Department of Economics

Essays in Competition Economics

Gregor Langus

Thesis submitted for assessment with a view to obtaining the degree of
Doctor of Economics of the European University Institute

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This thesis is dedicated to the coming generations of young inquisitive minds, one of which I hope my son will once belong to.

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CHAPTER 1

Introduction

This thesis consists of 3 essays on competition economics.

The first paper develops a model of interaction between strategic sellers with downstream power and a strategic buyer. Uncertain valuation of the product and imperfect price information confer upstream power on the buyer. The price that obtains in collusive equilibrium exhibits fluctuations, which are a reflection of the mechanism used to enforce collusion. An alternative mechanism by which buyer obtains strategic power against suppliers is characterized.

In the second paper, which is coauthored with Massimo Motta, we estimate, using event study techniques, the impact of the main events in an antitrust investigation on a firm's stock market value. A surprise inspection at the firm's premises has a strong and statistically significant effect on the firm's share price, with its cumulative average abnormal return being approximately 2.1%. Further, we find that a negative Decision by the European Commission results in a cumulative average abnormal return of about 2.4%. Overall, the fine accounts for approximately a half of this loss in value. Finally, if the Court annuls or reduces the fine, this has a positive (+2.1%) effect on the firm's valuation. The results suggest that anticompetitive behavior is indeed profitable and that the fines may not be high enough to effectively deter firms from behaving in this way.

The third paper builds a simple model of quantity competition to analyze the effect of switching costs on equilibrium behavior of two duopolists. Here I characterize an industry structure as a function of initial sales of two firms. Contrary to the literature, initial asymmetries persist in this model even though the firms are identical. When the disparity between initial sales is large, the smaller firm may become very aggressive and get more than half of the market in equilibrium. When the firms have similar initial positions, they tend to be locked in them. This paper extends the work on switching costs by considering a large set of equilibria depending on the initial sales of competing firms and by characterizing asymmetric Markov perfect equilibria where asymmetries are persistent.

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CHAPTER 2

Buyer Power under Imperfect Price Information and Uncertain Valuation

1. Introduction

The issue of buyer power has for a long been receiving attention of theorists and regulators. In the 1930's the Robinson–Patman Act in the United States sought to prohibit suppliers from offering preferential terms to selected buyers. This act was a consequence of a concern that the increased buyer power, with the growth in mass retailing, might impede the competition in the industry. Recently there has been a renewed attention to this issue. The reason is that in many industries suppliers are facing buyers with increasing power. One example where this is particularly true is, according to a study prepared for the European Commission Consulting (1999), food retailing, where the top ten grocers account for 40% of sales in Europe. Although less drastically, also other industries have undergone significant consolidations of buyers and increase in their power.

A source of welfare loss related to the buyer power is, according to a standard textbook treatment, the fact that a monopsonist, buying an intermediate input from a supplier would buy less than a socially efficient level of this input. Buyer power is particularly undesirable when the buyer has also power downstream. On the other hand, there is a positive welfare effect of the buyer power because it can counter the market power of the manufacturers. Because of these trade–offs, further insights on the nature of the interaction between the sellers the buyer and downstream firms are necessary to give a positive judgment on the structure of the industry.

In view of this natural questions of a regulator would be (1) how to identify a situation in which a powerful buyer is facing a powerful seller, (2) to what extent the buyer can exercise his power to counter the sellers' power and (3) what are the effects of the buyer's power on the social welfare. The first question might be complicated further if the regulator observes unstable industry performance and if the prices fluctuate significantly. Then it is not clear whether this is a reflection of the competition in the industry, a periodic exercise of the buyer power or a consequence of changes in the structure of the industry. The second question is no simpler to answer and a regulator using the static textbook theory could not identify most of the situations in which the buyer has some countervailing power. In order to account

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for many situations in which the buyer power arises and to evaluate its social significance we need different models of the buyer – seller interaction.

This paper proposes one such model, where the buyer's power is based on the privately observed prices and valuation and has two distinctive properties: it is appropriate in a situation where the industry exhibits unstable performance, as it generates price cycles, and it captures the role of private information about the valuation of the good in creation of the buyer power.

Specifically, I model a buyer with a stochastic valuation of the product who is deciding whether or not to purchase the product after he has observed the quoted prices and the realization of the valuation. The buyer cannot carry the consumption from one period to another (the consumption opportunity is forgone in the next period). The buyer's valuation is his private information. The sellers quote the prices of a homogeneous product and do not observe each other's quotes. The industry structure (the set of strategies and costs) is common knowledge.

On the side of the sellers non-cooperative collusive equilibria in the style of Green and Porter (1984) obtains. In their framework a collusive equilibrium results in the occasional and temporary price and output reversions to static Nash equilibrium values. These reversions are the reflection of the enforcement mechanism, which in the presence of imperfect information supports the monopolistic price and levels of production. In the model of Green and Porter the sellers are colluding at low quantities, whereas in my model the firms are colluding at a high price until they have observed a drop in demand when they revert to low price for a certain number of periods.

The buyer, acting strategically, turns out to obtain a lower price in the equilibrium compared to the price that can be obtained by the naive buyer. Another result is that in equilibrium the buyer is exercising his strategic power. Strategic behavior is reflected in the fact that the buyer postpones the purchase when his valuation is below a certain threshold value (higher than the quoted price) and forgoes a positive net surplus in the period to gain a higher surplus in the future when the sellers will revert to a low price static equilibrium for a fixed number of time periods.

2. Related Literature

A related model of the effect of the buyer power on the upstream competition in a dynamic setting is Snyder (1996). In his model a buyer with deterministic demand can accumulate a backlog of unfilled orders to mimic a boom in the demand and this way force the sellers to collude at a low price. The mechanism at work is that a large order would make it more tempting for the sellers to deviate in the period when the order arrives to the market, given the possible punishment in subsequent periods. It is this threat and not its actual execution that prevents collusion at the monopolistic price. That is why in Snyder's model in equilibrium demand cycles are not observed; the collusive price is just low enough for the buyer to purchase every period. One implication of the model, when extended to several buyers, is that the larger buyer should be charged a lower price in equilibrium than the smaller one.

In my model it is not the size, but the privately observed valuation of the product, together with strategic behavior of the buyer, that allows him to obtain a lower price. The reason for this is different than in the model of Snyder. There the buyer can increase the temptation of the sellers to deviate by increasing the size of the order, mimicking a boom, and with this the profit from deviation. In my model the buyer is using asymmetry of information and "mimics" a deviation of one of the sellers. Though the sellers know that neither of them has any incentive to deviate in equilibrium, they revert to an outcome of the static Nash equilibrium as this is the only credible enforcement mechanism.

The ability of the buyer to accumulate orders and postpone consumption at not too high costs are critical for Snyder's result. Therefore it is suitable for industries in which the good does not become obsolete and where the valuation of the good is relatively stable over time. In contrast, my model applies to industries where these two conditions are not satisfied. For example, consider government purchasing military equipment or high tech products. Another way in which the model of this paper is different from Snyder's is that it accounts for the possibility of the stochastic, privately observed valuation of the good on the side of the buyer. This is what confers the power to the buyer and generates equilibrium price reversions.

In the way the sellers are modelled, a closely related paper is Green and Porter (1984). Whereas in my model the firms are colluding in price as in a version of Green and Porter (1984) of Tirole (n.d.), in the original model the firms collude at the monopolistic level of output. A reversion is triggered by an observed drop in the market price below a certain trigger price, when the firms revert to Cournot equilibrium of the static game for a fixed number of time periods. By deviating a firm increases the probability that the market price falls below the trigger price. The reversion is just long enough to make the expected profits from deviation smaller than the expected loss incurred because of an increase of a probability that the market price falls below the trigger price.

To generate buyer power other literature makes assumptions on the cost structure of the sellers, the buyer, or it assumes some specific bargaining process. Moreover, it usually does not account for the repeated interaction between the buyer and the sellers.

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A strand of literature on the buyer power uses static Nash bargaining solution concepts. An example is Horn and Wolinsky (1988), where they show that when the prices are set in negotiations the market structure in the downstream industry affects the outcomes of negotiations with the supplier.

Chipty and Snyder (1999) and Inderst and Wey (2003) identify the increasing unit costs of production as a source of buyer power and apply cooperative solution concept to show that the two downstream firms are better off by merging. If the production costs are convex a large buyer can achieve a lower price in bargaining. While a small buyer is negotiating over additional production at the margin, holding the unit costs constant, a large buyer can negotiate an order that spans over a wide production interval and can achieve lower unit costs.

Biglaiser and Vettas (1993) analyze a set of two period dynamic models, where sellers are capacity constrained and cannot fulfill all the orders addressed to them individually. They show that these capacity constraints confer significant power on the buyers.

Overall, the models that do not use asymmetry of information to generate buyer power make restrictive assumptions either on the bargaining process or on the cost structure of the sellers. Though the assumption in the model of this paper, that the sellers have constant and equal marginal cost is restrictive as well, similar results would obtain under an alternative symmetric cost structure. On the other hand, the literature that makes use of asymmetric information does not consider an uncertain valuation on the side of the buyer and thus misses an important source of the buyer power. Moreover, the models in the literature do not identify the role of a powerful buyer in the industries with an unstable performance, as they generate constant equilibrium prices.

3. The Model

There is one buyer and two sellers. The buyer is facing uncertainty about his future valuation of the good. He can consume only one unit of the good each period. If he consumes less than one unit he obtains zero utility. He offers to buy zero or one unit of the good each period (this is called a purchase offer and is denoted by q_t). The good is homogeneous and divisible. The buyer can thus split the offer to buy the differently priced goods in shares $(q_t^1, q_t^2), q_t^1 + q_t^2 = 1$. After the buyer makes the offer the sellers can decide whether they will service his purchase offer or not. After the sellers respond the buyer can proceed with the purchase (denote this action as $a_t^i \in$)or decide not to purchase the good. His utility in period t, if both sellers agree with demands and he purchases the good from both is $\theta_t - p_t^1 q_t^{b1} - p_t^2 q_t^{b2}$. θ_t is a realization of the random variable drawn from an independent and identical distribution each period and p_t^i is the purchasing price for the seller i. Utility in case of no purchase is 0. At the time of the decision on the purchase the uncertainty about the valuation is resolved and remains the buyer's private knowledge.

Seller i is setting the price p_t^i of homogeneous product, observes purchase offer at that single price and decides upon whether or not to service the share of the purchase offer addressed to him (a zero one decision): $d_t^i \in \{0,1\}$. Sellers have zero marginal costs are risk neutral and are maximizing profits.

In every period the timing of the game is the following: Buyer observes his valuation and sellers quote the prices. After having observed the prices the buyer addresses his offers. Each of the sellers then observes the purchase offers for his product and decides whether or not to service the them. Finally the buyer can accept or reject the offer of individual sellers. I will call the realized purchases demand. This repeats every time period.

I now define the stage game strategies. Notice that in every period the game has four sub-stages. In the first sub-stage the sellers set the prices.

In the second sub-stage the buyer observes his θ and prices and chooses a policy vector from the space of policies $S^b \equiv \left\{(s_t^{b1}, s_t^{b2}) : s_t^{b1} + s_t^{b2} \in \{0,1\}\right\}$, $s_t^{bi} = s_t^{bi}(\theta_t, p_t^1, p_t^2)$.

In the third sub-stage the sellers choose a service policy function $l_t^i : [0,1] \times \mathbf{R}^+ \to 0,1$ (and $l_t^i = l_t^i(p_t^i, s_t^{bi})$, so that the decision for the seller whether to service or not depends both on his price and on the purchase offers addressed to him by the buyer.

In the forth sub-stage the buyer chooses a policy function (acceptance) from the set $A^b \equiv \{(a^1, a^2) \in \{0,1\} \times \{0,1\}\}$, $a_t = a_t(\theta_t, p_t^1, p_t^2, d_t^1, d_t^2))$.

To save notation I define the following concatenations $s_t^b \equiv [s_t^{b1}\ s_t^{b2}\ a_t^{b1}\ a_t^{b2}]$ $s_t^i \equiv [p_t^i\ l_t^i]$ and $s_t \equiv [s_t^b\ s_t^i]$. The stage game payoffs conditional on the realization of the buyer's type are given by $\pi^b(s(\theta), \theta)$ and $\pi^i(s(\theta), \theta)$ for the buyer and sellers, respectively.

The objective of the buyer in repeated game is to maximize the discounted stream of utility and the objective of the sellers is to maximize the discounted profits over infinite horizons. It will come handy to define the stages with a time index and a subindex denoting sub-stages. So t_k denotes the k-th sub-stage of the t-th stage game. I will not differentiate between sub-stages when this will not introduce any ambiguity. At time t in the first sub-stage seller i has observed a history of his offered prices, demands addressed to him and demand serviced in every period until t:

$$h_{t_1}^i = \{(p_0^i, q_0^i, d_0^i, a_0^i), (p_1^i, q_0^i, d_1^i, a_1^i), \ldots, (p_{t-1}^i, q_{t-1}^i, d_{t-1}^i, a_{t-1}^i)\}.$$

Thus a seller does not observe actions of the other seller or buyer directly.

In the second sub-stage of period t, when deciding about the purchase, the buyer has observed a history of realizations of θ of prices set by sellers and his purchase offers addressed to each of the sellers as well as service decisions:

$$h^b_{t_2} = \{(\theta_0, p_0, q_0, d_0, a_0), (\theta_1, p_1, q_1, d_1, a_1), \\ \dots, (\theta_{t-1}, p_{t-1}, q_{t-1}, d_{t-1}, a_{t-1}), (\theta_t, p_t)\}.$$

Thus a buyer observes prices in the period before making his move.

In the third sub-stage at t seller i has observed $h^i_{t_1}$ and the purchase offers that the buyer has addressed to him a^i_t. I denote this by $h^i_{t_3}$.

In the fourth sub-stage at t the buyer has observed $h^b_{t_2}$ and both sellers' decisions on whether or not they want to service his offers (d^1_t, d^2_t). I denote this by $h^b_{t_4}$.

Let h_t denote concatenation $[h^i_t\ h^b_t]$ of the histories observed for the buyer and sellers at the end of the fourth sub-stage at t.

I focus on the pure strategies which simplifies the analysis greatly. Moreover, when mixing is allowed for, the computation of equilibrium strategies becomes extremely costly, and it does not seem likely to me that firms would go through such calculations in such an uncertain environment. On the other hand, in pure strategies the equilibrium is simple to compute.

Strategy of the seller i in the first sub-stage of the period t_1 is a pricing function g^i_t : $\mathcal{H}^i_{t_1} \to \mathbf{R}^+$. At t_3 the strategy is a service function $l^i_t : \mathcal{H}^i_{t_3} \times [0,1] \times \mathbf{R}^+ \to 0, 1$. The period t strategy for the seller is a pair of functions (g_t, l_t), which I denote by f^i_t

The infinite sequence of these functions is denoted by $\mathscr{S}^i$. Seller i's continuation strategy at the last sub-stage of t is a t-tail subsequence of $\mathscr{S}^i$, denoted by $\mathscr{S}^i_t$. $\mathscr{S}^{i\infty}_t$ denotes the whole set of seller i's strategies.

Strategy of the buyer in sub-stage 2 of period t is a function $u^b_{t_2}$ from the set of all potential histories until that sub-stage $\mathcal{H}^b_{t_2}$ to the set of real pairs $\{(q^1_t, q^2_t) : q^1_t + q^2_t \in \{0, 1\}$. In the last (fourth) sub-stage the buyer's strategy is a function $a : \mathcal{H}^b_{t_4} \to \{0, 1\}$. Period t strategy of the buyer is a pair of functions (u_t, a_t) which I denote by f^b_t.

I denote an infinite sequence of these functions as $\mathscr{B}$. Buyer's continuation strategy at t is a t-tail subsequence of $\mathscr{B}$, denoted by $\mathscr{B}_t$. $\mathscr{B}^\infty$ denotes the whole set of strategies of the buyer.

A system of beliefs $[d_1\ d_2\ b]$ for the sellers and the buyer specifies at each time period t and observed private histories $h^i_t, i = 1, 2$ and h^b_t a probability distribution over other players' private histories.

This game roughly describes an environment in which the upstream market is oligopolistic and downstream market is monopolistic and the firms are not allowed to form horizontal agreements or to exchange their sales information. The buyer knows all the relevant parameters of his current utility before deciding upon the purchase. The firms do not communicate with each other, do not observe any of the relevant parameters of the buyer's current utility and are free to set their prices independently and to respond to the changes in the environment as long as this response is not concerted by means of an agreement or exchange of information.

The following assumptions are used:

: **Assumption 1** The buyer's valuation of the good is characterized by an iid continuous random variable Θ taking values on the interval $[0,1]$.

: **Assumption 2** The buyer can consume only one unit of the good per period. Consumption of less than one unit brings zero utility to him.

: **Assumption 3** The buyer and the sellers know the structure of the industry. The distribution function G of Θ is common knowledge.

Assumption 1 is not too restrictive in the sense, that the general results follow for any non-degenerate distribution of Θ. Assumption 3 is standard.

3.1. Equilibrium. To characterize equilibrium I define stochastic streams of action profiles called outcome paths, denoted $Q([\mathscr{B}\ \mathscr{S}],\{\theta_t\}_{t=1}^{\infty}) = \{s((f)(h_t\}_{t=1}^{\infty}$

These paths are induced by strategy profile $[\mathscr{B}\ \mathscr{S}]$ and by a sequence of realizations of buyer's valuation inductively in the following way (analogously as Abreu (1988) for non-stochastic repeated games): $s((f)(h_0,p_0,q_0,d_0)) = (f)(h_0,p_0,q_0,d_0)$ and

$$(1)\quad s((f)(h_t,p_t,q_t,d_t)) = \\ f(h_t,p_t,q_t,d_t)(s((f)(h_0,p_0,q_0,d_0))\dots s((f)(h_{t-1},p_{t-1},q_{t-1},d_{t-1})),p_t,q_t,d_t).$$

Define the expected continuation values of strategies depending on the observed history as expected discounted stream of per-period payoffs of the players from period $t+1$ on

$$\overline{V}^b(h_t^b,\mathscr{B}_t,\mathscr{S}_t) = \mathrm{E}_t\sum_{\tau=t}^{\infty}\delta^{\tau-t}\pi^b(s((f)(h_\tau,p_\tau,q_\tau,d_\tau)),$$

where the expectation is over the outcome paths induced by strategy profile $[\mathscr{B}_t\ \mathscr{S}_t]$ and a sequence of realizations of Θ. The continuation values for the sellers are defined analogously and are denoted $\overline{V}^i(h_t^i,[\mathscr{B}_t\ \mathscr{S}_t])$. Then we can describe the equilibrium as a strategy profile $[\mathscr{S}_i^*\ \mathscr{S}_j^*\ \mathscr{B}^*]$ and a consistent profile $[d_1\ d_2\ b]$ of beliefs, that satisfy the following conditions:

$$(2)\quad \mathrm{E}_t\pi^b(s((f_t^*\backslash f_t^b)(h_t,p_t,q_t,d_t))) + \delta\overline{V}^b(h_t^b,[\mathscr{B}_t^*\ \mathscr{S}_t^*]) \le \\ \mathrm{E}_t\pi^b(s((f_t^*)(h_t,p_t,q_t,d_t))) + \delta\overline{V}^b(h_t^b,[\mathscr{B}_t^*\ \mathscr{S}_t^*]),$$

for all t and $f_t^*\backslash f_t^b \in \mathscr{B}_t^\infty$, and

$$\text{(3)} \quad \mathrm{E}_t\pi^i(s((f_t^*\backslash f_t^i)(h_t, p_t, q_t, d_t))) + \delta\overline{V}^i(h_t^i, [\mathscr{B}_t^* \ \mathscr{S}_t^*]) \leq \mathrm{E}_t\pi^i(s((f_t^*)(h_t, p_t, q_t, d_t))) + \delta\overline{V}^i(h_t^i, [\mathscr{B}_t^* \ \mathscr{S}_t^*]),$$

for all t, i and $f_t^*\backslash f_t^i \in \mathscr{S}_t^{i\infty}$.

The expectation is taken over the possible outcomes of the stage game for given strategies and distribution of random variable Θ. That the conditions (2) and (3) are necessary is obvious. That they are sufficient follows from a single deviation principle (Abreu (1988)).

An equivalent characterization of equilibrium is given by the following conditions. Given sellers' equilibrium strategies in period t the buyer solves the following maximization problem:

$$\text{(4)} \qquad \max_{f_t^b} \left\{ \mathrm{E}_t\pi^b(s((f_t^*\backslash f_t^b)(h_t, p_t, q_t, d_t))) + \delta\overline{V}^b(h_t^b, [\mathscr{B}_t^* \ \mathscr{S}_t^*]) \right\},$$

where $f_t^*\backslash f_t^b$ denotes the optimal strategy profile at t with f_t^{b*} replaced by f_t^b.

Seller i, given other player's equilibrium play solves the following problem:

$$\text{(5)} \qquad \max_{f_t^i} \mathrm{E}_t\pi^i(s((f_t^*\backslash f_t^i)(h_t, p_t, q_t, d_t))) + \delta\overline{V}^i(h_t^i, [\mathscr{B}_t^* \ \mathscr{S}_t^*]),$$

where $f_t^*\backslash f_t^i$ is the optimal strategy profile with f_t^{i*} replaced by f_t^i.

Because of the stochastic valuation of the buyer it turns out that at any pricing $\min\{p_t^1, p_t^2\} > 0$ the buyer will optimally skip a purchase with a strictly positive probability. The reason for this is that seller i does not observe the actions of the buyer and seller $j \neq i$ and any punishment mechanism for the buyer (high price) would be a reward for the deviating seller. In effect there is no credible punishment mechanism that would deter the buyer from from skipping consumption of the good in the periods when his net per-period utility is non-positive.

The sellers cannot tell just by observing their own demand (realized purchases) whether there has been a deviation from equilibrium strategies or just a realization of a low valuation of the good. Because of this uncertainty they will have to periodically resort to punishment in equilibrium. Put differently, there cannot be an equilibrium in which the punishment were observed with zero probability. This observation leads us to focus on equilibrium strategies that are analogous to Green and Porter (1984). In equilibrium sellers start by pricing high and continue to do so as long as their private observations of demand remain high. After a low private realization of demand they price low for a certain number of period which lasts long enough to deter the sellers from deviating from equilibrium strategies. Following Greene and Porter I will call the periods in which firms set the high price *normal* and the periods of punishment phase *reversionary.*

I will focus on an equilibrium where the sellers set an equal price and expect to address 1/2 of the demand of the buyer and refuse to service any other demand, knowing that doing this they will start the price war. If the buyer in the last sub-stage for whatever reason vetoes this arrangement they will revert to the punishment price in the next period.

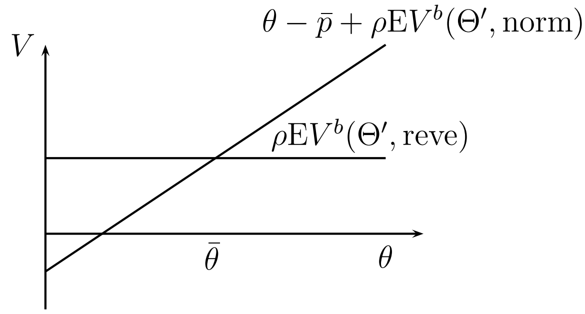
Notice that if the sellers will only service 1/2 of purchase offer every period then the buyer, when it is optimal for him to buy, will offer exactly this arrangement. The buyer would always want to provoke a price war but he can do this without opportunity costs only in periods of low valuation (otherwise he has to sacrifice a positive per-period surplus). At first sight it seems that the buyer could have provoked a price war by addressing the whole purchase offer to a single seller. The seller, however, will refuse to service such an arrangement if there is a credible punishment that can enforce this outcome. Note that the seller will also refuse to service anything but 1/2 of the purchase offer in the punishment phase. I proceed by solving the buyer's problem by assuming that there is such an enforcement mechanism and use the solution from the buyer's problem in characterization of the part of the feasible set of collusive strategies for the sellers.

The system of equilibrium beliefs is rather simple. First the buyer observes all the information. If the sellers observe a demand which is not equal to 1/2 in the normal phase they put probability one on an event that there has been a realization of low valuation on the side of the customer. In the punishment phase they put probability one on the event that the other seller is not punishing in case they observe demand which is not equal to 1/2 and they restart the punishment. The sellers put probability one on the event that both the sellers are punishing when they observe 1/2 demand in the punishment phase. Off equilibrium the beliefs are as follows:

(1) The seller who deviates and observes the whole demand puts probability one on the event where the other seller was quoting collusive price and the buyer's realization of valuation was high. In the beginning of the next period he believes that the other seller is punishing with probability one.
(2) The seller who deviates and observes zero demand puts probability one on the event that the buyer had a low realization of his valuation and that the other seller was quoting collusive price. In the beginning of the next period he believes that the other seller is punishing with probability one.

3.2. The buyer. The value function for the buyer' s problem, under the above assumptions satisfies the following Bellman equation:

$$V^b(\theta, \text{norm}) = \max\{\theta - \bar{p} + \rho \mathrm{E} V^b(\Theta', \text{norm}); \quad \rho \mathrm{E} V^b(\Theta', \text{reve})\}, \tag{6}$$



The value of purchase is increasing in θ and the expected value of postponing the purchase is constant. The value of θ at which the lines cross is the point of indifference between buying and postponing the purchase.

FIGURE 1. The function (46) and the reservation $\bar{\theta}$

where the maximization is over the actions: buy, not buy. Here the fact is used that the sellers will not service any other share of the demand but 1/2. In that case the buyer will only be able to start a price war if he does not purchase the good at all in the period. In the case he decides on the purchase it will then be rational for him to also accept the arrangement in the last sub-stage of the period. The decisions not to buy and to buy correspond to the first and the second expression on the r.h.s. of (46), respectively. If the buyer makes the purchase he obtains a flow of utility $\theta - \bar{p}$ in the current period and faces identical problem in the next period. By deciding not to purchase in a normal period the buyer gets no utility in the period and induces a reversion to the price $\underline{p}$. The second part of the r.h.s. of (46) summarizes the expected value for the buyer of being in the first period of a reversionary state.

It is easy to see that the optimality condition for the buyer in normal states takes the form of a reservation $\bar{\theta}$, where for $\theta \geq \bar{\theta}$ the buyer makes the purchase and does not make the purchase otherwise. The functional equation (46) is represented in Figure (1).

From Figure (1) we see that the solution will have the form:

$$V^b(\theta, \mathrm{norm}) = \begin{cases} \theta - \bar{p} + \rho \mathrm{E} V^b(\Theta', \mathrm{norm}) & \text{if} \quad \theta \geq \bar{\theta} \\ \rho \mathrm{E} V^b(\Theta', \mathrm{reve}) & \text{if} \quad \theta < \bar{\theta} \end{cases} \tag{7}$$

Moreover, the expected value in the first period of the reversionary period for the buyer follows equation:

$$\mathrm{E} V^b(\Theta', \mathrm{reve}) = \big(1 - G(\underline{p})\big)\, \mathrm{E} \sum_{t=0}^{T-1} \rho^t (\Theta' - \underline{p}) + \rho^T \mathrm{E} V^b(\Theta', \mathrm{norm}), \tag{8}$$

where the assumption of the stationarity of the random process was used. The stationarity is used to obtain the expectations about the value functions that are not functions of time, but only of states (realizations of Θ).

Equation (8) reflects maximization of the buyer, whereby in periods of reversion it is optimal for him to buy whenever $\theta \geq \bar{p}$. The first term on the r.h.s. of (8) captures the flow of utility during the reversion and the second term captures the value of being in the normal state after the reversionary period has finished, appropriately discounted.

$\bar{\theta}$ is the realization of Θ for which the buyer is indifferent between purchasing a unit and postponing the purchase. From (7) it can be seen that $\bar{\theta}$ solves the following equation:

$$\bar{\theta} - \bar{p} + \rho \mathrm{E}V^b(\Theta', \mathrm{norm}) = \rho \mathrm{E}V^b(\Theta', \mathrm{reve}) \tag{9}$$

Using (8) we get:

$$\bar{\theta} - \bar{p} + \rho \mathrm{E}V^b(\Theta', \mathrm{norm}) = \left(1 - G(\underline{p})\right) \rho \frac{1-\rho^T}{1-\rho} \left(\mathrm{E}[\Theta] - \underline{p}\right) + \rho^{T+1} \mathrm{E}V^b(\Theta', \mathrm{norm}). \tag{10}$$

Equation (10) gives $\bar{\theta}$ for given distribution of Θ, $\bar{p}$, $\underline{p}$ and T, where $\bar{p}$, $\underline{p}$ and T completely characterize equilibrium strategies of the sellers.

From (10) we can express $\bar{\theta}$ in the following way:

$$\bar{\theta} = \bar{p} + \mu + (\rho^{T+1} - \rho)\mathrm{E}V^b(\Theta', \mathrm{norm}), \tag{11}$$

where $\mu = \left(1 - G(\underline{p})\right) \rho \frac{1-\rho^T}{1-\rho} \left(\mathrm{E}[\Theta] - \underline{p}\right)$.

Using (7) and (8) we can further write:

$$\mathrm{E}V^b(\Theta', \mathrm{norm}) = \int_{-\infty}^{\bar{\theta}} \left(\mu + \rho^{T+1} \mathrm{E}V^b(\Theta', \mathrm{norm})\right) dG(x) + \int_{\bar{\theta}}^{+\infty} \left(x - \bar{p} + \rho \mathrm{E}V^b(\Theta', \mathrm{norm})\right) dG(x), \tag{12}$$

which can be solved for $\mathrm{E}V(\Theta', \mathrm{norm})$:

$$\mathrm{E}V^b(\Theta', \mathrm{norm}) = \frac{-\bar{p} + G(\bar{\theta})(\mu + \bar{p}) + \int_{\bar{\theta}}^{+\infty} x\, dG(x)}{1 - \rho + G(\bar{\theta})(\rho - \rho^{T+1})}. \tag{13}$$

(13) and (11) together implicitly define $\bar{\theta}$ as a function of the distribution, $\bar{p}$, $\underline{p}$ and T, which characterizes optimal strategy of the buyer.

More generally, the following lemma characterizes the relation between $\bar{\theta}$ and $\bar{p}$:

LEMMA 1. *For any continuous distribution of* Θ, $\bar{\theta} \geq \bar{p}$.

> **Proof.** Suppose to the opposite that $\bar{\theta} < \bar{p}$. Then a future realization of Θ, $\theta \in (\bar{\theta}, \bar{p})$ with positive probability. In this interval the buyer purchases the good and obtains a negative flow of utility $\theta - \bar{p}$. This is not consistent with utility maximization.■

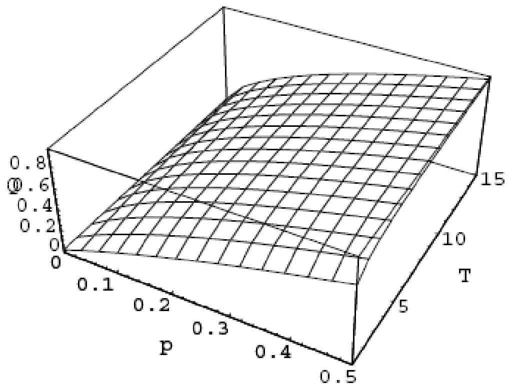


FIGURE 2. $\bar{\theta}$ as a function of $\bar{p}$ and T

$\bar{\theta}$ is increasing both in $\bar{p}$ and T. $\bar{\theta}$ is always greater than $\bar{p}$ and the rate of increase of $\bar{\theta}$ in $\bar{p}$ is increasing with T.

To be able to make more precise statements about the relation between the variables of interest I further assume that Θ is uniformly distributed over the interval $[0,1]$. Under this assumption we obtain the following expression for $\bar{\Theta}$:

$$\bar{\theta} = -\frac{1-\rho}{\rho(1-\rho^T)} - \frac{\sqrt{(1-\rho)^2 + \rho(1-\rho^T)\left(\rho\underline{p}(2\underline{p}-3)(1-\rho^T) + 2\bar{p}(1-\rho^{T+1})\right)}}{\rho(1-\rho^T)} \tag{14}$$

Figure 2 shows $\bar{\theta}$ for different combinations of pairs $(\bar{p}, T)$, under the assumption $\underline{p} = 0$.

3.3. Sellers. Sellers' marginal costs are zero and there are no fixed costs. Their objective is to maximize the flow of profits individually. In equilibrium that I consider the sellers initially set a collusive price $\bar{p}$ and service the demand addressed to each of them if that demand is $1/2$. They continue to do so until the demand for one or more of the sellers turns to be different than collusive share in normal periods or until the buyer rejects the arrangement in the last sub-stage. In these cases the sellers refuse to service demand and in the next period they revert to the punishment price $\underline{p}$ for T periods, after which they return back to normal price. Let $\mathcal{C}$ be the set of all t in which firms set a high and $\mathcal{R}$ be the set of all reversionary time periods. Given optimal behavior of the buyer and the mechanism of collusion of the sellers we can characterize the set of feasible values for $\bar{p}$, $\underline{p}$ and T, given distribution of Θ that can support tacit collusion.

Under the assumptions the value for the seller of being in collusive phase is:

$$V^s(\text{norm}) = \left[1 - G(\bar{\theta})\right]\left(\frac{1}{2}\bar{p} + \delta V^s(\text{norm})\right) + G(\bar{\theta})\delta V^s(\text{reve}), \tag{15}$$

where $V^s(\text{reve})$ denotes the value of the first period of the reversionary (punishment) phase. The first term on the r.h.s captures the value from the purchase of the good, and the second term captures the value of the buyer postponing the purchase.

The value for the seller of being in the first period of reversionary phase is:

$$V^s(\text{reve}) = \frac{1}{2}\left(1 - G(\underline{p})\right)\sum_{t=0}^{T-1}\delta^t \underline{p} + \delta^T V^s(\text{norm}), \tag{16}$$

where the probability of the purchase $(1 - G(\underline{p}))$ captures the fact that the buyer cannot, and does not want to, exercise his power in periods of reversion.

Equations (15) and (16) can be solved for $V^s(\text{norm})$:

$$V^s(\text{norm}) = \frac{\left(1 - G(\bar{\theta})\right)\bar{p} + G(\bar{\theta})\left(1 - G(\underline{p})\right)\delta\frac{1-\delta^T}{1-\delta}\underline{p}}{2\left(1 - \delta\left(1 - G(\bar{\theta}) + \delta^T G(\bar{\theta})\right)\right)}. \tag{17}$$

Since the punishment in the model happens with some probability in every period, we must have that in any Nash equilibrium the incentive for deviation in collusive and punishment states is absent. Immediate consequence is that along the punishment path we must have a Nash equilibrium of the static (one stage) game in every $t \in \mathcal{R}$ [1]. This has implications for the set of feasible $\underline{p}$ in equilibria.

LEMMA 2. *Under the assumptions of the model the only $\underline{p}$ that satisfies conditions of Nash equilibrium of the game is $\underline{p} = 0$.*

> **Proof.** Assume that the firms adopt $\bar{p}$ in normal periods and punish for T periods at price $\underline{p}$. Such a strategy with $p_t = 0$ for all $t \in \mathcal{R}$ constitutes a Nash equilibrium if the value of colluding for firms in a normal state is higher than the value of deviation. With $\underline{p} = 0$ there is no incentive for deviation on part of a seller. On the other hand, for any $\underline{p} > 0$ a seller has an incentive to undercut and gain the whole demand with certain probability, whereas by not undercutting he only gains half of the demand with weakly lower probability, given the other player's strategy. Therefore there is no Nash equilibrium for $\underline{p} > 0$.■

By Lemma 2 a seller would deviate only in periods preceded by a normal period or in the first period after the reversionary phase is over. The price to which it deviates is a monopolistic price 1/2 in the absence of any other internal restrictions on the side of the buyer. So, the optimal deviation is upwards[2]! The reason is that the seller that does not deviate will refuse to service the purchase offers that the buyer addresses to him.

[1] This is also true for perfect equilibrium, even if the punishment happens with zero probability.

[2] Of course in equilibrium this deviation will not ever be observed, so we need not worry about that.

Langus, Gregor (2008), Essays in Competition Economics
European University Institute 10.2870/20513

This complicates the presentation, but does not change the results qualitatively. Since in addition this is a rather surprising and at first sight counterintuitive result, I will consider a case in which a buyer is constrained to always purchase from the cheaper seller (think of a government purchasing via tenders - the tender commission would not allow the government to address the whole demand to a single seller).

In this case the optimal deviation is to price $\bar{p}$. If the buyer's valuation of the good is high enough the buyer will buy everything from the firm that deviates. If the buyer's valuation is too low then he does not buy the good at this price. In any case this will set the reversionary phase in the next period. By Lemma 2 the seller will never want to deviate in T.

The value of optimal deviation is therefore:

$$V^s(\text{opt.dev.}) = \max_{p} \left\{[1-G(p)]p + [1-G(\underline{p})]\frac{1-\delta^{T+1}}{1-\delta}\underline{p} + \delta^{T+1}V^s(\text{norm})\right\} \quad (18)$$
$$\text{subject to } p \leq \bar{p}.$$

The following lemma will be helpful in determining the value of optimal deviation.

LEMMA 3. *The optimal deviation price $p^* = \bar{p}$ for the class of unimodal distributions.*

Proof. The upper bound on $\bar{p}$ is monopolistic price p^M. Since the unconstrained maximization problem of the seller about to deviate (18) yields exactly p^M as the solution, and the value function V(opt.dev) is monotonically increasing in p for $p \in [0, \bar{p}]$ the constraint that the buyer is not allowed to purchase from the more expensive buyer is binding at optimum.■

Using Lemma 3 we can write the value of optimal deviation as:

$$V^s(\text{opt.dev.}) = [1-G(\bar{p})]\bar{p} + [1-G(\underline{p})]\frac{1-\delta^{T+1}}{1-\delta}\underline{p} + \delta^{T+1}V^s(\text{norm}). \quad (19)$$

The first term in (19) is the profit in the period of deviation. Since the buyer at the time of the decision observes both price quotes (and can predict the state of the world in the next period with certainty, so the incentive for the exercise of strategic power after one of the sellers has deviated is absent) he will purchase the good if there is any surplus to be gained in that period (with probability $[1-G(\bar{p})]$).

Tacit collusion is sustainable if:

$$V^s(\text{norm}) \geq V^s(\text{opt.dev.}), \quad (20)$$

Using $\underline{p} = 0$ in (17) together with (18), condition (20) becomes:

$$\frac{[1-G(\bar{\theta})](1-\delta^{T+1})}{2[1-G(\bar{p})]\left(1-\delta\left(1-G(\bar{\theta})+G(\bar{\theta})\delta^{T}\right)\right)} \geq 1, \quad (21)$$

or:

$$1-\delta^{T+1} \geq 2\frac{[1-G(\bar{p})]\left(1-\delta(1-G(\bar{\theta}))+\delta^{T}G(\bar{\theta})\right)}{[1-G(\bar{\theta})]} \tag{22}$$

At this stage I use the assumption of the uniform distribution of Θ to write (22) in the following way:

$$2[1-\bar{p}](1-\delta(1-\bar{\theta}+\bar{\theta}\delta^{T}))-(1-\delta^{T+1})(1-\bar{\theta}) \leq 0 \tag{23}$$

Using the fact that in equilibrium $\underline{p}=0$ in equation (14) we obtain $\bar{\theta}$ as a function of $\bar{p}$ and T, solely. By plugging this solution for $\bar{\theta}$ into (23) we get characterization of the set of pairs of $\bar{p}$ and T for which collusion is sustainable. The set, under the assumption of $\rho=\delta=0.95$ is represented in Figure 3.

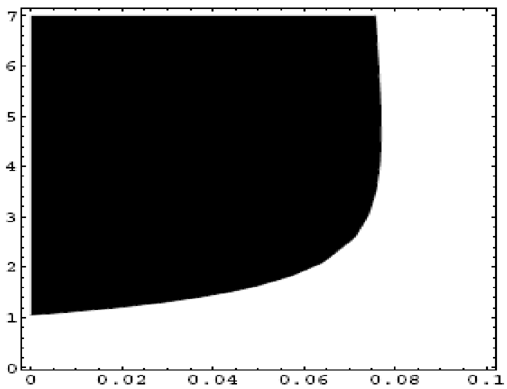


FIGURE 3. The feasible $(\bar{p},T)$ pairs (p is on the x axis)

With increases in T the set of feasible $\bar{p}$ is expanding for low values of T. However, as T becomes bigger than 4 the set starts shrinking with increases in T. This happens when the loss from the bigger temptation of the buyer to start a price war becomes so costly for the sellers that it is not outweighed by the gain in profits from higher price that is to be supported by a higher T.

A natural way to select the pair $(\bar{p},T)$ would be the pair that maximizes joint profits. The expression for joint profits is given by:

$$\Pi=\mathrm{E}\sum_{t=0}^{\infty}\iota[t\in\mathcal{C}]\delta^{t}\bar{p}, \tag{24}$$

where ι is an indicator function taking value 1 in periods of collusion and 0 in reversionary periods.

The maximization is subject to the constraint (23) which is the condition of Nash equilibrium. Maximizing (24) is equivalent to maximizing the following:

$$V^{s}(\text{norm})=\frac{1-\bar{\theta}}{2\left(1-\delta(1-\bar{\theta}+\delta^{T}\bar{\theta})\right)}\bar{p} \qquad \text{subject to (23),} \tag{25}$$

The value function is represented in Figure 4.

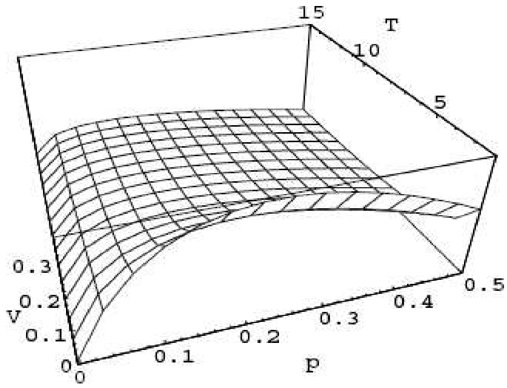


FIGURE 4. Value function of the firm

For a given T and for low values of $\bar{p}$ the value of the firms is increasing in $\bar{p}$. Above certain $\bar{p}$ the value starts decreasing in $\bar{p}$. This is because the gain in the value from the increase in price is outweighed by the loss due to the increase in the probability of the price war, which is determined by the $\bar{\theta}$ and the probability distribution of the buyer's valuation. For a given $\bar{p}$ the value of the seller is decreasing in T for obvious reasons. The problem of the sellers is to maximize this function subject to the constraint depicted in Figure 3.

I obtain the solution to this problem numerically, for $\delta = \rho = 0.95$. The optimal pair $(\bar{p}, T)$ is $(0.08, 2)$.

When the buyer has no internal restrictions the seller who deviates will set the monopolistic price. In this case, for the parameters as above there is no collusive equilibrium. The buyer is more powerful and achieves a better outcome for himself.

3.4. Naive buyer. It is interesting to compare the equilibrium results of the model with the results of the model where the buyer is naive. I model this case by assuming that the buyer, in case his net valuation is nonnegative ($\theta - p \geq 0$), always purchases the good from the cheaper seller, and splits the order equally between the sellers when quoted prices are the same. In case of the negative net valuation he does not purchase the good.

I hold the information set of the sellers to be the same as in the previous case. The value for the sellers, knowing that the buyer is naive, of being in a collusive state is given by the following equation, which is a version of (15):

$$V^s(\text{norm}) = [1 - G(\bar{p})]\left(\frac{1}{2}\bar{p} + \delta V^s(\text{norm})\right) + G(\bar{p})\delta V^s(\text{reve}), \tag{26}$$

where the interpretation is similar to the one for equation (15), with the difference that now the buyer accepts a simple purchasing rule, under which he buys with probability $1 - G(\bar{p})$ in normal periods.

The value of being in a punishment phase for $\underline{p} = 0$ is:

$$V^s(\text{reve}) = \delta^T V^s(\text{norm}). \tag{27}$$

(26) and (27) give the following expression for the value of collusion: $V^s(\text{norm})$:

$$V^s(\text{norm}) = \frac{(1 - G(\bar{p}))\,\bar{p}}{2\,(1 - \delta\,(1 - G(\bar{p}) + \delta^T G(\bar{p})))}. \tag{28}$$

Using Lemma 3 the optimal deviation is again to $\bar{p}$ and the value of optimal deviation for $\underline{p} = 0$ is:

$$V^s(\text{opt.dev.}) = [1 - G(\bar{p})]\bar{p} + \delta^{T+1} V^s(\text{norm}). \tag{29}$$

Using the condition for collusion to be feasible (20) we obtain the following set of pairs $(\bar{p}, T)$ for which the collusion is feasible:

$$-1 + \delta^{T+1} + 2(1 - \delta(1 - G(\bar{p}) + \delta^T G(\bar{p}))) \leq 0, \tag{30}$$

which,under the assumption of uniform distribution of Θ simplifies to:

$$-1 + \delta^{T+1} + 2(1 - \delta(1 - p + \delta^T p)) \leq 0 \tag{31}$$

Figure 5 represents pairs $(\bar{p}, T)$ that satisfy (31).

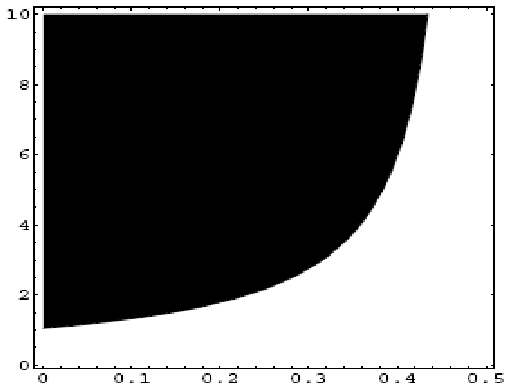


FIGURE 5. The feasible $(\bar{p}, T)$ pairs (p is on the x axis)

As in Figure 4 with higher T the set of feasible $\bar{p}$ is expanding for low values of T. Here, however, as T becomes bigger this set never starts shrinking with increases in T. This is due to the fact that the buyer is not acting strategically and is not tempted more to start a price war for higher T.

Maximizing the value of collusion for uniform Θ:

$$V^s(\text{norm}) = \frac{1 - \bar{p}}{2\,(1 - \delta(1 - \bar{p} + \delta^T \bar{p}))}\bar{p} \quad \text{subject to (30),} \tag{32}$$

we get the pair $(\bar{p}, T) = (0.23, 2)$, for the same parameter values as before. The price that the naive buyer obtains in equilibrium is more than twice higher than the price obtained by the strategic buyer exercising his upstream power.

The value function is represented in Figure 6.

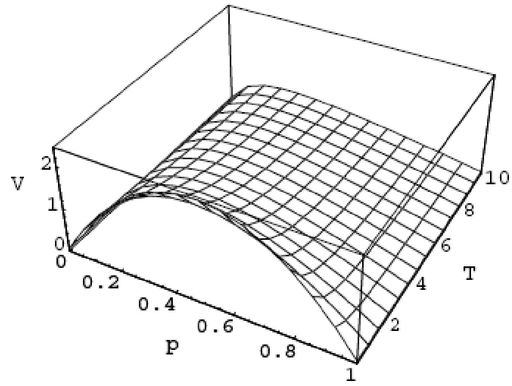


FIGURE 6. Value function for the sellers when facing naive buyer

The interpretation here is similar to interpretation in Figure 4. A difference to the value function when the sellers are facing a strategic buyer is that here the unconstrained maximum is achieved at monopolistic price $p = 0.5$, whereas before this price was lower.

3.5. Equilibria for beta distribution of valuation. More generally, we can characterize the equilibria under other distributions numerically. In this section I apply to the model the beta distribution, of which the uniform distribution over $[0, 1]$ is a special case, and which gives for different values of parameters very diverse patterns of stochastic valuations. This way I can compare different situations.

Beta probability density takes values only on the interval $(0, 1)$. The distributions that I take as an example are represented in Figure 7.

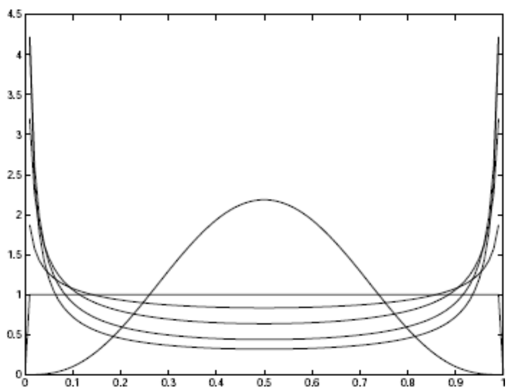


FIGURE 7. Beta distributions of Θ

The p.d.f. for the beta distribution is:

$$f(x|a, b) = \frac{1}{B(a, b)} x^{a-1}(1-x)^{b-1}\iota_{(0,1)}(x),$$

where $B(.,.)$ is a beta function, and ι is an indicator function taking value 1 when x is between 0 and 1 and value 0 otherwise.

By changing parameters a and b I obtain the distributions in the figure. (For $(a, b) = (4, 4)$ we get the bell shaped distribution, and for $(a, b) = (0.2, 0.2)$ we get the most extreme inverse bell shaped distribution. $(a, b) = (1, 1)$ gives the uniform distribution.

I dealt with the uniform distribution analytically above. It represents the case of highest level of uncertainty for the sellers about the valuation of the buyer. The bell shaped distribution represents a situation where the valuation of the buyer is centered around 0.5 most of the time and the distributions with the higher probabilities in the tails represent a situation

pdf	$\bar{p}$ naive	$\bar{p}$ str.	T naive	T str.	$\bar{\theta}$	V(coll) naive	V(coll) str.	prob. of rev. naive	prob. of rev. str.
Beta(1,1)	0.23	0.09	2	2	0.38	1.24	0.53	0.23	0.38
Beta(4,4)	0.3	0.12	2	2	0.32	2.12	0.79	0.13	0.15
Beta(0.75,0.75)	0.28	0.08	3	2	0.19	1.04	0.44	0.31	0.23
Beta(0.5, 0.5)	0.23	0.09	3	3	0.23	0.83	0.35	0.32	0.32
Beta(0.3,0.3)	0.25	0.09	5	4	0.21	0.58	0.25	0.38	0.36
Beta(0.2,0.2)	0.22	0.09	6	6	0.22	0.43	0.19	0.4	0.4

Optimal values are obtained for $\rho = \delta = 0.95$

TABLE 1. Parameters of collusive equilibria

where the buyer most of the time either has a relatively low or relatively high valuation for the good. The results are depicted in Table 3.

A notable feature of the results in Table 3 is the increase in the length of the optimal price wars as we move to a distribution which puts higher probabilities at the extreme values. Moreover, the probability of the buyer not making a purchase, thereby setting the price war, is increasing as well (with the exception of uniform distribution). This obviously implies an increasing frequency of price wars. In the model with a strategic buyer $\bar{\theta}$ is always higher than $\bar{p}$ (this holds more generally according to Lemma 1), which means that the buyer does sometimes forgo a positive current period utility to exercise his strategic power and start a price war.

A prediction of the model, which is intuitive, is that the optimal lengths of price wars are never longer when the sellers are facing strategic buyer. This is a consequence of the fact that $\bar{\theta}$ is increasing with T. A higher T can support a higher $\bar{p}$, but a higher $\bar{p}$ has an effect on profits in two directions. A direct positive effect and indirect negative effect through an increase in $\bar{\theta}$ which raises the probability of price war. When the buyer is naive, an increase in T does not affect directly the probability of price wars. Therefore an increase in T in the case of naive buyer will optimally support a higher increase in $\bar{p}$, compared to the situation with a strategic buyer.

4. Conclusion

In this paper I have analyzed a market in which buyer and two sellers of a homogeneous good interact in an infinitely repeated game. The buyer observes a realization of his stochastic valuation of the good, which remains his private information, and the price quotes. Then he decides whether or not to purchase the good, taking into account the fact that his decision may affect future prices.

A seller sets the price which is not directly observable by the other seller and observes the history of the demands addressed to him, but not to the other seller. I assumed that the sellers are colluding in price and adopt an enforcement mechanism proposed by Green and Porter (1984). The sellers revert to a marginal cost pricing (zero price) for a number periods after they have observed a drop in the demand addressed to them.

Because the prices are not directly observable by sellers they cannot monitor collusive compliance perfectly and have to rely on imperfect signals of the level of the demand addressed to each of them individually. The mechanism that enforces collusion of the sellers results in occasional reversions to the price of static Nash equilibrium. The buyer can use the enforcement mechanism of the sellers to induce a reversion to low price, when the cost of doing this (postponing the purchase) is lower than the benefits (low price for a certain number of periods). Because of the informational advantage the buyer, acting strategically, can achieve a lower collusive price in equilibrium, compared to the situation when the firms know that the buyer is naive.

Besides a lower price the strategic buyer pays for the good, the model predicts that the length of the reversions to low price in equilibrium increases with the increases in the probability of the extreme valuations of the good. Moreover, the price wars when the sellers are facing the strategic buyer are not longer than with naive buyer.

A rough welfare comparison, where the weights in total welfare are equal for the sellers and the buyer, picks up naive buyer situation as preferable for most of the valuations of the good. The intuition is simple. A strategic buyer "wastes" some of the available surplus to obtain lower prices.

This model can explain the nature of the interaction between a powerful buyer and powerful sellers in an industry which exhibits unstable performance and the buyer has stochastic valuation of the good. It shows that the buyer can effectively counter the seller power and obtain significantly lower price. Moreover, it sheds light on the possible source of welfare loss in interactions between the buyer with a power upstream and sellers with a downstream power. The traditional result of the static analysis, that the powerful buyer without downstream power facing powerful sellers is always preferable in terms of welfare, is in contradiction with the results of this model.

The model has a very simple structure and utility of the buyer is not very realistic. However, in case of a more full specification of utility the buyer would be using exactly the same mechanism to disturb collusion of the sellers. The optimal rules will be more complicated, but the results will go in the same direction.

The limitations of the model are suggestive of the possible extensions.

CHAPTER 3

The effect of EU antitrust investigations and fines on a firm's valuation

1. Introduction

Antitrust laws are fundamental in market economies, as they prevent firms from distorting competition in a way that is detrimental to economic efficiency, and fines are a crucial tool for the enforcement of antitrust laws. Only if the fines, and more generally the costs that firms incur when found guilty of antitrust infringement, are large enough, will the firms be deterred from engaging in cartels and other anti-competitive behavior.

In the US, managers who have been found guilty of a conspiracy can be given prison sentences, and firms are subject to fines and to the payment of treble damages in private actions. In the EU, which is the object of this study, competition law violators are not subject (at EU level) to criminal penalties, and private damages actions are extremely rare, but firms can in principle be given fines up to 10% of their previous year's turnover.

Yet, anecdotal evidence suggests that the impact of antitrust investigations and fines may not be that large for firms which are caught infringing EU competition law. Indeed, a large number of firms (and in fact some firms from the sample we analyze in this paper) are repeat offenders. Moreover, negative Commission decisions and Community Court judgments do not seem to trigger management changes very often. This raises the question of the extent to which firms are seriously affected by the fines they receive, or expect to receive.

In this paper, we carry out an empirical analysis to explore the effect of antitrust investigations on the share prices of firms which have infringed European competition law. To our knowledge, ours is the first work which tries to estimate the impact of European antitrust investigations on offending firms.[1] In an exercise carried out for the US, Bosch and Woodrow (1991) use a similar methodology to estimate the effect on the firm's stock market price of an indictment for price fixing.[2] They find that the shares of indicted firms in their sample

[1]For empirical analysis of the effects of EU merger notifications and decisions, which make use of the event study methodology also used here, see Duso, Neven and Röller (2006a) and Duso, Gugler and Yurtoglu (2006b).

[2]Bizjak and Coles (1995) carry out another event study analysis on US data relative to private antitrust litigation. They find that, on average, defendants lose approximately 0.6 percent of their equity value (and plaintiffs gain less than what defendants lose).

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on average lose a cumulative 1.08% of their value in the days immediately after the public announcement of the indictment.[3] They estimate that fines and damages account for only 13% of the total loss of stock market value caused by the firm's antitrust indictment.

The main reason why an antitrust investigation may create a loss in the firm's value which goes well beyond the fine is that the firm will likely have to put an end to a profitable activity (be it a cartel, an abusive practice, or any other business practice considered illegal by the antitrust agencies and the courts).[4,5]

The EU competition law institutional framework, in a nutshell. Since our objective is to analyze the effect of antitrust investigations, it is appropriate to briefly remind the reader of the main actors in the field of EU competition law, and of the main events which occur in a typical investigation. The European Commission is the primary competition authority for the enforcement of EU competition law, whose main provisions are contained in articles 81 and 82 of the Treaty establishing the European Community. Fines can be imposed on firms which have infringed articles 81 or 82, and Regulation 1/2003 (which has replaced Regulation 17/1962, which contained very similar provisions for the purposes of our article) establishes the main rules for the Commission's fining policy: in particular, fines are imposed at the discretion of the Commission, whose decisions are however subject to the review of the Community Courts, i.e. the Court of First Instance (CFI) and the European Court of Justice (ECJ); they can never be higher than 10% of the firm's worldwide turnover in the previous year; they should be proportional to the gravity and duration of the infringements; and they cannot consist of criminal penalties.

In 1998, the Commission published a Notice containing the Guidelines (i.e., a code of practice) that it would follow in deciding fines,[6] but several commentators still criticize the Commission for a lack of transparency and for exercising too much discretion in its fining decisions.

[3]An indictment by the US Department of Justice should be 'news' to the markets, as the indictment is preceded by investigations which are supposed to be secret. Bosch and Woodrow (1991) also check for possible leaks before the indictment takes place and take appropriate steps to deal with them.

[4]Furthermore, in some cases, the firm may also have to comply with (structural or behavioral) remedies which could lower its profits even more.

[5]Other sources of loss in value, in addition to the direct effect of the fines, could be: (i) legal and consulting fees for antitrust proceedings; (ii) the firm may have to give up profitable projects either because the management is distracted by the antitrust investigations, and/or because, in case of large fines, the firm will have lower retained earnings and cash: in imperfect financial markets, lower assets will limit the firm's ability to obtain credit; and (iii) the firm may be hurt by the negative publicity following an antitrust investigation.

[6]On 28 June 2006, the European Commission slightly revised the Guidelines for setting antitrust fines. However, all the observations in our sample date from before June 2006.

Note also that the turnover referred to in the Regulation is not necessarily the turnover in the relevant product (and geographic) market involved by the antitrust investigation.[7]

However calculated, commentators (and the Commission itself) agree that, until 1979 (with the *Pioneer* Decision, which is also the first Decision in our sample), the Commission was rather lenient when imposing fines.[8] Table A.1 in the Appendix provides information about the fines given to the firms in our sample: they range from 0 to 497 million euro.[9]

How an antitrust investigation proceeds. The European Commission, or more precisely its Directorate General for Competition (DG-COMP), begins its investigation either at its own initiative or on the basis of a complaint from a third party (although, if complaints occur, the Commission has no obligation to start an antitrust procedure). There is (generally) no announcement that an investigation has started, and no precise time frame for it. If during the preliminary stages the Commission has serious suspicions that there has been an antitrust infringement, it can carry out a surprise inspection, also called a *dawn raid*, on the premises of the firm(s), to gather documentary evidence (which is absolutely crucial for anticompetitive agreement cases, but relevant for abuse cases too).[10] A well-established jurisprudence obliges the Commission to take steps to respect the rights of the defendants during the investigation.[11] Among these, the Commission has to send a *Statement of Objections* to the firms under investigation, where it states its allegations regarding the practices of the firm and asks for the firm's response.

After having analyzed all the evidence and having heard from the parties, the Commission will take a *Decision*, which may be reached a long time after the Statement of Objections (in some cases, it may even take a few years). A relevant feature for our analysis is that the

[7]Since relevant market turnover data are typically not published in the Commission Decisions for confidentiality reasons, it is not possible to identify whether the base fine is computed as a percentage of turnover. This should change in the future: the June 2006 Guidelines provide that the base fines may be up to 30% of the company's annual sales in the market to which the antitrust infringement relates, multiplied by the number of years of participation in the infringement, provided the total is within the limit of 10% of the firm's total annual turnover.

[8]See for instance Geradin and David (2005, p. 20 and ff.).

[9]A noteworthy element of the Commission's fining policy is the possibility to grant, under its Leniency Program, reductions in fines to firms which cooperate in cartel investigations. A zero fine is due to the fact that the Commission can grant a 100% fine reduction to a firm which reports information allowing the Commission to have sufficient evidence to convict firms involved in a cartel. See Motta (2004) for a textbook analysis of leniency programs.

[10]Pursuant to Regulation 1/2003, the Commission can also conduct surprise inspections at the homes (and private vehicles) of firms' managers and employees.

[11]Indeed, several Commission Decisions have been annulled by the Community Courts on various procedural grounds.

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Decision is a collegial decision of the whole European Commission, not of DG-COMP, and before the Decision is taken several bodies are consulted, such as representatives of national competition authorities and members of other directorates general. Although all the people involved are bound by confidentiality clauses, leaks about (or speculations on) the content of the Decision and the level of the fines are common.

Firms which have been fined can appeal to the Community Courts, which can rule upon the merits of the Commission Decision, and whose *Judgments* can annul, reduce, uphold or even increase the fine (although to our knowledge neither the CFI nor the ECJ has ever increased the Commission's fines), as well as of course annul or uphold, completely or partly, the overall Decision. The last column of Table A.1 in the Appendix summarizes the fines as they appeared in the first Court judgments;[12] the penultimate column reports the ratio between the fine and the firm's capitalization.

The decisions taken by the Court are not made public until the moment they are announced, although in some cases there may be signs of the judges' views.[13]

Our approach. We use standard event study methodology to investigate the effect of the antitrust investigation on the firm's share price. More particularly, we try to do so by analyzing the effect of the three main events in the investigation procedure identified above: (i) the dawn raid, (ii) the Commission Decision, and (iii) the Court's judgment.[14] For each of these events there is a precise date on which they occur, even if in some cases it cannot be pinpointed (and when this happens, the observation is dropped). However, surprise inspections do not always take place and firms may decide not to appeal.

Note that these events differ in the extent to which they represent a genuine surprise to investors. In other words, some of the events may have been expected and thus may have already been reflected in the price of the relevant securities before the actual date of the event. In such circumstances, the event dates are not good proxies for the time when the news about the (expected) event reached the market. Thus, our analysis might lead us to reject the null hypothesis of no effect more often than it should be.[15]

[12]In older cases, the firms' appeal was decided by the ECJ. In more recent years, it is the CFI which decides; firms can also appeal the CFI's judgment. We do not look at this 'second' judgment, and only consider the first judgment, whichever Court takes it.

[13]In particular the opinion of the Advocate General often (though not always) anticipates the judgment of the Court. However, Advocates General are only involved in the ECJ's procedures and not the CFI's.

[14]We also looked at the effects of the Statement of Objections, but as expected we did not find any significant effect of this event on the value of the firm.

[15]In other words, when the news of the event reaches the market it may trigger an effect, but by using the date of the event, which is anticipated by the market, we may not be able to catch this effect.

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(i) The surprise inspection, or dawn raid, should represent a genuine surprise for the investors. To verify that this is really an unexpected event, we examined past issues of the *Financial Times* for any news about the (potential) investigation before the inspection took place, and we could not find any, for any of the firms for which we have dates of the raid.[16] Because the surprise inspection may allow the Commission to find incriminating evidence and because it is typically done only after the Commission already has some motivated suspicion of infringement, this event is likely to signal that a negative Decision of antitrust infringement will ultimately be taken.[17] Accordingly, a dawn raid should induce investors to revise downwards their valuation of the firm.

(ii) Next, we investigate the effect of the Commission Decision. As explained above, the market has already been aware that the Commission has been investigating the firm since the dawn raid or at least since the Statement of Objections. The investors should therefore be expecting the Decision to be taken at some time.[18] Under the efficient market hypothesis (see Section 2.2), this information should be included in the price so that we do not expect a large systematic under- or over–valuation of the possible effect of the publication of the Decision of the Commission on the value of the firm.

(iii) Finally, we investigate the effect of the Court's judgments, in particular when the judges significantly reduce or annul the fine, which we would expect to have a positive effect on the firm's valuation if it came as a surprise.

The paper continues in the following way. Section 3 describes our data and explains our estimation procedure. Section 4 reports the results of our analysis and discusses their robustness. Section 6 concludes the paper and discusses tentative policy implications.

2. Modelling the antitrust procedure

Since the antitrust procedure involves different (but related) events, we propose an extremely simplified model of this procedure. Although the model admittedly captures only some features of a real antitrust procedure, we show that it may help understand better our estimates, as well as make some explorative inferences on two variables which cannot

[16]It is of course possible that investors may none the less anticipate that an investigation will take place. This may be the case in particular for some of the international cartel cases which appear in our sample, where a US antitrust case precedes the EU investigation. We deal with this issue in Section 4.1 below.

[17]We were unable to verify in how many cases the firms that were raided were later found not to be guilty and therefore were not subject to any fine, because Decisions are taken only when an infringement is found. If in the course of the investigation the Commission finds no evidence that a firm has violated the law (a rare event after a dawn raid though), there is usually no public announcement that the investigation has ended.

[18]By examining past issues of the *Financial Times* we found that the news about the potential threat of a fine is concentrated in a period of a month before the date of the Decision.

be directly estimated by looking at our dataset: 1) the probability that a dawn raid takes place (that is, the probability that a firm might be investigated); and 2) the effect on firms' market profits (and in turn market prices) that is caused by an infringement Decision of the European Commission.

Assume that a firm has to decide whether to engage or not in a certain anticompetitive business practice, and that if such a practice is undertaken the Commission Decision and the Court Judgment are probabilistic.[19] This may be rationalised as a situation where the outcome of a certain investigation depends on some factors - such as the discovery of documental evidence and the respect of the procedures - that may be casual. Assume also that there is no investigation if the firm decides not to infringe antitrust law. This is an admittedly crude assumption, but recall that, first, we are just interested in a description of the antitrust procedure and, second, all the data we have refer to firms which have eventually been the object of an infringement decision by the Commission, so we have no information about firms which have certainly not violated the law.

The description of the antitrust game is as follows (see also Figure). At time 0, the firm decides whether to violate the law or not in a particular market. If it does not, it will get the payoff π^C forever, giving it a value of $\pi^C/(1-\delta)$ in the market concerned. At time 1, Nature determines whether the firm will be subject to a surprise inspection - event which takes place with probability m) or not. Since being subject to an investigation does not imply yet that the practice at hand is being sanctioned, the firm will receive a profit π^M independently of Nature's move. If no raid is undertaken, though, we assume that the firm will never be investigated any longer, and will enjoy profit π^M forever.[20] By denoting the discount factor by δ, the net present value of profits in this market will be $\pi^M/(1-\delta)$.

If a raid has taken place at time 1, the Commission will investigate the practice further. With probability $1-p$, the Commission will not find proof of the infringement and the case will be dropped. Therefore, the firm will not be investigated any longer and it will receive profits π^M in every period. With a probability p the Commission will find proof of an infringement and at time 2 it will issue a Decision imposing a fine, F, and ordering the firm

[19]The practice may concern either abusive behavior or cartel participation. We have chosen to consider a firm's infringement decision in isolation for simplicity. The model could be extended to deal with cartel decisions, by analyzing the incentive constraint for collusion of the firms involved. However, it would be more complex to deal with the existence of leniency programs: as in Motta and Polo (2003), the model should allow for firms to apply for leniency after an investigation is opened, and should also take into account the institutional features of the leniency programme in the EU. This is beyond the scope of the present paper.

[20]A slightly more sophisticated version of the model would be that in each period the Commission could do a surprise inspection from the pool of the firms which have not been investigated previously, but this would not qualitatively change the results.

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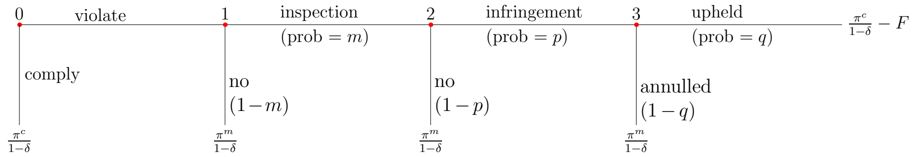

FIGURE 1. Game tree

to cease the business practice. We assume that if there is an infringement Decision, the firm will have to cease the business practice immediately (the per-period market profit will be π^C in the current period and all following periods), but it can delay the payment of the fine until the Court's judgment. This is consistent with what happens in cartel cases (which compose the majority of the observations in our sample), where the Commission takes a negative Decision only when there is documental evidence of the infringement (and it is unlikely that the firms will continue to engage in collusive behavior) and the Court usually annuls the fine only for procedural reasons and it reduces it only when it has a different assessment of the gravity and duration of the infringement.

At time 3, the Court will uphold the Commission's Decision with probability q and will annul the fine with the remaining probability $1 - q$.[21] If the Judgment is in favor of the Commission, the firm will pay the fine F, otherwise it does not. We assume that the firm always appeals the infringement Decision. (This is largely consistent with what happens in reality, and of course it makes sense in the model because the cost of appealing is taken to be zero for simplicity.)

Further, since the firms are in our sample are multi-product and multi-national firms, we assume that each firm operates not only in the market where the infringement and the antitrust investigation take place, but also in n other independent (product or geographic) markets, in each of which for simplicity the firm earns a profit π^C.

Finally, we assume for analytical convenience that the fine is set as a percentage of the firm's competitive value, i.e. $F = f(n+1)\pi^C/(1-\delta)$.[22]

In order to investigate how the occurrence of a certain antitrust event affects the valuation (that is, the net present value) of the firm, it is convenient to start from the last period, that is the Court's judgment.

[21]Of course, the Court is free to set any level of the fines it deems correct, so the fine should be a continuous variable. To simplify matters, though, we assume that it has a binary choice. In estimating the effects of the Court's judgment, we say that the Court 'annuls' a Decision whenever the fine is reduced to a level which is below the 2/3 of the fine proposed by the Commission, and 'upholds' it otherwise.

[22]In our sample, we calculate the fine as percentage of the value of the firm at the moment of the Commission Decision. Using this expression, however, would considerably complicate the model.

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If the judgment annuls the Commission Decision, the firm will not have to pay the fine, and its value will be:

$$V_A = \frac{(1+n)\,\pi^C}{1-\delta}. \tag{33}$$

If instead the Court upholds the fine, the firm's value will be:

$$V_U = \frac{\pi^C(1+n)(1-f)}{1-\delta}. \tag{34}$$

Immediately before the Court decides, the expected profits of the firm will be:

$$EV_J = qV_U + (1-q)V_A = \frac{(1+n)(1-fq)\pi^C}{1-\delta}. \tag{35}$$

Therefore, after a Court's Judgment which annuls the Decision, the change in the firm's value will be:

$$\Delta_A = \frac{V_A - EV_J}{EV_J} = \frac{fq}{1-fq}. \tag{36}$$

If the Commission issues a negative Decision, and before the Court judgment, the expected profits of the firm are:

$$V_D = \pi^C + n\pi^C + \delta EV_J = \frac{(1+n)(1-\delta fq)\pi^C}{1-\delta}, \tag{37}$$

whereas immediately before a Commission Decision is taken the firm's value will be:

$$EV_{CD} = pV_D + (1-p)\frac{\left(\pi^M + n\pi^C\right)}{1-\delta} = \frac{\left(n+p-\delta fpq\,(n-1)\right)\pi^C + (1-p)\pi^M}{1-\delta}. \tag{38}$$

After a Decision of infringement has been taken, the change in profits will be:

$$\Delta_D = \frac{V_D - EV_{CD}}{EV_{CD}} = -\frac{(1-p)(\pi^M - \pi^C(1-\delta fq\,(1+n)))}{\pi^M\,(1-p) + \pi^C\,(n\,(1-\delta fpq) + p\,(1-\delta fq))} < 0. \tag{39}$$

After a dawn raid, and before a Decision is taken, the firm's profits are:

$$(40)\quad V_R = \pi^M + n\pi^C + \delta EV_{CD} = \frac{\left(n(1-\delta^2 fpq) + \delta p(1-\delta fq)\right)\pi^C + (1-\delta p)\pi^M}{1-\delta}.$$

Immediately before Nature decides whether there is a dawn raid, the expected profits of the firm will be:

$$(41)\quad EV_R = (1-m)\frac{\left(\pi^M + n\pi^C\right)}{1-\delta} + mV_R = \frac{\left(n + \delta pm - (n+1)\,\delta^2 fpmq\right)\pi^C + (1-\delta pm)\pi^M}{1-\delta}.$$

We can now use these probabilities to calculate the change in expected profits caused by a certain antitrust event. Suppose that a Dawn Raid is made. The expected change in firm's value will be:

$$(42)\quad \Delta_R = \frac{V_R - EV_R}{EV_R} = -\frac{\delta p(1-m)(\pi^M - \pi^C(1-\delta fq\,(1+n)))}{\left(n + \delta pm - (n+1)\,\delta^2 fpmq\right)\pi^C + (1-\delta pm)\pi^M} < 0.$$

Finally, note that the firm will decide to violate antitrust laws if the expected profit in case of violation, which coincides with the expected profits before the raid is decided, EV_R, is higher than the expected profit in case of complying with the law, $V_{not} = (n+1)\pi^C/(1-\delta)$. The inequality $EV_R > V_{not}$ can be rewritten as:

$$\frac{\left(\pi^M - \pi^C\right)(1-\delta pm) - (n+1)\,\delta^2 fpmq\pi^C}{1-\delta} > 0,$$

or:

$$(43)\qquad f < \frac{1-\delta pm}{(n+1)\,\delta^2 pmq\pi^C}\left(\frac{1}{\pi^C/\pi^M} - 1\right) \equiv f^*.$$

Note that f^* is nothing else than the optimal fine, that is, the minimum fine necessary to achieve deterrence of anticompetitive behavior. If $f \geq f^*$, the firm will comply with law; If $f < f^*$, it prefers to violate it.

Independent estimates of probabilities. Before proceeding, note that it is possible to have some independent estimates of some of the parameters of the model; in particular, of the probabilities p and q.

To find have an estimate of the probability q that a Commission's fine is upheld by the Court, first of all recall that we have the sample of all European Commission's antitrust Decisions, but we could use only a very small subset of it, since only a minority of the firms fined by the Commission are (or were at the time of the Decision) publicly quoted. We have therefore looked at *all* the antitrust cases where the first Court judgment was available. In this way, we have computed the average probability q that the Court upholds the Commission's Decision.[23]

It is possible that the estimated probability is biased with respect to the expected probability of the firm in our sample. For instance, it may be that the Court is more lenient towards small firms, which are typically less likely to be publicly quoted, or the opposite - that largest firms are more likely to hire the best legal and economic counsel and therefore more likely to win a case in court. As a check, we have also looked at the average probability that a Commission Decision is upheld in our sub-sample of publicly quoted firms. As one can check from Table 1, there are 53 cases of fine reduction, 37 cases of upheld fines, and 32 cases where the firms filed no appeal (in the remaining cases in the sample, either we have no information if an appeal was made, or the appeal is still pending at the time of writing). Therefore, $\widehat{q} = 69/122 = .56$.

In order to find the probability p that a dawn raid is followed by the Commission's Decision and fine, recall that the Commission systematically reports information about dawn raids only when an infringement decision is taken (although since Monti's tenure as Commissioner, DG-Competition often makes press releases on surprise inspections). Further, recall that if the Commission undertakes a surprise inspection and later discovers that it does not have enough evidence for the successful prosecution of the case (or it becomes convinced that the firm's business practice is not unlawful), then it does not issue a formal Decision, but may make a public statement about its decision not to pursue the case further.

In order to estimate p, we therefore looked for information on dawn raids by analyzing several databases containing press agency statements, newspapers' articles, and European

[23] As mentioned above, we consider 'annulled' a judgment which imposes a fine which is lower than 2/3 of the Commission fine, and 'upheld' fines above this threshold. We also considered as 'upheld' all cases where the firms have not appealed the Commission's Decision (as presumably the firms in such cases were convinced that the Court would have not annulled the fine). Further details (the table with all the cases we have data for), are available from the authors upon request.

Commission's press reports.[24,25] In this way, we could uncover a large number of dawn raids, and we then checked whether after the raids there were infringement decisions or not.[26,27] Both because this was a very time-consuming operation, and because prior to the year 2000 there rarely was public disclosure of dawn raids, we limited ourselves to look for such information for the years from 1998 to 2004 (both inclusive). We excluded years too close to us because the Commission needs a few years to issue an infringement decision. The estimated value of the probability that a firm is fined after being raided by the Commission's officials is $\widehat{p} = .69$.[28]

We may also estimate the discount factor δ which can be written as $\delta = 1/(1+r)$, where r is the interest rate. On annual basis, with an interest rate of 5%, the discount factor would be $\widehat{\delta} = .95$, whereas if we consider an annual profitability rate (instead of the interest rate) of 10%, then we would have $\widehat{\delta} = .91$. Note, however, that if the period elapsing between one antitrust event and the other is not one but, say, two years, then the true discount factor should be $\delta = 1/(1+r)^2$, giving us estimates of respectively $\widehat{\delta} = .91$ and $\widehat{\delta} = .83$.

Finally, from our data in Table 1 we can proxy the parameter f with the percentage of the fine over the capitalization of the firm as $\widehat{f} = 1.9$.

Therefore, there are only two parameters of the model we could not independently estimate, that is, the ratio between competitive and anticompetitive per-period profits, π^C/π^M, and the probability that a firm which is violating antitrust law is being raided by the Commission. The latter is obviously impossible to estimate in the real world since we would need to know the number of firms which are infringing competition law, something that obviously we cannot observe. Note, however, that this is a crucial parameter for anyone interested in analyzing the deterrence power of the fines (the expected cost of infringing the law will

[24] More precisely, our sources were: Agence Europe, DG Competition website, Lexis-Nexis, and the European Commission's annual *Report on Competition Policy.* In all cases, the keywords used for our search were: "dawn raid", or "inspection", or "premises".

[25] Sometimes the Commission does release news that a case has been dropped and might mention that the case was opened by a surprise inspection in certain firms. In other occasions, it issues a press release that a dawn raid has been carried out.

[26] Note that - in order not to bias the estimate - when proceeding in this way we have not added to the sample of dawn raids unveiled by these databases the dawn raids referred to in the decisions (in some cases, it might happen that a Decision mentions a dawn raid that no database had published).

[27] Unfortunately, most of the data about dawn raids so obtained were not precise enough for them to be used to enlarge the sample that we later use for empirical estimates: either the precise firms were not mentioned, or the precise data was not mentioned, or the firms were not publicly quoted. But for the purpose of estimating p, it was enough to know the number of firms involved in the case and whether they ended up being fined or not.

[28] Details available from the authors upon request.

depend on m). Indeed, many people are trying to compute optimal fines by guessing m but there have been rare attempts to seriously estimating this value.

3. Estimation of abnormal returns

In this Section, we first describe our data, and then the estimation procedure we follow.

3.1. Data. Our data come from Commission Decisions, published in the Official Journal of the European Communities, and judgments of the Court of First Instance and the European Court of Justice, published in the European Court Reports and other sources. The data refer to all the Decisions resulting in a fine from 1969 until 2005. In the Decisions the Commission describes the investigation and usually reports the date of the surprise inspection, if it was made.

We have retained only decisions involving the firms quoted in a stock exchange for which data on share price are available in the Datastream database.[29] Our final sample refers to 58 decisions (the first of which dates from 1979) involving 97 firms. Some of the firms were repeat offenders.[30]

Data on share prices are not available for all the firms at the time of the events. For this reason we are forced to drop further observations from our sample. We have exact dates of Commission Decisions and data on the share prices at the time of the Decision for 147 infringements of either article 81 or 82. We also have dates of Court judgments for 74 infringements (38 annulments), as well as exact dates of surprise inspections for 59 infringements.

Table A.1 in the Appendix lists the firms in our sample, and indicates the type of antitrust infringement as well as the dates of the relevant events.

The firms in our sample are quoted on different stock exchanges. The majority are quoted in Frankfurt and Tokyo, followed by New York, London and Paris. The remaining stock exchanges where the firms from our sample are quoted are Amsterdam, Korea, Hong Kong,

[29]We are aware that sample selection is a possible concern of our analysis, to the extent that publicly quoted firms tend to be large, multi-product, and possibly multinational firms, for which the effect of a fine related to one particular product and geographic market may well be smaller than for a smaller, single-product firm operating in a domestic market. However, it should also be recalled that the Commission can impose fines up to 10% of the total (world) turnover of a firm, and that proportionality is one of the most important criteria in calculating fines, so that other things being equal a larger multi-product and multinational firm would generally be given a larger fine.

[30]One of the firms in our sample, BASF, was involved in 5 infringements; 2 firms, Solvay and Bayer were involved in 4 infringements; 7 firms were involved in 3 infringements; and the remaining firms were involved in two or one infringement.

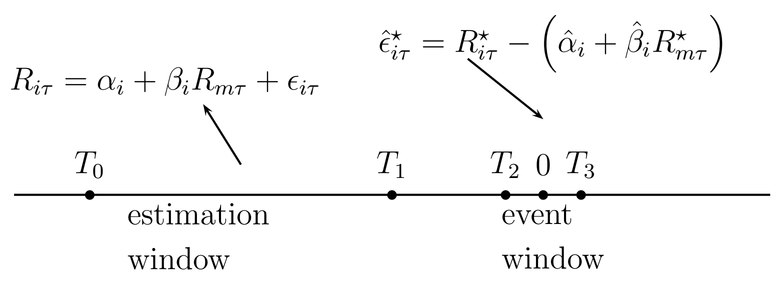

FIGURE 2. Timeline

Singapore, Stockholm, Oslo, Brussels, Copenhagen, Milan, Luxembourg, Taiwan, Malaysia, Athens and Vienna.

3.2. Event Study Methodology and Estimation Procedure. The central concept in the event study methodology is the efficient market hypothesis (EMH). Under this hypothesis, the price of the security reflects the value to investors of all the relevant available information about the fundamentals of the firm. Moreover, under the EMH, any news about the fundamentals are immediately reflected in the share price.

The question that the event study attempts to answer is: what is the value of a change of a particular fundamental. Under the EMH, if we knew the exact time in which the news became available to investors and the security price that would have prevailed in the absence of this news we could compute the value of the change of the fundamental that is reflected in the news, as the difference between the counterfactual and the actual price.

We use standard event study methodology to estimate the effect of the three above mentioned events (news about the four events) in the antitrust investigation on the value of the firm. Our main references for the event study methodology are Campbell et al. (1997) and MacKinlay (1997).[31]

To obtain a counterfactual return we use a simple market model of returns:[32]

$$R_{i\tau} = \alpha_i + \beta_i R_{m\tau} + \epsilon_{i\tau}, \tag{44}$$

where $R_{i\tau}$ and $R_{m\tau}$ are the period-τ returns on security i and the leading index of the stock exchange where the security is quoted, respectively. We compute the returns as $\ln P_{it} - \ln P_{it-1}$, where P_{it} is the price of the share on trading day t.

[31]See also Brown and Warner (1980, 1985).

[32]A convenient assumption that we will make is that the $(N \times 1)$ vector of asset returns, R_t, is independently multivariate normally distributed with mean μ and covariance matrix Ω for all t. Under this assumption, given that the model is correctly specified, the abnormal returns, conditionally on the market return, are jointly normally distributed. This result is the basis of our inference.

Figure 2 illustrates our approach. We define $\tau = 0$ as the event date, $\tau = T_2$ to $\tau = T_3$ form the event window and the periods from $\tau = T_0$ through $\tau = T_1$ form the estimation window. Let $L_1 = T_1 - T_0 + 1$ and $L_2 = T_3 - T_2 + 1$. We estimate parameters α_i and β_i for the firm i security using 101 trading days in the period $T_0 = -120$ to $T_1 = -20$, except in the case of the Commission Decision, where we use the window from $T_0 = -130$ to $T_1 = -30$.[33] Then we use the estimated model as the model of counterfactual returns in the periods of interest to construct *abnormal returns* in the event window as

$$\hat{\epsilon}^{\star}_{i\tau} = R^{\star}_{i\tau} - \left(\hat{\alpha}_i + \hat{\beta}_i R^{\star}_{m\tau}\right), \tag{45}$$

where $R^{\star}_i$ and $R^{\star}_m$ are $L_2 \times 1$ vectors of actual returns on the security i and of the leading index of the stock market where i is quoted.

Using the market model, the vector of abnormal returns for the event window for firm i is given by

$$\hat{\epsilon}^{\star}_i = \mathbf{R}^{\star}_i - \left(\hat{\alpha}_i \iota - \hat{\beta}_i \mathbf{R}^{\star}_m\right) \tag{46}$$

$$= \mathbf{R}^{\star}_i - \mathbf{X}^{\star}_i \hat{\Theta}_i \tag{47}$$

where $\mathbf{R}^{\star}_i$ is a $(L_2 \times 1)$ vector of event window returns and $\mathbf{X}^{\star}_i$ is a $(L_2 \times 2)$ matrix of ones and event window market returns. $\hat{\Theta}_i$ is the vector of parameter estimates $[\hat{\alpha}_i \ \hat{\beta}_i]'$.

Under the null hypothesis "the abnormal returns for an individual security are equal to zero",the following simple results are shown to hold in Campbell et al. (1997)

$$E[\hat{\epsilon}^{\star}_i] = 0 \tag{48}$$

and

$$\mathbf{V}_i = \mathbf{I}\sigma^2_{\epsilon_i} + \mathbf{X}^{\star}_i (\mathbf{X}'_i \mathbf{X}_i)^{-1} \mathbf{X}^{\star\prime}_i \sigma^2_{\epsilon_i}, \tag{49}$$

where I is an $L_2 \times L_2$ identity matrix.

We aggregate individual daily abnormal returns by averaging them over securities and thus obtain daily average abnormal returns

$$\overline{\epsilon}^{\star} = \frac{1}{N} \sum_{i=1}^{N} \hat{\epsilon}^{\star}_i, \tag{50}$$

and correspondingly the variance is

$$\text{Var}[\overline{\epsilon}^{\star}] = \mathbf{V} = \frac{1}{N^2} \sum_{i=1}^{N} \mathbf{V}_i. \tag{51}$$

[33] In one of the robustness checks we look at a long event window for the Commission Decision (from $T_2 = -25$ to $T_3 = 3$), and we need an estimation window which does not overlap with the event window. We have verified that the results are not sensitive to variations in the estimation window.

Since $\sigma^2_{\epsilon_i}$ in (49) is not known we use instead its consistent estimate

$$\sigma^2_{\epsilon_i} = \frac{1}{L_1 - 2}\hat{\epsilon}_i'\hat{\epsilon}_i. \tag{52}$$

Finally we also aggregate the average abnormal returns over the days of the event window to obtain *cumulative average abnormal returns* ($\overline{CAR}$) for the event. With ι a unit $(L_2 \times 1)$ vector we have

$$\overline{\text{CAR}}(\tau_1, \tau_2) \equiv \iota'\overline{\epsilon}^\star \tag{53}$$

and

$$\text{Var}[\overline{\text{CAR}}(\tau_1, \tau_2)] = \bar{\sigma}^2(\tau_1, \tau_2) = \iota'\mathbf{V}\iota. \tag{54}$$

Again, $\bar{\sigma}^2(\tau_1, \tau_2)$ is unknown and we use its consistent estimate

$$\hat{\bar{\sigma}}^2(\tau_1, \tau_2) = \frac{1}{N^2}\sum_{i=1}^{N}\iota'\mathbf{V}_i\iota. \tag{55}$$

We use

$$J_1 = \frac{\overline{\text{CAR}}}{\hat{\bar{\sigma}}^2(\tau_1, \tau_2)} \overset{a}{\sim} \mathcal{N}(0, 1), \tag{56}$$

to test the null hypothesis.[34]

As an alternative specification, to verify the robustness of our results, we use the *mean model*, where the mean return of the individual security is used as the counterfactual return. In this case the model is simply $R_{i\tau} = \alpha_i + \epsilon_{i\tau}$. This does not introduce changes in the computation of the test statistics, except that we have to adjust the matrices X and $X^\star$ so that now they are vectors of ones of dimensions L_1 and L_2, respectively. In principle, it is possible that a change in the share price of a very large firm may cause a change in the relevant stock market index, giving rise to endogeneity problems. Using the mean model rather than the market model avoids this problem. In Section 4.2 we estimate the mean model to deal with this issue.

4. Results

In this Section, we first describe our main results, then we report the various robustness checks we have carried out, and finally we discuss the issue of cross-sectional correlation and argue that it is not a problem in our case.

Summary statistics for abnormal returns in the estimation and event periods for all events are reported in Tables 1 and 2.

[34]The distributional result is for large samples and is not exact because an estimator of the variance appears in the denominator.

We report abnormal returns for the three events for an event window period of eleven days, together with their J-statistics in Table 3.[35] All tests are one-sided unless specifically stated otherwise.

	Raid	Comm.Dec.	Annul.	Upheld
N	59	147	38	36
mean	−0.002	−0.00081	0.0019	−0.00014
Std.Dev.	0.0057	0.0054	0.0074	0.0057
min	−0.024	−0.028	−0.0069	−0.015
Q1	−0.0048	−0.0028	−0.0014	−0.003
median	−0.002	−0.00083	0.00079	−0.0003
Q3	0.0011	0.0024	0.0027	0.003
max	0.014	0.014	0.033	0.016

TABLE 1. Summary of abnormal returns in the event window

	Raid	Comm.Dec.	Annul.	Upheld
mean	3.61E−20	−3.17E−20	3.85E−20	−2.94E−21
Std.Dev.	1.84E−19	2.40E−19	2.74E−19	2.32E−19
min	−3.93E−19	−1.03E−18	−5.32E−19	−4.53E−19
Q1	−5.38E−20	−1.09E−19	−8.48E−20	−1.48E−19
median	2.01E−20	−4.29E−21	4.29E−20	−3.17E−20
Q3	1.74E−19	8.90E−20	1.43E−19	6.65E−20
max	4.75E−19	6.04E−19	7.51E−19	6.41E−19

TABLE 2. Summary of abnormal returns in the estimation window

Abnormal return on the day of the raid is negative and highly statistically significant, suggesting a 1.04% drop in the firm's share price the very same day the dawn raid is carried out. This implies a very quick relay of the news to investors. A large number of studies indicate that stock markets react very quickly to unexpected news.[36] Similarly, negative

[35] In our sample the share prices data for three of the firms were no longer available in our database at the time of the decision of the Courts, even though these were available at the time of the Commission Decision.

[36] Brooks et al. (2003) investigate a sample of 21 fully unexpected negative news events - such as the Exxon-Valdez oil disaster, plant explosions, plane crashes, deaths of executives - and find that share prices fall by an average of 1.6% after a mere 15 minutes. They stress that they find longer response times (!) than reported by previous studies.

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	Raid 59	J	Com.D. 147	J	Annul. 38	J	Uphd 36	J
t= -5	0.00056	0.23	-0.00285*	-1.59	-0.00317	-0.94	-0.00299	-0.87
t= -4	0.00389*	1.62	-0.00113	-0.63	0.00273	0.81	-0.00148	-0.43
t= -3	-0.00296	-1.23	1e-05	0.01	0.00514*	1.51	-0.00218	-0.64
t= -2	-0.00187	-0.78	-0.00041	-0.23	0.00436*	1.29	0.00078	0.23
t= -1	0.00173	0.72	-0.00038	-0.21	0.0027	0.8	-0.0023	-0.67
t= 0	-0.01041***	-4.32	-0.00248*	-1.38	0.00047	0.14	-0.00301	-0.87
t= 1	-0.00252	-1.05	-0.00117	-0.66	0.00803***	2.39	0.00584**	1.7
t= 2	-0.00488**	-2.03	0.00118	0.66	0.00179	0.53	0.00131	0.38
t= 3	-0.00448**	-1.86	0.0019	1.06	0.00086	0.25	-0.00169	-0.49
t= 4	-0.00014	-0.06	-0.00155	-0.86	0.0012	0.36	0.00127	0.37
t= 5	-0.00102	-0.42	-0.00201	-1.12	-0.00319	-0.95	0.00291	0.84
Cum	-0.02208***	-2.64	-0.00888*	-1.43	0.02093**	1.78	-0.00153	-0.13

TABLE 3. Summary of results

returns of 0.49% and 0.45% two and three days after the raid are significant at the level of 5%. If we aggregate the abnormal returns over the window of Table 3, we find significant negative returns for the dawn raid, with an overall effect of the raid amounting to a 2.21% drop in the firm's stock market valuation.

In the column for the Commission Decision we have negative abnormal returns of 0.28% and 0.25%, significant at the level of 10% five days before the event and on the day of the event. The cumulative average abnormal return over the 11-day window is at -0.89% and is statistically significant at the level of 10%.

The last two columns in Table 3 show the effects of the Court judgments. We define as "annulments" all judgments which either annul the fine or reduce it by more than 50%, and "upheld" all remaining judgments.

In the column for the Court's annulment we have weakly significant positive abnormal returns two and three days before the date of the judgment of the Court, which may indicate that a favourable decision was expected by investors, and a strongly significant positive abnormal return a day after the annulment of 0.8% and a positive cumulative average abnormal return over the event window of 2.09%, which is significant at the level of 5%.

Finally, in the columns for upheld decisions, we find a positive abnormal return a day after the decision, which is not an expected result. However, cumulatively, the negative average abnormal return is not significant at any acceptable level of significance.

These are the base results. We now discuss them more thoroughly and refine our estimates, dealing with each of the antitrust events in turn.

4.1. Robustness of the results.

4.1.1. *Results for cartels only.* First of all, note that our sample is composed of different types of antitrust infringements. It may be legitimate to wonder to what extent the results are affected by such differences. To dispel doubts, we select the sub-sample of cartel cases (itself a subset of article 81 cases), which accounts for more than 4/5 of the whole sample, and carry out the same analysis executed above. The results are described in Table 4, which shows that the results are very similar to those obtained for the whole sample. We have not carried out estimates for the sub-sample of non-cartel cases because they involve very few cases.

	Raid 51	J	Com.D. 122	J	Annul. 38	J	Uphd 36	J
t= -5	-0.00033	-0.12	-0.00337*	-1.64	-0.00397	-1.13	-0.0022	-0.47
t= -4	0.00426*	1.57	-0.00207	-1	0.00376	1.06	-0.00109	-0.24
t= -3	-0.00337	-1.25	0.00038	0.19	0.00626**	1.77	-0.00478	-1.03
t= -2	-0.00175	-0.65	0.00029	0.14	0.00496*	1.41	0.00119	0.25
t= -1	0.00374*	1.38	-0.00031	-0.15	0.00232	0.65	-0.00455	-0.98
t= 0	-0.01264***	-4.67	-0.00321*	-1.55	-2e-04	-0.06	-0.00263	-0.56
t= 1	-0.00309	-1.14	-0.00173	-0.84	0.00793**	2.26	0.00989**	2.13
t= 2	-0.00371*	-1.37	0.00116	0.56	0.0017	0.48	0.00216	0.47
t= 3	-0.00473**	-1.75	0.00248	1.2	0.00018	0.05	-0.0014	-0.3
t= 4	-0.00071	-0.26	-0.00193	-0.94	0.0015	0.43	-0.00094	-0.2
t= 5	1e-05	0	-0.00293*	-1.43	-0.00274	-0.78	0.00514	1.11
Cum	-0.0223***	-2.38	-0.01125*	-1.57	0.02171**	1.77	8e-04	0.05

TABLE 4. Summary of results for article 81 cases only

4.1.2. *Dawn Raids.* Inspecting back issues of the *Financial Times* we were unable to find any evidence of a surprise inspection not being a genuine surprise. Thus, we take a shorter window of 5 days (-1..+3 days) for this event to increase the power of the test.

For this window, the cumulative abnormal return is $-\mathbf{2}\%$ with a J value of -3.75, which gives a statistical significance at the level of 1%. The significant negative abnormal return is robust to variations in the size of the event window.

As a further robustness check of our results, we inspect abnormal returns for individual firms. Most of the firms have negative abnormal returns, of which 5 are statistically significant in the 5-day event window. One of the firms from the sample had a positive significant abnormal return. Figure 3 depicts standardized abnormal returns for individual firms. The solid line represents a standard normal distribution. On the vertical axis are the indices of firms ordered by the size of the abnormal returns and on the horizontal axis are abnormal

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returns. From the figure we can see that the normal distribution first order stochastically dominates the distribution of abnormal returns.

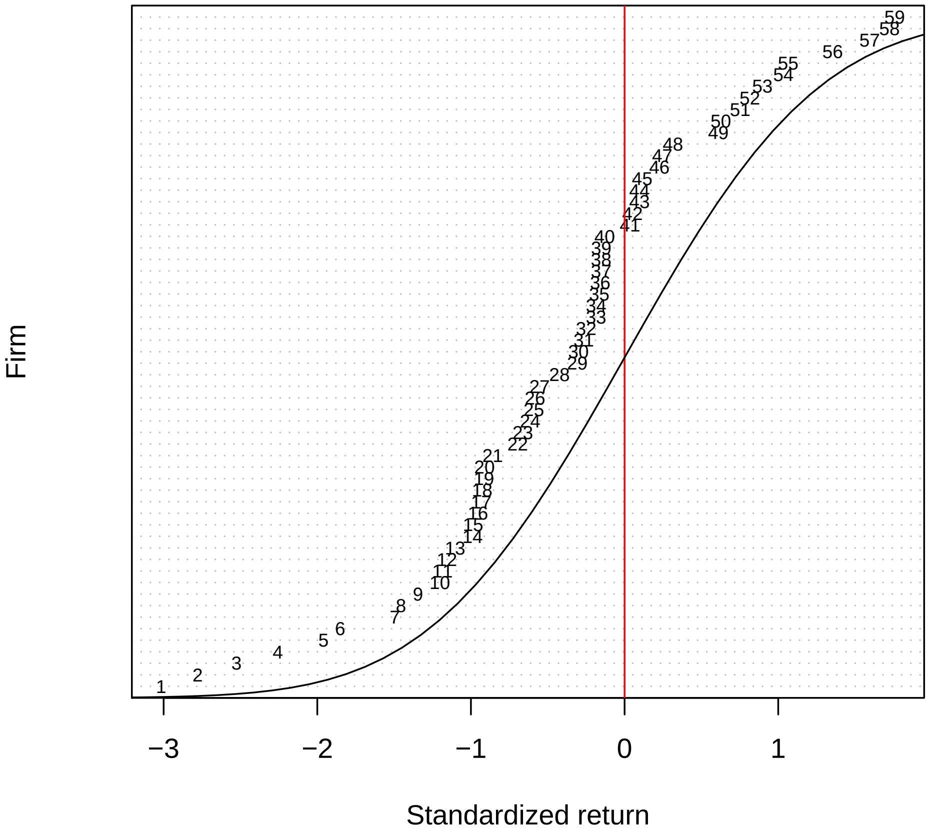

FIGURE 3. Cumulative abnormal returns for individual firms for Surprise Inspection($T_2 = -1$ $T_3 = 4$)

Additionally, we plot abnormal individual cumulative returns for each firm for 5 days before the dawn raid and 5 days after the dawn raid in Figure 5. Next to each of the lines depicting differences are indices of the firms, and on the horizontal axis are cumulative returns to individual securities for the five-day windows before and after the event. The dashed lines represent the securities for which the cumulative abnormal return in the window after the raid was higher than the cumulative abnormal return before the raid and the solid line is for the firms for which the opposite is true. It can be seen that only for 19 out of 59 firms are the lines dashed, i.e. their returns are higher after the raid. Moreover, the largest differences

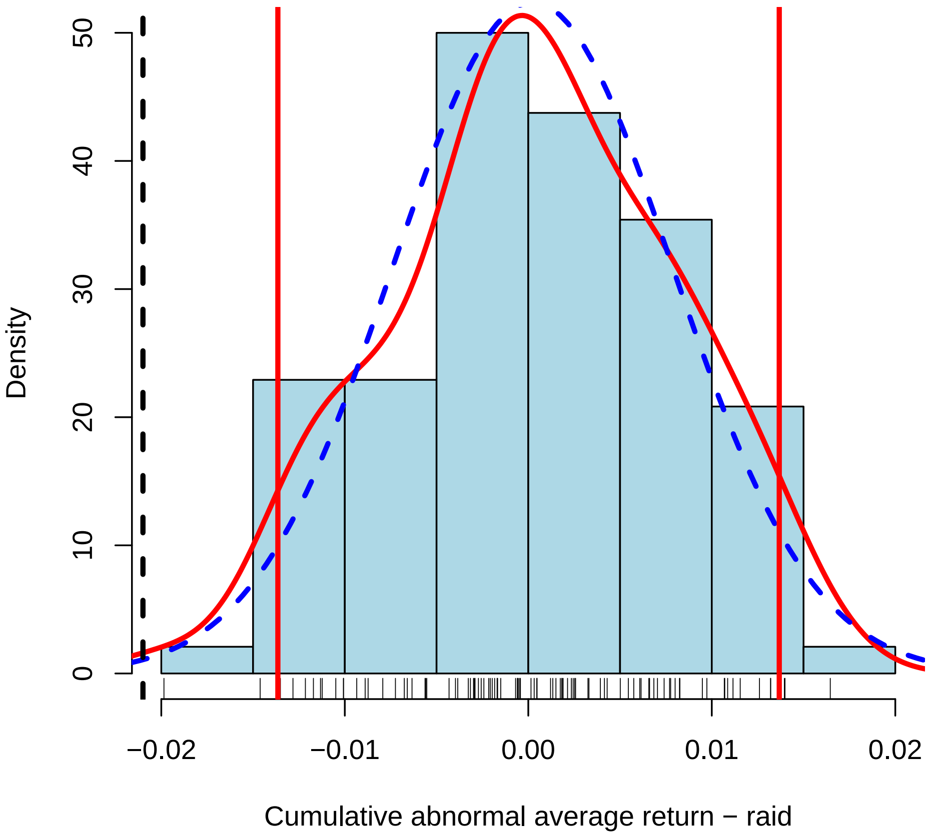

FIGURE 4. Empirical distribution of cumulative average abnormal returns for Surprise Inspection (sum over 5 periods).

among these firms tend to be smaller than the largest ones among firms whose returns are lower after the raid.

We also inspect the empirical distribution of the cumulative abnormal returns for our estimation window. For this purpose we compute abnormal returns using a moving window of the same size as the event window over the periods of the estimation window. We move the first date of the hypothetical event window from $T_0 = -130$ until $T_1 - L_2 = -14$ to obtain $L_1 - L_2 = 117$ hypothetical cumulative average abnormal returns. The distribution of these returns gives us an estimate of the distribution of abnormal returns under the null hypothesis. This distribution is depicted by a solid line in Figure 4. The dashed lines represent the normal distribution.

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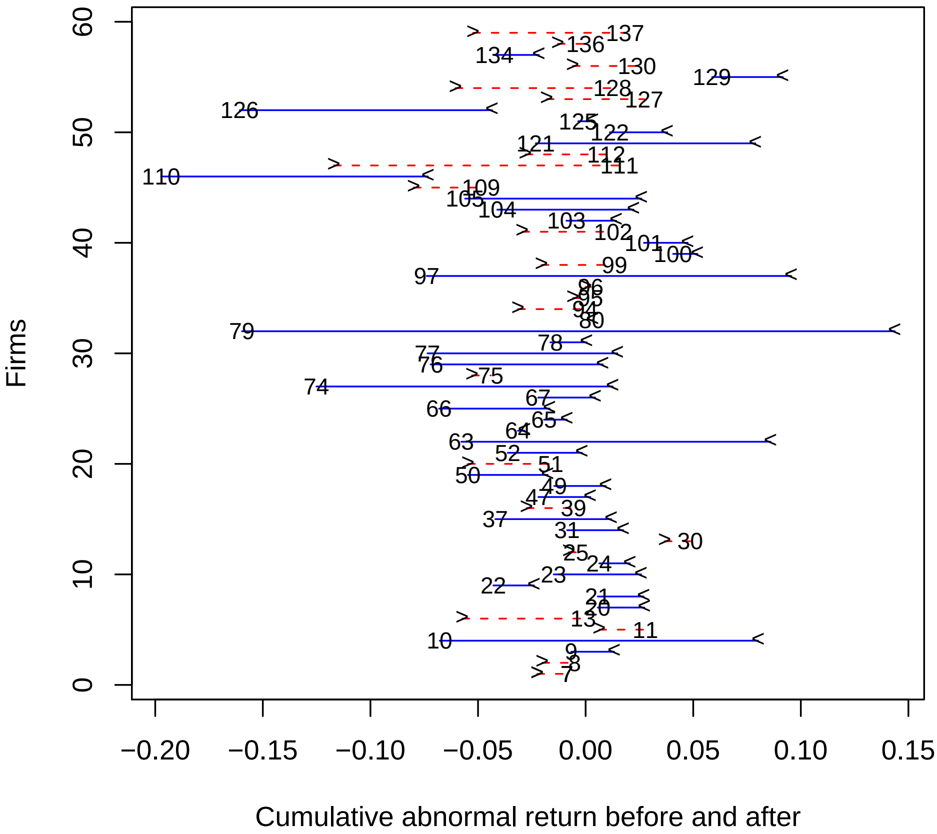

FIGURE 5. Before and after the event cumulative average abnormal returns for Surprise Inspection (before: -5..-1; after: 0..4)

The empirical distribution of cumulative average abnormal returns is not too far from normal. In the figure the 0.025th and 0.975th quantiles of the distribution are represented by solid vertical lines. It can be seen that the cumulative average abnormal return from the event window (−0.02) falls well outside the acceptance region if we accepted the empirical distribution as the true one under the null hypothesis. We view these results as an additional confirmation of the of significance of the J value and the significance of the negative effect of the surprise inspection on the value of the firm.

Given that there are good reasons to believe that the surprise inspection is really unexpected, and under the assumption of EMH, we can interpret the abnormal return in the window as the overall loss in the firm's value (due to expected fines, termination of profitable activities and so on) brought about by the Commission's investigation.

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One of the possible sources of information to investors that the Commission would start an investigation is when an investigation on the same infringement is already under way in the US. We have therefore excluded the observations for which we know that an antitrust procedure had already started in the US and this information was publicly accessible at the time of the raid by the Commission. The results we obtain with this restricted sample with 48 observations are similar to those obtained using the whole sample. For the 4-day window we have for surprise inspections a cumulative abnormal return of about -1.7% with the J-statistic of -3.15, which indicates statistical significance at the level of 1%.[37,38]

4.1.3. *Commission Decisions.* It is somewhat surprising that the Commission Decision results in a significant cumulative abnormal return in the 11-day window, as we would expect the market to incorporate expectations about it in the share price. To verify the robustness of these results we plot the analogue of Figure 4 also for the Decision of the Commission over the 11-day window. The empirical distribution (solid curve) and the normal distribution (dashed) with the same variance and mean are depicted in Figure 6. The area to the left of the first solid vertical line denotes a rejection region at the level of significance of 10% (one-sided test). The cumulative abnormal return of -0.89% falls into the rejection region. However, when we move to level of significance of 5% the cumulative abnormal return falls just outside the rejection region. This may be an indication that the results for the Commission Decision are somewhat less clearcut and less robust for the 11-day window than the results for the surprise inspection are.

Since we believe that there may be some informational leakages occurring prior to the date of the Decision, we extend the estimation window to the periods from 25 days before the event until 3 days after the event to try to account for this possibility. *Cumulative average (across firms) abnormal return for this event window is -0.024 and is significant at 5% with a J value of -2.23.*

[37]US cases that we exclude in this way are: (Lysine) Archer Daniels Midland, Ajinomoto, Kyowa Hakko Kogyo, Daesang; (Citric acid) Archer Daniels Midland, Bayer; (Graphite electrodes) SGL, Showa Denko K.K., Tokai Carbon, Nippon Carbon, SEC, The Carbide Graphite Group; (Vitamins) BASF, Aventis, Takeda, Merck, Daiichi, Lonza, Solvay, Eisai, Sumitomo, Tanabe Seiyaku, Roche; (Auction houses) Christie, Sotheby; (Sorbates) Hoechst; (Specialty graphite) Carbone Lorraine, SGL. Note, however, that for only 11 of these excluded firms do we have a date of the dawn raid and data on share prices available, so that the restricted sample has 48 observations.

[38]In a further check, we exclude those firms which have applied for leniency. This is because one may think that if a firm has applied for leniency and revealed information about a cartel, there may be some rumour in the market that an investigation may start soon. Again, the results for the dawn raid are very similar: for the 11-day window we get a cumulative abnormal return of -2.4% with a J-statistic of -2.54, thus significant at the level of 1%.

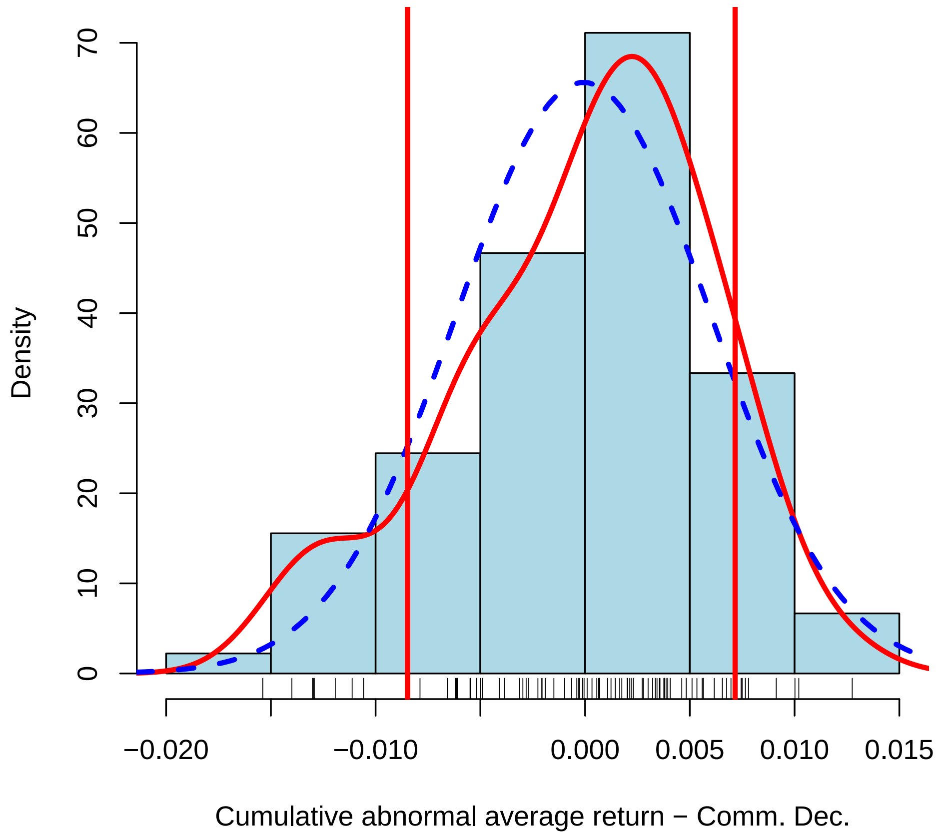

FIGURE 6. Empirical distribution of abnormal cumulative average returns for Commission Decision (sum over 11 periods).

Similarly, as for the 11-day window we also depict the empirical distribution of cumulative average returns for the 29-day moving window in Figure 7. This figure is the equivalent of Figure 4, discussed above for the case of raids. The empirical distribution of cumulative average abnormal returns for this case is not very far from normal, as can be seen by comparing the solid and the dashed curves. However, some concern about the validity of the significance of our results for the Commission Decision also for the 29-day event window remain, though the cumulative abnormal return in this case falls well into the rejection region at a 5% two-sided test significance.

Figure 8 depicts standardized abnormal returns for individual firms. The solid line represents a standard normal distribution. On the vertical axis are the indices of firms ordered by the size of the abnormal returns and on the horizontal axis are abnormal returns. From the

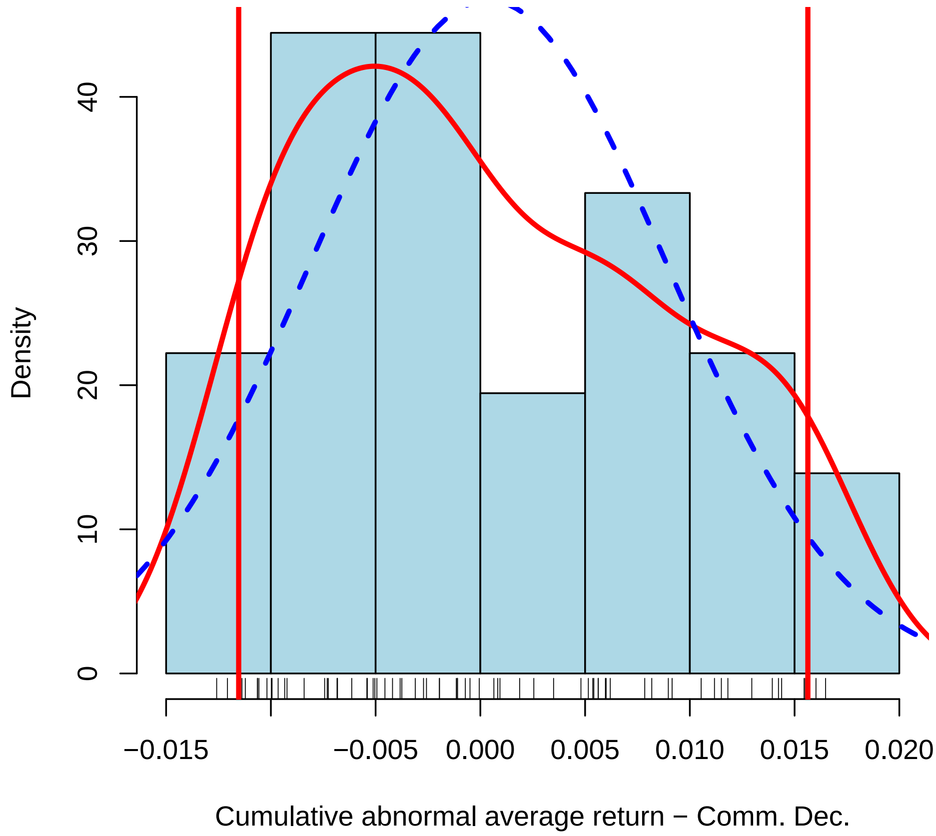

FIGURE 7. Empirical distribution of cumulative average abnormal returns for Commission Decision (sum over 29 periods).

figure we can see that the normal distribution first order stochastically dominates the distribution of abnormal returns. However, it is again clear that the result for the Commission Decision is not as strong as the one for the surprise inspection.

Overall, and albeit less robust and less statistically significant than for the dawn raid, it seems that the Commission Decision does have a negative effect on a firm's valuation. This result begs certain questions, since the Decision comes after other events (such as the raid and the Statement of Objections) which represent strong signals of the seriousness of the investigation.

It is not impossible that this result is caused by sample selection. Our sample includes only the cases where a negative Decision was reached (we do not have data for positive Decisions, since as explained above the Commission does not issue a Decision if it decides

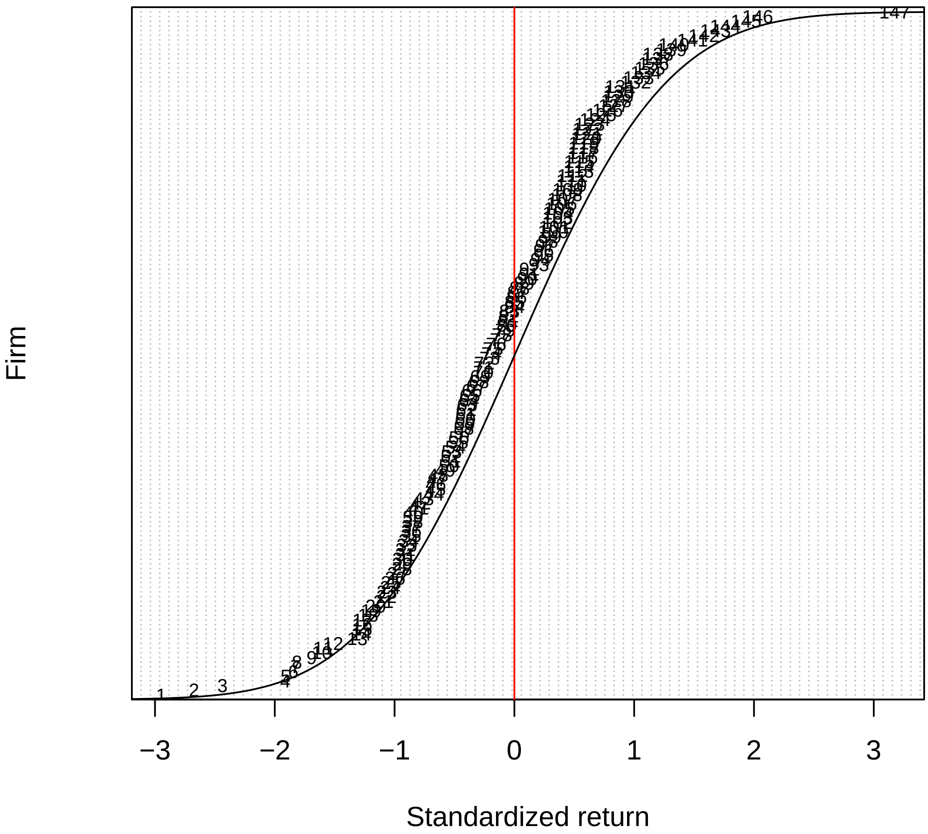

FIGURE 8. Distribution of cumulative abnormal returns for individual firms for Commission Decision ($T_2 = -25$ $T_3 = 3$)

not to pursue the case further). Thus, we only have a sub-sample of all the investigations. Those (rare) cases in which a favorable Decision has been reached are not included and this way the investors may be systematically negatively surprised by the negative Decision for our sample. It is widely believed that the Commission seldom drops a case after a dawn raid and a Statement of Objections, but it is difficult to objectively assess the extent to which this sample selection bias may be important.

4.1.4. *Court judgments.* As seen in Table 3 above for the sample of 38 observations for firms whose fine has been annulled by the Courts, we find a positive and significant average abnormal returns two and three days before the Court judgment and a day after the judgement. The cumulative average abnormal return is 2.09%, which is significant at the level of 5%.

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On the other hand, for the sub-sample of cases for which the Court has upheld the Decision of the Commission, the cumulative average abnormal return is negative, and significant at the 10% level.

In general, therefore, the Court's antitrust judgments do seem to have a significant effect on the firm's stock market value, at least in the cases of favorable judgment for the firm.

The positive market reaction (2.09%) allows the firms to recover almost half of the market value lost because of the dawn raid and the Commission decision (which amount to -4.5%).[39]

This means that the net effect of the antitrust investigation and of an infringement Decision is negative even after a Court judgment which annuls the fine. This can be explained by the fact that - as pointed out in the Introduction and confirmed in the discussion in Section 6 - the fine itself is only part of the loss that a firm may incur because of the investigation. Suppose, for instance, that the judgment annuls the Commission decision for procedural reasons; the firm has won the case, but still it is unlikely that it could continue a business practice which is regarded as anticompetitive by the European Commission, and ceasing a profitable activity will entail a loss in market value. But even when the judgment is favorable to the firm on the substance, the firm may still have incurred costs which it will not be able to recover, such as legal costs and the costs entailed by having the management occupied on antitrust rather than commercial matters.

As a check of robustness of our results we also plot empirical distributions of abnormal returns from the estimation windows for the annulling (Figure 9) and upholding (Figure 10) decisions, analogously as for the Raids and Commission Decisions. The empirical distribution for annulling decision is bimodal and the cumulative abnormal return does not fall into the 5% (two sided) significance rejection region of the empirical distribution. However, it does fall into the 10% significance rejection region. The plots roughly confirm our inference using theoretical distributions.

As a further check of robustness we varied the starting date and the length of the window for these two events and found that results are relatively robust to these changes, with abnormal return for annulment being significantly positive at least at 10 % level and for the upholding abnormal return remaining insignificant.

4.1.5. *Expectations of investors about the Court judgment.* It is conceivable that investors are able to predict to some extent whether the Decision of the Commission will be annulled by the Courts at the time of the raid or at the time of the Commission's Decision. In that case, we would expect the negative effect to be absent or at least weaker than in the case where the market expects the Decision to be upheld. For this purpose we re-estimate the

[39]We take here the values for the 5-day window for the raid and for the 29-day window for the Commission Decision.

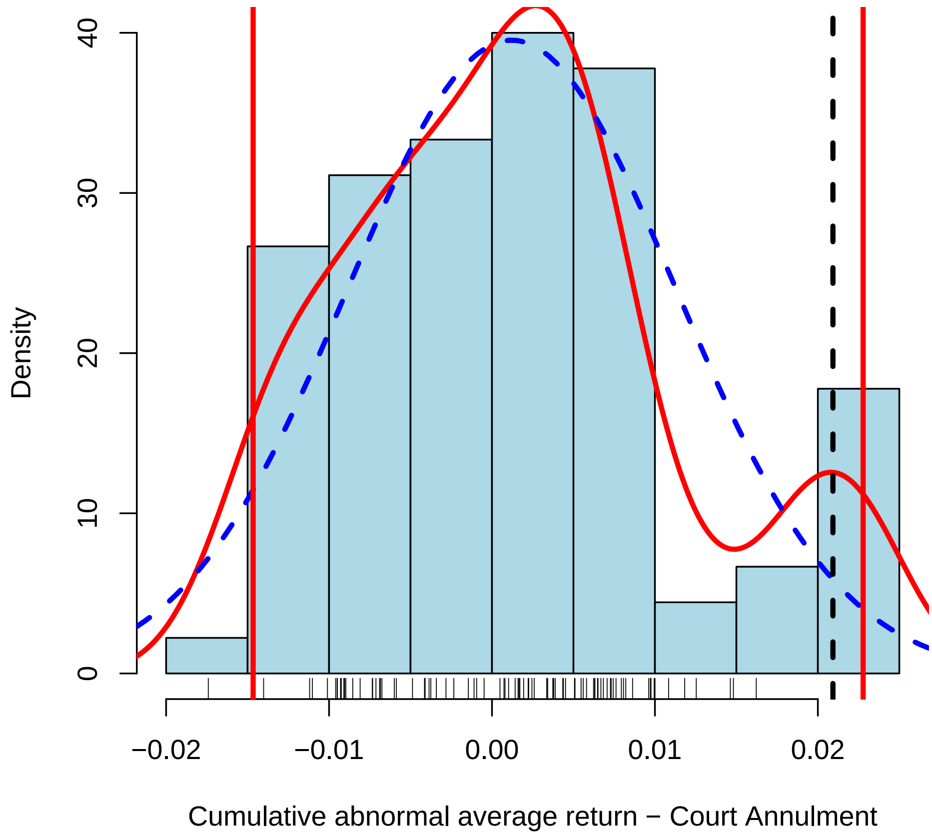

FIGURE 9. Empirical distribution of cumulative average abnormal returns for Court Annullment (sum over 11 periods).

effects for the raid and the Decision of the Commission for two separate sub-samples, i.e. the cases in which the Court ultimately annulled (or substantially reduced) the fine, and those in which the Court upheld (or only slightly reduced) them. The results are reported in Table 5.

For both the dawn raid and the Commission Decision we find an insignificant result for the sub-sample of cases for which the Decision of the Commission was later annulled by the Courts.

However, for the subsample of cases for which the Decision was later upheld we find a large negative and significant cumulative abnormal return at the time of the dawn raid. At the same time, the return for the Commission's Decision is negative and significant at the level of 10%. This, in comparison with the results for the Decisions which were later annulled, may

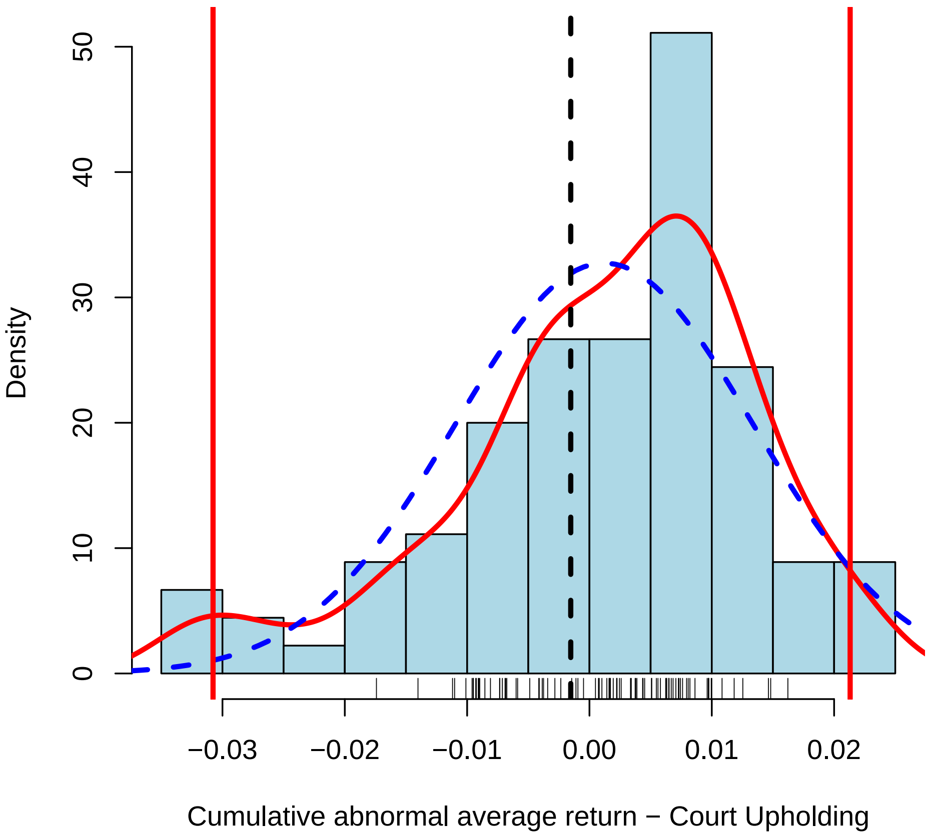

FIGURE 10. Empirical distribution of cumulative average abnormal returns for Court Upholding (sum over 11 periods).

be an indication that indeed the investors anticipate partially the infringements for which the Commission has a firm case likely to be upheld by the court.

4.2. Possible sources of endogeneity and bias. The fact that the firms in our sample are often big, established companies that enter in the composition of stock market indices, which, in turn, appear as independent variables in the model of counterfactual returns, may be a source of endogeneity bias in the estimates. As a further check of robustness of our estimates, we ran regressions using the mean-model of the counterfactual, described at the end of Section 3 above. The results go in the same direction, but the significance levels are - not surprisingly - lower than for the market model. The average abnormal return for a surprise inspection and its J-value are -0.021 and -2.07, respectively. For the Decision of

	RU 22	J	CU 47	J	RA 9	J	CA 39	J
t= -5	0.00013	0.03	-0.0079**	-2.03	0.01267**	2.24	-0.00135	-0.38
t= -4	0.00484	1.24	0.00321	0.82	0.00493	0.87	-0.00837***	-2.34
t= -3	-0.00404	-1.03	-0.00553*	-1.42	7e-04	0.12	0.00359	1
t= -2	0.00131	0.33	0.00192	0.49	0.00678	1.2	-0.00235	-0.66
t= -1	0.00058	0.15	5e-04	0.13	-0.00747*	-1.33	0.00271	0.76
t= 0	-0.01663***	-4.25	-0.00682**	-1.74	-0.00608	-1.08	0.00114	0.32
t= 1	-0.00202	-0.51	-0.00153	-0.39	0.00073	0.13	-0.00222	-0.62
t= 2	-0.00808**	-2.06	0.00155	0.4	0.00117	0.21	0.0012	0.34
t= 3	-0.00637*	-1.63	0.00306	0.78	-0.01046**	-1.86	0.0037	1.03
t= 4	-0.00538*	-1.38	0.00056	0.14	0.00199	0.35	-0.00536*	-1.48
t= 5	-0.00016	-0.04	-0.00086	-0.22	-0.01135**	-2	-0.00357	-1
Cum	-0.03583***	-2.63	-0.01184	-0.87	-0.00637	-0.33	-0.01088	-0.87

TABLE 5. Summary of results for (R)aid and (C)om. Decision when later (U)pheld and (A)nnuled

the Commission, however, the average abnormal return cumulated over the same period as for the market model estimates and the corresponding J-value are -0.005 and -0.71, and are thus not significant.

4.2.1. *Cross-sectional correlation.* In the presence of cross-sectional correlation the inference on the base of the derived J statistic may be biased upwards. The bias is a function of the number of the observations in the sample and the average correlation coefficient. In an influential paper, Bernard (1987) gives some empirical evidence on the seriousness of the problems of inference in the presence of cross-sectional correlation. He argues that the problem can become serious at the values of mean correlation coefficient of a magnitude of around 0.2 for a sample of the size of ours.

Because the firms in a cartel typically operate in the same industry, and as they are often raided on the same day (see Table A.1 in the Appendix), we have some clustering of abnormal returns across firms. However, the extent of clustering for our sample is not likely to cause a serious inference problem, according to Bernard's results: in our case, the mean correlation is 0.01, and is thus not likely to present a serious source of bias in our estimations of the standard error. Moreover, the distribution of covariances, summarized in Table 6 for all pairs of firms demonstrates that a relatively small fraction of all pairs of surprise inspections exceeds the reference 0.2 correlation coefficient for the mean correlation.

4.2.2. *Structural breaks.* One of the possible sources of bias in our estimates may also be the changes in the legal regime (for example, changes in the harshness of the fining policy),

Quant.	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
r^2	-0.28	-0.12	-0.07	-0.04	-0.02	0.01	0.03	0.06	0.09	0.13	0.5

TABLE 6. Distribution of correlation between abnormal returns of firms

which could introduce one or more structural changes in the data-generating process. To explore this issue we have plotted the estimated abnormal returns at the dates of the dawn raids chronologically ordered, with time on the horizontal axis. It is clear from that figure that it is hard to identify a structural break or a clear pattern of evolution of abnormal returns in time.

In addition we also regress fines .... nothing is significant even after the new data set is taken into account.

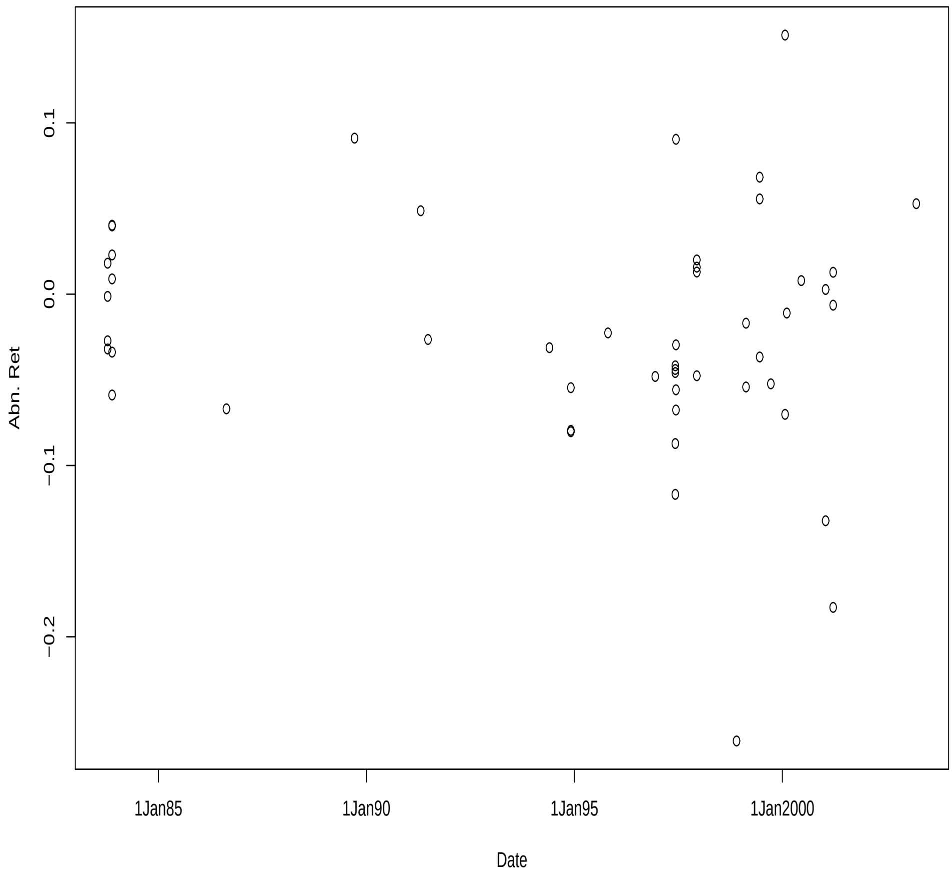

FIGURE 11. Abnormal returns by dates of dawn raids

5. Inferences on the probability of a dawn raid and anticompetitive margin profits

Armed with the simple model presented in Section 2, we can now try to make some exploratory inferences on two variables which are unknown to us, that is, the probability m that a firm is investigated by the Commission, and the (inverse of the) anticompetitive profits ratio π^C/π^M. To do so, recall that our event study methodology has given us estimates of the three changes in the firm's value caused by the three different antitrust events, and corresponding in our model with the three equations (42),(39), and (36). Call our estimated values (in absolute values) k^R, k^D and k^A. In other words, we can write the system:

$$(57) \qquad \begin{cases} \Delta_A = \frac{fq}{1-fq} = k_A. \\ \Delta_D = -\frac{(1-p)(\pi^M - \pi^C(1-\delta fq))}{\pi^M(1-p)+\pi^C(n+p(1-\delta fq))} = -k_D \\ \Delta_R = -\frac{\delta(1-m)p(\pi^M - \pi^C(1-\delta fq))}{\pi^M(1-\delta mp)+\pi^C(n+\delta mp(1-\delta fq))} = -k_R \end{cases}$$

This is a system in three unknowns $((\pi^C/\pi^M), m, n)$, and several parameters for which we have estimates (k^R, k^D, k^A), we know the average value (F), or we can find an independent estimated value (p, q).

However, there are two problems with the first equation of the system. First of all, we do not know to what extent to trust the estimate on the effects of the Court judgment because we find that only annulments have a statistically significant effect on the firm's valuation, whereas upheld judgments do not have any effect. Second, the solution to the first equation would be $\widehat{n} = -1 + fk_A + fq/k_A$. Unfortunately, given our estimates of f, q, and k_A, $\widehat{n}$ would turn out to be negative, which would not make sense.

Let us then disregard the first equation and turn to the two last equations of the system, to look for the solutions for (π^C/π^M) and m. Solving the system of the last two equations we obtain:

$$(58) \qquad \widehat{m} = \frac{p\delta k_D - k_R\left(1 - p\left(1 - k_D\right)\right)}{p\delta k_D(1-k_R)}$$

$$(59) \qquad \widehat{\frac{\pi^C}{\pi^M}} = \frac{\left(1-k_D\right)\left(1-p\right)}{\left(1-p\right)\left(1-\delta fq\right) + k_D\left(n + p\left(1-\delta fq\right)\right)}.$$

where $\widehat{m} \geq 0$ for $\delta \geq \frac{k_R(1-p(1-k_D))}{pk_D}$ and $\widehat{m} \leq 1$ for $\delta \leq \frac{1-p(1-k_D)}{pk_D}$ (which is always satisfied as $\frac{1-p(1-k_D)}{pk_D} > 1$); and $\widehat{\frac{\pi^C}{\pi^M}} \leq 1$ is satisfied.

The following step is to use the values of the parameters obtained from our empirical analysis to obtain $\widehat{m}$ and $\widehat{\frac{\pi^C}{\pi^M}}$ by applying the values so obtained. Table 7 summarizes the estimated values.

k_R	k_D	n	f	q	p	δ	=	$\widehat{m}$	$\widehat{\pi^C/\pi^M}$
.021	**.024**	**5**	**.019**	**.56**	**.69**	**.9**	=	**.55**	**.71**
.015	.024	5	.019	.56	.69	.9	=	.68	.71
.021	**.020**	5	.019	.56	.69	.9	=	.46	.75
.021	.024	**2**	.019	.56	.69	.9	=	.55	.83
.021	.024	5	**.010**	.56	.69	.9	=	.55	.69
.021	.024	5	.019	**.45**	.69	.9	=	.55	.70
.021	.024	5	.019	.56	**.60**	.9	=	.34	.76
.021	.024	5	.019	.56	.69	**.85**	=	.52	.71

TABLE 7. Estimated values for different parameters

The Table indicates the parameters used and the resulting estimated values of the probability of a dawn raid and of the inverse of the anticompetitive margin. The values in the first row represent our baseline values, while in each of the following rows we change (more precisely, reduce) one parameter in turn.

This calibration exercise suggests that the probability that a firm which violates EU competition law will be investigated with a probability between 30% and 70%, and that the normal competitive profits are between 65% and 85% of the anticompetitive profits. Of course, these are completely tentative results, but they may give an idea of the order of magnitude of two variables which one would like to know for policy purposes.

The probability that a firm will be investigated by the Commission, m, necessarily appears in discussions on the desirable level of antitrust fines for cartels (deterrence requires the fine to be at least as high as the ratio between the profit gains from cartels over the probability that a cartel will be discovered and successfully prosecuted), but it is impossible to observe, since we cannot know the proportion of firms infringing the law over the whole population of firms.

As for the gap between competitive and supra-competitive profits, it may help us understand the effects that antitrust actions have on prices. Let us briefly illustrate a simple way to do so, in which we refer to a cartel infringement, where there is a positive relationship between anticompetitive profits and prices (in abusive cases, e.g. predation cases, it is also possible that higher anticompetitive profits may correspond to *lower* prices).

Finally, it can be checked that for the range of parameter values used in the Table 7, and for the estimated values of m and π^C/π^M, the actual fine f is well below the minimum fine f^* which would ensure deterrence (see expression (43)). In other words, the estimated values are consistent with the firm having chosen to violate antitrust laws.

This can be also seen as indirect evidence that antitrust fines are too low. Suppose for instance that $n = 2, q = .56, p = .69, \delta = .9, m = .55, \pi^C/\pi^M = .83$: the minimum fine needed to achieve deterrence should be $f^* = 26\%$, rather than 1.9% as it is in our sample![40] Of course, our estimates should not be taken too literally, but the order of magnitude of the difference between optimal fine and actual fine is so large that it is indeed suggestive of under-deterrence. Fortunately, the European Commission has introduced in 2006 new guidelines which will lead to the imposition of much higher fines.

Inference on prices. Assume an extremely simple model with perfectly symmetric firms and where the competitive price (that is, the price at the equilibrium absent the anticompetitive practice) is determined by a mark-up μ over marginal costs. For simplicity, assume away fixed costs and assume that marginal costs are constant and equal to c. Then the competitive price p_c is given by:

$$p_c = c(1 + \mu). \tag{60}$$

In this extremely simple model (in which we abstract from the incentive compatibility constraints for collusion), we assume that the (industry-wide) cartel allows competing firms to increase the market price above the competitive level, by a factor k, which we call the price overcharge. The collusive price will then be:

$$p_m = p_c(1 + k) = c(1 + \mu)(1 + k). \tag{61}$$

Note, however, that an increase in prices will not generally be followed by an equally-proportionate increase in profits, since a price increase will decrease demand.[41] Assume a constant demand elasticity e, which can be written as:

$$e = -\frac{(q_m - q_c)p_c}{q_c(p_m - p_{c)}}, \tag{62}$$

where q_m is the quantity sold under cartel, and q_c is the quantity sold under "competitive" conditions.

Some algebra shows that:

$$q_m = q_c(1 - ek). \tag{63}$$

[40] If $n = 10$, and all other parameters unchanged, then $f^* = 7.1\%$. But note that if n was equal to 10, then the estimated values of m and π^C/π^M would decrease.

[41] Of course, profits might also be affected through a change in costs (for instance if production falls below optimal capacity) but these are absent here due to the constant marginal costs assumption.

s	e	m	$=$	$\widehat{k}_1$	$\widehat{k}_2$
.7	**.8**	**.3**	=	**.14**	**.88**
.6	.8	.3	=	.25	.77
.7	**.5**	.3	=	.12	1.64
.7	.8	**.2**	=	.09	.99

TABLE 8. Tentative estimates of parameters

The firm's "competitive" profits are:

$$\pi^C = (p_c - c)q_c = c\mu q_q \tag{64}$$

while the cartel profits will be equal to:

$$\pi^M = (p_m - c)q_m = c(1 - ek)(k + \mu + k\mu)q_c. \tag{65}$$

Therefore, we shall have:

$$\frac{\pi^C}{\pi^M} = \frac{\mu}{(1 - ek)(\mu + k + k\mu)}. \tag{66}$$

In the previous section, we have obtained estimates of (π^C/π^M). Call $s \equiv \widehat{\pi^C/\pi^M}$ such estimate. It is then possible to solve equation (66) for k to obtain:

$$\widehat{k} = \frac{s(1 + \mu(1 - e)) \pm \sqrt{(1 + \mu(1 - e))s^2 - 4\mu(1 - s)es(1 + \mu)}}{2es(1 + \mu)}.$$

Call $\widehat{k}_1$ and $\widehat{k}_2$ the lower and higher root respectively. We expect that the rational firms would choose the lower of the roots as overcharge, not least because they do not want to attract the attention of the antitrust authority. We use tentative estimates for the parameters, reported in Table 8, to get an idea of the order of magnitude of the price changes.

Given that the firms choose the lower of the roots for overcharge we estimate that the price overcharge would be between 9-25%.

6. Conclusions

We have estimated, by using event study techniques, the impact of various events in an antitrust investigation on a firm's stock market value. Our main result is that the dawn raid (i.e., the surprise inspection of the firm's premises carried out by the Commission), which is the first piece of information received by market operators indicating that the European Commission intends to investigate an antitrust infringement, has a strong and statistically significant effect on the firm's share price: on average, on the same day as the dawn raid the firm's return is around 1% lower than the counterfactual return provided by the market model; furthermore, the cumulative average abnormal return due to the dawn raid is approximately 2.1% over the 5 days window.

Somewhat surprisingly, since one might expect that after the dawn raid the market would be able to anticipate that the antitrust investigation will lead to serious consequences for the firm, we find that the Commission's infringement Decision also has some effect on the firm's valuation. Although the evidence is less clearcut and robust than the one obtained for the dawn raid (although this is also due to the fact that the Commission Decision, unlike the dawn raid, is preceded by rumors), we find that a negative Decision results in a (statistically significant) cumulative abnormal return of about −2.4%.

Our final result is that the judgment by the Court annulling (or considerably reducing) the fine has a positive impact on the firm's market valuation (the cumulative average abnormal return is about 2.1%), whereas a judgment which upholds the fine results in an insignificant decrease in the firm's valuation.

Deterrence is determined by the probability that an infringement will be uncovered and prosecuted by the Commission multiplied by the costs that the firm incurs if the investigation does take place. The former factor is difficult to estimate, and our paper is silent on this. But our analysis tells us something about the latter, which could be obtained as an estimated loss of 4.5% of the firm's stock market value, calculated by adding the loss in stock market value due to the dawn raid (-2.1%) and the loss due to the formal Decision (2.4%).

However, one should not conclude that antitrust penalties amount to a loss of 4.5% of stock market value. Indeed, the fine represents only part of this capitalization loss, the remaining part resulting predominantly from the (likely) cessation of a lucrative activity - which cannot be considered a penalty for an infringement. In the US, Bosch and Woodrow (1991) estimated that fines and damages account for 13% of the total loss in the firm's stock market value. In our case, the fine represents on average around 2% of the firms' market

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	coef. Raid	t	coef. Decision	t
const.	-0.018	-2.57	-0.026	-2.76
fine/cap	-0.062	-0.41	0.041	0.29

TABLE 9. Regression of abnormal return on fine/cap ratio

value as reported by Datastream.[42] Since the estimated total negative effect on the share price is about 4.5%, the fine accounts for less than 50% of the total loss.[43]

The higher weight of the fines in the total loss in the firm's value we obtain for our EU data is consistent with the existence of treble damages in the US (but not in the EU), which add to the negative effects of the fines and the likely cessation of lucrative activities.

To determine whether the magnitude of a negative market reaction at the time of the surprise inspection depends on the relative magnitude of the fine later imposed on the firm by the Commission, we regress the abnormal returns on a constant and the ratio of the fine over the total capitalization of the firm. The results are reported in Table 9. We find that the coefficient on the relative size of the fine is a small negative number for raid and a small positive number for the commission which are not significant even at the level of 10%. This may be seen as a further indication that the fines are not the main component of the cost of an antitrust investigation.

In recent years, there has been a wide debate in the EU on how to increase deterrence of anticompetitive practices, in particular cartels.[44] The fact that several firms are repeat antitrust offenders, and the fact that the breach of competition laws rarely triggers top management changes in firms, may be suggestive of a scarce deterrence effect of antitrust penalties.

[42]We were unable to retrieve data for capitalisation at the date of the raid; instead we have the outstanding value of shares that we use in computation of abnormal returns for the given firm and capitalisation in September 2006. To approximate capitalisation at the time of the raid we multiply the outstanding shares value at the time of the raid with the ratio of capitalisation in 2006 and outstanding value of the same share edition in 2006.

[43]If one took the most conservative estimate of the effects of the investigation, and thus did not consider the drop due to the Commission's Decision, one would conclude that fines would account for almost the total drop in share prices.

[44]Several countries have increased fines for antitrust infringements, and some (for instance the UK) have introduced criminal penalties. The European Commission has launched an initiative to facilitate the use of private actions for damages and has just revised its Guidelines for imposing fines with the objective of increasing their deterrent effect (see footnote 6 above).

So far, though, there has been no attempt to study the extent to which EU investigations and penalties have significant effects on the firms infringing competition laws. This paper's objective was precisely to help quantify these effects.

It is difficult to say whether the estimated effects of the antitrust investigations on the firms' share prices should be considered large or small. To help make comparisons, it may be useful to compare our results with those works estimating the effects of events with characteristics similar to those of antitrust events. Gunthorpe (1997) uses event study techniques to investigate the effect of the first announcement in the Wall Street Journal that a firm is involved in some form of illegal behavior, such as racketeering, patent infringements, or fraud (for instance, false advertising and securities fraud). She finds that on the very same day of the announcement, the average abnormal return is -1.325%, and that the cumulative average abnormal return on an 11-day event window (like the one we use in Table 2) is -2.3%. The magnitude of these effects (which on average probably concern legal infringements of less gravity than antitrust ones) is similar to that of the dawn raids, which are also unexpected events.

Since Commission Decisions, and to a minor extent the Court judgments, are not entirely unexpected events, we need to find events sharing these features for the sake of making comparisons. MacKinlay (1997) analyzes the effects on share prices of announcements that actual earnings are more than 2.5% less than expected. On the same day as this announcement is publicly made, the firm's share drops by -.68%, while the cumulative average abnormal return on the 41-day event window (comparable to the length of the long event window we used for the Decision) is of about -1.26%. The estimated effects of such relatively minor 'bad news' are therefore of an order of magnitude not so different from the estimated effects of the news that the European Commission has decided to fine a firm for an antitrust infringement.

Still, in our case the overall impact of the antitrust investigation is determined by the sum of the effects of the dawn raid and of the Decision, so the above comparisons taken individually just give some idea of the magnitude of the effects. Admittedly, therefore, it is very difficult to say anything on whether the estimated effects are "large" or not, and above all on whether they are sufficient to provide deterrence against anticompetitive actions. Hopefully, this paper will promote discussion and more empirical works on this issue.

We also believe that our paper offers some evidence on the effectiveness of antitrust intervention. Since most of the drop in the share prices we observe is not caused by the fines, it must be due to the likely cessation of profitable cartel activity (or other unlawful business practices). In turn, this should imply that investors expect investigated and fined firms not to be able to sustain high prices any longer. Therefore, although we cannot offer

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direct evidence on this issue, our paper indirectly suggests that antitrust intervention does have an effect on product market prices.

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CHAPTER 4

Cournot Duopoly with Switching Costs

1. Introduction

Since a series of pioneering work by Klemperer (1987a,b,c) and von Weizsäcker (1984) it has been widely accepted by economists that costs incurred by consumers while changing providers of goods and services play an important role in organization of industries. To list just a few aspects, switching costs affect competition intensity, attractiveness of entry, collusion possibilities, and the market structure. The costs themselves originate from different sources. Klemperer (1987c) identified three types: learning costs, transaction costs and artificial contractual costs.

Learning costs are the effort and time spent to reach an operating level of knowledge of special characteristics of the product that allows the consumer to use the product with the same relative ease as previous product. An example are computer operating systems, which are (arguably) functionally identical, but require different specific knowledge. Transaction costs arise, for example, while changing a bank account: it takes both time and effort to close one account and to open another. Contractual costs are caused by deliberate actions of firms creating cost of switching away from the current provider. This type of costs is exemplified by frequent-flyer programs. In total, it is hard to find a market in which products do not exhibit any of three types of switching costs. Klemperer and Farrell (2006) is a comprehensive survey of the literature on switching costs. They deal mainly with the effects of switching costs on competition.

The economic literature identifies two effects that switching costs have on entry. On one hand, they facilitate entry, as the incumbent is less interested in new customers. Without discrimination between the old and the new customers the price will have to be lower for the whole customer base, not only for the new customers. On the other hand, switching costs facilitate entry deterrence, as the incumbent can use limit pricing more easily. In particular, in the period of entry the entrant must price significantly below the incumbent to attract new consumers.

The former effect dominates in the model of Farrell and Shapiro (1988). Their demand stems from overlapping generations of buyers (in each period a cohort of young buyers enters the market and lives for two periods). On the supply side there are two sellers. In this model

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the firm with attached customers specializes in serving them and concedes new buyers to its rival. The switching costs lock in consumers and confer a significant market power that results in higher profits. However, these higher profits attract new entrants. Farrell and Shapiro (1988) introduce barriers to entry in the form of economies of scale and because of the effect of switching costs that facilitate entry (may even lead to inefficiently high entry). Klemperer (1987b) in a two period model with an isolated cohort shows, however, that the incumbent may preempt entry by capturing a large market share or in other circumstances by keeping a small customers base to remain an aggressive competitor.

Another problem discussed in the literature is the effect of switching costs on the competitiveness of markets. Klemperer (1987a) builds a two-period differentiated-products duopoly with switching costs and finds that the non-cooperative equilibrium in an oligopoly with switching costs leads to vigorous competition for market share in the early stages of the market's development. This results in the evolution of prices whereby the price in the first period is lower than the price in subsequent periods. This is because the firms compete for market share that is valuable later. However, the prices in this model may be higher in all periods than in competition without switching costs.

Padilla (1992) shows that switching costs always relax competition compared to the situation with no switching costs. However, the level of competition is not a monotonic function of switching costs. In his model not all customers are informed about the prices of both sellers and all equilibria are mixed strategy equilibria in prices. The larger firm sets a higher price with a higher probability than the smaller firm. There is a tendency to symmetric market shares as the bigger firm sets a higher price more often but in equilibrium market shares of firms are asymmetric. He thus finds that competition with switching costs will lead to equilibria where the firms naturally have asymmetric market shares.

Similarly, in the present model the firms have asymmetric market shares in equilibrium. However, it is not the fact that the firms use mixed strategies in equilibrium that generates this result. I assume that the firms start the game with exogenously allocated customer bases that need not be the equilibrium ones. Solving the game for all such allocations the resulting equilibria are characterized. In the present model the information is complete and perfect and pure strategy equilibria asymmetric equilibria exist also for a subset of initially symmetric market shares.

In an attempt to characterize industry dynamics Padilla (1992) interprets the mixed strategy random equilibrium realizations of very low prices as sales or stochastic price wars. In his model, when both firms set a low price as a realization of random equilibrium strategies, price wars obtain; when only one of the firms sets a low price, unilateral sales occur. I believe that the resulting fluctuating price series that this model generates do not reflect

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well the observed stability of industry prices. Moreover, his model cannot explain persistent asymmetric market shares that we observe in many industries. Namely in Padilla (1992) there is a persistent tendency to symmetric market shares and asymmetries will only result from randomization over strategies in equilibrium. The model of this paper, on the other hand, captures both these features of reality, relative stability of prices, and persistent asymmetries in market shares.

The focus of the paper, however, is the short-term industry dynamics rather than long-term outcome analyzed in the most of the literature. Switching costs allow for history dependence, which plays a crucial role in the short term. Despite the focus on short term dynamics I show that convergence to the classical symmetric Cournot equilibrium does not happen even in an infinitely repeated game even if switching costs are small.

I model the industry by a one-shot game where the firms simultaneously decide on the quantities they produce. Demand is given exogenously by a linear function. [1] I am looking for subgame perfect Nash equilibria.

For very small initial output levels, including zero output for both firms, unique symmetric equilibrium obtains, where the quantity produced increases from the initial one, is equal in subsequent periods, and lower than the quantity produced in equilibrium in the absence of switching costs. This is similar to the result of Klemperer (1987a) where the competition is most intensive in the initial period. When we increase the initial quantities of either of the firms we also obtain asymmetric equilibria. To the best of my knowledge, this result is not present in the literature to date. Given that quantity increases are relatively less attractive with a higher customers base, the initial allocations in which both firms have high outputs result in the set of equilibria where the quantities are equal to the initial allocation. These are situations in which the incentives for both firms to harvest existing customer base are stronger than the incentives for expansion.

An interpretation of these results is in the choice of entry mode when one can opt for an early entry with a limited capacity or for a later entry with a large capacity. The latter may be preferred in industries with switching costs even if after the entry capacity expansion is allowed. Namely, for large enough switching costs and captured market, the incentives for expansion are absent, and the firm might get locked in a less profitable equilibrium.

Interesting asymmetric equilibria obtain when either one or both of the firms have an initially allocated output in the medium range (The medium range shall be characterized

[1] We can think of this demand as being generated by uniformly distributed customers with valuation v and linear transportation costs. Only the farthest customers switch suppliers. A customer incurs fixed costs whenever he did not make a purchase from the same firm in the previous period. Thus, the costs are incurred whenever the customer switches a firm or when he first purchases the good. This is the same demand as Klemperer (1987b).

more precisely later). Each of the firms, given rival's initial output wants to increase the output - future profit increases are attractive. However, if the rival increases the quantity largely enough, lowering the price further, the firm no longer wants to increase the output and prefers to keep a high present price and harvest existing customers. This results in an asymmetric equilibrium where either of the firms ends up bigger, and the other does not change output from the initial one.

The quantitative results of our analysis survive in a multi-period setting. Thus, this model does not predict convergence to symmetric output allocations over time.

2. The Model

I consider a one-shot Cournot game with two firms, demand $p(q)$ and production costs $C(q)$. Switching costs of changing a provider are s. The suppliers cannot discriminate between different consumers according to whether or not they have made the purchase in the previous period. Thus, whenever the sellers want to expand the sales they have to offer a discount to all consumers. The formulation of demand is identical to Klemperer (1987b). I add initial sales to the model, whereby the firms start playing the game with some history, which proxies the customer base of the firm. The maximization problem of a seller is thus

$$\max\ \pi_i = \left(p\left(q_i^2 + q_j^2\right) - s\mathbb{I}_i\right) q_i^2 - C\left(q_i^2\right), \tag{67}$$

where

$$\mathbb{I}_i = \begin{cases} 1, & q_i^2 > q_i^1; \\ 0, & q_i^2 \le q_i^1. \end{cases}$$

$\mathbb{I}_i$ captures the discount when the seller wants to increase sales from that of previous period and q_i^1 denotes the volume of initial sales. The initial sales are treated as exogenous. To be able to obtain analytical results I look at the linear demand $p(q) = a - bq$ and linear costs $C(q) = cq$.

$$\pi_i = \left(a - b\left(q_i^2 + q_j^2\right) - s\mathbb{I}_i\right) q_i^2 - cq_i^2, \tag{68}$$

Denote for convenience $x = \frac{a-c}{3b}$ and $S = \frac{s}{3b}$. Next, fix the strategy of firm A to q_A^2. The best response of the firm B given its initial sales q_B^1 is to maximize

$$\pi_B\left(q_B^2 | q_B^1, q_A^2\right) = \begin{cases} b\left(3x - \left(q_B^2 + q_A^2\right)\right) q_B^2 & q_B^2 \le q_B^1; \\ b\left(3x - \left(q_B^2 + q_A^2\right) - 3S\right) q_B^2 & q_B^2 > q_B^1. \end{cases} \tag{69}$$

The problem is concave in q_B^1 on each interval, so optima can separately be found and then compared. Differentiation gives

$$\pi'_B\left(q_B^2|q_B^1,q_A^2\right)=\begin{cases} b\left(3x-(2q_B^2+q_A^2)\right), & q_B^2\leq q_B^1; \\ b\left(3x-(2q_B^2+q_A^2)-3S\right), & q_B^2>q_B^1. \end{cases} \tag{70}$$

From equation above the candidate best responses can be written as

$$q_B^2=\begin{cases} \frac{1}{2}\left(3x-q_A\right), & q_B^2\leq q_B^1; \\ \frac{1}{2}\left(3x-3S-q_A\right), & q_B^2>q_B^1. \end{cases} \tag{71}$$

This condition simply states that in the second period the seller B, when he is expanding the quantity will, given strategy of A, expand to $\frac{1}{2}(3x-3S-(q_A))$. When B is contracting sales, given strategy of A, he will set the quantity to $\frac{1}{2}(3x-(q_A))$. After plugging the corresponding expressions for the second period quantities into the conditions and the realizing that in the remaining interval B responds with no change in quantity, $q_B^2=q_B^1$, the following obtains:

$$q_B^2=\begin{cases} \frac{1}{2}\left(3x-q_A\right), & \frac{1}{2}\left(3x-q_A\right)\leq q_B; \\ q_B^1, & \frac{1}{2}\left(3x-3S-q_A\right)\leq q_B<\frac{1}{2}\left(3x-q_A\right); \\ \frac{1}{2}\left(3x-3S-q_A\right), & \frac{1}{2}\left(3x-3S-q_A\right)>q_B. \end{cases} \tag{72}$$

The superscript has been dropped for convenience, as now only initial sales are present in the rhs.

The part of the best response function that is relevant for quantity increase is computed under the assumption that it is optimal for a firm to increase the quantity. However, it may not be so for output values close to the best response. The firm would in that case prefer not to raise the quantity, because of the penalized price which it obtains in doing so. Therefore, I compute the set of initial allocations for which the firm is indifferent between increasing the quantity to best response and keeping it as it was before, and then define the global best response for the second period as

$$q_B^2=\begin{cases} \frac{1}{2}\left(3x-q_A\right), & \frac{1}{2}\left(3x-q_A\right)\leq q_B; \\ q_B, & y_B\leq q_B<\frac{1}{2}\left(3x-q_A\right); \\ \frac{1}{2}\left(3x-3S-q_A\right), & q_B<y_B. \end{cases} \tag{73}$$

Here

$$y_i=\frac{1}{2}(3x-q_j-\sqrt{3S}\sqrt{-3S+6x-2q_j}),$$

is the curve which characterizes the initial q_i for each strategy q_j for which the firm i is indifferent between increasing the quantity and not changing it from the one initially allocated. In Figure 1 these are plotted as dashed convex curves.

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It proves useful to take on the following notation. First, define

$$z = \frac{3}{25}(2S + 5x - 2\sqrt{6S}\sqrt{-4S + 5x}), \tag{74}$$

as q_i coordinate of the intersection of the higher best response line for firm j with the indifference set for firm i, y_i. In the figure this is denoted by dashed horizontal line. Moreover,

$$\phi = \frac{1}{2}(S + 2x - \sqrt{3}\sqrt{S}\sqrt{-S + 4x}) \tag{75}$$

is the q_i coordinate of the projection of the intersection of lower best responses $(x - S, x - S)$ on y_i. Finally,

$$\nu = \frac{1}{3}(-7S + 3x + 2\sqrt{S^2 + 3Sx}) \tag{76}$$

is the q_i coordinate of the intersection of lower best response of firm j with i's indifference set y_i.

I proceed to find the equilibria and characterize them in the following propositions. Assume in what follows, without loss of generality, that firm B never has higher initial sales than firm A.

Proposition 1. The unique Nash equilibrium of the game specified above is characterized by the following strategy profiles:

(i)

$$(x - S, x - S) \quad \text{if} \quad q_{A,B} \leq \nu, \tag{77}$$

$$(x, x) \quad \text{if} \quad q_{A,B} \geq x. \tag{78}$$

(ii)

$$(q_A, \frac{3}{2}(x - S) - \frac{1}{2}q_A) \text{ if} \tag{79}$$
$$((q_B \leq y_B) \cap (y_A \leq q_A \leq x + S)) \cup ((\phi \leq q_A \leq y_A) \cap (q_B \leq \nu)),$$

$$(x + S, x - 2S) \quad \text{if} \quad (q_A \geq x + S) \cap ((q_B \leq z) \cup (q_B \leq y_B)), \tag{80}$$

$$(\frac{3}{2}x - \frac{1}{2}q_B, q_B) \quad \text{if} \quad (q_A \geq \frac{3}{2}x - \frac{1}{2}q_B) \cap (x \geq q_B \geq z); \tag{81}$$

(iii)

$$(q_A, q_B) \quad \text{if} \quad (q_B \geq y_B) \cap (q_A \leq \frac{3}{2}x - \frac{1}{2}q_B), \tag{82}$$

Proof. The equilibrium is constructed from intersection of global best responses, as outlined by (7). ■

Equations (77) and (78) characterize the two symmetric equilibria denoted, respectively, by letters A and C in Figure 1. The first equilibrium results from low, including 0, initial sales for both sellers. In Figure 1 this initial allocation corresponds to the white area under the diagonal close to the origin. Both firms increase the quantity but total sales in the resulting equilibrium are low. Any other equilibrium in the model is characterized by higher total sales. The second symmetric equilibrium (denoted by C in the figure) results from both firms selling large volume in the previous period. This area of initial sales volumes is above the horizontal dashed line through C. In this equilibrium both firms decrease the quantity to the level of the equilibrium without switching costs. This is also the equilibrium where total quantity sold is the highest.

Equations (79)- (81) characterize equilibria in which the initially smaller firm (weakly) increases the quantity and the bigger one (weakly) decreases it. This type of equilibria results when the asymmetry in initial sales is large and the the larger firm A's sales exceed the threshold defined by y_A. Equation (79) thus characterizes the unique asymmetric equilibrium which in Figure 1 corresponds to the area (13) below the curve y_b to the left of $x + S$.

Equation (80) in turn characterizes the equilibrium resulting from the bigger of the firms inheriting large sales (in Figure 1 this means that A has sales beyond $\tilde{q}_A$), whereas the smaller firm had much smaller sales(B had initial sales below the dashed indifference curve or below the dashed horizontal line denoted by z). In equilibrium, the bigger firm will decrease its sales volume whereas the smaller one will increase it moderately. The equilibrium in the Figure is now at the intersection of best response lines, denoted by B.

Equation (81) gives equilibrium sales volumes for initial allocations which in Figure 1 fall into the region to the right of the higher of the best response lines for firm A and between the horizontal lines through C and z. In this case the large firm, A, will decrease the quantity the other firm will not change sales.

Equation (82) characterizes equilibrium resulting from levels of initial sales in the medium range. In this case none of the firms has an incentive neither to increase nor to decrease its sales from the initial ones. In the figure this set is represented by the grey central area. Clearly for relatively high levels of initial sales the opportunity costs of expansion are high for both firms and none of them has an incentive to increase sales.

As demonstrated earlier, at very low, including zero quantities in the first period there is only a symmetric equilibrium where both firms increase sales (the white area below the 45 degrees line close to the origin in the figure).

However, for a set of initial allocations where both firms still have relatively low, but at least one of the firms has initial sales larger than ν, multiple equilibria may obtain. This leads to the following proposition.

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Proposition 2. The multiple Nash equilibria of the game specified above are characterized by the following strategy profiles:

$$(q_A, \frac{3}{2}(x-S) - \frac{1}{2}q_A) \quad \text{together with}$$
$$(x-S, x-S) \quad \text{if} \quad (\phi \geq q_A \geq \nu) \cap (q_B \leq \nu), \tag{83}$$

$$(q_A, \frac{3}{2}(x-S) - \frac{1}{2}q_A) \quad \text{together with}$$
$$(x-S, x-S) \quad \text{and}$$
$$(\frac{3}{2}(x-S) - \frac{1}{2}q_B, q_B) \quad \text{if} \quad (\phi \geq q_A \geq \nu) \cap (\phi \geq q_B \geq \nu), \tag{84}$$

$$(q_A, \frac{3}{2}(x-S) - \frac{1}{2}q_A) \quad \text{together with}$$
$$(\frac{3}{2}(x-S) - \frac{1}{2}q_B, q_B) \quad \text{if} \quad (y_A \geq q_A \geq \phi) \cap (\nu \leq q_B). \tag{85}$$

Proof. Analogous to Proposition 1. ■

Multiple equilibria arise because of the interaction between the strategies played by the other player and incentives to increase the sales. A relatively large increase in sales by one of the players may cause the other player to be better off not changing its sales from the initial ones. For the set of initial sales which give multiple equilibria both firms are potentially interested in increasing sales, and at least one does so. If both firms indeed increase sales, this leads to a symmetric equilibrium. The larger, in our case firm A, however, has an incentive to increase sales only as long as B does not choose a large increase in sales. As A's customers base is no longer very small it becomes optimal not to increase the quantity for large increases in B's quantity. In turn, large increase, as a response to a strategy of no change of A for this strategy of B, becomes attractive for B. These strategic interactions imply an additional asymmetric equilibrium in conjunction with the symmetric one.

The first set of multiple equilibria which result from firm B being initially significantly smaller than A is characterized by (83), which can also be seen from the Figure 1. It is obvious that either the firm B will be bigger in equilibrium or both firms will have equal sales volumes at $x - S$.

Taking initial sales of B to be at the levels close to those of A we have 3 possible equilibria - where either A or B has a higher output and a symmetric equilibrium with both firms having equal outputs. In Figure 1 this set of initial sales volumes is denoted by (84). The resulting equilibria are characterized by the corresponding equation.

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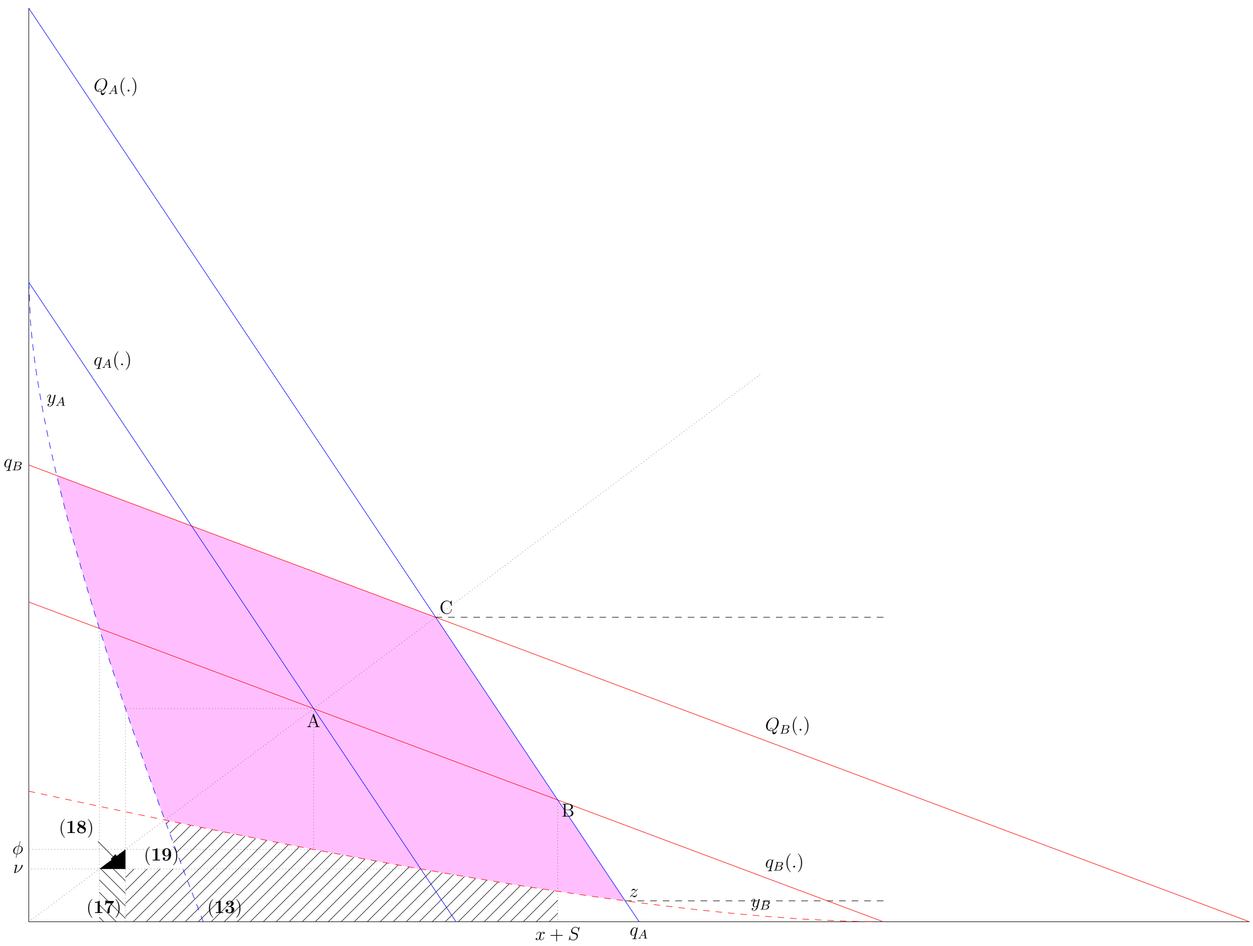

FIGURE 1. Equilibria

There is also a possibility of two asymmetric equilibria when sales volumes of the firms in the initial period are close. In the figure this set is the region (19). The resulting equilibria are characterized by the corresponding equation.

In line with the literature on the switching costs, the firm with a smaller initial market share is relatively more aggressive. The reason is that the larger firm has greater incentives to exploit its customer base and thus lacks incentives for costly expansion. In the present model, however, we can trace the adverse effect of aggressive strategies on the expansive intentions of the other player and obtain asymmetric equilibria, even when the firms are completely symmetric along all dimensions.

As the propositions make clear, equilibrium quantities depend on the initial allocation of output between firms in the presence of switching costs. The outcomes are sometimes sensitive to small changes in the initial conditions. This sensitivity is reflected in the abrupt changes of the equilibrium quantities for small changes in initial sales volumes of one or both firms. Together with possible multiple equilibria, this implies that an attempt at prediction of the industry structure outcomes in reality with switching costs may not be a very fruitful operation. This has been a recurrent, but never satisfactorily explained argument in the literature on switching costs.

I have shown that for a one period model asymmetric equilibria will result for a subset of asymmetric (and a subset of symmetric) initial sales allocations for otherwise identical firms. In the presence of switching costs this is a normal competitive outcome, which need not be a red flag for the antitrust authority. This is relevant, particularly because we often observe persistent asymmetries in market shares in reality and this seems to often be a great concern for a regulator or a competition authority.

Further, even if a firm has larger sales (larger customers base) initially, this may not be true in equilibrium. In the present model often it is the initially smaller firm, which is more aggressive, that has higher equilibrium sales. Taking this result to reality, we should not be surprised if such industries are exhibiting occasional volatile changes in leadership. Moreover, the result should serve as a warning for the regulator from hastily accepting a paternalistic attitude towards the small firms in industries characterized by switching costs.

3. Comparative statics

It is clear that the conventional Cournot duopoly is a limiting case in the model when switching costs tend to zero. The grey area of inaction on the Figure is growing larger with increase of costs s. This is very intuitive: none of the firms wants to adjust its position if the adjustment is costly. Notice that for very high costs there is no initial position that makes firms increase their sells even from zero - in such case entry is successfully blocked.

The size of the market a obviously has the opposite effect on the region where the firms do not change their positions in equilibrium. The slope of demand function b matters for this region in so far as it enters x and S, higher slop thus leading to smaller set of inaction. This also seems intuitive, as more elastic demand is more attractive for price cuts holding costs of switching constant.

Note also that the upper-right border of the grey region have the slope $-\frac{1}{2}$ and -2 regardless of the parameters of the model. Size of the market, elasticity of demand, production and switching costs all change position and size of the area of inaction, but do not change its form. This feature is a result of the assumption that the two firms are identical apart from initial positions.

The size of the region with multiple equilibria depends on how large is $\phi - \nu$. It can be shown that this difference is increasing in S and decreasing in x. Hence, the effect of switching costs and other parameters on this region is similar to that on grey region.

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4. Entry

Given that I have solved for all the initial allocations of consumers, the results can be used to examine entry into an industry characterized by switching costs. The entrant that does not face any sunk costs is equivalent to an incumbent which has no initial sales. Thus, Propositions 1 and 2 allow us to characterize the resulting equilibrium for any strictly positive initial sales of the incumbent, firm A. Namely, equations (77), (79), (80), (83) contain all the relevant information for entry analysis.

I start the discussion with monopolistic initial sales of the incumbent. Consider as monopolistic the points at zero production of the firm B between lower and best responses of firm A and most asymmetric equilibrium quantity of firm A, $q_A^m \in \left[\frac{3}{2}(x-S), x+S\right]$. In such case the entry will involve the entrant setting the quantity equal to $\frac{3}{2}(x-S) - \frac{1}{2}q_A^m$, which is the best response to monopolistic quantity q_A^m. This can also be seen in equation (79). The incumbent will not change its sales from the initial ones. The market share of the incumbent in the new equilibrium will be, under the assumptions made, somewhat higher than that of the entrant. The difference depends on how steep the best response is.

When we consider the initial sales of the incumbent below monopolistic, the entrant's equilibrium sales are higher. This is according to the same best response defined in (79). When the incumbent's initial sales are below $x - S$, the entrant's equilibrium market share is actually higher than that of the incumbent.

However, if we consider very small initial sales of the incumbent ($q_A \leq y_A$), the industry will exhibit symmetric sales $(x-S, x-S)$. This corresponds to equation (77) of Proposition 1. As a qualification, there is also a small interval $q_A \in [\nu, \phi]$ that results in two equilibria: symmetric $(x-S, x-S)$ and asymmetric $\left(q_A, \frac{3}{2}(x-S) - \frac{1}{2}q_A\right)$. This can be seen from equation (83) of proposition 2.

For larger than monopolistic initial sales of the incumbent, $q_A > x + S$, its equilibrium sales decrease. Despite this, the asymmetry in this case is maximal: the equilibrium is $(x+S, x-2S)$, as can be seen from equation (80).

5. Dynamics

The previous results can be applied to get insights into the adjustment of market structure to demand shocks. Initial sales in the model can be interpreted as the equilibrium sales in the previous period characterized by initial demand. Suppose now that between the periods a demand shock (symmetric or asymmetric) is realized, such that the new demand is as in the model. In this manner low initial sales allocations (those close to the origin in Figure 1) correspond to a positive shock in demand and the initial allocations with high sales

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correspond to negative demand shocks. This way any initial state can be chosen and the adjustment to shocks analyzed.

Evolving industries and growing markets exhibit large potential size, and this corresponds in the model to initial allocations at low sales close to the origin of the graph (increasing the constant term in the demand function would have exactly such an effect). On the other hand, in the model shrinking markets would exhibit small potential size and accordingly initial allocations further from the origin.

With this interpretation one can explore the implications of the model for industry dynamics. As shown in Proposition 1, relatively low initial sales and significant asymmetries in these give rise, in equilibrium, to large changes in sales by at least one of the sellers. Thus, it follows from the model that we should not be surprised to observe sudden shifts in the sales leadership in growing markets or after positive demand shocks. On the other hand, such reversals would be less likely for industries where sellers are operating in stagnating markets. The set of equilibria characterized by the proposition above also imply that these are the situations in which persistent asymmetries in market shares are more likely.

In the markets with small potential size the model predicts that large initial asymmetries will decrease in equilibrium through the smaller firm increasing its sales faster than the bigger one. Once a firm locks in sufficiently high a customers base the incentives for further expansion are low and the model predicts convergence to stable market shares. Note that the model does not predict that small asymmetries will decrease in such markets.

When the initial sales allocations are rather symmetric and shocks to the demand are small, the model implies that neither of the firms will be changing the level of sales in equilibrium. In this region the incentives of sellers to increase market share are weak. These initial allocations can be interpreted as historical customer bases for mature markets along the same lines as before. Thus in industries (markets) which are growing at slower rates the model predicts more stable symmetric or asymmetric market shares.

There are at least two testable hypotheses that come out of this analysis. Firstly, we are more likely to find alternating leadership in the growing industries with switching costs. Secondly, we should see stabilized market shares (symmetric or asymmetric) in mature industries.

6. Extension to multiple periods

In this section I extend the model to multiple (in fact, infinitely many) periods to see if it is robust to such a modification. In general formulation, the optimization problem of the firm A in an infinitely repeated Cournot game with switching costs is

$$V(q_A, q_B) = \max_{q'_A} \{\pi(q'_A, q'_B \| q_A, q_B) + \delta V(q'_A, q'_B)\},$$

s.t.

$$p = P(q'_A + q'_B) - s \quad \text{if} \quad q'_A > q_A$$
$$p = P(q'_A + q'_B) \quad \text{if} \quad q'_A \leq q_A$$

Now the candidate equilibrium is to move to a pair of output (q_A^*, q_B^*)in the first period. Suppose we start with initial vector $q^0 \ll q^*$. Consider a unilateral deviation of first moving to some quantity $q_i \| q_i^0 < q_i < q_i^*$. Then the corresponding values are

$$V^* = \frac{P(q_A^* + q_B^*) q_A^*}{1-\delta} - s q_A^*$$

and

$$V^{dev} = P(q_A + q_B^*) q_A + \frac{\delta P(q_A^* + q_B^*) q_A^*}{1-\delta} - s(q_A + \delta q_A^*).$$

The firm A will prefer not to deviate (and hence change production only once), if

$$V^* - V^{dev} = P(q_A^* + q_B^*) q_A^* - P(q_A + q_B^*) q_A + s(q_A + (\delta - 1) q_A^*) \geq 0.$$

Intuitively, the inverse demand should not react too drastically to the reduction of quantity. In case of linear demand we have

$$(q_A^* - q_A)(a - b(q_A + q_A^* + q_B^*)) + s(q_A + (\delta - 1) q_A^*) \geq 0.$$

Clearly, the first term is most likely to be negative, if $q_A \rightarrow q_A^*$, in which case we have $a - b(2q_A^* + q_B^*)$.

But this is just our demand function, the supremum of the argument is 3 times Cournot quantity, so the infinum of the function is exactly zero. Thus, the first term is always positive. The second term is positive, if $q_A > (1-\delta) q_A^*$. Note though that at in the opposite case (small quantities) the first term becomes large: $(\delta q_A^*)(a - b((2-\delta) q_A^* + q_B^*))$. Taken at the extreme, we have $q_A^*(a - b(q_A^* + q_B^*)) + s((\delta - 1) q_A^*) \geq 0$ meaning that frictionless Cournot profit should exceed switching costs, which is obviously satisfied if the market is to exhibit any changes in quantities at all.

In effect, with linear demand our candidate equilibrium brings larger value than deviation [2].

The fact that there exists a Markov perfect Nash equilibrium where the firms only move once allow computation of the regions of initial allocations for which a firm will not change its output in the same fashion as for the one-shot game. In fact, the shape of these regions

[2] It is standard to show that the same is true for a deviation in any other period and for deviations in multiple periods.

turns out to be very similar, except that the set is smaller, but not empty for $\delta > 0$. For $\delta = 1$ obviously this set is empty and the only Markov perfect equilibrium is the Cournot equilibrium of the frictionless game.

For any $0 < \delta < 1$ analysis similar to the one-shot game above can be performed to find both symmetric and asymmetric equilibria, analogously as in the one-shot game.

Thus the qualitative results of the model persist when we extend the number of periods to infinity (even when we consider infinitely many periods with the discount factor below 1) and restrict ourselves to the simplest equilibrium concept consistent with rational behavior in an infinitely repeated game setting.

7. Discussion of the results

The simple Cournot model of this paper shows that in the presence of switching costs equilibrium allocation depends on the initial allocation. The initial allocation in this model can be interpreted as the firms' market shares relative to potential demand. Thus, initial allocations close to the origin of the graph correspond to situations where the market has significant potential for growth, and the allocations where both firms have large initial sales corresponds to a situation in which market is shrinking. In this view a sudden shock, say increase in expected market size, could induce a change in relative market shares if it is large enough. This response could lead to a reversal in the order of market share sizes. One implication of the model is that the adjustment to shocks in demand is hard to predict and may involve sudden shifts in market positions of the firms. Industries exhibiting persistent asymmetries in market shares, periods of relatively stable division of market followed by sudden readjustments or longer periods of symmetric market division would all be consistent with the presence of switching costs and imperfect differentiation between old and new customers, as in the model.

Entry decision can be analyzed. In new industries with a large growth potential the model would predict a relatively symmetric market shares after the entry, as the entrant holds large sales upon entry and the incumbent does not fight aggressively for a market share. At the other extreme an entry to a shrinking monopolized market would result in a relatively asymmetric market allocation, despite the fact that the incumbent is even less aggressive in such a case.

Recently a theory of the stepping stones, or the ladder of investment theory, has become prominent in the literature and among regulators of some industries (telecommunication) where the cost of initial investment into infrastructure are high. The idea of the ladder of investment is that an entrant be given access to the infrastructure of the incumbent so he can build a customer base, which would then justify investment in own infrastructure. If the access to infrastructure is limited so that initially the entrant can not supply the whole market the model predicts that it could easily happen that after the entrant has captured a significant customers base it may lose the incentive to increase sales further and with it the incentive to invest in own infrastructure, thus defeating the purpose of the ladder idea. The entrant would invest in large infrastructure capacity in the absence of the ladder, but after capturing a significant customer base it may no longer be optimal for it to build his own infrastructure.

8. Conclusion

Our The analysis in this paper is centered around one basic feature of reality: history dependence. In the simple Cournot setup history matters because the customers have to incur switching costs whenever they buy from a new seller. Equilibrium of Cournot game for any initial allocation of sales is characterized. The main finding is persisting asymmetry in market shares of otherwise identical firms. This result survives extending the model to multiple periods, including an infinitely repeated game.

I also show that when initial asymmetries are small, they tend to remain small, as none of the firms is motivated to behave aggressively. When initial asymmetries are large, the smaller firm has an incentive to expand, and sometimes it does so to the extent that it takes more than half of the market. This gives us empirically testable hypotheses of stable market shares in the markets with uniform distribution of market shares and high volatility in the markets with very uneven distribution of market shares.

The model also provides rationale for a large-scale one-time entry versus gradual buildup of capacities. The intuition remains intact: with switching costs a fresh entrant is the one who has "nothing to lose" and is relatively more aggressive than a seller with an established customer base.

Linear demand and homogeneous good framework are the main limitations of the model. However, different demand functions do not change the nature of competition, so we do not expect our qualitative results to be altered significantly. Heterogeneous goods framework would be an interesting extension to our analysis, adding new channels for switching costs to work through. At the same time, the main effects of customer lock-in outlined here will remain on its place.

The analysis presented is general and can be applied to any industries characterized by switching costs. Telecommunications, banking, airlines are among classical examples of such industries.

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APPENDIX A

Observations for Effect of Fines

	Art.	Com..Dec.	Raid	Court	Firm	Fine.Com.	Fine.Court	Fine.Cap
1	82	1979/12/14		1983/06/07	Pioneer	0.30	0.20	0.00040
2	81	1980/11/25			Johnson & Johnson Inc.	0.20		0.00005
3	82	1981/12/17		1983/11/08	Siemens	0.04	0.04	0.00001
4	82	1985/12/14		1991/07/03	AKZO	10.00	7.50	0.04548
5	82	1985/12/18			Fanuc	1.00		0.00013
6	82	1985/12/18			Siemens	1.00		0.00007
7	81	1986/04/23	1983/10/13	1991/12/17	BASF	2.50	2.12	0.00035
8	81	1986/04/23	1983/10/13	1992/03/10	Hoechst	9.00	9.00	0.00128
9	81	1986/04/23	1983/10/13	1992/03/10	Shell	9.00	8.10	0.00025
10	81	1986/04/23	1983/10/13	1999/07/08	Imperial Chemical	10.00	9.00	
11	81	1986/04/23	1983/10/13	1992/03/10	Solvay	2.50	2.50	0.00170
12	82	1987/07/10		1990/02/08	Beiersdorf	0.01	0.01	0.00001
13	82	1988/12/05	1986/08/21	1993/04/01	BPB Industries	0.15	0.15	0.00009
14	81	1994/07/27		1990/06/19	Norsk Hydro	0.75		0.00025
15	81	1994/07/27			Solvay	3.50		0.00152
16	81	1994/07/27		1992/02/27	BASF	1.50	0.00	0.00021
17	81	1994/07/27		1992/02/27	Hoechst	1.50	0.00	
18	81	1994/07/27		1992/02/27	Imperial Chemical	2.50	0.00	
19	81	1994/07/27		1992/02/27	Shell	0.80	0.00	
20	81	1988/12/21	1983/11/21	1995/04/06	BASF	5.50	0.00	
21	81	1988/12/21	1983/11/21	1995/04/06	Bayer	2.50	0.00	0.00029
22	81	1988/12/21	1983/11/21	1995/04/06	Dow Chemical	2.25	0.00	0.00017
23	81	1988/12/21	1983/11/21	1995/04/06	Hoechst	1.00	0.00	0.00013
24	81	1988/12/21	1983/11/21	1995/04/06	Imperial Chemical	3.50	0.00	
25	81	1988/12/21	1983/11/21	1995/04/06	Shell	0.85	0.00	0.00002
26	82	1989/12/13		1991/06/29	Bayer	0.50	0.50	0.00006
27	81	1990/12/19		1995/06/29	Solvay	7.00	0.00	0.00362
28	81	1990/12/19		1995/06/29	Imperial Chemical	7.00	0.00	
29	83	1992/04/01			Nedlloyd	0.03		
30	82	1992/07/15	1989/09/19	1994/07/14	Herlitz	0.04	0.04	0.00008
31	81	1994/07/13	1991/04/23	1998/05/14	SCA Holding	2.20	2.20	0.00265
32	81	1994/12/21		2002/02/28	Kisen Kaisha	0.01	0.00	0.00001
33	81	1994/12/21		2002/02/28	Mitsui OSK Lines	0.01	0.00	0.00000
34	81	1994/12/21		2002/02/28	Neptune Orient	0.01	0.00	0.00001
35	81	1994/12/21		2002/02/28	Nippon Yusen	0.01	0.00	0.00000
36	81	1994/12/21		2002/02/28	Orient Overseas	0.01	0.00	0.00004
37	82	1995/07/12	1991/06/26	1999/05/19	BASF	2.70	2.70	0.00026
38	82	1996/01/10		2000/10/26	Bayer	3.00	0.00	0.00020
39	82	1998/01/28	1995/10/23	2000/07/06	Volkswagen	102.00	90.00	0.00574
40	83	1998/09/16		2003/09/30	A.P. Moller-Maersk	27.50	0.00	

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41	83	1998/09/16		2003/09/30	P & O Nedlloyd	41.26	0.00	
42	83	1998/09/16		2003/09/30	Orient Overseas	20.63	0.00	0.12999
43	83	1998/09/16		2003/09/30	Neptune Orient	13.75	0.00	0.04494
44	83	1998/09/16		2003/09/30	Nippon Yusen	20.63	0.00	0.00641
45	83	1998/09/16		2003/09/30	Hanjin Shipping	20.63	0.00	
46	83	1998/09/16		2003/09/30	Hyundai Merchant	18.56	0.00	0.08098
47	81	1998/10/14	1994/05/27	2001/07/12	Tate & Lyle	7.00	5.60	0.00354
48	81	1998/12/09	1994/07/05	2003/12/11	Minoan Lines	3.26	3.26	0.00697
49	82	1999/07/14	1997/06/12	2003/09/30	British Airways	6.80	6.80	0.00099
50	81	1999/12/08	1994/12/01	2004/07/08	Vallourec	8.10	8.10	0.02232
51	81	1999/12/08	1994/12/01	2004/07/08	Sumitomo Metal	13.50	10.94	0.00422
52	81	1999/12/08	1994/12/01	2004/07/08	Nippon Steel	13.50	10.94	0.00082
53	81	2000/05/16		2003/03/19	Kawasaki Kisen	0.62	0.00	0.00059
54	81	2000/05/16		2003/03/19	A.P. Moller - Maersk	0.84	0.00	
55	81	2000/05/16		2003/03/19	Malaysia Shipping	0.13	0.00	0.00004
56	81	2000/05/16		2003/03/19	Mitsui OSK	0.62	0.00	0.00022
57	81	2000/05/16		2003/03/19	Neptune Orient	0.37	0.00	0.00017
58	81	2000/05/16		2003/03/19	Nippon Yusen	0.62	0.00	0.00011
59	81	2000/05/16		2003/03/19	Orient Overseas	0.13	0.00	0.00045
60	81	2000/05/16		2003/03/19	P & O Nedlloyd	1.24	0.00	
61	81	2000/05/16		2003/03/19	Evergreen Marine	0.37	0.00	0.00020
62	81	2000/05/16		2003/03/19	Hanjin Shipping	0.62	0.00	0.00249
63	81	2000/06/07	1997/06/11	2003/07/09	Archer Daniels	47.30	43.88	0.00760
64	81	2000/06/07	1997/06/11		Ajinomoto	28.30		0.00338
65	81	2000/06/07	1997/06/11	2003/07/09	Kyowa Hakko	13.20	13.20	0.00303
66	81	2000/06/07	1997/06/11	2003/07/09	Daesang	8.90	7.13	0.05751
67	82	2000/09/20	1996/12/11	2003/10/21	General Motors	43.00	35.48	0.13213
68	82	2001/03/20		2006/01/26	Deutsche Post	24.00	24.00	0.00103
69	81	2001/12/05		2006/09/27	Archer Daniels	39.69	30.69	0.00344
70	81	2001/12/05			Bayer	14.22		0.00053
71	81	2001/12/05			Hoffman La Roche	63.50		0.00088
72	82	2001/06/20		2003/09/30	Michelin	19.76	19.76	0.00396
73	82	2001/06/29		2003/12/03	Volkswagen	30.96	0.00	0.00145
74	81	2001/07/18	1997/06/05	2004/04/29	SGL Carbon	80.20	69.11	0.08649
75	81	2001/07/18	1997/06/05	2004/04/29	Showa Denko	17.40	10.44	0.00714
76	81	2001/07/18	1997/06/05	2004/04/29	Tokai Carbon	24.50	12.28	0.04873
77	81	2001/07/18	1997/06/05	2004/04/29	Nippon Carbon	12.20	6.27	0.06620
78	81	2001/07/18	1997/06/05	2004/04/29	SEC Corporation	12.20	6.14	0.12904
79	81	2001/07/18	1997/06/05	2004/04/29	Carbide Graphite	10.30	6.48	
80	81	2001/07/18	2000/06/15		SAS	39.38		0.04771
81	82	2001/07/25	1997/06/05		Deutsche Post	0.00		0.00000
82	82	2001/10/10	1996/12/11	2005/09/15	DaimlerChrysler	71.83	9.80	0.00185
83	81	2001/11/21		2006/03/15	BASF	296.16	236.85	0.01127
84	81	2001/11/21			Aventis	5.04		0.00008
85	81	2001/11/21			Takeda Chemical	37.06		0.00080
86	81	2001/11/21			Merck	9.24		0.00171
87	81	2001/11/21		2006/03/15	Daiichi Pharm	23.40	18.00	0.00255
88	81	2001/11/21			Lonza	0.00		0.00000
89	81	2001/11/21			Solvay	9.10		0.00179
90	81	2001/11/21			Eisai	13.23		0.00154
91	81	2001/11/21			Sumitomo	0.00		0.00000

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92	81	2001/11/21			Tanabe Seiyaku	0.00		0.00000
93	81	2001/11/21			Roche	462.00		0.00637
94	81	2001/12/05	1999/07/13	2005/10/25	Danone	44.04	43.22	0.00228
95	81	2001/12/11	1999/02/16	2006/09/27	Commerzbank	28.00	0.00	0.00272
96	81	2001/12/11	1999/02/16	2006/09/27	Dresdner Bank	28.00	0.00	0.00123
97	81	2001/12/11	1999/02/16	2006/09/27	Bayerische Hypo	28.00	0.00	0.00117
98	81	2002/06/11		2006/12/14	Erste Bank	37.69	37.69	0.00985
99	81	2002/07/02	1999/06/16		Aventis	0.00		0.00000
100	81	2002/07/02	1999/06/16	2006/04/05	Degussa	118.12	91.12	0.01584
101	81	2002/07/02	1999/06/16		Nippon Soda	9.00		0.02837
102	81	2002/07/24	1997/12/11		Air Liquide	3.64		0.00028
103	81	2002/07/24	1997/12/11		Air Products	2.73		0.00027
104	81	2002/07/24	1997/12/11		BOC Group	1.17		0.00018
105	81	2002/07/24	1997/12/11		Linde	12.60		0.00228
106	82	2002/10/30			Nintendo	149.13		0.01105
107	81	2002/10/30			Christie	0.00		0.00000
108	81	2002/10/30			Sotheby	20.40		0.05831
109	81	2002/11/27	1998/11/25	Pending	Lafarge	249.60		0.02399
110	81	2002/11/27	1998/11/25	Pending	BPB	138.60		0.06790
111	81	2002/11/27	2001/01/15		Aventis group	2.85		0.00006
112	81	2002/11/27	2001/01/15		Merck	0.00		0.00000
113	82	2003/05/21		Pending	Deutsche Telekom	12.60		0.00025
114	82	2003/07/16			Yamaha	2.56		0.00095
115	81	2003/10/01		Pending	Hoechst	99.00		0.00476
116	81	2003/12/03		Pending	Carbone Lorraine	43.05		0.12892
117	81	2003/12/03		Pending	SGL Carbon	23.64		0.08190
118	81	2003/12/10			Akzo	0.00		0.00000
119	81	2003/12/10		2005/11/22	Degussa	16.73	16.73	0.00314
120	81	2003/12/10		No appeal	Atofina	43.47		0.00048
121	81	2003/12/16	2003/03/22	Pending	Outokumpu	18.13		0.00994
122	81	2003/12/16	2003/03/22		KME	18.99		0.08366
123	82	2004/03/24		Pending	Microsoft	497.20		0.00230
124	82	2004/05/26			Topps	1.59		0.00551
125	81	2004/09/03	2001/03/22	Pending	KME	32.75		0.22473
126	81	2004/09/03	2001/03/22	Pending	Outokumpu	36.14		0.01523
127	81	2004/09/03	2001/03/22	Pending	Halcor	9.16		0.05336
128	81	2004/09/29	2000/01/25		Danone	1.50		0.00009
129	81	2004/09/29	2000/01/25		Heineken	1.00		0.00008
130	82	2005/06/15	2000/02/09	Pending	AstraZeneca	14.00		0.00026
131	81	2004/12/09		Pending	AKZO	20.99		0.00233
132	81	2004/12/09		Pending	BASF	34.97		0.00124
133	81	2004/12/09		Pending	UCB	10.38		0.00180
134	82	2005/10/05	1999/09/22	Pending	Peugeot	49.50		0.00354
135	81	1984/11/23	1980/12/09		Solvay	3.00		0.00457
136	81	1984/11/23	1980/12/09		Degussa	3.00		0.00349
137	81	1984/11/23	1980/12/09		Air Liquide	0.50		0.00026
138	81	1992/07/15			Toshiba	2.00		0.00017
139	81	1994/11/30		2000/03/15	Dyckerhoff	13.28	8.04	0.01445
140	81	1994/11/30		2000/03/15	Heidelberger	15.65	7.06	
141	81	1994/11/30		2000/03/15	Ciments Francais	25.77	13.57	0.04221
142	81	1994/11/30		2000/03/15	Lafarge	23.90	15.28	0.00470

143	81	1994/11/30	2000/03/15	Titan Cement	5.62	0.00	0.02259
144	81	1994/11/30	2000/03/15	Buzzi Unicem	3.65	0.00	0.01310
145	81	1994/11/30	2000/03/15	Cementir-Cement	8.25	7.47	
146	81	1994/11/30	2000/03/15	Italcementi	33.58	26.79	
147	81	1998/01/21	2001/12/13	Acerinox	3.53	3.14	
148	81	1998/01/21	2001/12/13	Thyssenkrupp	8.10	4.03	

Table A.1: List of observations

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