

**"INFORMATION DISCLOSURE  
AND  
TECHNOLOGY CHOICE"**

**by**

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# Information Disclosure and Technology Choice

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## **Abstract**

Is it in the interest of a firm to disclose information on its technology or cost structure? Should another firm take such information into account in its market decisions? In what kind of industry should we expect firms to exchange information on their costs? How does it affect the firms' initial choice of technology? These are the questions that are addressed below. The crucial difference with previous work on this problem—Fried (1984), Gal-Or (1986), Li (1985) and Shapiro (1986)—is that a firm's cost structure, instead of being exogenously given, results from a strategic decision. This leads to radically different predictions.

# 1 Introduction

The analysis presented in this paper deals with the interfirm exchange of private information on technology choice and cost structures. The model focuses on the extreme case where the firms have complete control over their cost structures. This situation might correspond to a mature industry in which the firms can choose between a few well known production processes, each process leading to a different cost structure (e.g., a different ratio of fixed and variable costs). Previous work on the disclosure of cost information—e.g., Fried (1984), Gal-Or (1986), Li (1985) and Shapiro (1986)—focuses on the opposite case: in that literature, the firms don't have any control over their costs. This might correspond to a new industry in which nothing is known about production processes.

The interplay between technology choice and information disclosure is emphasized. In the work of Fried (1984), Gal-Or (1986), Li (1985), and Shapiro (1986), this interaction does not play a role: A firm's cost curve, instead of resulting from a strategic decision, is given exogenously from a probability distribution. Thus, a firm's cost is (probabilistically) the same whether or not the firms have agreed to share cost information. In this paper, the firms choose different cost structures depending on their competitor's ability to observe—which in turn depends on the firms disclosure policies. When the competitor is not able to observe, a firm simply chooses the most efficient technology for the quantity that it is going to produce. When the competitor is able to observe, however, the firm recognizes the strategic impact of its technological choice on the competitor's market behavior. Depending on the nature of the market competition, the firm may decide to increase or decrease its investment in order to make its competitor less aggressive on the market. This is one of the central themes in the strategic precommitment literature—e.g., Brander and Spencer (1983), Bulow et al (1985), Dixit (1980), Fudenberg and Tirole (1984), Kreps and Scheinkman (1983), and Spence (1977).

In some industries, technology choices (and hence, cost structures) are intrinsically observable. For example, it seems reasonable to assume that, in the airline industry, the number of planes and their type, as well as the location and capacity of the ground facilities, are observable by competitors. In many industries however, technology is

not so visible: the observability of a firm's cost structure depends in large part on the firms' voluntary disclosure of information. The object of this paper is to endogenize the observability of the firms' cost structures for those industries in which technology is not intrinsically visible. The analysis considers the disclosure of verifiable information. In this context, verifiable information corresponds to the disclosure of hard evidence about the physical design of the production process and its implementation (e.g., the number of machines, their size and brandname). Accounting information can also constitute evidence, to the extent that it can be audited and made available to the competitor.

One remark is in order. It concerns the disclosure of *proprietary* technological information. A firm discloses information on its technology to make its competitor less aggressive on the market. However, proprietary information on the firm's technology may allow the competitor eventually to improve its own technology—which would make it more aggressive on the market. The tradeoff is not clear. Evidence on the exchange of proprietary technological information is documented by von Hippel (1987). This situation is not considered here. We study the disclosure of information about strategic decisions (e.g., the amount invested in cost-reducing R&D); the disclosure of proprietary technological information implies the existence of some element of exogenous information (e.g., the random outcome of a firm's R&D effort).

The analysis of the exchange of information between firms has important antitrust implications. Antitrust authorities have long been worried about its meaning and welfare implications. A general discussion of these issues can be found in Scherer (1980) and Vives (1990). There is a vast literature that models the activities of trade associations and firms' incentives for the dissemination of their private information. Besides the four papers mentioned above (by Fried, Gal-Or, Li and Shapiro) that study the exchange of cost information, there are papers on the exchange of information about demand conditions; e.g., Clarke (1983), Gal-Or (1985), Novshek and Sonnenschein (1982), Ponssard (1979), Vives (1984), and Vives (1990). The literature stresses the importance of the type of market competition (prices or quantities; collusion or competition) and the nature of the information to be transmitted (information about demand conditions or cost structures and, in the latter case, whether or not costs are correlated). This paper is a contribution to that literature. It points to the effect

that the exchange of information about cost structures has on the firms' initial choice of processes and technologies.

The general structure of the problem analyzed in this paper is as follows: In period one, the firms decide whether or not they will disclose verifiable information on their cost structure. In period two, the firms simultaneously select a technology (a cost structure). Firms are not able to observe their competitor's choice unless their competitor had decided to disclose. Finally, in period three, the firms make market decisions (prices or quantities). This situation is to be contrasted with the situation considered by Fried (1984), Gal-Or (1986), Li (1985), and Shapiro (1986) where, in period two, the firms privately observe their exogenously given cost structure.

Shapiro (1986) considers the case in which the firms can *cooperatively* agree on a common disclosure policy. He finds that when the last period market competition is modeled as a Cournot duopoly, the firms do agree to exchange information on their costs. The present model leads to the reverse prediction: it is in the interest of the firms *not to* exchange information. Gal-Or (1986) considers the case in which the firms *unilaterally* commit to their disclosure policy. For the case of Cournot competition, she finds that full disclosure is a dominating strategy. Thus, the firms can achieve non-cooperatively the same outcome as in Shapiro's model. For the case of Bertrand competition, she finds that no disclosure is a dominating strategy; the firms are better off when information is not revealed. In the model presented in this paper, disclosure will also be shown to be dominating for the case of Cournot competition. However, disclosure makes the firms worse off than if cooperative agreements (not to disclose information) can be enforced. Thus, in this paper, the disclosure game has the payoff structure of a prisoner's dilemma. For the case of Bertrand competition, depending on the value of the problem parameters it can be dominating to disclose or not to disclose; however, the firms are always better off when information is disclosed.

More generally, this paper can be viewed as a game theoretic study on the disclosure of *endogenous* information—i.e., information on the actions of the players. It is to be contrasted with the extensive literature that deals with the disclosure of *exogenous* information—i.e., information on the state of the world. In that literature, the analysis of the exchange of cost and demand information between firms (references

above) is concerned with *ex ante* incentives for disclosure (i.e., situations in which the firms commit to disclosure before privately observing the actual value of their cost). Ex post incentives for the disclosure of exogenous information are studied by Grossman (1981), Milgrom (1981), Milgrom and Roberts (1986), and Okuno-Fujiwara et al (1990). The present analysis deals with the disclosure of verifiable endogenous information. The exchange of cost information between firms is emphasized, but the approach has general applicability.<sup>1</sup>

The remainder of the paper is organized as follows: The model, notation and assumptions are introduced in Section 2. Some useful results on the last two stages of the game (technology choice and market competition) are established. Sections 3 analyzes the firms' incentives for information disclosure. The outcome of the disclosure game critically depends on whether the market competition exhibits strategic substitutes or strategic complements. The paper is concluded, in Section 4, with a general discussion of the difference between the strategic disclosure of exogenous and endogenous information.

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<sup>1</sup>There is a related literature on the (payoff irrelevant) communication of unverifiable information (e.g., Crawford and Sobel, 1982). It is argued in de Groot (1990) that the disclosure of unverifiable information does not affect the outcome of a game when the revealed information is entirely endogenous.

## 2 Model and preliminary results

The following three stage duopoly model is considered: The firms are indexed by  $i$  or  $j$ . In stage one, the firms simultaneously decide whether or not to disclose perfect and verifiable information about their second-period technology choice. In stage two, the firms simultaneously select a technology  $k_i$  in the set of technologies  $\mathcal{K}_i \subset R$ . If firm  $i$  has decided, in stage one, to disclose information, then firm  $j$  observes  $k_i$ ; otherwise  $k_i$  is not observable by firm  $j$ . Finally, in stage three, the firms simultaneously select market decisions,  $x_i \in \mathcal{X}_i \subset R$  (e.g., price or quantity). The payoff function is denoted by  $\pi_i(x_i, x_j, k_j)$ ; disclosure is performed at no cost. Let  $\hat{x}_i(x_j, k_i) = \arg \max_{y \in \mathcal{X}_i} \pi_i(y, x_j, k_i)$ ; for fixed  $k_1$  and  $k_2$ ,  $\hat{x}_1$  and  $\hat{x}_2$  represent the usual reaction functions of the market subgame.

The analysis is restricted to pure strategies. The equilibrium concept is (roughly) that of *sequential* equilibrium (Kreps and Wilson, 1982), or *Bayesian* perfect equilibrium (Fudenberg and Tirole, 1991), which requires the explicit consideration of the players' beliefs.<sup>2</sup> Since there is no asymmetry of information *ex ante*, and since the players are restricted to pure strategies, their beliefs (whenever Bayes' rule applies) consist of single values; e.g., if player  $i$  does not observe  $k_j$  in equilibrium, the only consistent belief about  $k_j$  (on the equilibrium path) is that  $k_j$  equals the equilibrium value  $k_j^*$  with probability 1. In what follows, I will abuse terminology by saying that player  $i$ 's belief about player  $j$ 's technology is given by some  $k_j$ .

In order to study the firms' incentive for disclosure, we need to capture the effect that changes in the second-period technology choice have on the third-period mar-

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<sup>2</sup>It is interesting to note that, even though there is no asymmetry of information *ex ante*, the concept of subgame perfection is not strong enough to rule out unintuitive outcomes. To see this, consider the two-stage technology and market subgame where observability is exogenously specified. When both firms are observed, the set of sequential equilibria coincide with the set of subgame perfect equilibria; when both firms are not observed, sequential equilibria coincide with Nash equilibria. However, when one of the firms is observed and the other is not, the game does not include any proper subgame. Hence, the set of subgame perfect equilibria coincides with the set of Nash equilibria. In those equilibria, the firm that is observing can threaten to do something drastic on the market, unless the other chooses a particular technology. Such equilibria are ruled out by sequential rationality; however, they are not ruled out by subgame perfection.

ket subgame. If the market subgame exhibits multiple (pure strategy) equilibria, we need to select one particular market equilibrium for each possible value of  $k_i$  and  $k_j$ . Let  $X_i^*(k_i, k_j)$  denote the (selected) pure strategy equilibrium in the market subgame when  $k_i$  and  $k_j$  are observed by both firms. Whether technology is observed or not, firms have correct equilibrium beliefs about the technology choice of their competitor. Thus, the market stage decisions are always in equilibrium for the equilibrium technology choices; i.e., if  $k_i^*$  and  $k_j^*$  denote the equilibrium technology decisions, the equilibrium market decisions are given by  $X_i^*(k_i^*, k_j^*)$  and  $X_j^*(k_j^*, k_i^*)$  respectively. When technology is observed by both firms, then  $X_i^*(k_i, k_j)$  gives firm's  $i$  equilibrium decision in any market subgame; i.e., it applies off the equilibrium path as well. Let  $\Pi_i^*(k_i, k_j) = \pi_i(X_i^*(k_i, k_j), X_j^*(k_j, k_i), k_i)$  denote the firm's  $i$  payoff as a function of the technology choice  $(k_i, k_j)$  when the market decisions  $(x_i, x_j)$  are in equilibrium.

The solution to the above three stage duopoly model is analyzed in Section 3. The remainder of this section introduces some further notation and assumptions, and establishes some useful properties of the two-stage subgame corresponding to periods two and three of the overall game. In that subgame, the observability of a firm's technology is exogenously specified. Different versions of the subgame are to be distinguished depending on whether or not firms are able to observe their competitor's technology.

When technology is observed by both firms, the equilibrium payoff in the market subgame, for any  $(k_i, k_j)$ , is given by  $\Pi_i^*(k_i, k_j)$ . For any  $k_j$ , firm  $i$ 's best-response in the technology stage is given by

$$K_i^O(k_j) = \arg \max_{l \in \mathcal{K}_i} \Pi_i^*(l, k_j).$$

$K_i^O$  is called the *technology best-response when observed*. Next, consider the case where player's  $i$  technology is not observable. Let

$$K_i^N(k_j) = \{k_i \in \mathcal{K}_i : \exists \quad x_i \in \mathcal{X}_i, x_j \in \mathcal{X}_j \text{ such that}$$

$$(k_i, x_i, x_j) \text{ solves } \max_{k'_i, x'_i} \pi_i(x'_i, x_j, k'_i) \text{ and } \max_{x'_j} \pi_j(x'_j, x_i, k_j)\}.$$

$K_i^N$  is called the *technology best-response when not-observed*. Note that strictly speaking,  $K_i^O$  is an optimization concept, whereas  $K_i^N$  is an equilibrium concept.

A few observations are in order. First, note that  $k_1 \in K_1^N(k_2)$  implies that the market decisions satisfy  $x_1 = X_1^*(k_1, k_2)$  and  $x_2 = X_2^*(k_2, k_1)$ . When one of the firms is not observing, it is rational for the other firm to minimize its cost. Let  $\hat{k}_i(x_i, x_j) = \arg \max_{l \in \mathcal{K}_i} \pi_i(x_i, x_j, l)$  denote the cost-minimizing technology choice as a function of the market decisions  $(x_i, x_j)$ ;  $k_1 \in K_1^N(k_2)$  implies that  $k_1 \in \hat{k}_1(X_1^*(k_1, k_2), X_2^*(k_2, k_1))$ . Finally, by construction, if  $k'_1 \in K_1^O(k_2)$  and  $k''_1 \in K_1^N(k_2)$ , then  $\Pi_1^*(k'_1, k_2) \geq \Pi_1^*(k''_1, k_2)$ .

For a given specification of observability, the firms' choice of technology in a sequential equilibrium are given by a fixed point of the relevant technology best-responses. For example, when firm 1 is observed and firm 2 is not, the technology choices  $k_1^*$  and  $k_2^*$  must satisfy  $k_1^* \in K_1^O(k_2^*)$  and  $k_2^* \in K_2^N(k_1^*)$ . This is stated formally, for this special case, in the following lemma; the argument for the other cases is identical. A proof, which requires the explicit consideration of beliefs, is given in Appendix A.

#### LEMMA 1: (first-stage best responses)

*If firm's 1 technology is observed by firm 2 and firm's 2 technology is not observed by firm 1, then a pair of technologies  $k_1 \in \mathcal{K}_1$ ,  $k_2 \in \mathcal{K}_2$  can be part of a sequential equilibrium if and only if  $(k_1, k_2)$  is a solution to  $k_1 \in K_1^O(k_2)$  and  $k_2 \in K_2^N(k_1)$ .*

In order to proceed with the analysis we need to impose further structure on the market subgame. Typically, one would impose some structure on the payoff function,  $\pi_i$ , either based on a specific functional form, or based on differentiability, concavity and/or supermodularity assumptions. Since this paper focuses on the interaction between the first two stages of the game (information disclosure and technology choice), it is natural to make assumptions on the third stage equilibrium instead. The assumptions that follow are standard properties of duopoly models that can be shown to hold under a variety of assumptions. In particular, it can be checked, from the equilibrium payoffs derived by Singh and Vives (1984), that the assumptions hold for both price and quantity competition in case of differentiated products with a linear demand. The assumptions also hold for differentiable payoffs under standard assumptions on the second derivatives, as posed for example by Brander and Spencer (1983), Bulow et al (1985) and Fudenberg and Tirole (1984).

**ASSUMPTION 1:**  $\pi_i$  is nonincreasing in  $x_j$  for all  $i$ .

This first assumption is essentially a notational convention. For example, in case of price competition, a decrease in price should hurt the competitor; thus, in order to satisfy assumption 1, we have to assume that  $x_j$  is minus the price.

**DEFINITION:** When  $\hat{x}_i$  is nonincreasing in  $x_j$  for all  $k_i \in K_i$ ,  $i = 1, 2$ , we say that the market subgame exhibits *strategic substitutes*; when  $\hat{x}_i$  is nondecreasing in  $x_j$  for all  $k_i$ ,  $i = 1, 2$  we say that the market subgame exhibits *strategic complements*.

This terminology is introduced by Bulow, Geanakoplos, and Klemperer (1985) as a property of the cross-partial derivative of the payoff function. Fudenberg and Tirole (1984) make direct reference to the monotonicity of the reaction functions. In this paper, the importance of the distinction between strategic substitutes and strategic complements stems from the following well-known comparative statics property (posed here as an assumption).

**ASSUMPTION 2:**  $X_i^*(k_i, k_j)$  is nondecreasing in  $k_i$ . When the market game exhibits strategic substitutes,  $X_i^*$  is nonincreasing in  $k_j$ ; in case of strategic complements the reverse holds.

Intuitively, the first part of the assumption implies that the set of technologies is ordered so that an increase in  $k_i$  can be interpreted as a decrease in marginal cost. Hence, an increase in  $k_i$  induces a more aggressive behavior on the market (increase in  $x_i$ ). If the market subgame exhibits strategic substitutes, the increase in  $x_i$  induces in turn a decrease in  $x_j$  which, after adjustment of the equilibrium, yields an increase in  $X_i^*$  and a decrease in  $X_j^*$ . In case of strategic complements, the increase in  $x_i$  induces an increase in  $x_j$  and, after adjustment of the equilibrium, an increase in  $X_j^*$ . For differentiable payoffs, this property can be shown to hold for locally stable equilibria under a number of standard assumptions (see Bulow et al, 1985). It also holds for the largest and the smallest pure strategy equilibria in supermodular games (see Milgrom and Roberts, 1990). Finally, it can be shown to hold under very general assumptions if the selection of equilibria for different values of  $(k_1, k_2)$  is performed by iterated play (see Lippman et al, 1987; Sobel, 1988).

**ASSUMPTION 3:** In the symmetric case, the equilibrium market decision  $X_i^*(k, k)$  is non-decreasing in  $k$ .

Assumption 3 could be called *dominance of own effect*: It says that in the symmetric case (i.e.,  $k_i = k_j = k$ ), the *own* technology decision has the determinant effect on the *own* equilibrium market decision.

**ASSUMPTION 4:** The second-stage equilibrium profit  $\Pi_i^*(k_i, k_j)$  is quasi-concave in  $k_i$  and decreasing in  $k_j$ .

The first part of assumption 4 implies that given the technology of the competitor  $k_j$ , the profit of firm  $i$  is lower, the further its technology choice is from the best-response  $k_i = K_i^O(k_j)$ . The second part says that firm's  $i$  equilibrium profit on the market decreases when the competitor invests more (chooses a larger  $k_j$ ) in technology.

The last assumption concerns the technology best-responses. To simplify the notation, it is assumed that the sets  $K_i^N$  and  $K_i^O$  are singletons; the unique element is denoted by the set itself.

**ASSUMPTION 5:**  $K_i^N$  and  $K_i^O$  are continuous and non-increasing for  $i = 1, 2$ .

The continuity assumption is purely technical (see the proofs of Propositions 1 and 2 in Section 3). The assumption that the technology reactions are non-increasing deserves further comment. From an economic point of view, it amounts to the assumption that the firms' technology investments are strategic substitutes. Thus, the best-response to an increase in investment by the competitor is a decrease in investment. This property depends on the equilibrium payoff of the market subgame,  $\Pi_i^*(k_i, k_j)$ . When the payoff is twice differentiable, a sufficient condition is given by  $\partial^2 \Pi_i^*/\partial k_i \partial k_j \leq 0$ . This property holds for both price and quantity competition in case of a linear demand and constant marginal costs.

The section closes with two lemmas that show how and why the firms strategically increase or decrease their investment in technology when costs are observable by the competitor. Proofs are given in Appendix A.

**LEMMA 2:** (deviation with respect to the “best-response when not-observed”)

*If the market stage of the game exhibits strategic substitutes, then for any  $k_j$ , we must have  $K_i^N(k_j) \leq K_i^O(k_j)$ ; if the market stage of the game exhibits strategic complements, then the reverse inequality holds.*

The economic intuition behind Lemma 2 is straightforward: When technology is observable, a firm deviates from  $K_i^N$  in order to induce a less aggressive market behavior by its competitor (equilibrium choice of a lower  $x_j$ ). By assumption 2, this is achieved by an increase in  $k_i$  in case of strategic substitutes, and by a decrease in case of strategic complements.

**LEMMA 3:** (comparison of equilibrium profits: symmetric case)

*If the market game exhibits strategic substitutes, then for symmetric equilibria, the firms are better off when technology is not observable. If the market game exhibits strategic complements, then for symmetric equilibria, the firms are better off when technology is observable.*

The economic intuition behind Lemma 3 is also straightforward. First note that the duopolists would be better off if they could cooperatively agree to act less aggressively on the market. In case of strategic substitutes, observability induces both firms to overinvest in technology, which (by assumption 3) induces them both to act more aggressively on the market, thereby generating lower equilibrium profits. In case of strategic complements, on the other hand, observability yields underinvestments in technology, a less aggressive market behavior by both firms, and higher equilibrium profits.<sup>3</sup>

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<sup>3</sup>The reason why this lemma is restricted to the case of symmetric equilibria is that it is possible—for large levels of asymmetry—to construct examples in which one firm invests less in the observable case while the other invests more. This anomaly is discussed in details, and a numerical example is given, in de Groote (1991).

### 3 Incentives for disclosure

This section considers the firms' disclosure policy and its impact on their choice of technology. For a fixed choice of technology by its competitor, a firm always wants to disclose its (strategically chosen) technology. Indeed, by committing to disclosure, the firm operates on  $K_i^O$  instead of  $K_i^N$ ; as discussed in Section 2,  $\Pi_i^*(K_i^O(k_j), k_j) \geq \Pi_i^*(K_i^N(k_j), k_j)$ . A firm's first-stage commitment to disclosure has one additional effect which complicates the analysis substantially: the commitment influences the competitor's second-stage choice of a technology. The effect of the competitor's change in technology depends on whether the market subgame exhibits strategic substitutes or strategic complements.

Fixing the disclosure decisions leads to a two stage subgame where the observability of the technology decision is given exogenously. Four cases have to be considered according to whose technology is observed and whose is not. Let  $\pi_i^O$  and  $\pi_i^N$  denote the *equilibrium payoff* of firm  $i$  in the two stage subgame where both technologies are observed and not-observed respectively. The equilibrium payoff when firm's 1 technology is observed, and firm's 2 is not, is denoted by  $\pi_1^1$ . The payoff when firm's 2 technology is observed, and firm's 1 is not, is denoted by  $\pi_2^1$ .

	Disclose	Don't
Disclose	$\pi_2^O$	$\pi_2^1$
Don't	$\pi_1^2$	$\pi_1^N$

Table 1: the first-stage disclosure game

With this notation, the payoff structure of the first-stage disclosure game is given in reduced form in Table 1: firm 1 chooses a row, and firm 2 chooses a column. The analysis of this game critically depends on the relative values of  $\pi_1^1$ ,  $\pi_2^1$ ,  $\pi_1^O$ , and  $\pi_1^N$ , which in turn depend on whether the market stage of the game exhibits strategic substitutes or strategic complements.

### 3.1 Strategic substitutes

We first consider the case of strategic substitutes in the market subgame. With a linear demand, and when the products are (conventional) substitutes, this corresponds to the case of quantity competition. Since the market subgame exhibits strategic substitutes, we know, by Lemma 2, that the firms overinvest in stage one; i.e., the technology best-responses satisfy  $K_i^N(k_j) \leq K_i^O(k_j)$ .

**PROPOSITION 1:** (firm's 1 equilibrium profit: quantity competition)

*When the first and the second stage of the game exhibit strategic substitutes, we have  $\pi_1^2 \leq \pi_1^O \leq \pi_1^1$  and  $\pi_1^2 \leq \pi_1^N \leq \pi_1^1$ .*

**PROOF:** Let  $k_i^1$ ,  $k_i^N$ ,  $k_i^O$ , and  $k_i^2$  denote firm's  $i$  equilibrium technology choices in the four different cases. By Lemma 1, the equilibrium technology choices must be at the intersection of the relevant technology best responses. For example, we have  $k_1^2 = K_1^N(k_2^2)$  and  $k_2^2 = K_2^O(k_1^2)$ . Starting from  $(k_1^2, k_2^2)$ , and repetitively applying the best-response mapping  $(K_1^N, K_2^N)$ , we generate a non-decreasing sequence of  $k_1$ 's, and a non-increasing sequence of  $k_2$ 's; by compactness of  $\mathcal{K}_1$  and  $\mathcal{K}_2$ , and by continuity of  $K_1^N$  and  $K_2^N$ , the sequence converges to  $(k_1^N, k_2^N)$ . Thus, we have  $k_1^2 \leq k_1^N$ , and  $k_2^2 \geq k_2^N$ . By assumption 4, this implies  $\pi_1^2 = \Pi_1^*(k_1^2, k_2^2) \leq \Pi_1^*(k_1^2, k_2^N) \leq \Pi_1^*(k_1^N, k_2^N) = \pi_1^N$ . By similar arguments, we can show  $\pi_1^N \leq \pi_1^1$ , and  $\pi_1^2 \leq \pi_1^O \leq \pi_1^1$ . ■

**COROLLARY:**

*When the market subgame exhibits strategic substitutes, it is a dominating strategy to disclose.*

The corollary follows directly from Proposition 1 by inspection of the payoff structure of the game, as given in Table 1. The result is in accordance with the economic intuition: We know that disclosure is desirable for a fixed choice of technology by the competitor—this induces the competitor to act less aggressively on the market. The precommitment to disclose has the additional effect of changing the competitor's choice of a technology. Since the competitor's first-stage reaction (either  $K_j^O$  or  $K_j^N$

according to whether the competitor is disclosing or not) is nonincreasing, by choosing to disclose, and hence by choosing to operate on  $K_i^O \geq K_i^N$  instead of  $K_i^N$ , the firm makes it in the interest of its competitor to invest less (choose a smaller  $k_j$ ). This makes the competitor even less aggressive on the market. Thus, disclosure is a dominating strategy.

The disclosure game has the structure of the prisoner's dilemma: Each firm wants to disclose in order to influence its competitor; both firms end up overinvesting, which makes them more aggressive on the market and moves them further away from the joint profit maximization solution (Lemma 3). This result is to be contrasted with the results of Gal-Or (1986) and Shapiro (1986): In their model, it is also a dominating strategy to disclose information, but this makes the firms better off in equilibrium.

### 3.2 Strategic complements

We next consider the case of strategic complements in the market subgame. With a linear demand, and when the products are (conventional) substitutes, this corresponds to the case of price competition. Since the market stage exhibits strategic complements, we know, by Lemma 2, that the firms underinvest in stage one; i.e., the technology best responses satisfy  $K_i^N(k_j) \geq K_1^O(k_j)$ . In this case the commitment to disclose has ambiguous implications. On the one hand, for a fixed choice of technology by its competitor, it is in the interest of the firm to underinvest, and to disclose that information, in order to make its competitor less aggressive on the market. On the other hand, since the competitor's first-stage reaction is decreasing, this makes it in the interest of the competitor to invest more, and hence, to be more aggressive on the market. The tradeoff is not clear.

**PROPOSITION 2:** (firm's 1 equilibrium profit: price competition)

*When the first stage exhibits strategic substitutes and the second stage exhibits strategic complements, we have  $\pi_1^O \geq \pi_1^1$ .*

**PROOF:** Using the same technique as in lemma 4, we can establish that  $k_1^1 \leq k_1^O$ , and  $k_2^1 \geq k_2^O$ . Then, by assumption 4, we have  $\pi_1^1 = \Pi_1^*(k_1^1, k_2^1) \leq \Pi_1^*(k_1^1, k_2^O) \leq$

$$\Pi_1^*(k_1^O, k_2^O) = \pi_1^O. \quad \blacksquare$$

It is not possible, in general, to establish a relation between  $\pi_1^N$  and  $\pi_1^2$ . Even with a linear demand and technologies that exhibit constant marginal costs, it is possible to construct examples where, depending on the value of the parameters, it is dominating to disclose or not to disclose. The first case corresponds to  $\pi_1^2 > \pi_1^O > \pi_1^N > \pi_1^1$ , while the second case corresponds to  $\pi_1^O > \pi_1^2 > \pi_1^1 > \pi_1^N$ . Note that, by Lemma 3, we always have  $\pi_1^O \geq \pi_1^N$ , and, by Proposition 2,  $\pi_1^O \geq \pi_1^1$ . Thus, since the firms are better off when they both disclose (Lemma 3), there are cases where the disclosure game has the structure of a prisoner's dilemma. In Gal-Or (1986), it is a dominating strategy not to disclose, and the firms are better off than if they were to disclose.

## 4 Conclusion

This section concludes with a discussion of the essential differences between incentives for the disclosure of endogenous and exogenous (verifiable) information. The main results are summarized in Table 2: The first row compares the firms' equilibrium payoffs, in the symmetric case, when both firms are observed and when they are not. The next two rows tell whether the firms should be expected to disclose information in equilibrium. Two situations are distinguished according to whether disclosure policies are fixed before or after the choice of technologies. The case discussed above, where the disclosure policy is committed to before the start of the technology/market game, leads to the analysis of the firms *ex ante* incentives for communication. The difference between the results presented in this paper and the results of Fried (1984), Gal-Or (1986), Li (1985), and Shapiro (1986) has been discussed extensively in Sections 1 and 3. In both cases, incentives for disclosure depend on whether the third-stage market subgame exhibits strategic substitutes or strategic complements.

	Exogenous cost		Endogenous cost	
	Strat Subst	Strat Compl	Strat Subst	Strat Compl
Payoff when observed	Better	Worse	Worse	Better
Ex ante disclosure	YES	NO	YES	Parameter dependent
Ex post disclosure	YES	YES	YES	YES

Table 2: comparison of exogenous and endogenous information

Ex post disclosure corresponds to a different three stage game: in period one the firms choose (or observe) their technologies, in period two they decide whether or not to disclose information, and in period three they compete on the market. In that case, the distinction between strategic substitutes and complements does not play a role.

A firm's *ex post* incentive for disclosure critically depends on its competitor's beliefs when the firm fails to disclose. For the case of *exogenous* information, this yields full disclosure in equilibrium—Grossman (1981), Milgrom (1981), Milgrom and Roberts (1986), and Okuno-Fujiwara et al. (1990). The argument is now classical: A firm discloses if by doing so it induces a more favorable decision on the part of its competitor than the decision induced by the competitor's beliefs had the firm not disclosed. When the firm does not disclose, the competitor assumes the worse (from the point of view of the firm); i.e., assumes that the firm's technology is the one that would induce the most aggressive market behavior on the part of the competitor. Such beliefs imply that it is always in the interest of the firm to disclose.

The analysis of the *ex post* disclosure of *endogenous* information is formally different, but the intuition is similar: a firm deviates from cost-minimization and discloses that information in order to make its competitor less aggressive on the market. When the firm does not disclose, the competitor assumes that the firm did not deviate from cost minimization, and hence does not adopt a less aggressive market behavior. This leads to full disclosure in equilibrium. This intuitive argument is formalized in Appendix B.

As a final remark, it is worth noting that, for the case of endogenous information, the disclosure of imperfect information does not affect the outcome of the game. Indeed, when a firm observes a noisy signal of its competitor's technology—with no moving support—it does not revise its (correct) prior belief: the firm always believes that the competitor's technology is whatever it is supposed to be in equilibrium, with probability one. Therefore, a firm cannot, by deviating from cost-minimization, change its competitor's (correct) beliefs, and hence, cannot make its competitor less aggressive on the market.<sup>4</sup>

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<sup>4</sup>This is to be contrasted with the principal-agent literature in which imperfect signals about the agent's action do play a role (Holstöm, 1979). As in the above reasoning, the observation of the signal does not change the principal's (correct) beliefs about the agent's action. Yet, an imperfect monitor plays a role because the principal can commit to take its observation into account in the agent's compensation. In the present model, no such commitments are possible.

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## Appendix A: Proofs of Lemmas 1-3

### PROOF OF LEMMA 1:

We show that the above condition is equivalent to sequential rationality for both the technology and the market stages. Let  $k_1^*$  and  $k_2^*$  denote the equilibrium technology choices. In the market stage, firm 1's decision is a function of its own technology only (it does not observe firm's 2 technology), whereas firm's 2 decision is a function of both technologies. Let  $\tilde{x}_1(k_1)$  and  $\tilde{x}_2(k_2, k_1)$  denote the firms' market decisions.

Fix  $k_2$  to  $k_2^*$ , and look at the sequential rationality of firm's 1 choice of technology. Firm 1 solves

$$\max_{k_1} \pi_1(\tilde{x}_1(k_1), k_1, \tilde{x}_2(k_2^*, k_1), k_1).$$

For  $k_2 = k_2^*$ , sequential rationality in the market stage is equivalent to  $\tilde{x}_1(k_1) = X_1^*(k_1, k_2^*)$  (firm 1 always believes that  $k_2 = k_2^*$ ), and  $\tilde{x}_2(k_2^*, k_1) = X_2^*(k_2^*, k_1)$ . Firm's 1 technology choice becomes

$$\max_{k_1} \pi_1(X_1^*(k_1, k_2^*), X_2^*(k_2^*, k_1), k_1) = \max_{k_1} \Pi_1^*(k_1, k_2^*).$$

By definition, the last expression is equivalent to  $k_1^* \in K_1^O(k_2^*)$ .

Next, fix  $k_1$  to  $k_1^*$ , and look at the sequential rationality of firm's 2 choice of technology. Firm 2 solves

$$\max_{k_2} \pi_2(\tilde{x}_2(k_2, k_1^*), \tilde{x}_1(k_1^*), k_2).$$

Sequential rationality in the market stage is equivalent to

$$\tilde{x}_1(k_1^*) \in \arg \max_{x_1} \pi_1(\tilde{x}_2(k_2, k_1^*), k_1),$$

$$\tilde{x}_2(k_2, k_1^*) \in \arg \max_{x_2} \pi_2(\tilde{x}_1(k_1^*), k_2).$$

By definition, the last three equations are equivalent to  $k_2^* \in K_2^N(k_1^*)$ . ■

### PROOF OF LEMMA 2:

[Lemma 2 is taken from de Groot (1991); a proof is included here for the sake of completeness.]

Consider the case of strategic substitutes in the market stage of the game. Take any  $k_j$  and let  $k_i = K_i^N(k_j)$ ,  $x_i = X_i^*(k_i, k_j)$ ,  $x_j = X_j^*(k_j, k_i)$ . Take any  $k'_i < K_i^N(k_j)$ . The proof is by contradiction: by picking  $k'_i$  firm  $i$  is worse off than by sticking to  $k_i$ ; hence the best-response to  $k_j$  in the two-stage game (when technology is observed)

is at least  $k_i = K_i^N(k_j)$ . Let  $x'_i = X_i^*(k'_i, k_j)$  and  $x'_j = X_j^*(k'_j, k_i)$ . By Assumption 2,  $k_i > k'_i$  implies  $x_j \leq x'_j$  and thus by Assumption 1

$$\pi_i(x'_i, x'_j, k'_i) \leq \pi_i(x'_i, x_j, k'_i).$$

By construction,  $(x_i, k_i)$  is the best-response to  $(x_j, k_j)$ . We get

$$\pi_i(x'_i, x_j, k'_i) < \pi_i(x_i, x_j, k_i).$$

A similar argument applies in case of strategic complements. ■

### PROOF OF LEMMA 3:

Subscripts are dropped. Let  $(k', x')$  be any symmetric equilibrium when technology is not observable, let  $(k'', x'')$  be any symmetric equilibrium when technology is observable, and let  $\pi'$  and  $\pi''$  be the corresponding equilibrium profits.

We first show that when the market stage of the game exhibits strategic substitutes, we have  $k' \leq k''$ , and when the market stage of the game exhibits strategic complements, we have  $k' \geq k''$ . The proof is given for the case of strategic substitutes; the line of argument is identical for the case of strategic complements. By Lemma 1, we have  $k' = K^N(k')$  and  $k'' = K^O(k'')$ . Suppose, a contrario, that  $k' > k''$ . By Lemma 2, and since the first-stage reaction,  $K^O$ , is non-increasing, this yields a contradiction:

$$k' = K^N(k') \leq K^O(k') \leq K^O(k'') = k''.$$

We next show that, for strategic substitutes in the market stage of the game,  $\pi' \geq \pi''$ . By assumption 3,  $k' \leq k''$  implies  $x' \leq x''$ . By assumption 1 we then have (subscripts are added for clarity)

$$\pi'' = \pi_i(x''_i, x''_j, k''_i) \leq \pi_i(x''_i, x'_j, k''_i).$$

Since  $(k'_i, x'_i)$  is the best-response to  $x'_j$  we next get

$$\pi_i(x''_i, x'_j, k''_i) \leq \pi_i(x'_i, x'_j, k'_i) = \pi',$$

which completes the proof for strategic substitutes.

Finally, we show that, for strategic complements in the market stage of the game,  $\pi' \leq \pi''$ . Since  $k'' < k'$ , we have, by Assumption 4

$$\pi' = \Pi_i^*(k'_i, k'_j) \leq \Pi_i^*(k''_i, k''_j).$$

Then, since when technology is observable  $k''_i$  is the best-response to  $k''_j$ ,

$$\Pi_i^*(k'_i, k''_j) \leq \Pi_i^*(k''_i, k''_j) = \pi'',$$

which completes the proof. ■

## Appendix B: Ex post incentives for disclosure

I proceed by making a (quite general) assumptions that can be loosely paraphrased: *observation matters*.

**ASSUMPTION:** (observation matters)

*For all  $k_j \in \mathcal{K}_j$ ,  $K_i^O(k_j)$  and  $K_i^N(k_j)$  are disjoint, for  $i, j = 1, 2$  and  $i \neq j$ .*

Note that a firm is always *weakly better off* when the competitor is able to observe. The assumption rules out the situation where the firm's choice of technology is the same whether or not the competitor is able to observe. This could happen, for example, if the set of technologies contains only a few discrete points that are too distant from each other to justify a strategic deviation from cost-minimization in case of observability. Thus, under the above assumption, for any fixed technology choice by its competitor, a firm's best-response is different when the competitor is able to observe and when it is not. The assumption also implies that, for a fixed technology choice by the competitor, a firm is always *strictly better off* if the competitor is able to observe.

**LEMMA:** (ex post incentives for disclosure)

*In the game where disclosure policies cannot be committed to ex ante, firms always disclose in equilibrium.*

**PROOF:** Fix the strategy of firm 2 to its equilibrium strategy; the equilibrium is denoted by  $(k_2^*, d_2^*, v_2^*, x_2^*)$ . The proof is by contradiction: Suppose that, in equilibrium, firm 1 is not disclosing. By Lemma 1, we must have  $k_1^* = K_1^N(k_2^*)$ ,  $x_1^* = X_1^*(k_1^*, k_2^*)$ , and  $x_2^* = X_2^*(k_2^*, k_1^*)$ . The rest of the proof consists of showing that the above equilibrium cannot be sequentially rational with consistent beliefs.

Suppose that 1 deviates to  $k'_1 \in K_1^O(k_2^*)$  and discloses. That deviation cannot change firm's 1 (consistent) belief that  $k_2 = k_2^*$  if she doesn't observe; if she observes then, since firm's 2 strategy is kept fixed, she sees  $k_2^*$ . Firm's 2 prior belief about  $k_1$  is given by  $k_1^*$ , but after observation, its belief changes to  $k'_1$ . Thus, the market subgame equilibrium has to be  $x'_1 = X_1^*(k'_1, k_2^*)$  and  $x'_2 = X_2^*(k_2^*, k'_1)$ . By the above assumption, firm 1's payoff  $\Pi_1^*(k'_1, k_2^*)$  is *strictly greater* than  $\Pi_1^*(k_1^*, k_2^*)$ —a contradiction. ■

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89/12	Wilfried VANHONACKER	"Estimating dynamic response models when the data are subject to different temporal aggregation", January 1989.	89/22	Manfred KETS DE VRIES and Sydney PERZOW	"What is the role of character in psychoanalysis?" April 1989.
			89/23	Robert KORAJCZYK and Claude VIALLET	"Equity risk premia and the pricing of foreign exchange risk" April 1989.
			89/24	Martin KILDUFF and Mitchel ABOLAFIA	"The social destruction of reality: Organisational conflict as social drama" zApril 1989.

89/25	Roger BETANCOURT and David GAUTSCHI	"Two essential characteristics of retail markets and their economic consequences" March 1989.	89/36	Martin KILDUFF	"A dispositional approach to social networks: the case of organizational choice", May 1989.
89/26	Charles BEAN, Edmond MALINVAUD, Peter BERNHOLZ, Francesco GIAVAZZI and Charles WYPLOSZ	"Macroeconomic policies for 1992: the transition and after", April 1989.	89/37	Manfred KETS DE VRIES	"The organisational fool: balancing a leader's hubris", May 1989.
89/27	David KRACKHARDT and Martin KILDUFF	"Friendship patterns and cultural attributions: the control of organizational diversity", April 1989.	89/38	Manfred KETS DE VRIES	"The CEO blues", June 1989.
89/28	Martin KILDUFF	"The interpersonal structure of decision making: a social comparison approach to organizational choice", Revised April 1989.	89/39	Robert KORAJCZYK and Claude VIALLET	"An empirical investigation of international asset pricing", (Revised June 1989).
89/29	Robert GOGEL and Jean-Claude LARRECHE	"The battlefield for 1992: product strength and geographic coverage", May 1989.	89/40	Balaji CHAKRAVARTHY	"Management systems for innovation and productivity", June 1989.
89/30	Lars-Hendrik ROLLER and Mihkel M. TOMBAK	"Competition and Investment in Flexible Technologies", May 1989.	89/41	B. SINCLAIR-DESGAGNE and Nathalie DIERKENS	"The strategic supply of precision", June 1989.
89/31	Michael C. BURDA and Stefan GERLACH	"Intertemporal prices and the US trade balance in durable goods", July 1989.	89/42	Robert ANSON and Tawfik JELASSI	"A development framework for computer-supported conflict resolution", July 1989.
89/32	Peter HAUG and Tawfik JELASSI	"Application and evaluation of a multi-criteria decision support system for the dynamic selection of U.S. manufacturing locations", May 1989.	89/43	Michael BURDA	"A note on firing costs and severance benefits in equilibrium unemployment", June 1989.
89/33	Bernard SINCLAIR-DESGAGNÉ	"Design flexibility in monopsonistic industries", May 1989.	89/44	Balaji CHAKRAVARTHY and Peter LORANGE	"Strategic adaptation in multi-business firms", June 1989.
89/34	Sumantra GHOSHAL and Nittin NOHRIA	"Requisite variety versus shared values: managing corporate-division relationships in the M-Form organisation", May 1989.	89/45	Rob WEITZ and Arnoud DE MEYER	"Managing expert systems: a framework and case study", June 1989.
89/35	Jean DERMINE and Pierre HILLION	"Deposit rate ceilings and the market value of banks: The case of France 1971-1981", May 1989.	89/46	Marcel CORSTJENS, Carmen MATUTES and Damien NEVEN	"Entry Encouragement", July 1989.
			89/47	Manfred KETS DE VRIES and Christine MEAD	"The global dimension in leadership and organization: issues and controversies", April 1989.
			89/48	Damien NEVEN and Lars-Hendrik RÖLLER	"European integration and trade flows", August 1989.

89/49	Jean DERMINE	"Home country control and mutual recognition", July 1989.	89/62 (TM)	Arnoud DE MEYER	"Technology strategy and international R&D operations", October 1989.
89/50	Jean DERMINE	"The specialization of financial institutions, the EEC model", August 1989.	89/63 (TM)	Enver YUCESAN and Lee SCHRUBEN	"Equivalence of simulations: A graph approach", November 1989.
89/51	Spyros MAKRIDAKIS	"Sliding simulation: a new approach to time series forecasting", July 1989.	89/64 (TM)	Enver YUCESAN and Lee SCHRUBEN	"Complexity of simulation models: A graph theoretic approach", November 1989.
89/52	Arnoud DE MEYER	"Shortening development cycle times: a manufacturer's perspective", August 1989.	89/65 (TM, AC, FIN)	Soumitra DUTTA and Piero BONISSONE	"MARS: A mergers and acquisitions reasoning system", November 1989.
89/53	Spyros MAKRIDAKIS	"Why combining works?", July 1989.	89/66 (TM,EP)	B. SINCLAIR-DESGAGNÉ	"On the regulation of procurement bids", November 1989.
89/54	S. BALAKRISHNAN and Mitchell KOZA	"Organisation costs and a theory of joint ventures", September 1989.	89/67 (FIN)	Peter BOSSAERTS and Pierre HILLION	"Market microstructure effects of government intervention in the foreign exchange market", December 1989.
89/55	H. SCHUTTE	"Euro-Japanese cooperation in information technology", September 1989.			
89/56	Wilfried VANHONACKER and Lydia PRICE	"On the practical usefulness of meta-analysis results", September 1989.			
89/57	Taekwon KIM, Lars-Hendrik RÖLLER and Mihkel TOMBAK	"Market growth and the diffusion of multiproduct technologies", September 1989.	1990		
89/58	Lars-Hendrik RÖLLER and Mihkel TOMBAK	"Strategic aspects of flexible production technologies", October 1989.	90/01 TM/EP/AC	B. SINCLAIR-DESGAGNÉ	"Unavoidable Mechanisms", January 1990.
89/59	Manfred KETS DE VRIES, Daphna ZEVADI, Alain NOEL and Mihkel TOMBAK	"Locus of control and entrepreneurship: a three-country comparative study", October 1989.	90/02 EP	Michael BURDA	"Monopolistic Competition, Costs of Adjustment, and the Behaviour of European Manufacturing Employment", January 1990.
89/60	Enver YUCESAN and Lee SCHRUBEN	"Simulation graphs for design and analysis of discrete event simulation models", October 1989.	90/03 TM	Arnoud DE MEYER	"Management of Communication in International Research and Development", January 1990.
89/61	Susan SCHNEIDER and Arnoud DE MEYER	"Interpreting and responding to strategic issues: The impact of national culture", October 1989.	90/04 FIN/EP	Gabriel HAWAWINI and Eric RAJENDRA	"The Transformation of the European Financial Services Industry: From Fragmentation to Integration", January 1990.
			90/05 FIN/EP	Gabriel HAWAWINI and Bertrand JACQUILLAT	"European Equity Markets: Toward 1992 and Beyond", January 1990.

90/06 FIN/EP	Gabriel HAWAWINI and Eric RAJENDRA	"Integration of European Equity Markets: Implications of Structural Change for Key Market Participants to and Beyond 1992", January 1990.	90/17 FIN	Nathalie DIERKENS	"Information Asymmetry and Equity Issues", Revised January 1990.
90/07 FIN/EP	Gabriel HAWAWINI	"Stock Market Anomalies and the Pricing of Equity on the Tokyo Stock Exchange", January 1990.	90/18 MKT	Wilfried VANHONACKER	"Managerial Decision Rules and the Estimation of Dynamic Sales Response Models", Revised January 1990.
90/08 TM/EP	Tawfik JELASSI and B. SINCLAIR-DESGAGNÉ	"Modelling with MCDSS: What about Ethics?", January 1990.	90/19 TM	Beth JONES and Tawfik JELASSI	"The Effect of Computer Intervention and Task Structure on Bargaining Outcome", February 1990.
90/09 EP/FIN	Alberto GIOVANNINI and Jae WON PARK	"Capital Controls and International Trade Finance", January 1990.	90/20 TM	Tawfik JELASSI, Gregory KERSTEN and Stanley ZIONTS	"An Introduction to Group Decision and Negotiation Support", February 1990.
90/10 TM	Joyce BRYER and Tawfik JELASSI	"The Impact of Language Theories on DSS Dialog", January 1990.	90/21 FIN	Roy SMITH and Ingo WALTER	"Reconfiguration of the Global Securities Industry in the 1990's", February 1990.
90/11 TM	Enver YUCESAN	"An Overview of Frequency Domain Methodology for Simulation Sensitivity Analysis", January 1990.	90/22 FIN	Ingo WALTER	"European Financial Integration and Its Implications for the United States", February 1990.
90/12 EP	Michael BURDA	"Structural Change, Unemployment Benefits and High Unemployment: A U.S.-European Comparison", January 1990.	90/23 EP/SM	Damien NEVEN	"EEC Integration towards 1992: Some Distributional Aspects", Revised December 1989
90/13 TM	Soumitra DUTTA and Shashi SHEKHAR	"Approximate Reasoning about Temporal Constraints in Real Time Planning and Search", January 1990.	90/24 FIN/EP	Lars Tyge NIELSEN	"Positive Prices in CAPM", January 1990.
90/14 TM	Albert ANGEHRN and Hans-Jakob LÜTHI	"Visual Interactive Modelling and Intelligent DSS: Putting Theory Into Practice", January 1990.	90/25 FIN/EP	Lars Tyge NIELSEN	"Existence of Equilibrium in CAPM", January 1990.
90/15 TM	Arnoud DE MEYER, Dirk DESCHOOLMEESTER, Rudy MOENAERT and Jan BARBE	"The Internal Technological Renewal of a Business Unit with a Mature Technology", January 1990.	90/26 OB/BP	Charles KADUSHIN and Michael BRIMM	"Why networking Fails: Double Binds and the Limitations of Shadow Networks", February 1990.
90/16 FIN	Richard LEVICH and Ingo WALTER	"Tax-Driven Regulatory Drag: European Financial Centers in the 1990's", January 1990.	90/27 TM	Abbas FOROUGHI and Tawfik JELASSI	"NSS Solutions to Major Negotiation Stumbling Blocks", February 1990.
			90/28 TM	Arnoud DE MEYER	"The Manufacturing Contribution to Innovation", February 1990.

90/29 FIN/AC	Nathalie DIERKENS	"A Discussion of Correct Measures of Information Asymmetry", January 1990.	90/40 OB	Manfred KETS DE VRIES	"Leaders on the Couch: The case of Roberto Calvi", April 1990.
90/30 FIN/EP	Lars Tyge NIELSEN	"The Expected Utility of Portfolios of Assets", March 1990.	90/41 FIN/EP	Gabriel HAWAWINI, Itzhak SWARY and Ik HWAN JANG	"Capital Market Reaction to the Announcement of Interstate Banking Legislation", March 1990.
90/31 MKT/EP	David GAUTSCHI and Roger BETANCOURT	"What Determines U.S. Retail Margins?", February 1990.	90/42 MKT	Joel STECKEL and Wilfried VANHONACKER	"Cross-Validating Regression Models in Marketing Research", (Revised April 1990).
90/32 SM	Srinivasan BALAK-RISHNAN and Mitchell KOZA	"Information Asymmetry, Adverse Selection and Joint-Ventures: Theory and Evidence", Revised, January 1990.	90/43 FIN	Robert KORAJCZYK and Claude VIALLET	"Equity Risk Premia and the Pricing of Foreign Exchange Risk", May 1990.
90/33 OB	Caren SIEHL, David BOWEN and Christine PEARSON	"The Role of Rites of Integration in Service Delivery", March 1990.	90/44 OB	Gilles AMADO, Claude FAUCHEUX and André LAURENT	"Organisational Change and Cultural Realities: Franco-American Contrasts", April 1990.
90/34 FIN/EP	Jean DERMINE	"The Gains from European Banking Integration, a Call for a Pro-Active Competition Policy", April 1990.	90/45 TM	Soumitra DUTTA and Piero BONISSTONE	"Integrating Case Based and Rule Based Reasoning: The Possibilistic Connection", May 1990.
90/35 EP	Jae Won PARK	"Changing Uncertainty and the Time-Varying Risk Premia in the Term Structure of Nominal Interest Rates", December 1988, Revised March 1990.	90/46 TM	Spyros MAKRIDAKIS and Michèle HIBON	"Exponential Smoothing: The Effect of Initial Values and Loss Functions on Post-Sample Forecasting Accuracy".
90/36 TM	Arnoud DE MEYER	"An Empirical Investigation of Manufacturing Strategies in European Industry", April 1990.	90/47 MKT	Lydia PRICE and Wilfried VANHONACKER	"Improper Sampling in Natural Experiments: Limitations on the Use of Meta-Analysis Results in Bayesian Updating", Revised May 1990.
90/37 TM/OB/SM	William CATS-BARIL	"Executive Information Systems: Developing an Approach to Open the Possibles", April 1990.	90/48 EP	Jae WON PARK	"The Information in the Term Structure of Interest Rates: Out-of-Sample Forecasting Performance", June 1990.
90/38 MKT	Wilfried VANHONACKER	"Managerial Decision Behaviour and the Estimation of Dynamic Sales Response Models", (Revised February 1990).	90/49 TM	Soumitra DUTTA	"Approximate Reasoning by Analogy to Answer Null Queries", June 1990.
90/39 TM	Louis LE BLANC and Tawfik JELASSI	"An Evaluation and Selection Methodology for Expert System Shells", May 1990.	90/50 EP	Daniel COHEN and Charles WYPLOZ	"Price and Trade Effects of Exchange Rates Fluctuations and the Design of Policy Coordination", April 1990.

90/51 EP	Michael BURDA and Charles WYPLOSZ	"Gross Labour Market Flows in Europe: Some Stylized Facts", June 1990.	90/63 SM	Sumantra GHOSHAL and Eleanor WESTNEY	"Organising Competitor Analysis Systems", August 1990
90/52 FIN	Lars Tyge NIELSEN	"The Utility of Infinite Menus", June 1990.	90/64 SM	Sumantra GHOSHAL	"Internal Differentiation and Corporate Performance: Case of the Multinational Corporation", August 1990
90/53 EP	Michael Burda	"The Consequences of German Economic and Monetary Union", June 1990.	90/65 EP	Charles WYPLOSZ	"A Note on the Real Exchange Rate Effect of German Unification", August 1990
90/54 EP	Damien NEVEN and Colin MEYER	"European Financial Regulation: A Framework for Policy Analysis", (Revised May 1990).	90/66 TM/SE/FIN	Soumitra DUTTA and Piero BONISSONE	"Computer Support for Strategic and Tactical Planning in Mergers and Acquisitions", September 1990
90/55 EP	Michael BURDA and Stefan GERLACH	"Intertemporal Prices and the US Trade Balance", (Revised July 1990).	90/67 TM/SE/FIN	Soumitra DUTTA and Piero BONISSONE	"Integrating Prior Cases and Expert Knowledge In a Mergers and Acquisitions Reasoning System", September 1990
90/56 EP	Damien NEVEN and Lars-Hendrik RÖLLER	"The Structure and Determinants of East-West Trade: A Preliminary Analysis of the Manufacturing Sector", July 1990	90/68 TM/SE	Soumitra DUTTA	"A Framework and Methodology for Enhancing the Business Impact of Artificial Intelligence Applications", September 1990
90/57 FIN/EP/ TM	Lars Tyge NIELSEN	Common Knowledge of a Multivariate Aggregate Statistic", July 1990	90/69 TM	Soumitra DUTTA	"A Model for Temporal Reasoning in Medical Expert Systems", September 1990
90/58 FIN/EP/TM	Lars Tyge NIELSEN	"Common Knowledge of Price and Expected Cost in an Oligopolistic Market", August 1990	90/70 TM	Albert ANGEHRN	"Triple C': A Visual Interactive MCDSS", September 1990
90/59 FIN	Jean DERMINE and Lars-Hendrik RÖLLER	"Economies of Scale and Scope in the French Mutual Funds (SICAV) Industry", August 1990	90/71 MKT	Philip PARKER and Hubert GATIGNON	"Competitive Effects in Diffusion Models: An Empirical Analysis", September 1990
90/60 TM	Peri IZ and Tawfik JELASSI	"An Interactive Group Decision Aid for Multiobjective Problems: An Empirical Assessment", September 1990	90/72 TM	Enver YÜCESAN	"Analysis of Markov Chains Using Simulation Graph Models", October 1990
90/61 TM	Pankaj CHANDRA and Mihkel TOMBAK	"Models for the Evaluation of Manufacturing Flexibility", August 1990	90/73 TM	Arnoud DE MEYER and Kasra FERDOWS	"Removing the Barriers in Manufacturing", October 1990
90/62 EP	Damien NEVEN and Menno VAN DIJK	"Public Policy Towards TV Broadcasting in the Netherlands", August 1990	90/74 SM	Sumantra GHOSHAL and Nitin NOHRIA	"Requisite Complexity: Organising Headquarters-Subsidiary Relations in MNCs", October 1990

90/75 MKT	Roger BETANCOURT and David GAUTSCHI	"The Outputs of Retail Activities: Concepts, Measurement and Evidence", October 1990	90/87 FIN/EP	Lars Tyge NIELSEN	"Existence of Equilibrium in CAPM: Further Results", December 1990
90/76 MKT	Wilfried VANHONACKER	"Managerial Decision Behaviour and the Estimation of Dynamic Sales Response Models", Revised October 1990	90/88 OB/MKT	Susan C. SCHNEIDER and Reinhard ANGELMAR	"Cognition in Organisational Analysis: Who's Minding the Store?" Revised, December 1990
90/77 MKT	Wilfried VANHONACKER	"Testing the Koyck Scheme of Sales Response to Advertising: An Aggregation-Independent Autocorrelation Test", October 1990	90/89 OB	Manfred F.R. KETS DE VRIES	"The CEO Who Couldn't Talk Straight and Other Tales from the Board Room," December 1990
90/78 EP	Michael BURDA and Stefan GERLACH	"Exchange Rate Dynamics and Currency Unification: The Ostmark - DM Rate", October 1990	90/90 MKT	Philip PARKER	"Price Elasticity Dynamics over the Adoption Lifecycle: An Empirical Study," December 1990
90/79 TM	Anil GABA	"Inferences with an Unknown Noise Level in a Bernoulli Process", October 1990			
90/80 TM	Anil GABA and Robert WINKLER	"Using Survey Data in Inferences about Purchase Behaviour", October 1990	<u>1991</u>		
90/81 TM	Tawfik JELASSI	"Du Présent au Futur: Bilans et Orientations des Systèmes Interactifs d'Aide à la Décision," October 1990	91/01 TM/SM	Luk VAN WASSENHOVE, Leonard FORTUIN and Paul VAN BEEK	"Operational Research Can Do More for Managers Than They Think!," January 1991
90/82 EP	Charles WYPLOSZ	"Monetary Union and Fiscal Policy Discipline," November 1990	91/02 TM/SM	Luk VAN WASSENHOVE, Leonard FORTUIN and Paul VAN BEEK	"Operational Research and Environment," January 1991
90/83 FIN/TM	Nathalie DIERKENS and Bernard SINCLAIR-DESGAGNE	"Information Asymmetry and Corporate Communication: Results of a Pilot Study", November 1990	91/03 FIN	Pekka HIETALA and Timo LÖYTTYNIEMI	"An Implicit Dividend Increase in Rights Issues: Theory and Evidence," January 1991
90/84 MKT	Philip M. PARKER	"The Effect of Advertising on Price and Quality: The Optometric Industry Revisited," December 1990	91/04 FIN	Lars Tyge NIELSEN	"Two-Fund Separation, Factor Structure and Robustness," January 1991
90/85 MKT	Avijit GHOSH and Vikas TIBREWALA	"Optimal Timing and Location in Competitive Markets," November 1990	91/05 OB	Susan SCHNEIDER	"Managing Boundaries in Organisations," January 1991
90/86 EP/TM	Olivier CADOT and Bernard SINCLAIR-DESGAGNE	"Prudence and Success in Politics," November 1990	91/06 OB	Manfred KETS DE VRIES, Denny MILLER and Alain NOËL	"Understanding the Leader-Strategy Interface: Application of the Strategic Relationship Interview Method," January 1990 (89/11, revised April 1990)

91/07 EP	Olivier CADOT	"Leading to Insolvent Countries: A Paradoxical Story," January 1991	91/19 MKT	Vikas TIBREWALA and Bruce BUCHANAN	"An Aggregate Test of Purchase Regularity", March 1991
91/08 EP	Charles WYPLOSZ	"Post-Reform East and West: Capital Accumulation and the Labour Mobility Constraint," January 1991	91/20 MKT	Darius SABAVALA and Vikas TIBREWALA	"Monitoring Short-Run Changes in Purchasing Behaviour", March 1991
91/09 TM	Spyros MAKRIDAKIS	"What can we Learn from Failure?", February 1991	91/21 SM	Sumantra GHOSHAL, Harry KORINE and Gabriel SZULANSKI	"Interunit Communication within MNCs: The Influence of Formal Structure Versus Integrative Processes", April 1991
91/10 TM	Luc Van WASSENHOVE and C. N. POTTS	"Integrating Scheduling with Batching and Lot-Sizing: A Review of Algorithms and Complexity", February 1991	91/22 EP	David GOOD, Lars-Hendrik RÖLLER and Robin SICKLES	"EC Integration and the Structure of the Franco-American Airline Industries: Implications for Efficiency and Welfare", April 1991
91/11 TM	Luc VAN WASSENHOVE et al.	"Multi-Item Lotsizing in Capacitated Multi-Stage Serial Systems", February 1991	91/23 TM	Spyros MAKRIDAKIS and Michèle HIBON	"Exponential Smoothing: The Effect of Initial Values and Loss Functions on Post-Sample Forecasting Accuracy", April 1991 (Revision of 90/46)
91/12 TM	Albert ANGEHRN	"Interpretative Computer Intelligence: A Link between Users, Models and Methods in DSS", February 1991	91/24 TM	Louis LE BLANC and Tawfik JELASSI	"An Empirical Assessment of Choice Models for Software Evaluation and Selection", May 1991
91/13 EP	Michael BURDA	"Labor and Product Markets in Czechoslovakia and the Ex-GDR: A Twin Study", February 1991	91/25 SM/TM	Luk N. VAN WASSENHOVE and Charles J. CORBETT	"Trade-Offs? What Trade-Offs?" April 1991
91/14 MKT	Roger BETANCOURT and David GAUTSCHI	"The Output of Retail Activities: French Evidence", February 1991	91/26 TM	Luk N. VAN WASSENHOVE and C.N. POTTS	"Single Machine Scheduling to Minimize Total Late Work", April 1991
91/15 OB	Manfred F.R. KETS DE VRIES	"Exploding the Myth about Rational Organisations and Executives", March 1991	91/27 FIN	Nathalie DIERKENS	"A Discussion of Correct Measures of Information Asymmetry: The Example of Myers and Majluf's Model or the Importance of the Asset Structure of the Firm", May 1991
91/16 TM	Arnoud DE MEYER and Kasra FERDOWS et.al.	"Factories of the Future: Executive Summary of the 1990 International Manufacturing Futures Survey", March 1991	91/28 MKT	Philip M. PARKER	"A Note on: 'Advertising and the Price and Quality of Optometric Services', June 1991
91/17 TM	Dirk CATTRYSSE, Roelof KUIK, Marc SALOMON and Luk VAN WASSENHOVE	"Heuristics for the Discrete Lotsizing and Scheduling Problem with Setup Times", March 1991	91/29 TM	Tawfik JELASSI and Abbas FOROUGHI	"An Empirical Study of an Interactive, Session-Oriented Computerised Negotiation Support System (NSS)", June 1991
91/18 TM	C.N. POTTS and Luk VAN WASSENHOVE	"Approximation Algorithms for Scheduling a Single Machine to Minimize Total Late Work", March 1991			

91/30 MKT	Wilfried R. VANHONACKER and Lydia J. PRICE	"Using Meta-Analysis Results in Bayesian Updating: The Empty Cell Problem", June 1991	91/43 SM	Sumantra GHOSHAL and Christopher BARTLETT	"Building Transnational Capabilities: The Management Challenge", September 1991
91/31 FIN	Rezaul KABIR and Theo VERMAELEN	"Insider Trading Restrictions and the Stock Market", June 1991	91/44 SM	Sumantra GHOSHAL and Nitin NOHRIA	"Distributed Innovation in the 'Differentiated Network' Multinational", September 1991
91/32 OB	Susan C. SCHNEIDER	"Organisational Sensemaking: 1992", June 1991	91/45 MKT	Philip M. PARKER	"The Effect of Advertising on Price and Quality: An Empirical Study of Eye Examinations, Sweet Lemons and Self-Deceivers", September 1991
91/33 EP	Michael C. BURDA and Michael FUNKE	"German Trade Unions after Unification - Third Degree Wage Discriminating Monopolists?", June 1991	91/46 MKT	Philip M. PARKER	"Pricing Strategies in Markets with Dynamic Elasticities", October 1991
91/34 FIN	Jean DERMINE	"The BIS Proposal for the Measurement of Interest Rate Risk, Some Pitfalls", June 1991	91/47 MKT	Philip M. PARKER	"A Study of Price Elasticity Dynamics Using Parsimonious Replacement/Multiple Purchase Diffusion Models", October 1991
91/35 FIN	Jean DERMINE	"The Regulation of Financial Services in the EC, Centralization or National Autonomy?" June 1991	91/48 EP/TM	H. Landis GABEL and Bernard SINCLAIR-DESGAGNE	"Managerial Incentives and Environmental Compliance", October 1991
91/36 TM	Albert ANGEHRN	"Supporting Multicriteria Decision Making: New Perspectives and New Systems", August 1991	91/49 TM	Bernard SINCLAIR-DESGAGNE	"The First-Order Approach to Multi-Task Principal-Agent Problems", October 1991
91/37 EP	Ingo WALTER and Hugh THOMAS	"The Introduction of Universal Banking in Canada: An Event Study", August 1991	91/50 SM/TM	Luk VAN WASSENHOVE and Charles CORBETT	"How Green is Your Manufacturing Strategy?" October 1991
91/38 EP	Ingo WALTER and Anthony SAUNDERS	"National and Global Competitiveness of New York City as a Financial Center", August 1991	91/51 MKT	Philip M. PARKER	"Choosing Among Diffusion Models: Some Empirical Guidelines", October 1991
91/39 EP	Ingo WALTER and Anthony SAUNDERS	"Reconfiguration of Banking and Capital Markets in Eastern Europe", August 1991	91/52 EP	Michael BURDA and Charles WYPLOZ	"Human Capital, Investment and Migration in an Integrated Europe", October 1991
91/40 TM	Luk VAN WASSENHOVE, Dirk CATTRYSSE and Marc SALOMON	"A Set Partitioning Heuristic for the Generalized Assignment Problem", August 1991	91/53 EP	Michael BURDA and Charles WYPLOZ	"Labour Mobility and German Integration: Some Vignettes", October 1991
91/41 TM	Luk VAN WASSENHOVE, M.Y. KOVALYOU and C.N. POTTS	"A Fully Polynomial Approximation Scheme for Scheduling a Single Machine to Minimize Total Weighted Late Work", August 1991	91/54 TM	Albert ANGEHRN	"Stimulus Agents: An Alternative Framework for Computer-Aided Decision Making", October 1991
91/42 TM	Rob R. WEITZ and Tawfik JELASSI	"Solving A Multi-Criteria Allocation Problem: A Decision Support System Approach", August 1991			

91/55 EP/SM	Robin HOGARTH, Claude MICHAUD, Yves DOZ and Ludo VAN DER HEYDEN	"Longevity of Business Firms: A Four-Stage Framework for Analysis", November 1991	92/03 OB	Manfred F.R. KETS DE VRIES	"The Family Firm: An Owner's Manual", January 1992
91/56 TM/EP	Bernard SINCLAIR-DESGAGNE	"Aspirations and Economic Development", November 1991	92/04 SM	Philippe HASPELAGH and David JEMISON	"Making Acquisitions Work", January 1992
91/57 MKT	Lydia J. PRICE	"The Indirect Effects of Negative Information on Attitude Change", November 1991	92/05 TM	Xavier DE GROOTE	"Flexibility and Product Diversity in Lot-Sizing Models", January 1992 (revised)
91/58 OB	Manfred F. R. KETS DE VRIES	"Leaders Who Go Crazy", November 1991	92/06 FIN	Theo VERMAELEN and Kees COOLS	"Financial Innovation: Self Tender Offers in the U.K.", January 1992
91/59 OB	Paul A. L. EVANS	"Management Development as Glue Technology", November 1991	92/07 TM	Xavier DE GROOTE	"The Flexibility of Production Processes: A General Framework", January 1992 (revised)
91/60 TM	Xavier DE GROOTE	"Flexibility and Marketing/Manufacturing Coordination", November 1991 (revised)	92/08 TM	Luk VAN WASSENHOVE, Leo KROON and Marc SALOMON	"Exact and Approximation Algorithms for the Operational Fixed Interval Scheduling Problem", January 1992
91/61 TM	Arnoud DE MEYER	"Product Development in the Textile Machinery Industry", November 1991	92/09 TM	Luk VAN WASSENHOVE, Roelof KUIK and Marc SALOMON	"Statistical Search Methods for Lotsizing Problems", January 1992
91/62 MKT	Philip PARKER and Hubert GATIGNON	"Specifying Competitive Effects in Diffusion Models: An Empirical Analysis", November 1991	92/10 SM	Yves DOZ and Heinz THANHEISER	"Regaining Competitiveness: A Process of Organisational Renewal", January 1992
91/63 EP	Michael BURDA	"Some New Insights on the Interindustry Wage Structure from the German Socioeconomic Panel", December 1991	92/11 TM	Enver YUCESAN and Sheldon JACOBSON	"On the Intractability of Verifying Structural Properties of Discrete Event Simulation Models", February 1992
91/64 FIN	Jean DERMINE	"Internationalisation of Financial Markets, Efficiency and Stability", December 1991	92/12 FIN	Gabriel HAWAWINI	"Valuation of Cross-Border Mergers and Acquisitions", February 1992
<u>1992</u>			92/13 TM	Spyros MAKRIDAKIS and Michèle HIBON et.al.	"The M2-Competition: A Budget Related Empirical Forecasting Study", February 1992
92/01 MKT/EP/TM	Wilfried VANHONACKER	"CONPRO*DOGIT: A New Brand Choice Model Incorporating a Consideration Set Formation Process", January 1992	92/14 MKT	Lydia PRICE	"Identifying Cluster Overlap with NORMIX Population Membership Probabilities", February 1992
92/02 MKT/EP/TM	Wilfried VANHONACKER	"The Dynamics of the Consideration Set Formation Process: A Rational Modelling Perspective and Some Numerical Results", January 1992			

- 92/15**      **Vikas TIBREWALA,**  
**MKT**      **Peter LENK and**  
                **Ambar RAO**
- 92/16**      **Xavier DE GROOTE and**  
**TM**      **Yu-Sheng ZHENG**
- 92/17**      **Xavier DE GROOTE and**  
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