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

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Abstract

A typical EU antitrust investigation involves a sequence of events (surprise inspection, Commission decision, Court judgment) which affect the investigated firm's market value. We first model these relationships, and then use event study techniques to estimate the impact of these antitrust events on a firm's share prices. A surprise inspection reduces on average the firm's share price by between 1.9% and 4.8%, a negative Decision by the European Commission reduces it by 3.6%. If the Court annuls or strongly reduces the Commission's fine, this has a positive (1%-1.9%) effect on the firm's valuation. Finally, we find that the fine accounts for only between one quarter and one third of the loss in the firm's value due to the antitrust procedure. Most of the loss will therefore likely be due to the cessation of illegal activities (e.g., the uncovering of a cartel will decrease prices). We regard this result as indirect evidence that antitrust intervention does have a sizeable effect on market prices.

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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 penalties 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 behaviour.

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 be weak. Indeed, a large number of firms (and in fact several firms from the sample we analyse 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.[1]

In this paper, we carry out (by using event study techniques) an empirical analysis to explore the effect of antitrust investigations on the share prices of firms which have infringed European competition law. There are two main novelties in our work. Firstly, this is the first work which estimates the impact of European antitrust investigations on offending firms, and to this purpose we have constructed an original database.[2] Bosch and Eckard (1991) carried out a similar exercise for the US, to estimate the effect on the firm's stock market price of an indictment for price fixing.[3] They find that the shares of indicted firms in their sample on average lose a cumulative 1.08% of their value in the days immediately after the public announcement of the indictment.[4]

Secondly, since we analyze the effect of different but related events, we

[1] Connor and Bolotova (2006), building on a large number of studies, estimate the mean cartel overcharge at around 29% per year. With such margins over the competitive prices, one may expect antitrust fines to result in considerable under-deterrence.

[2] See Duso et al. (2006) and Duso et al. (2006) for empirical analyses of the effects of EU merger notifications and decisions. They also make use of the event study methodology.

[3] 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). See also Detre and Golub (2004) for an analysis on recent US antitrust data.

[4] 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 Eckard (1991) also check for possible leakages before the indictment takes place and take appropriate steps to deal with them.

propose a simple model of the antitrust procedure which captures the relationships between these antitrust events. The model allows us to predict the sign that each of these events would have on the firm's share prices, and to see why each event brings new information to the market.

Our estimates suggest that on average the total effect of an antitrust action that is eventually upheld by the judges is a fall in the firm's stock market value by 5.5%-8.4%. Importantly, less than a third of this effect is due to the fine, and we conjecture that most of the loss is due to the fact that the market anticipates that after an antitrust action an anticompetitive practice will cease, leading to lower profits. In the case of cartels (which account for 4/5 of our observations), the cessation of the practice will imply that collusive prices cannot be sustained any longer. This is indirect evidence that antitrust actions might be effective in decreasing market prices.

The EU competition law institutional framework, in a nutshell

Since our objective is to estimate the effect of antitrust investigations in the European Union, 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 main competition authority for the enforcement of EU competition law, whose main provisions are contained in articles 81 (anticompetitive agreements) and 82 (abuse of dominant positions) of the Treaty establishing the European Community. Fines can be imposed on firms which have infringed articles 81 or 82, and they are decided 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). Fines 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,[5] but several commentators still criticise the Commission for a lack of transparency and for exercising too much discretion in its fining decisions.

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.[6]

[5] 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.

[6] 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

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.[7] 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.[8]

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).[9] This inspection 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.[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

firm's total annual turnover.

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

[8] A noteworthy element of the Commission's fining policy is the possibility to grant, under its Leniency Programme, 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 programmes. At date of writing the maximum fine given by the Commission reached a record 1.06 billion euro. The fine was given to Intel for violating antitrust rules in the computer chip market.

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

[10] It is of course possible that investors may nonetheless 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. To deal with this issue we shall omit dawn raid data when the case has already started in another jurisdiction and when there has been an immunity applicant within the leniency program.

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

the firm and asks for the firm's response.[12]

After having analyzed all the evidence and having heard from the parties, the Commission might either take a formal infringement *Decision* or decide to close the case. If the latter, there may be a non-infringement Decision (very rarely), an announcement through a press release, or no public statement at all. Whatever the Commission's verdict, it may be reached a long time after the dawn raid and the statement of objections (in some cases, it may take a few years).

A relevant feature for our analysis is that the Decision is a collegial decision of the whole European Commission, not of DG-COMP, and before taking it 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, leakages about (or speculations on) the content of the Decision and the level of the fines are common.[13]

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 column *F.Court* of Table A.1 in the Appendix summarises the fines as they appeared in the first Court judgments;[14] the column *Fine/Cap.* 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.[15]

We shall use standard event study methodology to estimate the effect on the firm's share price 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. Note, however, that while we know all the Commission Decisions and their dates, surprise inspections do not always take place or sometimes their date is not made public by the Commission

[12] We also carried out an empirical analysis of the effects of the Statement of Objections, but as expected - it is largely a procedural step which does not reveal substantial new information to the market - we did not find any significant effect of this event on the value of the firm. Accordingly, we shall not discuss it any longer.

[13] By examining past issues of the *Financial Times* we found that rumors on the potential infringement Decision, and speculation on the magnitude of the fines, may occur but - if they do - are typically concentrated in a period of one month before the date of the Decision.

[14] 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.

[15] 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.

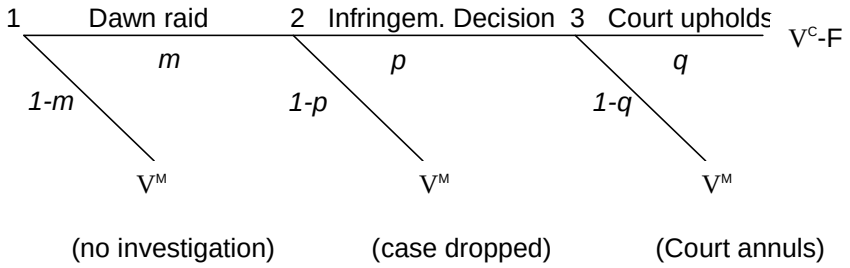

Figure 1: Description of the antitrust procedure

(we dropped several dawn raids observations because their dates were not revealed or were not made precise); also, firms may decide not to appeal. Therefore, we have a different number of observations for the three different antitrust events.

The paper continues in the following way. Section 2 presents a model of the antitrust procedure. Section 3 describes our data and explains our estimation procedure. Section 4 reports the results of our analysis and discusses their robustness. Section 5 concludes the paper by assessing the results obtained and discussing policy issues.

2 Modelling the antitrust procedure

Since the antitrust procedure involves different events which take place successively and are clearly related, we propose a simple model of this procedure. Although very stylised, the model guides our analysis by predicting the sign of the effects of the events.

Assume that a firm has followed a business practice which violates competition law, and that the start of the investigation, the Commission Decision and the Court Judgment are all probabilistic. 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 - that may be casual. Assume also that there is no investigation if the firm has not infringed antitrust law. For simplicity, we also ignore the fact that time elapses between one event and the following one, and accordingly we consider neither discount factors nor interest rates.[16] These assumptions are admittedly very crude, but they allow us to emphasise some simple relationships among the antitrust events.

[16] In a previous version of the paper, we considered a more sophisticated model including also time and discount factors, but the qualitative results were the same.

A simple formalisation of the antitrust procedure is given in Figure 1.[17] At time 1, Nature determines whether the firm will be subject to a surprise inspection - event which takes place with probability m - or not. If no raid is undertaken, we assume that the firm will never be investigated any longer, and it will have (anticompetitive) net present value V^M.[18]

If a raid takes 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. The firm will not be investigated any longer and it will have value V^M. With a probability p the Commission will find proof of an infringement and at time 2 it will issue an Infringement Decision imposing a fine, F, and ordering the firm to cease the anti-competitive practice. We assume that both the payment of the fine and the ceasing of the business practice will take place only if the Court upholds the Commission's Decision.[19]

At time 3, the Court upholds the Commission's Decision with probability q and annuls the fine with the remaining probability $1-q$. 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.[20]

If the Judgment is in favour of the Commission, the firm will pay the fine F and will have competitive profits forever, resulting in a firm's net present value V^C. Otherwise, the firm will have expected value V^M. We assume that the firm always appeals the infringement decision. (This is largely consistent with what happens in reality - where most Decisions are appealed -, and of course it makes sense in the model because the cost of appealing is taken to be zero for simplicity.)

In order to investigate how the occurrence of a certain antitrust event affects the valuation (that is, the net present value) of the firm, let us find first the value of the firm after a particular event.

The expected value of a firm that violates competition law is:

[17] One may extend this simple model to consider the firm's choice between violating or complying. It would be sufficient to include a time 0 node where the firm decides whether to violate the law or not in a particular market. If it does not, its (competitive) present discounted value will be V^C. The model could then be used, for instance, to identify the optimal fine necessary for deterrence.

[18] Assuming that in each period the Commission could inspect firms which have not been investigated previously would not qualitatively change the results.

[19] In the previous version of the paper, we assumed that after an infringement Decision, the firm would have to cease the business practice immediately, but it could delay the payment of the fine until the Court's judgment. Again, the two models lead to similar qualitative predictions, and accordingly we have chosen here the simplest formulation.

[20] In our event study analysis, we define as 'annulment' a Court judgment which reduces the fine to below the 1/2 of the fine proposed by the Commission, and 'upholding' when either firms do not appeal (there are a few such cases in our sample) or the Court fine is above 1/2 of the original one.

$$V_{Violation} = mpq\left(V^C - F\right) + \left[1 - mpq\right]V^M. \quad (1)$$

After a dawn raid, and before a Decision, it is:

$$V_{Raid} = pq(V^C - F) + \left[1 - pq)\right]V^M. \quad (2)$$

After an infringement Decision, it is:

$$V_{Decision} = q(V^C - F) + (1 - q)V^M. \quad (3)$$

Finally, after a judgment upholding or annulling the Commission's Decision, the firm's expected value will respectively be:

$$V_{Upheld} = V^C - F; V_{Annulled} = V^M \quad (4)$$

We can now compute the effect of an event on the expected value of the firm. First of all, the occurrence of a dawn raid will change the firm's value as follows:

$$\Delta_{Raid} = \frac{V_{Raid} - V_{Violation}}{V_{Violation}} = -\frac{pq(1-m)(V^M - V^C + F)}{mpq\left(V^C - F\right) + (1 - mpq)V^M} < 0. \quad (5)$$

When a dawn raid takes place, the market correctly understands that the probability that the firm may be obliged to stop the lucrative anticompetitive conduct and pay the fine is now higher than before the dawn raid took place, resulting in the firm's expected market value to decrease. This leads to:

> **Prediction 1:** *If the event "Commission undertakes a dawn raid" is observed, then we should expect the share price of the firm to decrease.*

An infringement decision will change the expected firm's value as:

$$\Delta_{Decision} = \frac{V_{Decision} - V_{Raid}}{V_{Raid}} = -\frac{q(1-p)(V^M - V^C + F)}{pq(V^C - F) + (1 - pq)V^M} < 0. \quad (6)$$

In words, if the Commission issues a negative Decision, the firm's expected market value will decrease because it is more likely that the firm will have to stop anticompetitive conduct and it will ultimately have to pay the fine. We can then state:

> **Prediction 2:** *If the event "Commission issues an infringement Decision" is observed, then we should expect the share price of the firm to decrease.*

After a Court's Judgment which upholds the Decision, the change in the firm's value will be:

$$\Delta_{Upheld} = \frac{V_{Upheld} - V_{Decision}}{V_{Decision}} = -\frac{(1-q)(V^M - V^C + F)}{q(V^C - F) + (1-q)V^M} < 0, \qquad (7)$$

whereas after a judgment which annuls the Decision, it will be:

$$\Delta_{Annulled} = \frac{V_{Annulled} - V_{Decision}}{V_{Decision}} = \frac{q(V^M - V^C + F)}{q(V^C - F) + (1-q)V^M} > 0. \qquad (8)$$

This results in the following:

> **Prediction 3:** *If the event "Judgment upholds the fine" is observed, then we should expect the share price of the firm to decrease. If the event "Judgment annuls the fine" is observed, then we should expect the share price of the firm to increase.*

Our stylised description of the antitrust procedure also allows us to perform some comparative static analysis. In particular, we are interested in studying the effects of q and F, since there are clear indications that in the period we consider these variables change value over time. It is easy to see that the probability that the Court upholds the Commission's decision affects the expected changes in the firm's value as follows:

$$\frac{\partial \Delta_{Raid}}{\partial q} < 0, \frac{\partial \Delta_{Decision}}{\partial q} < 0 \frac{\partial \Delta_{Upheld}}{\partial q} > 0, \frac{\partial \Delta_{Annulled}}{\partial q} > 0,$$

That is: if the court upheld the Commission's Decision with a higher probability one would expect to find a higher loss in value at the raid and at the Decision stage (implying that both Δ_{Raid} and $\Delta_{Decision}$ will decrease). An upheld decision would now *reduce* the value of the firm by a lower amount and an annulment decision will imply a higher recoupment in the value of the firm (annulment decisions are more "unexpected events").

The severity of the fines imposed by the Commission affects the expected changes as follows:

$$\frac{\partial \Delta_{Raid}}{\partial F} < 0, \frac{\partial \Delta_{Decision}}{\partial F} < 0 \frac{\partial \Delta_{Upheld}}{\partial F} < 0, \frac{\partial \Delta_{Annulled}}{\partial F} > 0.$$

That is: a more severe fine will increase the loss in market value for the "negative events" while it will increase the market value recoupment for the positive event. Since the fine is bigger it increases the magnitude of the change of market value.

Several commentators have expressed the view that the probability that the Court's approved the Commission's decisions has increased over time,

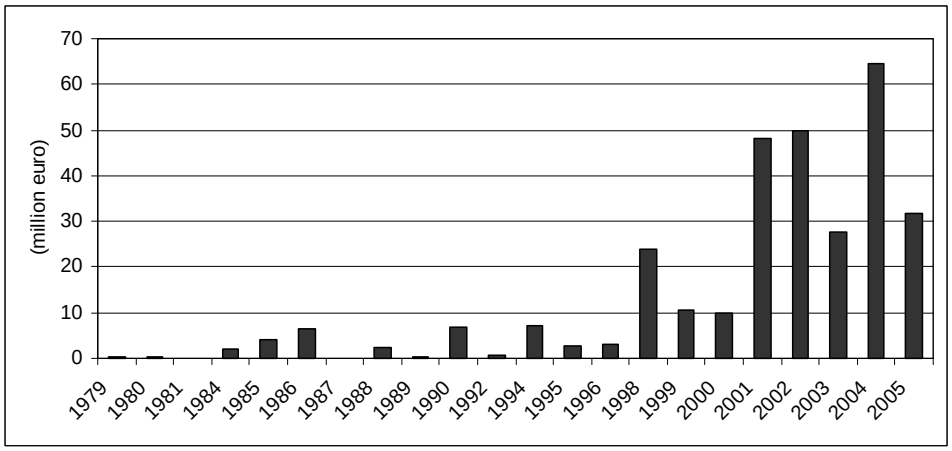

Figure 2: Average antitrust fine by year

reflecting the fact that the Commission has dealt with the rights of defence of the firms more carefully, and that it has imposed fines in a less arbitrary way (for instance by issuing guidelines), both leading to higher upholding rates by the Courts. Indeed, in our sample it appears that, for instance, for decisions taken in the period 1979-1997 the probability of the Court upholding a Decision is 54%, while in the period 1998-2004 is 70%.[21]

Similarly, it is well established that fines have increased over time. This has been a declared policy of the European Commission, which introduced more severe administrative fines in both the 1998 and the 2006 Guidelines on the imposition of fines; it is also a well-documented empirical fact, stressed by several papers and which is consistent with our sample data, where the average fines are clearly higher from the year 1998 onwards.

Unfortunately, though, the fact that around the year 1998 both q and F increase makes it difficult to evaluate separately the role played by these two variables. However, we can identify the following prediction.

Prediction 4: *If both the probability that the Court upholds the fine, q, and the fines imposed by the Commission, F, increase, then we should expect the events "Raid", "Infringement Decision", and "Judgment annuls the Decision" to result in a stronger effect on the share price.*

[21] It makes sense to break the sample around the year 1998 because this is when the first Notice on the imposition of guidelines was issued. Similar results are obtained if one breaks the sample in slightly different years. For instance, in the period 1979-1998, $q = 52\%$ and for 1999-2004, $q = 76\%$.

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 infringement Decisions 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 listed in a stock exchange for which data on share price are available in the Datastream database.[22] Our final sample refers to 58 decisions (the first of which dates from 1979) involving 97 firms. Some of the firms were repeat offenders.[23]

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 annullments), 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 listed on different stock exchanges. The majority are listed in Frankfurt and Tokyo, followed by New York, London and Paris. The remaining stock exchanges where the firms from our sample are listed are Amsterdam, Korea, Hong Kong, Singapore, Stockholm, Oslo, Brussels, Copenhagen, Milan, Luxembourg, Taiwan, Malaysia, Athens and Vienna[24].

[22] We are aware that sample selection is a possible concern of our analysis, to the extent that publicly listed firms tend to be large, multiproduct, 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, so that for any given violation a larger multiproduct and multinational firm would generally be given a larger fine.

[23] 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.

[24] In case of multiple listing we select the stock exchange with higher capitalization.

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 at 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 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).[25]

To obtain a counterfactual return we use a simple market model of returns:[26]

$$R_{i\tau} = \alpha_i + \beta_i R_{m\tau} + \epsilon_{i\tau}, \tag{9}$$

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 listed, 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.

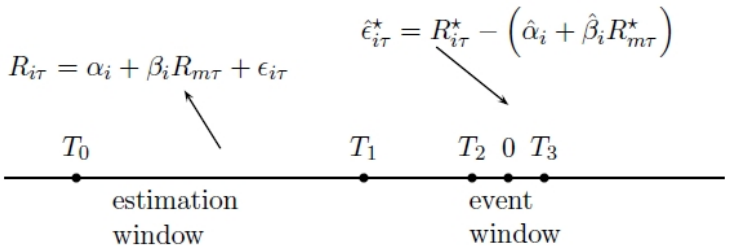

Figure 3: Timeline

Figure 3 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 $\tau = T_0$

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

[26] 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.

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 $T_0 = -130$ to $T_1 = -30$.[27] 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

$$\hat{\epsilon}^{\star}_{i\tau} = R^{\star}_{i\tau} - \left(\hat{\alpha}_i + \hat{\beta}_i R^{\star}_{m\tau}\right), \tag{10}$$

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 listed.

We aggregate individual daily abnormal returns by averaging them over securities and summing them over the days of the event window to obtain *cumulative average abnormal returns* ($\overline{CAR}$) for the event.

$$\overline{CAR} = \sum_{\tau=T_2}^{T_3} \left(\frac{1}{N} \sum_{i=1}^{N} \hat{\epsilon}^{\star}_{i\tau} \right) \tag{11}$$

Under the null hypothesis the event has no effect on the mean returns and we use the test statistic below to draw inference about the cumulative abnormal return[28]

$$J_1 = \frac{\overline{\mathrm{CAR}}}{\hat{\bar{\sigma}}_{CAR}(\tau_1, \tau_2)} \tag{12}$$

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 $R_{i\tau} = \alpha_i + \epsilon_{i\tau}$. 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.

[27] We have also performed robustness checks by modifying the length of the estimation windows, and checked that the results are not very sensitive to such variations.

[28] The test is asymptotically distributed as a standard normal (asymptotics with respect to number of securities and lenght of estimation window). For a detailed derivation of the test see the Appendix A.2.

We report abnormal returns for the three events for an event window period of 31 days, together with their J-statistics in Table A.2.[29] All tests are one-sided unless specifically stated otherwise.

Abnormal return on the day of the raid is negative and highly statistically significant, suggesting a 1% 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.[30] Contrary to our expectations (since surprise inspections are widely considered truly unexpected events, and since no mention of possible investigations were found in newspapers before the surprise inspection), we also find that for particular days before the inspection there are negative (statistically significant) returns (note, though, that these are less strong than the negative return taking place the day of the inspection).[31] If we aggregate the abnormal returns over the window of Table A.2, we find a significant (at 1% significance level) negative return for the dawn raid, with an overall effect of the raid amounting to a 4.8% drop in the firm's stock market valuation.

In the column for the Commission Decision we have negative abnormal returns for some particular days before the event and on the day of the event there is a fall of 0.25% (significant at 10%). The most economically and statistically significant drop takes place 20 days before the Decision. This is not entirely unexpected, since - as explained above - there are rumours and possible anticipations before the Decision.[32] There are also negative returns a few days after the event (the same happens for the dawn raid) which can be interpreted as market adjustments to the news. The cumulative average abnormal return over the 31-day window is at -3.6% and is statistically

[29] 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.

[30] 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.

[31] In case of investigations already under way in other jurisdictions, it is possible that the market knows - or suspects - that investigations may be under way in the EU. For this reason, we have not included these observations in the data of the dawn raid. 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. We have also excluded cases of full immunity recipients within the EU leniency programme, excluding one further observation.

[32] We have also found that no other significant effects take place between 20 and 35 days before the Decision.

significant at the level of 1%.

The last two columns in Table A.2 show the effects of the Court judgments. We define as "annullments" 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 annullment we have a strongly significant positive abnormal return (0.8% significant at 1%) the day after the judgment of the Court. Weakly significant returns are found before the event, but they carry positive and negative signs, which suggests they should be disregarded. For this 31-day event window, the cumulative average abnormal return is not statistically significant. (But we shall see later that when we restrict the event window we find statistically significant estimates.)

Finally, in the columns for upheld decisions, we find a positive abnormal return a day after the decision, which is not an expected result; and a -0.7% return 20 days before the Judgment. However, cumulatively, the negative average abnormal return is not significant at any acceptable level of significance and for all the different event windows we have tried.

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 Refinements and robustness of the results

4.1.1 Dawn Raids

Antitrust experts and practitioners would agree that - apart from exceptional cases - "dawn raids" come unexpectedly and really are "surprise" inspections. For a further confirmation, we have searched the database of the *Financial Times* and we were unable to find any evidence suggesting an investigation was likely for several weeks ahead of a surprise inspection. It is difficult to reconcile these facts with the negative (and significant) returns before the dawn raid. As a robustness check, we have therefore carried out the same analysis with shorter windows of 11, 7, and 3 days. The results remain highly significant, even though the magnitude of the effects is reduced. Since we believe that surprise inspections are not expected by the market, and are unable to explain the significant estimated abnormal returns taking place several days before the dawn raid, we suggest that a more cautious result is given by the estimation with the 7-day window, which is the one with the highest J-test among the estimations restricting the event window to very few days before the raid. This estimation finds that the surprise inspection decreases the raided firm's market return by 1.9% (significant at 1%).

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 7-day event window. Two of the firms from the sample had a positive significant abnormal return.

Event W.	Raid 48	J	Com. D. 147	J	Annul. 38	J	Uphd 36	J
(-20...+10)	-4.84***	-3.11	-3.58***	-3.16	-0.20	-0.09	-0.51	-0.24
(-5...+5)	-1.69**	-1.98	-0.89*	-1.43	1.92**	1.63	-0.21	-0.17
(-1...+5)	-1.89***	-2.83	-0.45	-0.93	1.10	1.19	0.43	0.46
(-1...+1)	-1.07***	-2.48	-0.40*	-1.29	1.05**	1.76	0.03	0.04

Abnormal Returns as percentage; One-sided test, significance levels *** 1% ** 5% * 10%

Table 1: Summary of results: cumulative estimates

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

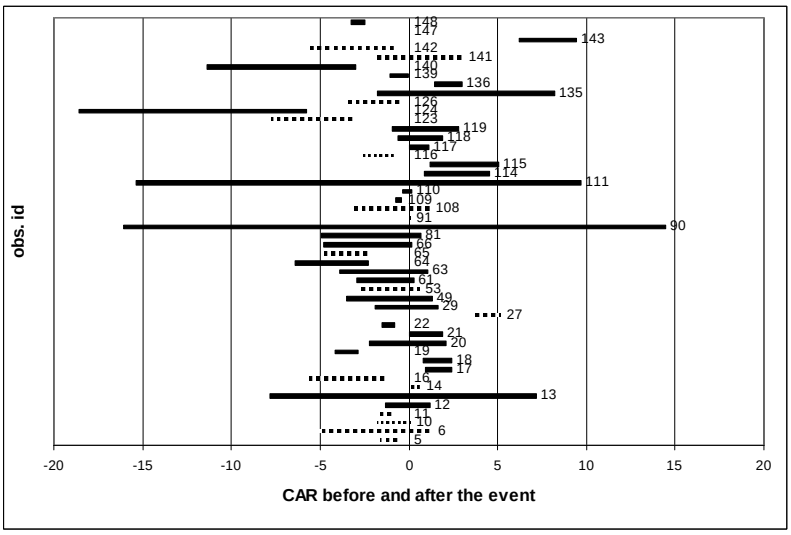

Figure 4: Before and after the event cumulative average abnormal returns for surprise inspection (before: -5..-1; after: 0..4)

Overall, these results show that the surprise inspection has a strong negative effect on the investigated firm's valuation, although the precise magnitude of the effect is sensitive to the length of the event window used. By taking into account the above comments, we state the following result.

> *Prediction 1 seems consistent with the data: If the event "Commission undertakes a dawn raid" is observed, then the share price of the raided firm decreases on average by between 1.9% and 4.8%.*

4.1.2 Commission Decisions

We have verified the impact of the infringement Decision of the Commission by considering different event windows. The results reported in Table 1 indicate that omitting to consider what happens several days ahead of the Decision lowers the significance of the results considerably. This is not surprising, since it is well known that there are informational leakages occurring prior to the date of the Decision. Accordingly, our favourite estimate remains the one obtained with the 31-day window: cumulative average (across firms) abnormal return for this event window is -3.6% and is significant at 1% with a J value of -3.16.

> *Prediction 2 seems consistent with the data: If the event "Commission issues an infringement Decision" is observed, then the share price of the firm decreases on average by 3.6%.*

4.1.3 Court judgments

As seen in Table 1 above for the sample of 38 observations, those firms whose fine has been annulled by the Courts, we find that the cumulative average abnormal return is not significant at the 31-day event window, but that restricting the event window (like for the dawn raids, Court judgments are less subject to information leakages) gives rise to statistically significant results. Results are sensitive to the window used, but they are suggestive of a positive increase of the order of $1\% - 1.9\%$ of the Court annullment of the Commission decision.

Note that this positive market reaction allows the firms to recover only a fraction of the market value lost because of the dawn raid and the Commission decision (whose sum ranges between 5.5% and 8.4%). This can be explained by the fact that - as discussed in Section 5 below - the fine itself is only part of the loss that a firm may incur because of the antitrust investigation. In most cases, the judgment annuls the Commission Decision for procedural reasons or for disagreement on the amount of the fine: the firm might have won the case, but 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 favourable to the firm on substantive issues, 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.

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 not statistically significant. We therefore state the following:

> *Prediction 3 finds only mixed support from the data: If the "event Court annuls the Commission Decision" is observed, the share price of the firm rises on average by around 1%-1.9%, the magnitude of this effect not being very robust to changes in the length of the event window. Also, we cannot reject the null hypothesis that the "event Court upholds the Commission Decision" has no effect on the firm's share price.*

It is clear from our results that among the antitrust events the Court judgments are those which least affect the firm's market valuation. This might be due to the fact that in most cases the judgment does not modify substantively the Commission Decision (recall that 4/5 of observations in our sample are cartel cases). The Court might reduce the fine, or annul a Decision on formal grounds, but this will not eliminate the consequences of the Decision: the market already knows that the firm will be unable to continue a profitable activity already deemed illegal by the Commission, and has already discounted this effect from the firm's market valuation.

4.1.4 Changes over time

Our sample spans over 25 years, during which antitrust policy has consolidated and changed. In particular, all parties involved have gained considerable experience in dealing with competition law issues, markets may have become increasingly aware of the role played by antitrust and the risks faced by firms, and the European Commission has been harsher in dealing with antitrust violators. This has been a continuous process, but one can conceivably identify in the 1998 "Guidelines on the imposition of the fines" a landmark in European competition policy, giving rise to a more transparent (less arbitrary) imposition of fines as well as an increased severity in handing them out. Accordingly, we have split our data in two sub-samples, the first for Decision which took place between 1979 and 1997, and the second for Decisions from 1998 onwards. As one can see from Table 2, the estimates suggest that both the raid and the Commission's decision have a stronger effect in the second part of the sample (the Decision is not even statistically significant in the first part of the sample), as suggested by our formalisation above in response of an increase of both q and F. More ambiguous is instead

the effect on the Court's decisions, with the annullment showing a slightly lower effect (rather than the expected stronger effect), and upholding being statistically significant (with the expected sign) in the first part of the period but not significant in the second part, consistent with an increase in q but not with an increase in the severity of the fines F.

Sample selection: beginning of period - 1997								
Event W.	Raid 17	J	Com.D. 50	J	Annul. 16	J	Uphd.16	J
(-20;+10)	-2.20*	-1.29	-0.79	-0.64	2.63	1.24	-0.80	-0.26
(-5...+5)	-0.66	-0.71	0.08	0.12	1.64*	1.39	1.10	0.64
(-1...+5)	-1.49**	-2.04	0.00	0.00	1.77**	1.93	2.28	1.71
(-1...+1)	-0.38	-0.81	0.08	0.23	0.45	0.77	0.81	0.94
Sample selection: 1998 - onwards								
Event W.	Raid 31	J	Com.D. 97	J	Annul. 22	J	Uphd 20	J
(-20;+10)	-6.29***	-2.83	-5.01***	-3.15	-2.25	-0.67	-0.28	-0.09
(-5...+5)	-2.26**	-1.85	-1.39*	-1.58	2.12	1.15	-1.25	-0.76
(-1...+5)	-2.11**	-2.21	-0.68	-1.00	0.60	0.42	-1.05	-0.82
(-1...+1)	-1.44***	-2.35	-0.65*	-1.48	1.48*	1.59	-0.60	-0.73
Abnormal Returns as percentage; One-sided test, significance levels *** 1% ** 5% * 10%								

Table 2: Structural break

Prediction 4 finds mixed support from the data: The increase in both q and F which took place in 1998 leads to the expected increase in the effects on firms' share prices of both dawn raids and Commission's decisions. However, the effects of annullments does not seem to increase.

4.2 Possible sources of endogeneity and bias

The fact that the firms in our sample are often large 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. Table 3 reports the cumulative abnormal return estimates, for the same event windows used in Table 1. The results go in the same direction as the market model. For the Dawn Raid event, looking at the 7-day event window, the cumulative average abnormal return for a surprise inspection and its J-value are -2.6% and -3.16. This estimate suggests even a bigger drop than the one implied by the market model. For the Decision of the Commission, looking at the 31-day event window, the mean model estimates a drop of 2.16% significant at 5%, that is slightly lower than the one suggested using the market model. If we turn to the annullment event, for the event window of 11, 7 and 3 days, we find highly significant positive cumulative abnormal return suggesting

an increase in market value between 2% and 4.8% (depending on the event window chosen). The estimated abnormal returns are significantly higher than those suggested by the market model, thus confirming that there is indeed a statistically significant increase in the firm's valuation following the annullment of the Decision, although the magnitude of this effect is sensitive to both the model specification and the length of the event window. The last column of Table 3 presents the estimates for the Upheld event. Consistently with our previous findings, the market model, also using the mean model we cannot reject the hypothesis (at the conventional significance level) that the Court Upheld decision has no impact on the firms' market value.

Event W.	Raid 48	J	Com. D. 147	J	Annul. 38	J	Uphd 36	J
(-20;+10)	-4.40**	-2.29	-2.16**	-1.67	-0.85	-0.35	-2.41	-0.97
(-5...+5)	-2.18**	-2.07	-0.50	-0.71	4.77***	3.62	-1.34	-0.99
(-1...+5)	-2.61***	-3.16	-0.60	-1.08	2.73***	2.65	-0.67	-0.62
(-1...+1)	-1.82***	-3.43	-0.32	-0.90	2.05***	3.10	-0.82	-1.19
Abnormal Returns as percentage; One-sided test, significance levels *** 1% ** 5% * 10%								

Table 3: Mean Model cumulative estimates

Although the OLS estimation of the market model is the traditional choice in the majority of event studies Dombrow et al. (2000) show that when the normality condition (in the stock return distribution) fails to hold other non-linear estimators may be preferred. Indeed, under non-normality, OLS is only the best linear unbiased estimator. Hence the same authors argue for the adoption of robust statistics when the underlying distribution of the errors is uncertain. They then propose the joint use of a nonparametric estimator, developed by Theil (1950), for its high efficiency and ease of computation and implementation, and non-parametric test statistics. As a robustness check we then also perform a complete non-parametric event study implementing Theil's non-parametric estimator in combination with a non-parametric test statistic (the rank test suggested by Corrado (1989)). Table A.3 presents the estimates for the non-paramatric event studies at the four main event windows of interest. The non-parametric estimates confirm the main results of the OLS event study for the events Raid, Commission Decision and Upheld decision. Only for the Annullment decision we do find that the non-parametric estimates are not statistically significant although they have the same sign and comparable magnitude to the OLS estimates.

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, summarised in Table 4 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.

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 4: Distribution of correlation between abnormal returns of firms

5 Conclusions

We have modelled the effects of successive events in an antitrust investigation on a firm's stock market value and we have estimated, by using event study techniques, these effects by making use of an original database on EU antitrust law proceedings. 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 between -1.9% and -4.8% depending of the length of the window chosen. We also find that the Commission's infringement Decision results in a (statistically significant) cumulative abnormal return of about -3.6%.

Although less clear-cut and robust, it turns out 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 between 1% and 1.9% depending on the event window used), whereas a

judgment which upholds the fine does not appear to have a statistically significant impact on the firm's valuation.[33]

The role of the fines Our estimations indicate that a firm which is the object of an infringement Decision by the European Commission has an estimated loss of between 5.5% and 8.4% of its stock market value, calculated by adding the loss in stock market value due to the dawn raid and to the infringement Decision.[34]

In the US, Bosch and Eckard (1991) 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).[35,36]

In our case, the fine represents on average around 1.9% of the firms' market value as reported by Datastream.[37] Since the estimated total negative effect on the share price is about $5.5\% - 8.4\%$, the fine accounts for between 22% and 34% of the total loss.

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

[33] The results summarised here refer to the market model. We have also used as a robustness check the mean model. In that case, the effect of the dawn raid varies between -2.2% and -4.4%; the effect of the Commission is -2.2%; and of the annullment ranges betweem -2% and -4.8%.

[34] This is likely to be an underestimation of the effects of the investigations. If the market expects some of the antitrust events (perhaps because there are rumours that a firm is involved in violations and that might be subject to a Commission's investigation), these news may be reflected in the share price well before the actual date of the event.

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

[36] 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.

[37] 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.

	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 5: Regression of abnormal return on fine/cap ratio

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 capitalisation of the firm. The results are reported in Table 5. 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, to the firm, of an antitrust investigation.

Economic significance of the estimated effects To see whether the estimated effects of the antitrust investigations on the firms' share prices should be considered large or small, it may be useful to compare our results with those obtained in 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 behaviour, such as racketeering, patent infringements, or fraud (for instance, misleading 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 1) is -2.3%. The magnitude of these effects is similar to that of the dawn raids, which are also unexpected events.

Since Commission Decisions are not entirely unexpected events, we need to find events sharing these features for the sake of making comparisons. MacKinlay (1997) analyses 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.

However, 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. When combined, they result in a $5.5\% - 8.4\%$ drop in share prices, a rather sizeable effect on the investigated firms, especially if one considers

that some of the firms in our sample are huge conglomerates which have been investigated in markets which represent a very small subset of their business operations.

In a recent book, Whinston (2008) expresses doubts on the effectiveness of antitrust intervention, referring to some empirical work which suggests that anti-cartel activities may have not led to a price decrease in the markets at hand. We regard our paper as offering instead some evidence on the effectiveness of antitrust intervention. In our sample, composed predominantly by cartels, most of the drop in the share prices is probably due to the cessation of profitable cartel activity. In turn, this should imply that investors expect investigated and fined firms not to be able to sustain such high prices as in the past. Therefore, although we cannot offer direct evidence on this issue, our paper indirectly suggests that antitrust intervention does have an effect on market prices.

References

Bernard, V. (1987). Cross–sectional Dependence and Problems in Inference in Market–Based Accounting Research. *Journal of Accounting Research 20*(1).

Bizjak, J. M. and J. L. Coles (1995). The Effect of Private Antitrust Litigation on the Stock-Market Valuation of the Firm. *American Economic Review 85*(3), 436–461.

Bosch, J.-C. and W. Eckard, Jr. (1991, May). The Profitability of Price Fixing: Evidence From Stock Market Reaction to Federal Indictments. *The review of Economics and Statistics 73*(2), 309–317.

Brooks, R. M., A. Patel, and T. Su (2003). How The Equity Market Responds to Unanticipated Events. *Journal of Business 76*.

Brown, S. J. and J. B. Warner (1980). Measuring Security Price Performance. *Journal of Financial Economics 8*, 205–258.

Brown, S. J. and J. B. Warner (1985). Using Daily Stock Returns: The Case of Event Studies. *Journal of Financial Economics 14*, 3–31.

Campbell, J. Y., A. W. Lo, and C. A. MacKinlay (1997). *The Econometrics of Financial Markets*. Princeton University Press.

Connor, J. M. and Y. Bolotova (2006, November). Cartel overcharges: Survey and meta-analysis. *International Journal of Industrial Organization 24*(6), 1109–1137.

Corrado, C. J. (1989, August). A nonparametric test for abnormal security-price performance in event studies. *Journal of Financial Economics 23*(2), 385–395.

Detre, J. and A. Golub (2004, February). A reexamination of the profitability of price fixing using stock price movement: Has new antitrust legislation been a more effective deterrent of price fixing? *Staff Paper 04-03 - Department of Agricultural Economics - Purdue University*.

Dombrow, J., M. Rodriguez, and C. F. Sirmans (2000, June). A complete nonparametric event study approach. *Review of Quantitative Finance and Accounting 14*(4), 361–80.

Duso, T., K. Gugler, and B. Yurtoglu (2006). How Effective is European Merger Control. *mimeo*.

Duso, T., D. Neven, and L.-H. Röller (2006). The Political Economy of European Merger Control: Evidence Using Stock Market Data. *Journal of Law and Economics, forthcoming*.

Geradin, D. and H. David (2005). The EC Fining Policy for Violations of Competition Law: An Empirical Review of the Commission Decisional Practice and the Community Courts' Judgments. *Bruges: Global Competition Law Centre Working Paper 03/05*.

Gunthorpe, D. L. (1997). Business Ethics: A Quantitative Analysis of the Impact of Unethical Behavior by Publicly Traded Corporations. *Journal of Business Ethics 16*.

MacKinlay, C. A. (1997). Event Studies in Economics and Finance. *Journal of Economic Literature 35*(13-39).

Motta, M. (2004). *Competition Policy, Theory and Practice.* Cambridge: Cambridge University Press.

Theil, H. (1950). A rank invariant method of linear and polynomial regression analysis. *I, II, and III Nederl. Akad. Wektensch. Proc. 53*(4), 386–392, 521–525 and 1897–1912.

Whinston, M. D. (2008, October). *Lectures on Antitrust Economics*, Volume 1 of *MIT Press Books*. The MIT Press.

A Appendix

A.1 Tables

	Art.	Raid	Com. Dec.	Court	Firm	F.Com.	F.Court	Fine/Cap.	R	C.D.	C
1	82		14/12/79	07/06/83	Pioneer	0.3	0.2	0.04		x	x
2	81		25/11/80		Johnson & Johnson Inc.	0.2		0.005		x	
3	82		17/12/81	08/11/83	Siemens	0.04	0.04	0.001		x	x
4	81	09/12/80	23/11/84		Solvay	3		0.457		x	
5	81	09/12/80	23/11/84		Degussa	3		0.349	x	x	
6	81	09/12/80	23/11/84		Air Liquide	0.5		0.026	x	x	
7	82		14/12/85	03/07/91	AKZO	10	7.5	4.548		x	x
8	82		18/12/85		Fanuc	1		0.013		x	
9	82		18/12/85		Siemens	1		0.007		x	
10	81	13/10/83	23/04/86	17/12/91	BASF	2.5	2.12	0.035	x	x	
11	81	13/10/83	23/04/86	10/03/92	Hoechst	9	9	0.128	x	x	x
12	81	13/10/83	23/04/86	10/03/92	Shell	9	8.1	0.025	x	x	
13	81	13/10/83	23/04/86	08/07/99	Imperial Chemical	10	9		x	x	
14	81	13/10/83	23/04/86	10/03/92	Solvay	2.5	2.5	0.17	x	x	
15	82		10/07/87	08/02/90	Beiersdorf	0.01	0.01	0.001		x	x
16	82	21/08/86	05/12/88	01/04/93	BPB Industries	0.15	0.15	0.009	x	x	x
17	81	21/11/83	21/12/88	06/04/95	BASF	5.5	0		x	x	x
18	81	21/11/83	21/12/88	06/04/95	Bayer	2.5	0	0.029	x	x	x
19	81	21/11/83	21/12/88	06/04/95	Dow Chemical	2.25	0	0.017	x	x	x
20	81	21/11/83	21/12/88	06/04/95	Hoechst	1	0	0.013	x	x	x
21	81	21/11/83	21/12/88	06/04/95	Imperial Chemical	3.5	0		x	x	x
22	81	21/11/83	21/12/88	06/04/95	Shell	0.85	0	0.002	x	x	x
23	82		13/12/89	29/06/91	Bayer	0.5	0.5	0.006		x	x
24	81		19/12/90	29/06/95	Solvay	7	0	0.362		x	x
25	81		19/12/90	29/06/95	Imperial Chemical	7	0			x	x
26	81		01/04/92		Nedlloyd	0.03				x	
27	82	19/09/89	15/07/92	14/07/94	Herlitz	0.04	0.04	0.008	x	x	x
28	81		15/07/92		Toshiba	2		0.017		x	
29	81	23/04/91	13/07/94	14/05/98	SCA Holding	2.2	2.2	0.265	x	x	x
30	81		27/07/94	19/06/90	Norsk Hydro	0.75		0.025		x	x
31	81		27/07/94		Solvay	3.5		0.152		x	
32	81		27/07/94	27/02/92	BASF	1.5	0	0.021		x	x
33	81		27/07/94	27/02/92	Hoechst	1.5	0			x	x
34	81		27/07/94	27/02/92	Imperial Chemical	2.5	0			x	x
35	81		27/07/94	27/02/92	Shell	0.8	0			x	x
36	81		30/11/94	15/03/00	Dyckerhoff	13.28	8.04	1.445		x	x
37	81		30/11/94	15/03/00	Heidelberger	15.65	7.06			x	x
38	81		30/11/94	15/03/00	Ciments Francais	25.77	13.57	4.221		x	x
39	81		30/11/94	15/03/00	Lafarge	23.9	15.28	0.47		x	x
40	81		30/11/94	15/03/00	Titan Cement	5.62	0	2.259		x	x
41	81		30/11/94	15/03/00	Buzzi Unicem	3.65	0	1.31		x	x
42	81		30/11/94	15/03/00	Cementir-Cement	8.25	7.47			x	x
43	81		30/11/94	15/03/00	Italcementi	33.58	26.79			x	x
44	81		21/12/94	28/02/02	Kisen Kaisha	0.01	0	0.001		x	
45	81		21/12/94	28/02/02	Mitsui OSK Lines	0.01	0	0		x	
46	81		21/12/94	28/02/02	Neptune Orient	0.01	0	0.001		x	
47	81		21/12/94	28/02/02	Nippon Yusen	0.01	0	0		x	
48	81		21/12/94	28/02/02	Orient Overseas	0.01	0	0.004		x	
49	82	26/06/91	12/07/95	19/05/99	BASF	2.7	2.7	0.026	x	x	x
50	82		10/01/96	26/10/00	Bayer	3	0	0.02		x	x
51	81		21/01/98	13/12/01	Acerinox	3.53	3.14			x	x
52	81		21/01/98	13/12/01	Thyssenkrupp	8.1	4.03			x	x
53	82	23/10/95	28/01/98	06/07/00	Volkswagen	102	90	0.574	x	x	x
54	81		16/09/98	30/09/03	A.P. Moller-Maersk	27.5	0			x	x
55	81		16/09/98	30/09/03	P & O Nedlloyd	41.26	0	0		x	x
56	81		16/09/98	30/09/03	Orient Overseas	20.63	0	12.999		x	x
57	81		16/09/98	30/09/03	Neptune Orient	13.75	0	4.494		x	x
58	81		16/09/98	30/09/03	Nippon Yusen	20.63	0	0.641		x	x
59	81		16/09/98	30/09/03	Hanjin Shipping	20.63	0			x	x
60	81		16/09/98	30/09/03	Hyundai Merchant	18.56	0	8.098		x	x
61	81	27/05/94	14/10/98	12/07/01	Tate & Lyle	7	5.6	0	x	x	x
62	81	05/07/94	09/12/98	11/12/03	Minoan Lines	3.26	3.26	0.697		x	x
63	82	12/06/97	14/07/99	30/09/03	British Airways	6.8	6.8	0.099	x	x	x
64	81	01/12/94	08/12/99	08/07/04	Vallourec	8.1	8.1	2.232	x	x	x
65	81	01/12/94	08/12/99	08/07/04	Sumitomo Metal	13.5	10.94	0.422	x	x	x
66	81	01/12/94	08/12/99	08/07/04	Nippon Steel	13.5	10.94	0.082	x	x	x
67	81		16/05/00	19/03/03	Kawasaki Kisen	0.62	0	0.059		x	x
68	81		16/05/00	19/03/03	A.P. Moller - Maersk	0.84	0			x	x
69	81		16/05/00	19/03/03	Malaysia Shipping	0.13	0	0.004		x	x
70	81		16/05/00	19/03/03	Mitsui OSK	0.62	0	0.022		x	x
71	81		16/05/00	19/03/03	Neptune Orient	0.37	0	0.017		x	x
72	81		16/05/00	19/03/03	Nippon Yusen	0.62	0	0.011		x	x
73	81		16/05/00	19/03/03	Orient Overseas	0.13	0	0.045		x	x
74	81		16/05/00	19/03/03	P & O Nedlloyd	1.24	0	0		x	x
75	81		16/05/00	19/03/03	Evergreen Marine	0.37	0	0.02		x	x
76	81		16/05/00	19/03/03	Hanjin Shipping	0.62	0	0.249		x	x

77	81	11/06/97	07/06/00	09/07/03	Archer Daniels	47.3	43.88	0.76		x	x
78	81	11/06/97	07/06/00		Ajinomoto	28.3		0.338		x	
79	81	11/06/97	07/06/00	09/07/03	Kyowa Hakko	13.2	13.2	0.303		x	x
80	81	11/06/97	07/06/00	09/07/03	Daesang	8.9	7.13	5.751		x	x
81	82	11/12/96	20/09/00	21/10/03	General Motors	43	35.48	13.213	x	x	x
82	82		20/03/01	26/01/06	Deutsche Post	24	24	0.103			
83	82		20/06/01	30/09/03	Michelin	19.76	19.76	0.396		x	x
84	82		29/06/01	03/12/03	Volkswagen	30.96	0	0.145		x	x
85	81	05/06/97	18/07/01	29/04/04	SGL Carbon	80.2	69.11	8.649		x	x
86	81	05/06/97	18/07/01	29/04/04	Showa Denko	17.4	10.44	0.714		x	x
87	81	05/06/97	18/07/01	29/04/04	Tokai Carbon	24.5	12.28	4.873		x	x
88	81	05/06/97	18/07/01	29/04/04	Nippon Carbon	12.2	6.27	6.62		x	x
89	81	05/06/97	18/07/01	29/04/04	SEC Corporation	12.2	6.14	12.904		x	x
90	81	05/06/97	18/07/01	29/04/04	Carbide Graphite	10.3	6.48		x	x	
91	81	15/06/00	18/07/01		SAS	39.38		4.771	x	x	
92	82	05/06/97	25/07/01		Deutsche Post	0		0		x	
93	82	11/12/96	10/10/01	15/09/05	DaimlerChrysler	71.83	9.8	0.185		x	
94	81		21/11/01	15/03/06	BASF	296.16	236.85	1.127		x	x
95	81		21/11/01		Aventis	5.04		0.008		x	
96	81		21/11/01		Takeda Chemical	37.06		0.08		x	
97	81		21/11/01		Merck	9.24		0.171		x	
98	81		21/11/01	15/03/06	Daiichi Pharm	23.4	18	0.255		x	x
99	81		21/11/01		Lonza	0		0		x	
100	81		21/11/01		Solvay	9.1		0.179		x	
101	81		21/11/01		Eisai	13.23		0.154		x	
102	81		21/11/01		Sumitomo	0		0		x	
103	81		21/11/01		Tanabe Seiyaku	0		0		x	
104	81		21/11/01		Roche	462		0.637		x	
105	81		05/12/01	27/09/06	Archer Daniels	39.69	30.69	0.344		x	
106	81		05/12/01		Bayer	14.22		0.053		x	
107	81		05/12/01		Hoffman La Roche	63.5		0.088		x	
108	81	13/07/99	05/12/01	25/10/05	Danone	44.04	43.22	0.228	x	x	
109	81	16/02/99	11/12/01	27/09/06	Commerzbank	28	0	0.272	x	x	x
110	81	16/02/99	11/12/01	27/09/06	Dresdner Bank	28	0	0.123	x	x	
111	81	16/02/99	11/12/01	27/09/06	Bayerische Hypo	28	0	0.117	x	x	x
112	81		11/06/02	14/12/06	Erste Bank	37.69	37.69	0.985		x	x
113	81	16/06/99	02/07/02		Aventis	0		0		x	
114	81	16/06/99	02/07/02	05/04/06	Degussa	118.12	91.12	1.584	x	x	
115	81	16/06/99	02/07/02		Nippon Soda	9		2.837	x	x	
116	81	11/12/97	24/07/02		Air Liquide	3.64		0.028	x	x	
117	81	11/12/97	24/07/02		Air Products	2.73		0.027	x	x	
118	81	11/12/97	24/07/02		BOC Group	1.17		0.018	x	x	
119	81	11/12/97	24/07/02		Linde	12.6		0.228	x	x	
120	82		30/10/02		Nintendo	149.13		1.105		x	
121	81		30/10/02		Christie	0		0		x	
122	81		30/10/02		Sotheby	20.4		5.831		x	
123	81	25/11/98	27/11/02	Pending	Lafarge	249.6		2.399	x	x	
124	81	25/11/98	27/11/02	Pending	BPB	138.6		6.79	x	x	
125	81	15/01/01	27/11/02		Aventis group	2.85		0.006		x	
126	81	15/01/01	27/11/02		Merck	0		0	x	x	
127	82		21/05/03	Pending	Deutsche Telekom	12.6		0.025		x	
128	82		16/07/03		Yamaha	2.56		0.095		x	
129	81		01/10/03	Pending	Hoechst	99		0.476		x	
130	81		03/12/03	Pending	Carbone Lorraine	43.05		12.892		x	
131	81		03/12/03	Pending	SGL Carbon	23.64		8.19		x	
132	81		10/12/03		Akzo	0		0		x	
133	81		10/12/03	02/01/00	Degussa	16.73	16.73	0.314		x	
134	81		10/12/03	No appeal	Atofina	43.47		0.048		x	
135	81	22/03/03	16/12/03	Pending	Outokumpu	18.13		0.994	x	x	
136	81	22/03/03	16/12/03		KME	18.99		8.366	x	x	
137	82		24/03/04	Pending	Microsoft	497.2		0.23		x	
138	82		26/05/04		Topps	1.59		0.551		x	
139	81	22/03/01	03/09/04	Pending	KME	32.75		22.473	x	x	
140	81	22/03/01	03/09/04	Pending	Outokumpu	36.14		1.523	x	x	
141	81	22/03/01	03/09/04	Pending	Halcor	9.16		5.336	x	x	
142	81	25/01/00	29/09/04		Danone	1.5		0.009	x	x	
143	81	25/01/00	29/09/04		Heineken	1		0.008	x	x	
144	81		09/12/04	Pending	AKZO	20.99		0.233		x	
145	81		09/12/04	Pending	BASF	34.97		0.124		x	
146	81		09/12/04	Pending	UCB	10.38		0.18		x	
147	82	09/02/00	15/06/05	Pending	AstraZeneca	14		0.026	x	x	
148	82	22/09/99	05/10/05	Pending	Peugeot	49.5		0.354	x	x	

Note 1: Fine/Cap, ratio of fine to firm's capitalization as percentage
Note 2: An "x" in the last three columns means the observation was used in the respective event estimation
Note 3: F.Com. fine given by EU Commission in million euro
Note 4: F.Court final fine after Court Judgement in million euro

Table A.1: List of observations

Day	Raid 48	J	Com.D. 147	J	Annul. 38	J	Uphd 36	J
t= -20	-0.41**	-1.67	-0.54***	-3.02	-0.01	-0.04	-0.74**	-2.16
t= -19	-0.16	-0.65	-0.08	-0.43	-0.50	-1.50	0.46	1.34
t= -18	-0.43**	-1.74	0.05	0.27	-0.23	-0.67	-0.12	-0.36
t= -17	-0.22	-0.90	-0.36**	-2.10	0.18	0.53	-0.05	-0.15
t= -16	0.00	0.00	0.19	1.09	-0.58	-1.72	-0.23	-0.66
t= -15	0.20	0.82	0.20	1.14	-0.12	-0.34	-0.23	-0.66
t= -14	-0.19	-0.77	-0.24*	-1.36	-0.29	-0.86	-0.21	-0.61
t= -13	0.32*	1.30	-0.20	-1.13	-0.10	-0.28	0.12	0.36
t= -12	-0.46**	-1.85	-0.14	-0.77	0.12	0.36	0.01	0.02
t= -11	-0.30	-1.22	-0.11	-0.60	0.55*	1.63	0.38	1.10
t= -10	-0.04	-0.17	-0.24*	-1.36	-0.13	-0.39	0.14	0.41
t= -9	0.23	0.91	-0.25*	-1.37	-0.06	-0.19	0.51	1.50
t= -8	-0.44**	-1.80	-0.35**	-1.95	-0.54	-1.61	0.03	0.09
t= -7	-0.57**	-2.32	0.23	1.27	-0.39	-1.15	0.23	0.66
t= -6	-0.04	-0.16	-0.04	-0.23	-0.64	-1.89	0.13	0.37
t= -5	0.21	0.86	-0.29*	-1.59	-0.32	-0.94	-0.32	-0.93
t= -4	0.37	1.52	-0.11	-0.63	0.24	0.70	-0.16	-0.46
t= -3	-0.20	-0.79	0.00	0.01	0.46*	1.35	-0.23	-0.67
t= -2	-0.19	-0.76	-0.04	-0.23	0.45*	1.32	0.07	0.20
t= -1	0.22	0.89	-0.04	-0.21	0.24	0.70	-0.21	-0.62
t= 0	-0.99**	-4.01	-0.25*	-1.38	0.03	0.08	-0.34	-0.97
t= -1	-0.30	-1.21	-0.12	-0.66	0.78**	2.32	0.57	1.67
t= -2	-0.37*	-1.51	0.12	0.66	0.17	0.50	0.14	0.40
t= -3	-0.31*	-1.28	0.19	1.06	0.08	0.23	-0.17	-0.48
t= -4	0.23	0.93	-0.16	-0.86	0.14	0.41	0.13	0.38
t= -5	-0.37*	-1.50	-0.20	-1.12	-0.34	-0.99	0.30	0.88
t= -6	-0.28	-1.14	-0.12	-0.69	0.27	0.80	-0.63*	-1.85
t= -7	-0.02	-0.07	-0.02	-0.09	-0.07	-0.22	-0.27	-0.77
t= -8	-0.21	-0.86	-0.28*	-1.57	-0.45	-1.33	-0.05	-0.14
t= -9	-0.02	-0.07	0.03	0.19	0.18	0.52	-0.26	-0.75
t= -10	-0.10	-0.42	-0.41**	-2.31	0.70**	2.07	0.47	1.37
Abnormal Returns as percentage; One-sided test, significance levels *** 1% ** 5% * 10%								

Table A.2: Summary of results: daily estimates

Event W.	Raid 48	Rank t	Com.D. 147	Rank t	Annul. 38	Rank t	Uphd 36	Rank t
(-20;+10)	-4.18***	-3.37	-2.44***	-4.59	3.43	-0.07	1.83	-0.37
(-5. . . +5)	-1.45**	-2.00	-0.52***	-2.66	2.97	0.39	0.54	0.11
(-1...+5)	-1.76***	-2.88	-0.25**	-1.82	1.87	-0.45	0.77	0.57
(-1...+1)	-0.97**	-1.86	-0.30*	-1.36	1.40	-0.59	0.15	-0.39
Abnormal Returns as percentage; One-sided test, significance levels *** 1% ** 5% * 10%								

Table A.3: Non-Parametric Estimates: Theil's estimator and Rank test

A.2 Event Study Methodology and Estimation Procedure

This sections briefly derives the Abnorma Return estimator and the relevant test statistics. Our main references for the event study methodology are Campbell et al. (1997) and MacKinlay (1997).[38]

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

$$\hat{\boldsymbol{\epsilon}}_i^\star = \mathbf{R}_i^\star - \left(\hat{\alpha}_i \iota - \hat{\beta}_i \mathbf{R}_m^\star\right) \tag{13}$$

$$= \mathbf{R}_i^\star - \mathbf{X}_i^\star \hat{\Theta}_i \tag{14}$$

where $\mathbf{R}_i^\star$ is a $(L_2 \times 1)$ vector of event window returns and $\mathbf{X}_i^\star$ 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)

$$E[\hat{\boldsymbol{\epsilon}}_i^\star] = 0 \tag{15}$$

and

$$\mathbf{V}_i = \mathbf{I}\sigma^2_{\boldsymbol{\epsilon}_i} + \mathbf{X}_i^\star (\mathbf{X'}_i \mathbf{X}_i)^{-1} \mathbf{X}_i^{\star\prime} \sigma^2_{\boldsymbol{\epsilon}_i}, \tag{16}$$

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

$$\overline{\boldsymbol{\epsilon}}^\star = \frac{1}{N} \sum_{i=1}^{N} \hat{\boldsymbol{\epsilon}}_i^\star, \tag{17}$$

and correspondingly the variance is

$$\mathrm{Var}[\overline{\boldsymbol{\epsilon}}^\star] = \mathbf{V} = \frac{1}{N^2} \sum_{i=1}^{N} \mathbf{V}_i. \tag{18}$$

Since $\sigma^2_{\boldsymbol{\epsilon}_i}$ in (16) is not known we use instead its consistent estimate

$$\sigma^2_{\boldsymbol{\epsilon}_i} = \frac{1}{L_1 - 2} \hat{\boldsymbol{\epsilon}}_i' \hat{\boldsymbol{\epsilon}}_i. \tag{19}$$

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

$$\overline{\mathrm{CAR}}(\tau_1, \tau_2) \equiv \iota' \overline{\boldsymbol{\epsilon}}^\star \tag{20}$$

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

and

$$\text{Var}[\overline{\text{CAR}}(\tau_1, \tau_2)] = \bar{\sigma}^2(\tau_1, \tau_2) = \iota' \mathbf{V} \iota. \tag{21}$$

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

$$\hat{\bar{\sigma}}^2(\tau_1, \tau_2) = \frac{1}{N^2} \sum_{i=1}^{N} \iota' \mathbf{V}_i \iota. \tag{22}$$

We use the following result

$$J_1 = \frac{\overline{\text{CAR}}}{\hat{\bar{\sigma}}^2(\tau_1, \tau_2)} \overset{a}{\sim} \mathcal{N}(0, 1), \tag{23}$$

to test the null hypothesis.[39]

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