Mergers after cartels: How markets react to cartel breakdown

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Mergers after cartels: How markets react to cartel breakdown*

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Abstract

Most literature assessing the effectiveness of competition policy focuses on short term impacts, ignoring the likelihood that firms and market mechanisms may take some time to respond to policy interventions. This paper adopts a more dynamic perspective in the context of cartel detection by analysing subsequent developments in market structures through merger. With data for a sample of 84 EC cartels, it employs a novel application of recurrent event survival analysis to establish that cartel breakdown is typically followed by intensive merger activity. This is most likely for cartels which had been detected via leniency applications and where concentration was relatively lower. The paper also shows that in most markets where mergers do not occur, the post-cartel structure is already consistent with potential dominance, and in a number of those where it is not, the mergers move the market in that direction. Surprisingly very few post-cartel mergers were intervened by the competition authority, and this appears to be because many were individually small, but cumulatively had significant impact on concentration.

Keywords: tacit and overt collusion, mergers, long-term effects, recurrent events, survival analysis

JEL Classification codes: C41, L10, L41

1 Introduction

Anti-cartel enforcement is widely heralded as the single most important part of antitrust policy. For this reason it is somewhat surprising that there have only been a few studies analysing how markets react to the elimination of cartels. This paper takes a dynamic approach in examining what happens in markets in the years after a competition authority has successfully prosecuted a cartel. It examines whether markets revert to competitive behaviour or whether firms find alternative ways of reinstating collusive equilibria (short of cartelisation) in the longer run.

The most common approach to this question in the past has been to examine post-cartel prices, and a fairly common method for quantifying cartel overcharge is

to compare post-cartel against within cartel period prices. While such an approach can sometimes be illuminating, suitable price data are often unavailable, especially over anything more than the short-term. Here instead we turn to a more indirect approach in order to use types of longer-run data which are more readily available, namely on quantity and market structure. This follows the insight of seminal works in the early 1990s by Sutton (1991), and Bresnahan and Reiss (1991) who showed, using very different analytical approaches, how information about market shares and structure can be informative about the competitive process, even without information on price and profits.

Such market structure changes are often typically achieved in the form of mergers. For this paper, data were collected on mergers, acquisitions and joint ventures (hereafter referred to under the catch-all 'merger') between firms involved in those cartels for which the European Commission (EC) issued decision documents between 1990 and 2012. We pose three questions. Was there more intense merger activity amongst the former cartelists in the years immediately following breakdown? Were certain types of cartels more likely than others to be followed by merger? Is there evidence that the CA subsequently intervened in those proposed mergers which were most likely to raise potential anti-competitive concerns, or is there evidence of deterrence of such mergers?

The task of establishing whether or not there was indeed a higher than normal rate of mergers following breakdown is not straightforward, and the practical and conceptual difficulties in applying a standard difference-in-differences methodology rule it out in this case. Our alternative is a novel application of survival analysis, with the complication that there may be recurrent deaths (multiple mergers). This establishes that there is indeed evidence of more intensive post-breakdown merger activity, but especially for the subset of cartels which were detected via leniency applications, and in relatively less concentrated markets. Our explanation is that leniency applications are most common in cartels which have already, or are about to, breakdown for 'natural causes' (i.e. are internally unstable). It follows that formal collusion has become unsustainable, and if so it is even less likely that the parties will be able to effectively collude tacitly (without formal communication). Mergers may

then offer the best prospect for a restructuring which would be more conducive to tacit collusion. However, there is another intuitive explanation of abnormal merger activity post-breakdown in leniency cases – this could be the natural means by which firms restructure in the face of tougher price competition.

The second part of the paper looks for indirect evidence for discriminating between these explanations. It disaggregates and examines which firms do the acquiring and who they acquire, in which types of market structure mergers were most common, and what were the implications of the mergers for the post-merger market structures in terms of dominance. It also examines the response of the CA: which mergers it investigated, and what were its decisions. Surprisingly, very few post-cartel mergers were intervened by the competition authority, and this appears to be because many were individually small, but cumulatively had significant impact on concentration.

The literature on mergers subsequent to cartel can be traced back, through Bittlingmayer (1985) and Mueller (1996), to the first great merger wave in the US at the beginning of the 20th century, following the Sherman Act prohibition of cartels. Something very similar was observed in the UK following the Restrictive Trade Practices Act in the 1950s. Symeonides' extensive research (e.g. 2002) on this provides more indirect evidence that prohibition of cartels preceded a major restructuring in parts of the UK economy. The main implication for policy makers was highlighted by Evenett et al. (2001, pp.1245): "*(V)igilance should not end with a cartels' punishment, as former price-fixers often try to effectively restore the status quo ante by merging or by taking other steps that lessen competitive pressures and raise prices.*"

More recently, two studies have returned to the topic, but at a more micro level within a jurisdiction (the EU) in which cartels are already illegal, and where the event is not some major natural experiment but rather the busting of individual cartels. Kumar et al. (2013) show that for 45% of cartels reported by the EC between 2001-2010, there were mergers between the former cartelists in following years, and that this was twice as likely in markets where buyers were fragmented rather than concentrated. They use this to motivate their theoretical modelling of the choice between collusion and merger when faced with buyer resistance. Hüschelrath and

Smuda (2013) also employ a sample of EC cartels. But in their case, the merger data do not relate directly to the cartelists, but rather the amount of aggregate worldwide/EEA merger activity in the industries to which the cartel markets belong. Pooling the industries, they calculate that merger activity was (up to) 83% higher in the 3 years after than in the 3 years before cartel detection.

Our own study is based on a similar sample of EU cartels, and is motivated by the same proposition that merger is a second best which is only pursued once the first best (cartel) is no longer possible, but it differs in two important respects. Kumar et al's empirical objective is limited to motivating their theoretical model, establishing whether merger after cartel varies with buyer resistance – they provide no evidence on whether mergers were more prevalent after detection than before. The primary objective of Hüschelrath and Smuda is much closer to ours, but we suggest that their empirical analysis is far too aggregate and casual to justify the conclusions they draw. Their merger data relate not to the cartelists themselves, but to all firms worldwide in the NACE 3 or 4 digit industries to which the cartel markets belong. So for example, they employ aggregate data on mergers by all firms worldwide in industries such as "manufacture of pharmaceutical preparations" or "manufacture of other chemical products" to proxy the cartel markets in Europe in finely disaggregated markets such as Citric Acid or Vitamins. The cartel markets often form only very small proportions of the NACE industries to which their merger data relate. Moreover, all data are pooled across all industries/cartels, there are no controls for mergers in industries in which there were no cartels, and their empirical analysis is confined to simple comparisons of two aggregate figures, before and after, without any tests of statistical significance. Our study is less aggregate, and relates to subsequent mergers between only the former cartelists, and addresses head-on the methodological problem of how best to represent the counterfactual.

Section 2 draws on theory and previous literature to propose the key hypotheses. Section 3 describes the data and presents some opening descriptive statistics. Sections 4 and 5 present the main results, using survival analysis of the time series merger data observed at market level, and identifying the sizes of firms and types of market structure most likely to have mergers. Section 6 explores the policy im-

plications by examining the CA's merger interventions in these markets. Section 7 concludes.

2 Restructuring after cartel breakdown

Drawing from the previous literature, this section first identifies two alternative explanations for merger activity following cartel breakdown. These provide two main hypotheses which are testable with the data at our disposal.

2.1 Two competing explanations

The '*anti-competitive*' explanation is that, post-cartel, the now frustrated cartelists attempt to re-instate 'soft' competition. This necessitates a new market structure via merger which is conducive to soft rather than intense competition. Soft competition might be tacit collusion or some form of leadership, in which respective cases, the mergers would have coordinated or unilateral effects.

On the other hand, under the '*efficiency*' explanation, the cartel breakdown has the desired objective from the CA's perspective, leading to a change in prevailing conduct from collusion to competition: price falls, the market restructures and marginal firms exit, and some of the exit is via acquisition by other members of the cartel. For example in a free entry model, replacing collusion with, say, Cournot or Bertrand competition will lead to a reduced number of firms (Sutton, 1991, section 2.2, pp.28-37), and in an asymmetric market the ones that exit are the least efficient firms (the smallest in Cournot). Alternatively, if the post-cartel equilibrium is still tacitly collusive, price is lower than under cartel, so even in this case the likelihood of marginal exit through merger remains.

With a well-informed and diligent CA, the latter explanation should dominate.

2.2 The revealed preference argument

Most of the existing literature described above has focused on the anti-competitive motive, employing what we refer to as revealed preference type reasoning.[1]

In principle, firms in any market choose between competing and colluding. In turn, collusion might take the form of hard-core cartel, or it might be softer - tacit collusion or price leadership. In order to achieve and sustain soft collusion, market structure must be right, and this may require mergers between at least some of the firms. The choice may be constrained by the basic demand, cost and entry conditions, which may effectively preclude any form of collusion, and the presence of the CA may deter either cartel formation and/or anti-competitive mergers.

In the case of a cartelised market, collusion is clearly feasible, and firms have revealed a preference for formal over tacit collusion. Thus the revealed preference argument has two steps:

(a) The cartel solution dominates soft competition via merger. Were this not so, firms would have opted for mergers in place of a cartel in the first place.

(b) Once the cartel option is removed, firms turn to the second best - tacit collusion or price leadership - and this may require restructuring through merger.

However, there are two important qualifications to this logic.

2.2.1 Merger may not be necessary

First, without disputing (a), this need not imply (b): with the cartel option no longer open, mergers may not always be necessary in order to achieve the second best of tacit collusion.

Much of the conventional theory of collusion can be applied equally to - and does not always distinguish between - tacit collusion and cartels. For example, the

[1] In addition to Kumar et al. (2013) and Hüschelrath and Smuda (2013), see Cosnita-Langlais and Tropeano (2013) who model the choice of two firms between forming a cartel and merging in order to facilitate subsequent collusion, when faced with a CA which optimises its policy mix between cartel enforcement and merger control.

basic predictions of the repeated game - that collusion is more likely the fewer is the number of firms and the more symmetric they are - are invoked in both the literatures on cartels and coordinated effects mergers.

This raises the question of why firms sometimes choose to overtly collude when tacit collusion is also possible and does not carry the same risk of sanctions? Harrington (2012) offers one explanation - given symmetric firms, he shows that the profit from tacit collusion has an upper bound which is the cartel profit, so where the cartel option is chosen, it follows that cartel profit must exceed tacitly collusive profits sufficiently comfortably to exceed the expected cost of detection.

However, given that the cartel has been chosen but is now busted, it might still be profitable and sustainable for the firms to switch to the second best, even without merger. There is some evidence to suggest that this is exactly what happens in some cases. Harrington (2004) refers to the idea of 'residual collusion', where a busted cartel is followed by tacit collusion. Connor (2001) uses the same argument to explain what happened in the aftermath of the exposure of the Lysine cartel. A study by Kovacic et al. (2007) on prices in the post-breakdown period for different types of vitamins implies a simple switch to tacit collusion in some cases. They find that vitamin products with two conspirators continue as if the explicit conspiracy never stopped, while products with three or four conspirators return to pre-conspiracy pricing, or lower. This is also confirmed in an experimental setting by Fonseca and Normann (2012), who find that, after formal communication is no longer possible, 'firms' carry on successfully colluding in small numbers cases. If this previous communication is a sufficient condition to sustain tacit collusion, then we would expect at least some markets to still display collusive outcomes after cartels are detected, without any change in market conditions (structure, entry conditions, etc).

Nevertheless, there are important differences between explicit and tacit collusion – the cartel has organisational and communication advantages, and without these, collusion may not be possible. So although collusion may sometimes continue in tacit form post-breakdown without merger, in other cases, the existing market structure cannot support collusion without formal communication, and in those cases part (b) of the above argument remains valid: re-structuring by merger is necessary to

facilitate a collusive outcome given no communication, and larger numbers.

2.2.2 Cartels which die a 'natural death'

Second, part (a) of the argument need not always apply. While this may be reasonable if the cartel has been detected ex-officio, i.e. through the CA's own detection activities sometimes stimulated by customer complaints, if it has already broken down before detection by the CA (i.e. died a 'natural death'), it follows that collusion is no longer sustainable even with communication, and we can no longer infer that cartel is preferred to merger *at the time of breakdown.* By extension, in these circumstances it is also unlikely that tacit collusion is sustainable either, and it follows that merger is even more necessary.

In other words, while mergers may sometimes be unnecessary for tacit collusion where the cartels remained 'effective' (in terms of stability and high price) at the time of detection, they are more likely in those which had already failed.

Empirically, a frequent signal that a cartel has effectively already died a natural death is detection via a leniency application, and we exploit this fact in the following empirics.

2.3 Testable hypotheses

This leads to the following testable hypotheses:

H1 *The probability of merger will be higher in the years immediately following cartel breakdown.*

This follows from either of the competing explanations. Because cartels that have already died before the start of the CAs investigation are not sustainable at the time of breakdown a further specification follows:

H1a *H1 is especially pronounced for cartels having died a natural death before detection.*

However,

H2 *The probability of merger is lower, ceteris paribus, in concentrated markets.*

This follows because markets which are already concentrated: (i) are more likely to be able to sustain subsequent tacit collusion without merger, (ii) will include fewer firms, so there are fewer opportunities to merge, and (iii) are more likely to be deterred by the fear of CA merger intervention.

This hypothesis can be refined by disaggregating 'concentration': in a statistical sense, the concentration of any size distribution depends on the number of firms (inversely) and the asymmetry in their market shares (positively)[2].

H2a *The probability of merger is lower in small number markets; and*

H2b *The probability of merger is lower in more symmetric markets.*

Assuming tacit collusion is more likely where firms are of roughly equal size, further mergers may be unnecessary for tacit collusion, but are also more likely to be deterred for fear of CA intervention under a coordinated theory of harm.[3] Where size asymmetries are large, this implies the presence of a dominant firm and, without the organisational advantages of the cartel, mergers may be necessary to consolidate the leader's position.[4]

[2]For instance, measuring concentration by the conventional HHI index, it is easily shown that: $HHI = \sum_{i=1}^{n} s_i^2 = (1+CV^2)/n$. where n is number of firms, s is the market share of firm i and CV is the coefficient of variation (standard deviation/mean) of market shares. CV can be interpreted as an index of size asymmetries.

[3]On collusion and symmetry, see, inter alia, Mason et al. (1992), Lambson (1995), Davidson and Deneckere (1990), Pénard (1997) and Ivaldi et al. (2003). Similarly, Vasconcelos (2005) finds that collusion is hindered by asymmetry-increasing mergers, as do Compte et al. (2002), but only if aggregate capacity in the market is limited.

[4]This is the single dominance story, where collusion may work through price leadership (Mouraviev and Rey, 2011), but others show that some level of asymmetry is conducive to collusion (Ganslandt et al., 2012), rather than forbearance amongst a small group of equals. Mouraviev (2011) finds that in a Bertrand setting, price leadership restores the scope for (perfect) collusion in markets where collusion would not be sustainable otherwise. Ganslandt et al. (2012) introduce an indivisible cost of collusion, which one of the firms in the collusion has to bear, and which creates an incentive for firms to make markets more asymmetric by mergers. The intuition behind this is that the indivisible cost should be borne by a single (large) firm. In this setting firms may merge

These are the core hypotheses of the paper, but additional institutional characteristics should also be relevant, for example, the nature of the agreement and organisation of the cartel. These are devices designed to facilitate coordination within the cartel, and without them, uncoordinated collusion may be impracticable. We capture this empirically below by distinguishing cartels which were market-sharing as opposed to price-fixing. Some forms of market sharing (notably territorial and/or customer allocations) are largely self-enforcing because defection is transparent, and if so, the same should be true for tacit collusion. We also identify whether or not the cartel had a ringleader – if so, it is less likely that collusion could survive a cartel bust and implicitly the loss of its leader to monitor and enforce, without restructuring.

3 Data and descriptive statistics

The data, as summarised in Table 7 in the Appendix, contains information on both cartels and mergers.

3.1 The cartels

The dataset draws on decision documents published by the European Commission (EC) since 1990. The useable sample is 84 cartels that were detected between 1984 and 2009 - the published report typically lags the date of detection by one or more years.[5]

36 cartels (43%) broke down before they were detected, and most of these (31) were detected under leniency. On average, the cartels had lasted over 8 years at time of breakdown, and covered 84% of the market (the remainder being supplied

to increase asymmetry. Andreoli-Versbach and Franck (2013) show that in the Italian retail petrol market price leadership work only after the market leader introduced a policy of sticky prices. Harrington (2006) suggests that it is typically one firm who undertakes the price and quantity monitoring tasks in a cartel.

[5]For this purpose, we consolidated two decision documents which cover the rubber market, and a number of reports relating to International Container Shipping cartels. In some other cases (notably vitamins) a single decision document relates to more than one cartel, but since these are always in very closely related submarkets, we count them here as a single case.

by outsiders and imports). 82% colluded on price fixing and 70% employed market sharing practices; more than half (52%) combined both practices. Bid rigging as well as specific quota allocations were more common practice in larger cartels (with 10 or more firms). Ringleaders were identified in one third of cartels (see Davies and De, 2013).

3.2 The mergers

The cartels involved a total of 593 firms at the dates of breakdown. Data was collected on all mergers, acquisitions and joint ventures between former cartelists from the same cartel.[6] The sources were: (i) companies' websites, in particular annual reports, press releases, investor information, company timelines/histories, etc.; (ii) merger decisions documents published by the European Commission;[7] (iii) National Competition Authorities (CA); and (iv) business and financial websites (e.g. Bloomberg, etc.).

In almost exactly half (41) of the cartels, the breakdown was followed by one or more mergers between previous cartelists. In these, there were 128 qualifying mergers,[8] (on average 3.12 per cartel, and the mode was 1, but the distribution is highly skewed, with as many as 19 transactions between cartelists in one extreme case).

50% of mergers occurred within 5 years of cartel breakdown. Figure 1 plots the cumulated number pooled across all cartels with time measured after cartel breakdown. In aggregate (bold line), the rate of increase is higher within the first five to seven years, but slows down thereafter.

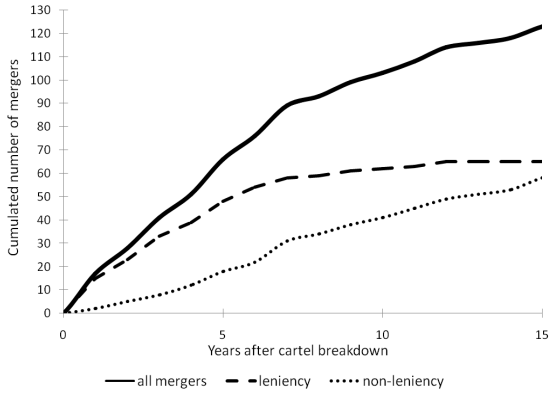
The figure also disaggregates by leniency/non-leniency detection. Post-breakdown mergers in leniency cases occur on average 43 months after cartel failure, compared

[6] 'Relevant' is defined by the 3 or 4 digit NACE industry identified by the Commission in its decision document. In fact, many of the cartel markets are much more finely defined than even the 4 digit level. In that case, the cartel market belongs to the 3 or 4 digit industry identified by the EC, but is only a part of that industry. See also Section 6 below.

[7] http://ec.europa.eu/competition/mergers/cases/

[8] The dataset assembled by Kumar et.al (2013) is a subset of 55 of the cartels in our sample. They identify mergers in 25 cases: 45% of their sample. We find mergers in 49% of our sample.

Figure 1: Cumulated number of mergers after cartel breakdown



to 97 months in non-leniency cases. The concavity of the curve is more pronounced in leniency cases, and this provides an early sign that firms tend to engage in merger activity most intensively relatively soon after breakdown – especially for cartels detected under leniency.

However, this finding should be treated with caution for two reasons. First, given that the population of all firms (and thus all potential mergers) must decline over time due to exit by acquisition, this curve does not necessarily imply concavity in the merger *rate*. Second, due to variability across cartels in the year of breakdown, there is also heterogeneity in the composition of the pool – later observations are based on increasingly fewer cartels. These limitations motivate our use of the hazard curve technology in the next section.[9]

The above statistics on cartel characteristics are familiar and typical for samples such as this,[10] but in addition, we have also collected useable data on market shares of the individual cartelists in 64 of the cases,[11] using sources such as (i) cartel and merger decision documents published by the EC and national CAs (ii) companies' annual

[9]This also partly accounts for the fact that no mergers are observed in half the markets - often these are the most recent cartels for which few post-breakdown years are observed at the time of writing.

[10]See for example Levenstein and Suslow (2006), De (2010).

[11]The mean number of mergers per cartel is almost identical for the 64 for which we have market share data (1.53) and the 20 for which we do not (1.50).

reports (iii) reports and information issued by relevant trade/industry associations and market intelligence firms/platforms (iv) business and financial websites etc.[12] Using these estimated market shares, the HHI index at the time of breakdown for each cartel was also computed,[13] as were its two constituent parts, firm numbers (n) and the coefficient of variation (CV).

4 Empirical analysis

We first explain why an orthodox difference-in-differences (DiD) approach, comparing post- and pre-breakdown using control markets to represent the counterfactual, will be inappropriate. The reasons are both practical and conceptual. In this context, 'pre' would be either the cartel period itself, which would not be an appropriate representation of what might happen in a 'competitive' world, or the period before cartel formation, which would require extensive historical data collection - for some markets many decades before the availability of internet sources. Second, choice of appropriate control markets for such a large sample is problematic. There would be prohibitive costs in collecting comparable data, given the very disaggregated market definitions of most cartel markets, and the absence of detailed sources such as the EC cartel decision documents which are the key source for our cartel markets. Moreover, the most appropriate control markets, in terms of demand and cost conditions, would almost certainly lie within the same 3 or 4 digit industries as the cartels, and therefore very often be populated by the same large diversified multinationals as the cartel markets or even operate under the cartel's umbrella.

Even putting aside these generic issues which confront many applications of DiD, two further features of the present context would constrain its effectiveness. First,

[12] The EC does not routinely report exact market share data in its decision documents, but it is possible to infer individual market shares for most cartels, if sometimes only approximately. Firms' shares are often reported as ranges, e.g. 10-20%; in such cases we typically employ the midpoints, subject to moderation where other information is available on an ad hoc basis. Our estimates were also corroborated for most of the cartels, using De's (2010, pp.109-111) estimates based on similar data and methods.

[13] This is computed using the shares of members in the cartel (Table 7 shows that on average this is around 84 per cent of the market).

the data here are right censored: the merger history in each market is only observed up to the common year of observation (2013), whilst the start date differs between cartels, defined by their breakdowns, so we have relatively little data on more recent cartels. Second, because we focus on mergers between the former cartelists, with each successive merger, there are fewer firms remaining who can merge.

To address these issues we employ a methodology based on an application of survival analysis. Survival analysis originates from health applications in which the event of interest is time until failure (perhaps the malfunctioning of some medical device, sometime after its original fitting), here, 'failure' is defined by merger.[14] One comparative advantage of survival models is that they allow the analysis of censored observations. At the heart of survival analysis is the hazard (intensity) of an event at time t given the event history and characteristics of the context. Here, time starts at the date of cartel breakdown, the event is merger, and the context is the market. As a hazard function is conditional on previous event history, it is an obvious tool to be used in a situation where successive mergers leave fewer and fewer firms to merge in the future.

The central hypothesis - more intensive merger activity after breakdown - can be tested by examining the behaviour of the hazard curve over time. The counterfactual in this case would be a constant hazard rate which is undisturbed by the event of cartel breakdown. On the other hand a monotonically declining hazard rate in the years after breakdown would indicate a stimulus to merger which then gradually subsides over later years.

4.1 The survival model

If there was only one post-cartel merger in each market the analysis would reduce to a standard application of single-event survival analysis requiring an examination of the distribution of the duration between cartel breakdown and the merger, and

[14] Previously, Levenstein and Suslow (2006) and others have successfully employed survival analysis for cartel duration, where failure is naturally defined by breakdown, but our application differs from theirs in that we focus on the shape of the hazard curve, whilst accounting for the additional problem of multiple failures (mergers) of cartels.

the shape of the corresponding hazard curve. Any distribution that can have an increasing, decreasing, or constant hazard function could be used for this purpose (for example the Weibull or gamma distributions). Because of its simplicity, we employ the Weibull distribution, for which the hazard is:

$$h(t) = \lambda\rho t^{\rho-1},\ t \geq 0 \tag{1}$$

ρ and λ are conventionally referred to as the shape and scale parameters of the distribution. The λ parameter captures the pace of merger activity, and in cross-industry analysis this will allow the underlying magnitude of merger activity to differ between markets. If $\rho = 1$ the hazard is constant, with $\rho < 1$ it is monotonically decreasing, and with $\rho > 1$ it is monotonically increasing. Therefore our hypothesis that merger activity in the years immediately following cartel breakdown is more intense can be tested by:

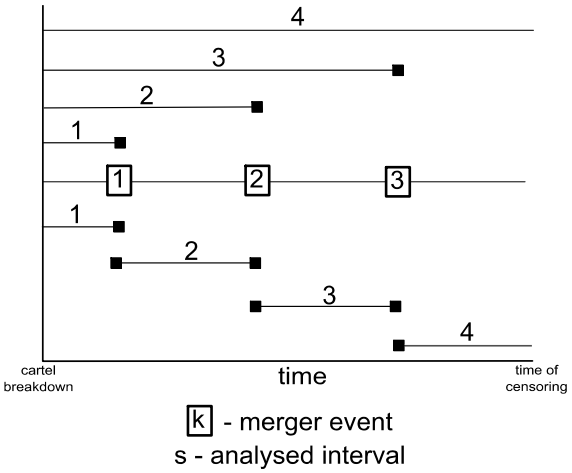
$$\begin{aligned} H_0 &: \rho \geq 1 \\ H_1 &: \rho < 1 \end{aligned}$$

However, we wish to allow for multiple mergers in each market, and this requires a modification of this model to allow for recurrent events. To illustrate, Figure 2 plots the history of a given industry with three mergers on the central line. To allow for recurrent events (here, subsequent mergers) the previous literature[15] most commonly uses one of two main options depending on the assumption about when individuals (industries) are entered into the risk set (i.e. exposed to the risk of a merger). First (shown below the central line), time is measured from the previous event. In this case, the first interval starts at breakdown and subsequent intervals are measured from the preceding merger. Second, (shown above the central line), each interval is measure from the start (cartel breakdown.)

Thus, depending on how intervals are treated, there are three alternative ways

[15] See Lin et al. (1989), Andersen and Gill (1982), or Prentice et al. (1981).

Figure 2: Time measured from breakdown and time measured from previous event



of approaching our research question. Firstly, one could ignore recurrent events and focus only on the rate at which we observe the first merger following a cartel (irrespective of how many mergers are to follow). We refer to this as the '*naive' model* as it discards important information on subsequent mergers.

Secondly, in allowing for recurrent mergers one could assume that the waiting times between mergers are independent and thus, for every merger, time scales from the preceding event (*renewed entry*). This would be appropriate if every subsequent merger is a reaction to the preceding merger and not to the cartel breakdown. As such, this model allows for mergers to endogenously trigger subsequent mergers.[16]

Thirdly, one could assume that waiting times between cartel breakdown and each merger are independent - i.e. every merger is timed from the start of the study (*entry at start*). This would imply assuming that every merger - no matter how late it occurs - is a reaction to the cartel breakdown and not to the preceding merger.

Following conventional notation in recurrent event analysis[17] denote the merger

[16]By looking at how the probability of subsequent mergers change in light of previous merger history. For a theoretical discussion of endogeneous mergers see Qiu and Zhou (2007) or Gowrisankaran (1999).

[17]For example a comprehensive treatment of recurrent event models in the area of biostatistics is given by Cook and Lawless (2007).

event history in any market by $N(t) = \{n(u) : u \leq t\}$, where $n(u)$ is the number of mergers in $[0; t)$.[18] We also allow for the possibility that hazard rates are a function of market and cartel characteristics (denoted by $\mathbf{X}$). Then the hazard (intensity) function is:

$$h\{t \mid N(t), \mathbf{X}\} = \lim_{\Delta t \to 0} \Pr \frac{[t \leq T_{n(t)+1} < t + \Delta t \mid N(t), \mathbf{X}]}{\Delta t} \tag{2}$$

By combining (1) and (2) the above three scenarios can be modelled in the following way:

1. 'Naive' model: $h(t \mid \mathbf{X}) = \lambda\rho t^{\rho-1}$.

2. Renewed entry model: $h(t \mid N(t), \mathbf{X}) = \lambda\rho(t - t_{n(t)})^{\rho-1}$. This follows Andersen and Gill (1982) and the first model in Prentice et al. (1981).[19]

3. Entry at start model: $h(t \mid N(t), \mathbf{X}) = \lambda\rho t^{\rho-1}$. This model is loosely based on the second model in Prentice et al. (1981).[20]

Models 2 and 3 can be thought of as setting two bounds on the estimate of ρ when multiple mergers can happen in an industry. In Model 2 each industry spends a relatively shorter time in the risk set (time starts at previous event), which means that we are more likely to have many short spells and few long spells in the sample, implying that ρ should be the lowest in these models. In Model 3 mergers that happen later are treated as independent, therefore the analysed time spells are more likely to be longer, implying a higher ρ.

Now consider the implication for a sample of m industries, when the set of all industries is $\{G_1, G_2, ..., G_m\}$. Denote the total number of mergers in industry G_i ($i =$

[18] The counting process $N(t)$ is equivalent of the random failure times $T_1 < ... < T_{n(t)}$, and $n(t)$ records the cumulative number of mergers, $n(t) = \sum_{k=1}^{\infty} I(T_k \leq t)$, where T_k is the time of the k-th merger.

[19] We replace the Cox PH model used in these papers by a fully parametric approach.

[20] Both Andersen and Gill (1982) and Prentice et al. (1981) used a stratified model. We opt against this, as it would require estimating parameters of a baseline hazard for each industry for each possible strata (interval), which would have been too demanding from our relatively small sample.

$1, 2, ..., m$) by k_i. Allowing for right-censoring in each industry there are $s_i = k_i + 1$ intervals in each industry. For each interval denote the total number of industries at risk by m_s, and the number of industries with mergers by r_s.

Let $t_{s1}, t_{s2}, ..., t_{sr_s}, t^+_{sr_s+1}, ..., t^+_{sm_s}$ be the ordered failure (merger) times in interval s,[21] with $\sum_{s\geq 1} r_s$ exact times, and - because the study period has a natural cutoff point at the time of writing this study - we also have $\sum_{s\geq 1}(m_s - r_s)$ right-censored intervals. The likelihood of observing this sequence is given by:

$$L = \prod_{s\geq 1} \left[\prod_{j=1}^{r_s} f(t_j) \prod_{j=r_s+1}^{m_s} S(t_j^+) \right] \tag{3}$$

Where the density function $f(t)$ represents the information that can be obtained from observed uncensored survival times and the survival function $S(t)$ captures observed right-censored times.

Using the Weibull density ($\rho\lambda^\rho t^{\rho-1} e^{-(\lambda t)^\rho}$) and survival functions ($e^{-(\lambda t)^\rho}$) together with (3) the recurrent event, right-censored likelihood functions to be estimated for the three models described are given below. For each model we assumed that the sample is progressively censored (i.e. markets are entered at different times and the study lasts a predetermined period of time).

In the *naive* model there is only one interval analysed, therefore the ordered survival data is: $t_1 \leq t_2 \leq ... \leq t_r, t^+_{r+1}, ..., t^+_m$ and the likelihood of observing this data given a Weibull distribution is:

$$L_1 = \prod_{j=1}^{r} \rho\lambda^\rho t_j^{\rho-1} e^{-(\lambda t_j)^\rho} \prod_{j=r+1}^{m} e^{-(\lambda t_j^+)^\rho},\ t > 0 \tag{L_1}$$

In the *renewed entry* model denote the gap time between two events in the same industry by $u_s = t_s - t_{(s-1)}$. In this case the ordered (observed and censored) gap times are given by: $u_{s1} \leq u_{s2} \leq ... \leq u_{sr_s}, u^+_{sr_s+1}, ..., u^+_{sm_s}$ and the likelihood function:

$$L_2 = \prod_{s\geq 1} \left[\prod_{j=1}^{r_s} \rho\lambda^\rho u_{sj}^{\rho-1} e^{-(\lambda u_{sj})^\rho} \prod_{j=r_s+1}^{m_s} e^{-(\lambda u_{sj})^\rho} \right],\ t > 0 \tag{L_2}$$

In the *entry at start* model the ordered survival data is: $t_{s1} \leq t_{s2} \leq ... \leq$

[21] For simplicity we assume that the failure process is orderly, i.e. there cannot be two mergers in the same month.

$t_{sr_s}, t^+_{sr_s+1}, ..., t^+_{sm_s}$ and the likelihood function is:

$$L_3 = \prod_{s\geq 1}\left[\prod_{j=1}^{r_s}\rho\lambda^\rho t_{sj}^{\rho-1}e^{-(\lambda t_{sj})^\rho}\prod_{j=R+1}^{m_s}e^{-(\lambda t^+_{sj})^\rho}\right], t>0 \qquad (L_3)$$

As the emphasis is on estimating ρ initially we estimate λ and ρ without allowing for heterogeneity across cartels.[22]

4.2 Results

The MLE estimates of ρ for Models 1-3 are reported in Table 1.[23] The 'Full sample' column shows that $\rho < 1$ in all three models, but only at the 90% confidence level for Model 3.

Table 1: Values of ρ for the full sample and leniency cases only

	Full sample [95% CI]	Leniency only [95% CI]
Model 1	0.619 [0.471;0.816]	0.530 [0.419;0.670]
Model 2	0.767 [0.624;0.943]	0.612 [0.514;0.729]
Model 3	0.936 [0.804;1.089]	0.744 [0.626;0.883]

Result 1 (H1): *There is higher merger activity in the years immediately following cartel breakdown, although the power of the test that confirms this depends on model choice.*

[22]Note that $1-3$ differ from Prentice et al (1981) not only in that they are fully parametric but also in that ρ and λ are homogeneous across intervals. Assuming different hazard functions for each time interval between events would mean estimating $\max(K_i)\times 2$ parameters (in the model without covariates), which we rejected for dimensionality reasons.

[23]The standard errors used to calculate the confidence intervals are based on a 'robust' variance-covariance matrix to account for the possible dependence between failure times (subsequent mergers). See the Appendix for further explanation.

However, when the model is estimated only for cartels detected under leniency ('leniency only' column), MLE estimates of ρ are lower and significantly less than unity in all three models:

Result 1a (H1a) *For cartels that died a natural death, there is significantly higher mergers activity*[24] *in the years immediately following, and this is robust across all model treatments.*

4.3 Allowing heterogeneity across industries

The above results are conditional on the Weibull parameters being constant across all industries. This assumption is now relaxed by allowing the underlying merger rate to vary across industries, using an exponential link function: $\lambda = e^{\boldsymbol{\beta}'\mathbf{x}_i(t_j)}$, where $\mathbf{x}_i$ is a vector of covariates. The model is specified such that ρ is constant (i.e. covariates do not affect the shape only the position of the hazard function).

To test hypothesis H2 in Section 2.3, estimates now control for market structure (HHI, or n and CV), the type of the cartel agreement (price fixing - pf or market sharing - ms), and whether there was a ringleader at the time of cartel breakdown (rl). Table 2 reports estimates for the two alternative recurrent event models 2 and 3. In Variant A HHI is used as a control for market structure; this is replaced by n and CV in Variant B.

The results for variant A in Table 2 show that estimates for the shape parameter ρ remain in the same range as above, i.e. significantly less than unity.

Result 1b (H1 and H1a): *There is robust evidence of higher merger activity following the natural death of cartels when also allowing for heterogeneity across markets.*

Since HHI has a significantly negative coefficient in all model specifications:

Result 2 (H2): *The underlying merger rate is lower in more concentrated markets.*

[24] In fact, this result holds at the 99% confidence level.

Table 2: Introducing heterogeneity

	Model 2		Model 3	
	Variant A	Variant B	Variant A	Variant B
HHI	**-7.470*** **		**-6.586*** **	
	(1.701)		(1.477)	
CV	**2.342*** **			**1.507*** **
	(0.673)			(0.488)
n	**0.149*** **			**0.127*** **
	(0.375)			(0.035)
rl	-0.312	**-0.747***	-0.251	**-0.581** **
	(0.443)	(0.420)	(0.237)	(0.261)
pf	0.515	**1.410** **	0.242	**0.930***
	(0.683)	(0.620)	(0.620)	(0.484)
ms	-0.308	-0.195	-0.228	-0.300
	(0.539)	(0.466)	(0.269)	(0.281)
$\_cons$	-0.945	**-5.958*** **	**-2.447** **	**-6.563**
	(0.865)	(0.905)	(0.717)	(0.860)
ρ	**0.582*** **	**0.576*** **	**0.778** **	**0.781** **
(z-stat)	(-5.70)	(-5.93)	(-2.33)	(-2.20)

This may imply that firms in more concentrated markets are more likely to be deterred from merging (as there is a higher chance of regulatory disapproval), but it can also mean that these markets are already sufficiently concentrated to sustain tacit collusion. The results do now allow us to distinguish between these two possible explanations.

Results 2a and 2b (H2a and H2b): *Market asymmetry and a larger number of firms both lead to an increased underlying merger rate.*

This follows from the variant B results: in markets with symmetric structure the merger rate is less intensive following cartel breakdown, and higher if there are more firms in the market. These again may be due to deterrence (high symmetry and few firms typically imply less likely merger approval) or due to the fact that these markets are already conducive to collusion.[25]

[25]Because we were focusing on the hazard of mergers (the probability of an imminent merger conditional on previous merger history) there was no need to control for the fact that with every merger there are fewer firms in the market and thus the probability of mergers is reduced.

The results on the other covariates show that in general having a previous ringleader in the cartel reduces the rate of mergers following cartel breakdown, and that market sharing cartels have higher merger rates after the cartel. These results are robust across all specifications.[26]

5 Mergers: competitive consequence or second-best collusion?

These results support both main hypotheses of section 2.3, but they cannot discriminate between the two competing explanations - efficiency or anti-competitive. In any cross-section as such, it is likely that the relative strengths of the two will vary between cases, and this will be examined in future work on a case-by-case basis. Nevertheless, a preliminary screening is possible here making use of the data we have collected on the individual mergers and market shares of merging firms.

As explained earlier, such data are available for 72 of the mergers in 64 of the cartels.[27] In order not to attach undue reliance on market share estimates of smaller firms, we employ a simple dichotomy: distinguishing the two largest, 'leading', firms from the others for each of these cartels. Using information only on the shares of the two leaders (S_1 and S_2), three types of market structure can be distinguished:

- If $S_1 > 0.5$ 'single dominance' (SD)

[26] In a slightly modified set of models we controlled for the ordering of susequent mergers by including a covariate counting the number of previous mergers. Estimates remain in the same region. These results are available on request from the authors.

[27] In addition to the mergers for which we have no market share data, we also exclude 29 mergers for which closer investigation reveals that there was no direct impact on market shares in the cartel markets as precisely defined by the EC. This reflects a feature of how the data for the merger database was collected – we identified all mergers between previous members of a given cartel, where the merger occurred within the NACE industry to which the cartel market belonged. However, often the cartel market, as identified by EC, was more disaggregated than the NACE industry to which it belongs. Thus these 29 mergers (or joint ventures/transfers of assets) were confined to the firms' activities in another country/product line than the specific market in which the cartel was detected. These are excluded for present purposes but merit attention in future research - on the possibility that the EC may have defined the cartel's product market or geographic reach too narrowly, or lacked hard evidence that the cartel had a wider reach.

- If $S_1 < 0.5$ but $S_1 + S_2 > 0.5$, 'collective dominance' (CD)
- If $S_1 + S_2 < 0.5$, 'no dominance' (ND)

This typology corresponds broadly with traditional definitions of market dominance often used in the competition policy literature.

Tables 3 and 4 report the frequencies of merger by firm types, and cartels by market structures respectively, and they provide the following four descriptive insights.

Table 3: Participants in mergers by market share

		Larger firm in merger		
		Leading firm*	Others**	Total
Other firm in merger	Leading firm	7 (2)		
	Others	36 (29)	29 (41)	65 (70)
	Total	43 (31)		

Figures in parentheses are expectations on the null that there is no association between firm identity and propensity to merge, using the mean number of leaders (2) and others (6.3) per cartel.

Finding 1: *Leading firms are disproportionately more involved in mergers.*

According to the efficiency explanation, we would expect most exit by acquisition to involve marginal firms, and if merger control deters large firms from merger, we would expect few to involve leaders. However, assuming that 'marginal' firms are typically from the 'other' group, the results in Table 3 offer little support for these expectations. There were 7 mergers between the two leaders in a previous cartel; and where one of the parties was an 'other', more often than not its partner was a leader rather than another 'other' (36 compared to 29). More formally, if these observed frequencies are compared with expectations based on a null hypothesis of no association between firm type and propensity to merge, the null is rejected at the 0.05 level.

Finding 2: *Most markets include dominant firms at the time of breakdown.*

Table 4 reveals that in 60% (39/64) of the cartel markets, there was dominance by either the leading (SD) or, more often, the two leading firms (CD) at the date of breakdown. This is unsurprising - cartelised markets tend to be concentrated - but it nevertheless highlights that mergers in markets such as this would usually attract the attention of competition agencies - even without knowledge of any prior cartel activity.

Table 4: Mergers by market structure, and their impact

			Structure after mergers		
Structure at breakdown	Number of cartels	Number of cartels with mergers	SD	CD	ND
SD	6	1	6		
CD	33	11	1	32	
ND	25	20		8	17
total	64	32	7	40	17

Finding 3: *Mergers are less frequent in markets with dominant firms, but nevertheless still occur in 30% of such cases.*

There were mergers in 80% of the ND markets, but in only 33% of the CD markets, and 1 SD market (Table 4 column 2). This is consistent with the results on concentration from the survival analysis, and is broadly consistent with the deterrence expectation. Nevertheless, there were mergers in 12 of the markets with already dominant firms, and close CA scrutiny would be expected in those cases.

Finding 4: *Mixed evidence on the likely impact on market structure.*

The last three columns of Table 4 are in transition matrix form, showing how the mergers would impact on the structure of the market, if not intervened by the CA.[28]

[28] Post-merger market shares and structures are computed following conventional CA practice

(In those markets where there was more than one merger, this is their cumulated effect.)

As already noted there were mergers in 20 of the 25 markets which were ND at the time of breakdown. Of these in 12 the impact was insufficient to create dominant firms, but in 8 the effect would be to move the market to collective dominance. It is these 8 markets which, at least potentially, correspond to the anti-competitive explanation of merger activity, and which conflict with the expectation that the threat of CA intervention will be sufficient to deter such mergers.[29]

6 The response from competition authorities

It is not the primary purpose of the current paper to exhaustively evaluate the EC's merger control subsequent to cartel investigation, but both Findings 3 and 4 would lead us to expect considerable CA merger control activity in a number of markets (those involving already dominant firms or creating dominance.) Therefore, we have identified how many mergers were actually investigated by the Commission, and what were its decisions (Table 5).

In fact, only half (41) of the 83 mergers for which we have sufficient market share data were investigated by the EC or a national CA[30]. Of these, most (34) were cleared without remedies, and of the 7 where remedies were agreed, only 1 had any impact on the cartel market, whilst the other 6 only impacted on the parties' activities in other markets.

The table reveals that this relative inactivity is largely explicable by the 'small'

in merger investigations - the market share of a newly merged firm is assumed to be the combined shares of the two merging parties. This is subject to two obvious qualifications: (i) most oligopoly theory suggests that following merger, any nearly merged firm will raise price and contract scale rather than maintain it at the combined pre-merging scales of the parties, (ii) we abstract from any other changes in market structure which are independent of the merger.

[29]The Table also shows that there is one market in which there was already CD, but mergers would increase the share of the larger leader, such that it would become SD.

[30]For this part of the analysis, we also include 13 cement mergers. These were excluded from previous Tables, because we were unable to estimate the market shares for all firms, and therefore the cartel HHI. However, we do know the shares of the merging parties, and this is sufficient to compute the change in HHI.

Table 5: Merger investigations by the EC

			$\Delta HHI > 250$	$\Delta HHI < 250$
Total mergers		83	21	62
Investigated		41	11	30
by EC		25		
of which:	cleared	18	3	15
	remedied	7	4	3
by national CA		16		
of which:	cleared	16	4	12
	remedied	0		
Uninvestigated		42	10	32
of which:	below turnover threshold	36	10	26
	no turnover information	6		6

size of most of the mergers. Nearly all, or perhaps all[31] of the 42 un-investigated mergers involved a turnover below the EC's minimum disclosure threshold, and in 30 of the 41 cases which were investigated, the increase in concentration implied by the merger would have been lower than the level identified in the EC's merger guidelines as significant (ΔHHI<250).[32]

These findings are at least superficially encouraging (for the CAs), but they seem to be inconsistent with findings 3 and 4. However, the explanation becomes clear by focusing on 8 markets in which mergers introduced collective dominance where previously it was absent, and one where single dominance replaced collective dominance (Table 6).

Here, intervention was indeed minimal: of the 24 mergers, only 7 were investigated and only 1 required a remedy. However, as can be seen, these were multi-merger markets (on average 2.67 per market), and the changes in structure recorded in Table 4 reflect the combined effect of all mergers in each market. While all 17

[31] In Table 5, we have been unable to identify the aggregate turnovers of the parties in 6 mergers, and it is likely that none of these was 'large'; if so, all 42 un-investigated mergers were below the EC turnover threshold.

[32] Computed from our estimates of the market shares of the merging parties.

Table 6: Cartels in which mergers moved the market towards collective dominance

Cartel	Mergers	Investigated	Outcome	Uninvestigated	Below turnover threshold	$\Delta HHI < 250$
Copper Fittings	3	0		3	3	3
Industrial Thread	5	0		5	5	2
Copper Plumbing Tubes	3	1*	cleared	2	2	1
Specialty Graphite	2	0		2	2	2
Lux. Brewers	2	0		2	2	1
Carbonless Paper	1	0		1	1	0
Alloy Surcharge	2	2	cleared	0	0	0
Ferry Operators	3	2**	cleared	1	1	0
UK Tractors	3	2***	remedy	1	1	1
Total	24	7		17	17	10

* This was the last of the three mergers which triggered the move from ND to CD, but $\Delta HHI < 250$.
** This was initially picked up as an antitrust case and the EC granted exemption for the JV which it later renewed before finally approving the concentration.
*** The remedy was a large divestment (approx. 1/3 of acquired company) to new entrant.

un-investigated mergers was 'small' relative to the EC's turnover threshold, taken together their effect was to reinforce the dominance of leading firms. Moreover, in 7 of the 17, we estimate that, even when treated separately, the merger had more than a trivial impact on concentration (ΔHHI>250). This evidently occurs in those cases where the cartel market, often defined very narrowly, is small relative to the merger size threshold.

7 Conclusions and directions for further research

The main finding of this paper is a confirmation that after a cartel breaks down, typically, there is increased merger activity amongst the former cartelists. This evidence therefore reinforces the more aggregate historical evidence drawing on natural experiments of periods when cartels became prohibited. The novelty of the paper lies not so much with the headline result, but more with the application of survival curves to handle the problem that we have differing post-cartel periods for different cartels and that for some at least no mergers have yet been observed.

The increased merger activity post breakdown is most pronounced in those cartels which are detected under leniency. In that these are 'failed' cartels this might be

evidence that firms use merger to re-instate a structure which facilitates (now tacit) collusion. Similarly a disproportionately high number of acquisitions are undertaken by the leading firms.

Nevertheless, the findings of the paper could be consistent with either the efficiency explanation – cartel breakdown stiffens competition and this forces weaker firms to exit – or a collusive explanation – with the cartel option denied, firms strive for tacit collusion via merger. A more detailed look at market share changes caused by mergers suggests that both explanations might be at work in some markets, however, on balance they point towards the 'anti-competitive' explanation.

Turning to the paper's policy relevance, a cross-market study of as many different markets as this is not well-suited to definitive conclusions, and the purpose of the paper was not to conduct an exhaustive evaluation of the efficacy of EC merger control. Future in-depth case analysis will be required for that purpose.

Nevertheless, some relevant results have emerged. Of particular interest are the markets where post-breakdown merger activity is least pronounced (or even non-existent). These tend to be highly concentrated, with only a few relatively symmetric firms. This could be because second best tacit collusion is already attainable without merger. But it could be that firms in such markets are deterred from proposing mergers which they know will be blocked. However, deterrence does not seem to have been effective in the subset of markets in which mergers did occur and appear to have resulted in a structure where the leading firms emerged as dominant. In a number of the markets, mergers are relatively frequent, and, although each one might be small, they do involve the leading firms, and when taken together their combined effect is to increase dominance. Superficially at least, this tends to undermine the deterrence argument. It also points to a doubt concerning the use of size thresholds in merger control: a sequence of relatively small mergers may have a significant deadening impact on competition, even although none in itself seems significant. This possibility is particularly pronounced where the markets themselves are small – as is the case for many cartels.

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A Obtaining MLE of λ and ρ

For Model 1 the MLE of λ and ρ can be obtained following procedures on parametric censored survival models, such as Lee and Wang (2003, p.178). In previous literature we did not find derivation of the MLE of the two Weibull parameters in the two recurrent-event models used in this paper therefore we briefly report how the Model 3 estimates were obtained (Model 2 is derived analogously but time is measured by $u_s = t_s - t_{(s-1)}$).

Denote the set of estimable parameters by $\boldsymbol{\beta} = \{\lambda, \rho\}$, then the loglikelihood function is given by :

$$l_3(\boldsymbol{\beta}) = \sum\nolimits_{s\geq 1} \left\{ \begin{array}{c} r_s \ln(\rho) + r_s \rho \ln(\lambda) + \\ \sum_{j=1}^{r_s} \left[(\rho-1)\ln(t_{sj}) - (\lambda t_s)^{\rho}\right] - \sum_{j=r_s+1}^{m_s} (\lambda t_{sj}^{+})^{\rho} \end{array} \right\}$$

For $l_3(\boldsymbol{\beta})$ the MLE of λ and ρ can be obtained by solving the following two equations simultaneously:

$$\begin{aligned} \sum\nolimits_{s\geq 1} \left\{ \frac{r_s \rho}{\lambda} + \sum\nolimits_{j=1}^{r_s} \rho \lambda^{\rho-1} {t_{sj}}^{\rho} - \sum\nolimits_{j=r_s+1}^{m_s} \rho \lambda^{\rho-1} {t_{sj}^{+}}^{\rho} \right\} &= 0 \\ \sum\nolimits_{s\geq 1} \left\{ \frac{r_s}{\rho} + \sum\nolimits_{j=1}^{r_s} \ln(t_{sj}) - (\lambda t_{sj})^{\rho} \ln(\lambda t_{sj}) - \sum\nolimits_{j=r_s+1}^{m_s} (\lambda t_{sj}^{+})^{\rho} \ln(\lambda t_{sj}^{+}) \right\} &= 0 \end{aligned}$$

There is no closed solution for this system so iterative techniques a lá Newton-Raphson were used.

The 95% confidence intervals given in Table 1 were obtained using:

$$[\widehat{\lambda} - Z_{0.025}\sqrt{v_{\lambda\lambda}}, \widehat{\lambda} + Z_{0.025}\sqrt{v_{\lambda\lambda}}]$$

and

$$[\widehat{\rho} - Z_{0.025}\sqrt{v_{\rho\rho}}, \widehat{\rho} + Z_{0.025}\sqrt{v_{\rho\rho}}]$$

where $Z_{0.025}$ is the 0.975 percentile point of the standard normal distribution. $v_{\lambda\lambda}$ and $v_{\rho\rho}$ are the two diagonal elements of an adjusted covariance matrix. Lin (1994) showed that the covariance matrix given by $\mathbf{I}^{-1} = -\partial^2 l(\widehat{\boldsymbol{\beta}})/\partial\beta\partial\beta'$ does not take into account the additional correlation in the data due to the potential lack of independence among mergers in the same industry. Therefore it is not appropriate for testing or constructing confidence intervals for recurrent event data. Lin and Wei (1989) proposed dealing with this in the following way.

Divide the sample into m industries $\{G_1, G_2, ..., G_m\}$, and denote the matrix of the group efficient score residuals by $\mathbf{G}$, which has dimensions $m \times 2$ because there are m industries and 2 parameters to be estimated. Then the robust covariance matrix is given by:

$$\mathbf{V} = \mathbf{I}^{-1}\mathbf{G}'\mathbf{G}\mathbf{I}^{-1}$$

B Additional tables

Table 7: Descriptive statistics

Cartels	*Mean*	*Std. dev.*	*Min*	*Max*
no. of cartel members at breakdown	7.07	5.114	2	32
cartel duration (years)	8.32	6.42	0	34.8
coverage (cartel share of market)	0.842	0.166	0.22	1
HHI at cartel breakdown (64 cartels only)	0.292	0.136	0.078	0.844
CV at cartel breakdown (64 cartels only)	0.714	0.338	0.094	1.958
Proportions				
cartels with ringleaders	0.333			
price fixing cartels	0.819			
bid rigging cartels	0.217			
market sharing cartels	0.699			
cartels detected under leniency	0.714			
Frequencies of mergers:				
Cartels followed by				
No mergers	43			
1 merger	14			
2 mergers	8			
3 mergers	8			
4+ mergers	11			

Table 8: List of post-breakdown Mergers, Acquisitions and Joint Ventures

Cartel	Year of Merger	Firm 1 in Merger	Firm 2 in Merger
CRT Glass	2008	Asahi Glass	Schott
LCD	2008	LG Philipps	Hannstar
Airfreight	2011	KLM	Martinair
	2008	Japan Airlines	Quantas
Prestressing Steel	2005	Companhia Previdente	Italcables
	2004	Companhia Previdente	Emesa-Trefilería/Industrias Galycas
DRAM	2002	Mitsubishi	Hitachi
	2003	Infineon	Nanya
	2003	Elpida	Mitsubishi
	2003	Mitsubishi	Toshiba
	2003	Samsung	Toshiba
	2008	Micron	Inotera (Infineon/Nanya)
	2011	Hynix	Toshiba
	2013	Micron	Elpida
Power Transformers	2003	Siemens	Alstom
	2004	Areva	Alstom
	2009	Areva	Siemens
	2010	Alstom	Schneider/Areva
Removal Service	2007	Team Relocations	Arthur Pierre
Parafin Wax	2007	Eni	Exxon
	2007	Sasol	Shell
GIS	2005	Siemens	VA Tech
	2007	Mitsubishi	Areva
	2008	Schneider	Fuji
	2010	Alstom	Areva
Rubber	2006	Bayer	Dow
Hydrogen Peroxide	2001	FMC	Degussa
	2001	Degussa	Edison SpA / Ausimont
	2002	Solvay	Ausimont
	2002	Degussa	Edison SpA / Ausimont
	2003	Kemira (Polargas)	Air Liquide
	2012	Solvay	Air Liquide
Copper Fittings	2002	Aalberts	Yorkshire (IMI)
	2005	Aalberts	Pegler/Tomkins
	2006	Aalberts	Legris / Comap
Bitumen Netherlands	2002	BAM	HBG
Raw Tobacco Italy	2005	Dimon	Transcatab
MCAA	1999	Akzo	Hoechst
Industrial Thread	1999	Coats	Hicking Pentecost (Barbour)
	2000	Coats	Dollfus/Donisthorpe
	2001	Amann	Donisthorpe
	2000	Guetermann	Zwicky
	2008	Amann	Oxley

Cartel	Year of Merger	Firm 1 in Merger	Firm 2 in Merger
Copper Plumbing Tubes	2001	Outokumpu	Boliden
	2002	KME	IMI
	2002	Boliden	HME
	2003	Outokumpu	Boliden
Sorbates	2002	Daicel	Hoechst Nanning
Carbon and Graphite	1999	Schunk	Hoffmann & Co
Specialty Graphite	2002	SGL	Tokai
	2005	Carbone Lorraine	NSCC
Plasterboard	2002	Lafarge	BPB
	2002	BPB	Gyproc BeNeLux
	2011	Knauf	Lafarge
Food Flavour Enhancers	2006	Takeda	Deasang
Dutch Industrial Gases	1998	Air Liquide	BOC
	1999	Air Liquide	BOC
	2000	Air Products	AGA
	2001	Air Liquide	Messer
	2001	Air Products	Messer
	2002	Air Liquide	BOC
	2004	Air Liquide	Messer
	2007	Air Products	BOC
Austrian Banks	1999	ÖVAG	NÖ Landesbank-Hypothekenbank
	2000	BAWAG	PSK
Vitamins	2000	BASF	Takeda
	2001	Sumitomo	Aventis
	2002	Takeda	Sumitomo
Sodium Gluconate	1995	Avebe	Akzo
Luxemburg Brewers	2000	Diekirch	Les brasseries réunies (Mousel)
	2005	Nationale-Bofferding	Battin
Graphite Electrodes	2002	SGL	Tokai
German Banks	2002	Commerzbank	Dresdner Bank
	2009	Commerzbank	Dresdner Bank
Carbonless Paper	1998	AWA	Bollore
Shipping Agreements	1993	TMM	Tacomar
	1994	Senator	DSR
	1996	P&O	Nedlloyd
	1997	Hanjin	Senator
	1999	Maersk	Land-Sea Service
	2003	MISC	NOL
	2005	Maersk	P&O Nedlloyd

Cartel	Year of Merger	Firm 1 in Merger	Firm 2 in Merger
Seamless Steel Tubes	1997	Mannesmann	Vallourec
	2002	NKK	Kawasaki
	2012	Nippon Steel	Sumitomo Metal
Pre-insulated pipe	1997	Logostor	Pan Isovit
	1999	Logostor	Tarco
	2009	Logostor	Dansk Rorindustri (Starpipe)
British Sugar	2004	Napier	James Bugett
Alloy Surcharge	1996	Krupp	Acciai Speciali Terni
	2000	Krupp Thyssen	Usinor
Ferry Operators	1996	P&O	North Sea
	1998	P&O	Stena
	2002	P&O	Stena
Steel Beam	1997	Aceralia (Empresa)	Siderúrgica Aristrain
	1997	Arbed	Empresa Nacional
	1999	Thyssen	Krupp Hoesch
PVC	1997	BASF	Hoechst
	1998	Wacker	Huels
	1999	Solvay	BASF
	2000	BASF	Shell
	2002	Solvay	Montedison (Edison / Ausimont)
Cement	1990	Aalborg	Blue Circle
	1992	Italcementi	Ciments Français
	1993	Heidelberger	SA Cimenteries CBR
	1993	Heidelberger	NV-ENCI
	1994	Holderbank	Cedest
	1994	Dyckerhoff	Ciments Luxembourgeois
	1995	Unicem	Italcementi
	1995	EUROC AB	Aker A/S (Norcem)
	1996	Heracles	Halkis
	1997	Alsen-Breitenburg	Nordcement
	1999	Heidelberger	Aker / Scancem
	1999	Fratelli (Buzzi)	Unicem
	1999	Blue Circle	Heracles
	2001	Lafarge	Blue Circle
	2003	Holcim	Hispacement
	2004	Buzzi-Unicem	Dyckerhoff
	2004	Cementir	Aalborg
	2004	Irish Cement / CRH	SECIL
	2007	Heidelberger	Hanson
Carton Board	1992	Mayr-Melnhof	Laakmann Karton GmbH
	1994	Enso-Gutzeit	Tampella Española (Enso)
	1998	Stora	Enso-Gutzeit
	2001	Mayr-Melnhof	Gruber & Weber GmbH
UK Tractors	1991	Fiat	Ford New Holland
	1995	Same-Lamborghini	Deutz-Fahr
	1999	New Holland (Fiat)	Case