] As long as it is not confusing, I will simplify the notation by the use of only one index. t and b always refer to the second period, while i and j will be used only in the first period.

where G is the distribution function of the random variable $\varepsilon_t - \varepsilon_b$ and g denotes its density function. I assume g is a symmetric function $g(x) = g(-x)$ and decreasing for positive values $g'(x) < 0$ for $x > 0$.

From the original problem, it is quite straightforward to check that any solution implies the use of strictly positive effort levels. Therefore, we present here the solution to a modified problem where the only constraints are the upper-limit to effort. For the time being, I will ignore the participation and the incentive compatibility constraints. Later in this section, we will reconsider these issues.

The first-order conditions for the suppliers' efforts are

$$\alpha\lambda + \frac{\partial P}{\partial e_t}Y - e_t - \mu_t \quad = 0 \tag{9}$$

$$\alpha(1 - \lambda) - \frac{\partial P}{\partial e_b}Y - e_b - \mu_b = 0 \tag{10}$$

or,

$$\alpha\lambda + g(e_t - e_b)Y - \mu_t \quad = e_t \tag{11}$$

$$\alpha(1 - \lambda) + g(e_t - e_b)Y - \mu_b \quad = e_b \tag{12}$$

where $\mu_t, \mu_b \geq 0$ are the multipliers on the constraints and and the complementary slackness conditions are

$$(e_t - \gamma c_1)\mu_t \quad = 0, \quad (e_b - \gamma c_1)\mu_b \quad = 0 \tag{13}$$

After looking for solutions to the F.O.C. and the inequalities above, we come out with three candidates depending on the value of Y.

Scenario 1: for values of $Y < Y_t = \frac{\gamma c_1 - \alpha\lambda}{g^*}$

$$e_t^* \quad = \quad \alpha\lambda + g^*Y < \gamma c_1 \tag{14}$$

$$e_b^* \quad = \quad \alpha(1 - \lambda) + g^*Y < \gamma c_1 \tag{15}$$

$$\mu_t \quad = \quad \mu_b = 0 \tag{16}$$

where $g^* = g(e_t^* - e_b^*) = g\left(\alpha(2\lambda - 1)\right)$.

Scenario 2: for values of $Y \geq Y_b = (\gamma c_1 - \alpha(1 - \lambda))2b$

$$e_t^* \quad = \quad e_b^* = \gamma c_1 \tag{17}$$

$$\mu_b \quad = \quad \mu_t + \alpha(1 - 2\lambda) \geq 0, \quad \mu_t > 0 \tag{18}$$

Scenario 3: for values of $Y_t \geq Y < Y_b$

$$e_t^* = \gamma c_1 \tag{19}$$

$$e_b^* = \frac{4b^2\alpha(1-\lambda) + (2b-\gamma c_1)Y}{4b^2 - Y} \tag{20}$$

$$\mu_b = 0, \; \mu_t = e_b^* - e_t^* - \alpha(1-2\lambda) \geq 0 \tag{21}$$

Figure 2 summarizes the previous analysis.

To ensure the existence of an optimum, we also need to check the second-order conditions,

$$g'Y - 1 < 0 \tag{22}$$

$$g'Y + 1 > 0 \tag{23}$$

Equation (22) is always satisfied, so we are left with equation (23) as the only constraint.

Proposition 1 : *In the second period, the top-ranked supplier never invests less effort than the second-ranked.*

In this framework, the cost of effort is independent of the production level and the top supplier enjoys a larger share of the production. These two factors together determine that *top's* interest be to invest no less than his rival in specific effort.

Proof. Using the solutions of the different scenarios we obtain

$$e_t^* - e_b^* = \alpha(2\lambda - 1) \geq 0 \, in \, Scenario 1 \tag{24}$$

$$= 0 \, in \, Scenario 2 \tag{25}$$

$$= \gamma c_1 - \frac{4b^2\alpha(1-\lambda) + (2b-\gamma c_1)Y}{4b^2 - Y} > 0 \, in \, Scenario 3 \tag{26}$$

Proposition 2 : *An increase in the size of the offered prize generates, whenever possible, a positive increase in each supplier's effort, with a shrinking difference between top's and bottom's effort. For Scenario 1, the effort increases are identical.*

$$\frac{\partial e_t^*}{\partial Y} > 0 \qquad \frac{\partial e_b^*}{\partial Y} > 0 \qquad \frac{\partial (e_t^* - e_b^*)}{\partial Y} \leq 0 \tag{27}$$

To understand this result, we need to remember that the prize is assigned on the basis of second-period cost performance only and, given our transfer of knowledge assumption, both suppliers start the second period under equal cost conditions. Thus, it is reasonable to expect that increases in the second-period prize affect both efforts positively. However, each supplier starts with a different production allocation. Therefore, given the convex nature of the cost function, additional increases in the prize will translate into higher levels of effort for both suppliers but at a higher cost for the top supplier.

Proof: Suppose $\psi(e) = \frac{e^2}{2}$. See the appendix for a proof under more general conditions. Using equations (11) and (12), the optimal effort levels become

$$e_t^* = \alpha\lambda + g^*Y \tag{28}$$
$$e_b^* = \alpha(1 - \lambda) + g^*Y \tag{29}$$

where $g^* = g(e_t^* - e_b^*) = g\Big(\alpha(2\lambda - 1)\Big)$. Statement 27 becomes

$$\frac{\partial e_t^*}{\partial Y} = \frac{\partial e_b^*}{\partial Y} = g^* > 0 \qquad \frac{\partial (e_t^* - e_b^*)}{\partial Y} = 0 \tag{30}$$

implying that prize increases affect suppliers' efforts positively and in equal terms.

Concerning the buyer's second-period objective function. $PM's$ problem consists in selecting a prize, Y, such that

$$Y^* \in arg \max_Y \; \Pi_{2,d}$$

$$\Pi_{2,d} = E_{\beta,e}\Big\{(1 - \alpha)\Big(\tilde{v} + \lambda e_t^* + (1 - \lambda)e_b^*\Big) - Y\Big\} \tag{31}$$

Due to the linearity of this objective function in the quadratic cost case, the buyer faces a corner solution: no prize or a prize as large as possible (i.e. $Y^* = 0, Y^* = \bar{Y}$). Her choice depends on the sign of the linear coefficient. Furthermore, two constraints play a role to determine the optimal prize size: a non-negative cost condition and the participation constraints of the players.

Condition H: Positive prize.

$$H \equiv (1 - \alpha)g^* - 1 \geq 0$$

H represents the linear coefficient of the prize in the corresponding buyer's objective function. As I show later, those environments for which Condition H is satisfied favor the use of dual sourcing. On the other hand, situations for which the condition is not satisfied force the implementation of a single sourcing approach.

Later in the paper, I assume the error is uniformly distributed on the interval $[-b, b]$.

Proposition 3 *: Condition H behaves in the following ways*

$$\frac{\partial H}{\partial \alpha} < 0 \qquad \frac{\partial H}{\partial b} \leq 0 \qquad (32)$$

The interpretation of these results is as follows: an increase in the bargaining power of the suppliers, or in the variance (dispersion) of the distribution of errors reduces the chances of satisfying the condition and, as a consequence of this, favors the single-sourcing system.

Proposition 4 *About the optimal size of the prize,*

$$\frac{\partial \bar{Y}}{\partial \alpha} > 0 \qquad \frac{\partial \bar{Y}}{\partial b} > 0 \qquad (33)$$

If a buyer must face a more powerful supplier or a worse error distribution, the optimal prize will be larger.

$\uparrow \alpha --- \uparrow \bar{Y}$. If α, the relative bargaining power of the supplier increases, the buyer facing this supplier will offer larger prizes. Now suppliers get a larger share of the added value and effort is still costly to them. Therefore, in order to successfully motivate a supplier to increase his second-period efforts, the buyer will have to offer him higher rewards.

With these optimal efforts, the optimal prize and Condition H, the corresponding second-period buyer's and suppliers' expected profits are,

$$\Pi^*_{2,d} = (1-\alpha)\Big\{ E(\tilde{v}) + \alpha\{1 - 2\lambda(1-\lambda)\} + g^*Y^* \Big\} - Y^*$$
$$S^*_{2,t} = \alpha\lambda E(\tilde{v} + e^*_t) + PY^* - \psi(e^*_t)$$
$$S^*_{2,b} = \alpha(1-\lambda)E(\tilde{v} + e^*_b) + (1-P)Y^* - \psi(e^*_b)$$
$$\Delta_S \equiv S^*_{2,t} - S^*_{2,b} = \alpha(2\lambda - 1)\Big\{ E(\tilde{v}) + \alpha - \frac{\alpha^2}{2} \Big\} + Y^*(2P - 1)$$

3.1.2 Single-vendor approach.

By Assumption 2, the transaction surplus for the single-supplier case, is divided according to α and the following results apply,

Proposition 5 : *At the time of deciding his effort level, the single supplier invests as much as his bargaining power. PM does not provide any prize and the players obtain these expected outcomes,*

That is,

$$e_s = \alpha, \ Y = 0$$
$$\Pi_{2,s} = (1-\alpha)E(\tilde{v} + \alpha)$$
$$S_{2,s} = \alpha\Big\{ E(\tilde{v} + \frac{\alpha}{2}) \Big\}$$

Proof: This is quite straightforward. A prize here would be a net subsidy to suppliers. The buyer cannot induce competition among the participants and should discontinue the use of a prize. The remaining results follow the maximization problem.

3.1.3 The overinvestment issue.

The last result shows the presence of an underinvestment situation. This fact does not come as a surprise in a moral hazard context as the one I present here, where the agent investing specifically keeps only a proportion of the additional value. In this context, there is , nevertheless, a second scenario: the presence of overinvestment in the dual-sourcing approach. Before comparing the different alternatives' investment levels, I need to distinguish between

installed effort and **operative effort**. Installed effort is the one suppliers must pay for, while operative effort is the proportion of installed effort which goes to production. This proportion is determined by λ. To illustrate the difference, I proceed now to specify the effort levels for each alternative. For the single-sourcing case, both installed and operative effort report the same result: $e = \alpha$ is both installed and operational effort. For the two-vendor case we have

$$e_t^* + e_b^* = \alpha + 2g^*Y^* \qquad (34)$$
$$\lambda e_t^* + (1 - \lambda)e_b^* = \alpha + g^*Y^* - 2\alpha\lambda(1 - \lambda) \qquad (35)$$

where equation (34) refers to the installed effort and equation (35) denotes the operative effort. From the expressions, it is easy to conclude that the installed effort is always larger (in the two-vendor case). The comparison of operative efforts across alternatives deserves a special analysis later in the paper. I proceed now to compare single sourcing and the dual-vendor system in terms of profit and effort differences for the second period.

3.2 Second-period gains

Considering only the second period and the buyer's perspective, the use of a dual sourcing over a single-vendor policy generates additional profits if

$$\Pi_{2,d}^* - \Pi_{2,s} \equiv \Delta \geq 0 \ or \qquad (36)$$
$$(1 - \alpha)(l_d - l_s) + Y^*\{(1 - \alpha)g^* - 1\} - (1 - \alpha)\{2\alpha\lambda(1 - \lambda)\} \geq 0 \qquad (37)$$

The three components of the previous expression correspond to: a) gains on increased effort level, b) gains due to the existence of a second-period prize, and c) lost effort (i.e., operative effort smaller than installed effort). This analysis does not provide the whole picture to compare both systems. We still need to take into consideration the effect of a dual-vendor system on first-period outcomes. It is nevertheless helpful to determine the direction of the effects.

I pass now to compare efforts across alternatives. Let $\Delta(e)$ be the difference of operative efforts.

$$\Delta(e) = g^*Y^* - 2\alpha\lambda(1 - \lambda) = \beta_1 + \beta_2 - l_1 - \alpha\lambda(3 - 2\lambda) \qquad (38)$$

$$\frac{\partial \Delta(e)}{\partial \alpha} < 0 \qquad \frac{\partial \Delta(e)}{\partial b} < 0 \tag{39}$$

Thus , for situations where $\alpha \to 1$ (i.e., quite powerful suppliers) it will be better for PM to use single sourcing. Also if b is large, one supplier will be chosen too. So, there is some room for dual sourcing if the uncertainty is not very big and suppliers are not very powerful. Empirical evidence, industries with small variations...

3.2.1 Constraints

Until now we have neglected the participation constraints. We first assume the suppliers' reservation value is equal to zero.

$$S_{2,t}^* = \alpha \lambda E(\tilde{v} + e_t^*) + PY^* - \psi(e_t^*) \geq 0$$
$$S_{2,b}^* = \alpha(1 - \lambda)E(\tilde{v} + e_b^*) + (1 - P)Y^* - \psi(e_b^*) \geq 0$$

It is enough to check that *bottom's* constraint is satisfied. To show this, notice the following

$$e_t^* \in arg \max_{e_t} \; S_{2,t} \qquad \Longrightarrow \qquad S_{2,t}(e_t^*) \geq S_{2,t}(e_b^*)$$

Also, from the corresponding profit expressions $P > 1 - P$, $\lambda > \frac{1}{2}$, $e_t^* > e_b^*$ imply

$$S_{2,t}(e_b^*) > S_{2,b}(e_b^*)$$

Writing both partial results together, we obtain what we wanted to prove: as long as *bottom's* participation constraint is satisfied, *top* will participate too.

$$S_{2,t}(e_t^*) \geq S_{2,t}(e_b^*) > S_{2,b}(e_b^*)$$

In this section we have analyzed the second period actions for both approaches, single and dual sourcing. The two vendors participate in a tournament, where the winner (in terms of the second-period production cost)

gets $\bar{Y}$, a fixed amount endogenously determined by the buyer. This prize provides incentives to suppliers to get involved in specific investments also in the second period. Recall this is a two-period economy and the production cost presents an intertemporal link: yesterday's investments are important to reduce today's cost.

4   First Period

We turn now the analysis to the first period, where the buyer faces homogenous suppliers. PM must decide whether to employ both suppliers (denoted by i, j in both periods (splitting the production equally during the first period) or to employ only one of them. PM announces the organizational structure (one or two suppliers) and the second-period production allocation (based on the rank). Then suppliers select a first-period effort level, l, to maximize their expected net profits. Similarly to the previous analysis, supplier i's production cost becomes $\tilde{c}_{1i} = \tilde{\beta}_1 - l_i + \tilde{\varepsilon}_i$.

$Q(l)$ denotes the probability that supplier i gets the first-period lowest cost. That is,

$$Q = Prob(c_{1i} \leq c_{1j}) = Prob(\varepsilon_i - \varepsilon_j \leq l_i - l_j) = F(l_i - l_j) \qquad (40)$$

- ν is the buyer's first-period output value.

- c_{1i} is supplier i's production cost.

- ε is the first-period noise and F is the distribution function of the random variable $\varepsilon_i - \varepsilon_j$.

For the dual-sourcing approach, suppliers solve

$$\max_{l_i} \quad E_{\beta,\varepsilon}\left\{\frac{\alpha}{2}(\nu - \tilde{c}_{1i}) + Q(l)S_{2,t}^* + (1 - Q(l))S_{2,b}^*\right\} - \psi(l_i) \qquad (41)$$

Where the first component of the expression corresponds to the supplier's first-period expected profit: his bargaining power is α and gets 50% of the first-period production. The next two components are the expected second-period profit depending on the supplier's position within the first-period rank. The last component is the cost of investing in effort level l.

We can express the single-vendor approach in similar terms,

$$\max_{l_i} \quad E_{\beta,\varepsilon}\left\{\frac{\alpha}{2}(\tilde{\nu} + l_i) + Q(l)S_{2,s}\right\} - \psi(l_i) \qquad (42)$$

At the time of comparing the different alternatives, I split the dual-sourcing scenario in two depending on the presence of a prize. Therefore

we compare three alternatives: single sourcing (S), dual sourcing (D) and dual sourcing with prize (DY).

Solving the maximization problem, we obtain the first-order conditions to the suppliers' problem for the three scenarios,

$$(D),(DY) \quad \frac{\alpha}{2} + \frac{\partial Q}{\partial l_i} \Delta s + Q \frac{\partial \Delta s}{\partial l_i} + \frac{\partial S^*_{2,b}}{\partial l_i} - l_i = 0 \tag{43}$$

$$(S) \quad \frac{\alpha}{2} + \alpha Q(l) + \frac{\partial Q}{\partial l_i} S_{2,s} - l_i = 0 \tag{44}$$

Similar conditions could be derived for player j One important difference with respect to the second-period analysis is that both suppliers are ex-ante identical. Therefore, in equilibrium $l_i = l_j, Q(l) = Q(0) = \frac{1}{2}$ and the solution is characterized by the following first-order conditions:

$$(DY) \qquad \alpha + f(0)(\Delta s) - g^2 \bar{Y} \frac{\partial \bar{Y}}{\partial l} = \quad l$$

$$(D) \quad \alpha + f(0)\alpha(2\lambda - 1)\left\{ E(\tilde{v}) + \frac{\alpha}{2} \right\} = \quad l$$

$$(S) \qquad \alpha \left\{ 1 + f(0)\{ E(\tilde{v}) + \frac{\alpha}{2} \} \right\} = \quad l$$

The optimal effort levels come from solving

$$(S) \quad l_s = \frac{\alpha \left\{ 1 + f(0)\{ E(\tilde{v}) + \frac{\alpha}{2} \} \right\}}{1 - \alpha f(0)} \tag{45}$$

To ensure the existence of an optimum, we also need to check the second order conditions,

$$(DY) \qquad f(0)\frac{\partial \Delta s}{\partial l} - 2 < 0$$

$$(D) \quad \alpha(2\lambda - 1)f(0) - 1 < 0$$

$$(S) \qquad \alpha f(0) - 1 < 0$$

where

$$\Delta s = (S^*_{2,t} - S^*_{2,b}) = \alpha(2\lambda - 1)\left\{ E(\tilde{v}) + \alpha - \frac{\alpha^2}{2} \right\} + \bar{Y}(2P - 1) \tag{46}$$

and

$$\frac{\partial \bar{Y}}{\partial l} = \frac{-1}{g^*} < 0 \tag{47}$$

From these equations, we can check that our technical assumption guarantees the fulfilment of the SOC.

Assumption 3 *In terms of the variability of the error distribution, we make the following assumption*
$$1 < 2b < \beta_2$$

The optimal effort levels come from solving the first order conditions,

$$l_{dY} = \frac{\alpha(1-\lambda) + \beta_1 + \beta_2 + \alpha(2\lambda-1)f(0)\Big\{\{E(\tilde{v}) + \alpha(1-\frac{\alpha}{2})\} + (1+C)(\beta_1 + \beta_2 - c}{2 + \alpha(2\lambda-1)f(0)C} \tag{48}$$

$$l_d = \frac{\alpha\Big\{1 + (2\lambda-1)f(0)\{E(\tilde{v}) + \frac{\alpha}{2}\}\Big\}}{1 - \alpha(2\lambda-1)f(0)} \tag{49}$$

where

$$C = \frac{2b}{2b - \alpha(2\lambda-1)}$$

4.1 PM's problem

Finally, we focus our attention on the buyer's objective function. In the first period, $PM's$ problem consists in selecting λ such that

$$(D, DY)\max_{\lambda} \ (1-\alpha)\{E(\tilde{v}) + l^*\} + \Pi_{2,d} \tag{50}$$

FOC

$$(1-\alpha)\left(2\frac{\partial l^*}{\partial \lambda} + \bar{Y}\frac{\partial g^*}{\partial \lambda} + g^*\frac{\partial \bar{Y}}{\partial \lambda} + 2\alpha(2\lambda-1)\right) - \frac{\partial \bar{Y}}{\partial \lambda} = 0 \tag{51}$$

And from this, we can find the optimal allocation of the production for the dual sourcing case.

Now we proceed to compare both approaches.

5 Inter-temporal Comparison

I compare first the single-sourcing case with dual sourcing and no prize.

Proposition 6 : *The adoption of dual-sourcing always implies the use of a positive prize.*

The previous result indicates that dual-sourcing is always dominated by single sourcing in those regions where the corner solution is to offer no prize. Only for those scenarios where the buyer implements dual sourcing with a positive prize, will a two-vendor approach have a chance to prevail over single sourcing.

Proof: It is straightforward. Consider $Y = 0$. From the inspection of the optimal effort expressions, and the nature of λ (i.e., $\lambda < 1$), it follows

$$l_s > l_d, \quad e_s > e_d \tag{52}$$

That is, a single-vendor system implements larger (operative) effort levels in both periods. At the time of comparing the organizational alternatives, the buyer is only interested in suppliers' efforts and her payments (which are zero). Obviously, single sourcing is preferred when the optimal dual-sourcing approach calls for the use of no prize. Proposition 6 reduces the analysis to the study of scenarios where Condition H is satisfied.

Now we proceed to compare dual sourcing with positive prize versus single sourcing. Thanks to the prize, the buyer can achieve higher levels of effort from the suppliers. These effort increases may be large enough to compensate (the buyer) for the use of dual sourcing, that is for the efficiency loss due to the presence of economies of scale and the prize given to the winner.

Proposition 7 *The presence of strong suppliers and/or cost distributions with high variance favor single sourcing. That is,*

$$\frac{\partial l_d - l_s}{\partial \alpha} < 0, \quad \frac{\partial l_d - l_s}{\partial b} < 0 \tag{53}$$

For 'strong suppliers' I understand here suppliers with high values of α, their bargaining parameter.

6 Conclusions

If we analyze the ratio added value over sales, as a rough measure of vertical integration, we observe a trend in many industries to move closer to lower degrees of operating integration. A greater level of subcontracting emerges then as an alternative to vertical integration, and pushes us to search for explanations of existing purchasing structures. In particular, I refer to a multiple supplier scenario in this paper: a short-term inefficiency (the use of two suppliers splitting production) may help to achieve a more efficient solution in the long-run. Implementing a dual-source procurement policy, the prime manufacturer mitigates the possibility of being held up by a single supplier and can induce competition among existing suppliers which may prove crucial in the periods to come. The situation that I describe is favored by contexts in which both suppliers get involved in specific investments. The two-vendor policy allows the firm to go ahead with the necessary investments without the fear of being hold-up. On the other hand, reputation considerations[13] refrain the PM from holding-up the suppliers.

Further work is needed in terms of making the bargaining parameter a function of the number of existent suppliers. We could think that the number of suppliers works in favor of the buyer, increasing her bargaining power or, on the contrary, more suppliers could mean a stronger supplier coalition, able to obtain more concessions from a buyer. That is,

$$\frac{\partial \alpha(n)}{\partial n} > 0 \quad or \quad \frac{\partial \alpha(n)}{\partial n} < 0 \tag{54}$$

Also, the number of suppliers may be an endogenous variable. We have simplified the analysis to a dual sourcing approach but when we take into account the presence of economies of scale and investment costs, we may calculate an optimal number of suppliers to be kept by the manufacturer.

Finally, we could bring new elements into the analysis: a competitive bidding approach and buyer's specific investments. At the end of the first period, the buyer could consider the possibility of entry by outsiders. This would aggravate the underinvestment problem but could be preferred by

---

[13]In the auto-manufacturing industry, it is frequently observed the presence of supplier groups. Members of these groups make investments based on the contractor's reputation.

the buyer as long as the improvement coming from the new supplier be significantly large. The external threat might serve as a disciplinary device for the existent suppliers too.

Concerning specific investments, I only considered suppliers' specific investments in the model. We could think of a prime manufacturer able to affect the probabilities of product success by investing specifically. Now, there would be a double hold-up situation, with each side underinvesting.

7   Appendix

Proposition 2: An increase in the size of the prize generates positive increases in each supplier's effort, with a shrinking difference between *top's* and *bottom's* effort.

Proof: Differentiating equations (11) and (12), and setting $d\lambda = d\alpha = 0$, we get the following system of equations,

$$\begin{pmatrix} g'Y - \psi''(e_t) & -g'Y \\ g'Y & -g'Y - \psi''(e_b) \end{pmatrix} \begin{pmatrix} \frac{\partial e_t^*}{\partial Y} \\ \frac{\partial e_b^*}{\partial Y} \end{pmatrix} = \begin{pmatrix} -g \\ -g \end{pmatrix}$$

Or $A \times e = -g$ with

$$|A| = \psi''(e_t)\{g'Y + \psi''(e_b)\} - g'Y\psi''(e_b) > 0 \tag{55}$$

The positive sign from the SOC and the specifications of g and ψ. Solving the system, we obtain

$$\frac{\partial e_t^*}{\partial Y} = \frac{|A_1|}{|A|} = \frac{g\psi''(e_b)}{|A|} > 0 \tag{56}$$

$$\frac{\partial e_b^*}{\partial Y} = \frac{|A_2|}{|A|} = \frac{g\psi''(e_t)}{|A|} > 0 \tag{57}$$

And concerning the difference in optimal efforts,

$$\frac{\partial(e_t^* - e_b^*)}{\partial Y} = \frac{g\{\psi''(e_b) - \psi''(e_t)\}}{D} \leq 0 \tag{58}$$

The negative relation comes from $\psi''' \geq 0$, $e_t^* \geq e_b^*$ and

$$D = \psi''(e_b)\{-g'Y + \psi''(e_t)\} + g'Y\{g'Y - \psi''(e_t)\} > 0 \tag{59}$$

INFORMATION

Cost distributions are known

c_i, c_j are publicly observed.

Transfer of knowledge

Dual suppliers start with the same cost distribution

c_{2i}, c_{2j} become known

ACTIONS

First Period

The buyer sets lambda and a prize

Suppliers make specific and simultaneous investments, l

A ranking is established

Payments follow

Production occurs

Second Period

The buyer sets the prize

Lambda is assigned

More specific investments, e

Prize is assigned

Payments follow

Production occurs

$t=0$ $t=1$ $t=2$
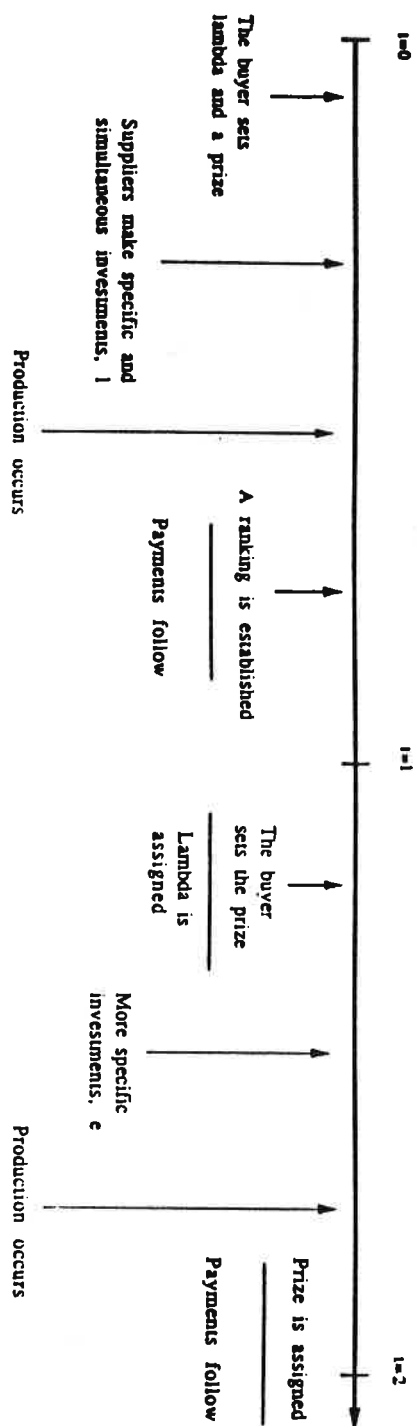
Figure 1

Figure 1: Time line of the model

Density Function

Density function

$\varepsilon_r - \varepsilon_b$
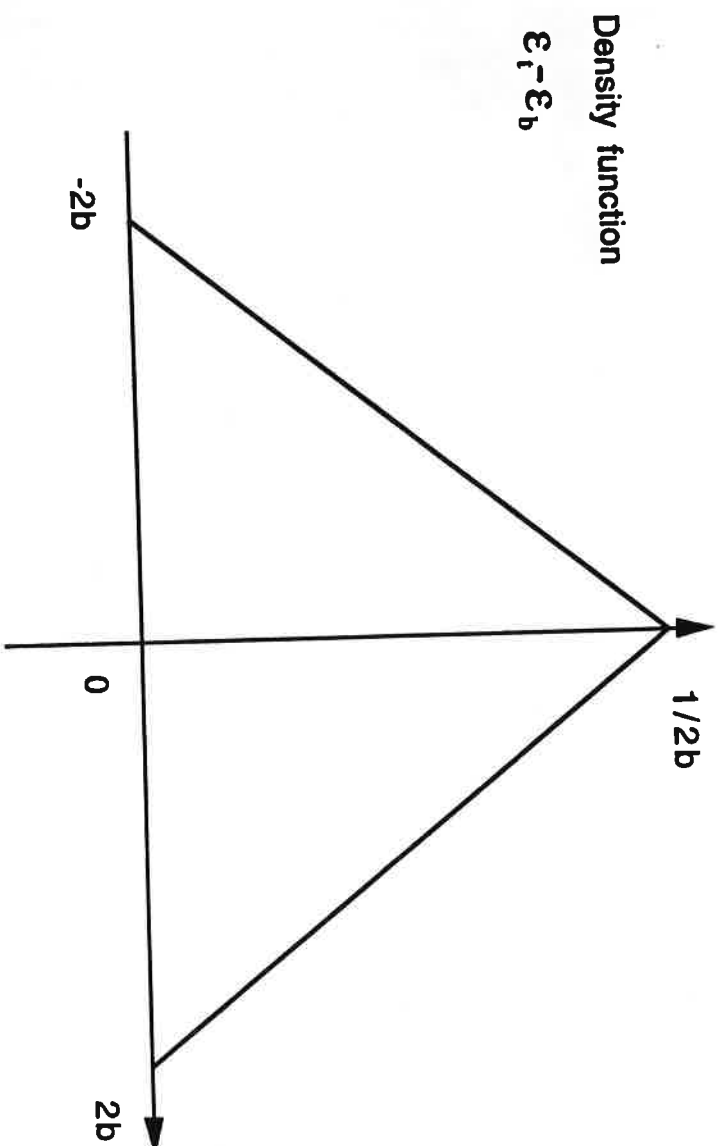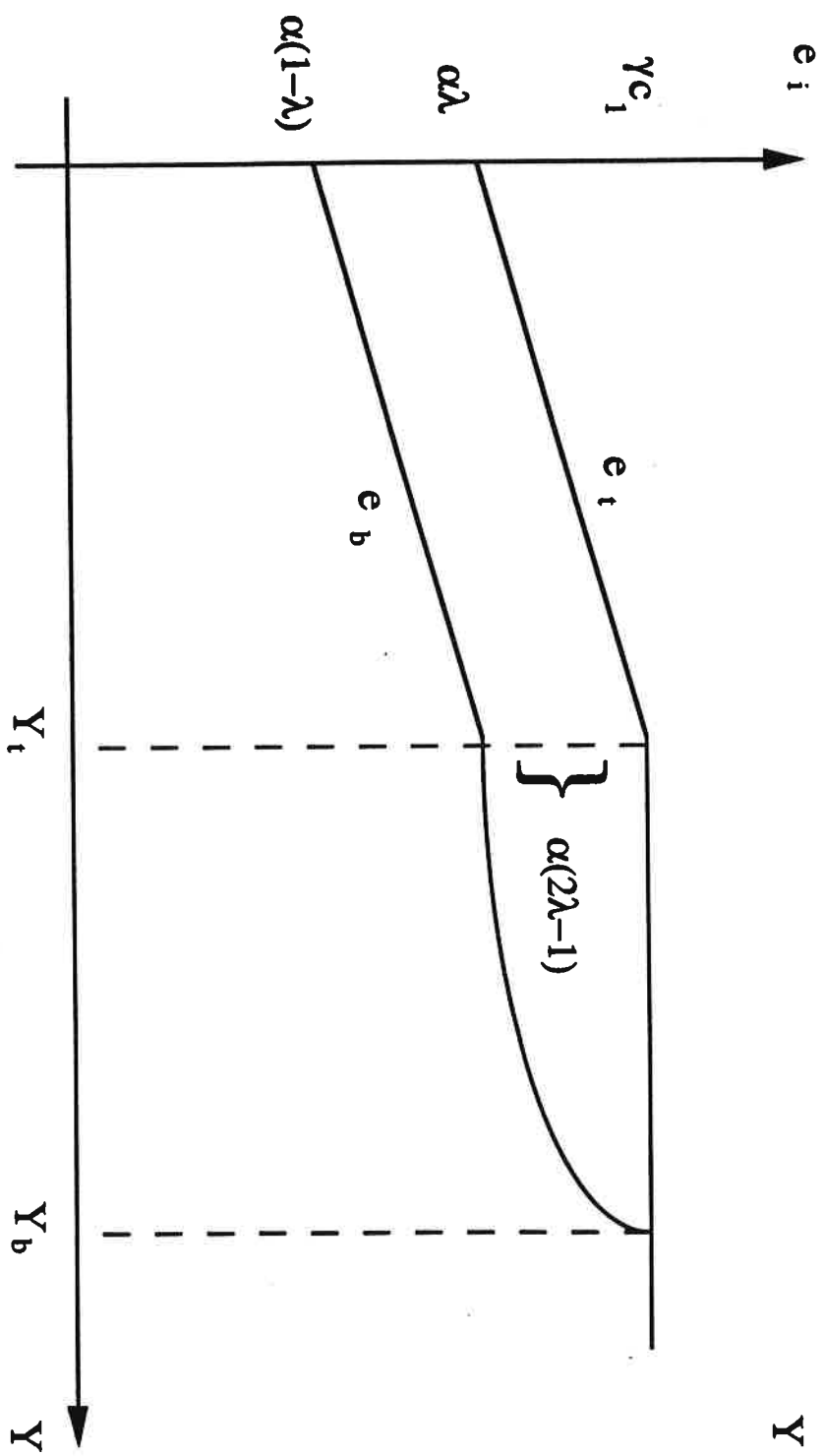

$g(x) = 1/2b \ (x/2b +1)$ if $x<0$

$g(x) = 1/2b \ (-x/2b +1)$ if $x>0$

Suppliers' efforts

References

[1] Alchian, A. and H. Demsetz (1972). "Production, information Costs, and Economic Organization", *American Economic Review*, 62 , pp. 777-795.

[2] Aoki, M. (1988). Information, Incentives, and Bargaining in the Japanese Economy, *Cambridge University Press*, Cambridge.

[3] Aoki, M. (1989). "The Nature of the Japanese Firm as a Nexus of Employment and Financial Contracts: An Overview", *Journal of the Japanese and International Economies* 3, pp. 345-366.

[4] Aoki, M. (1990). "Toward an Economic Model of the Japanese Firm", *Journal of the Economic Literature* 28, pp. 1-27.

[5] Arrow, K. J. (1974). *The Limits of Organization*, New York: W. W. Norton.

[6] Arrow, K. J. (1985). "Informational Structure of the Firm", *American Economic Review*, 75, pp. 303-307.

[7] Asanuma, B. (1988). "Japanese Manufacturer-Supplier Relationships in International Perspective: The Automobile Case", *Working Paper 8, Kyoto University*.

[8] Asanuma, B. (1989). "Manufacturer-Supplier Relationships in Japan and the Concept of Relation-Specific Skill", *Journal of the Japanese and International Economies* 3, pp. 1-30.

[9] Geanokoplos, J. and P. Milgrom (1985). "A Theory of Hierarchies Based on Limited Managerial Attention", Cowles Foundation Discussion Paper No. 775.

[10] Grossman, S.J.and O.Hart (1986). "The Costs and Benefits of Ownership: a Theory of Vertical and Lateral Integration", *Journal of Political Economy*, 94, pp. 691-719.

[11] Katz, M.L. (1989). *Handbook of Industrial Organization*, Vol. 1, North-Holland. (Chapter 11).

[12] Kawasaki, S. and McMillan, J. (1987). "The Design of Contracts: Evidence from Japanese Subcontracting",*Journal of the Japanese and International Economies* 1, pp. 327-349.

[13] Milgrom, P. and J. Roberts (1989). "The Economics of Modern Manufacturing: Technology, Strategy and Organization". *American Economic Review*, 80, 511-528.

[14] Riordan, M. H. (1991). "Ownership without Control: Towards a Theory of Backward Integration", *Journal of the Japanese and International Economies*, 5, pp.101- 119.

[15] Seshadri, S., K. Chatterjee and G. Lilien (1991). "Multiple Source Procurement Competitions", *Marketing Science*, vol 10, 3, pp. 246-263.

[16] Tirole, J. (1988). *The Theory of Industrial Organization.* Cambridge, MA: The MIT Press.

[17] Williamson, Oliver E. (1975). *Markets and Hierarchies: Analysis and Antitrust Implication*, New York: Free Press. (Chapters 8 and 9).