Probability of cartel detection in Spain: an assessment

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Abstract

The probability of cartel detection is crucial with a view to establishing dissuasive penalties. Bryant and Eckard (1991) estimated a probability of detection between 13% and 17% for the United States. Using the same approach, Combe et al. (2008) gave an estimate for Europe between 12.9% and 13.3%. This article uses the same model to estimate the probability of cartel detection in Spain, by means of the maximum likelihood method, at 10.7%. This probability represents an upper limit for the real probability of detection, as the model employed only makes it possible to estimate the probability that a cartel will terminate, without being able to differentiate whether this was due to the work of competition authorities or for other reasons.

I. Introduction

Cartels are among the most harmful anticompetitive practices for society. Cartels increase prices, reduce the quality of the products and services provided by companies, and are frequently associated with a decrease in the options available to consumers. For this reason, competition authorities attempt to detect and dismantle as many cartels as possible, and to impose dissuasive penalties on them. The aim of these penalties is to deter both the offenders themselves (specific deterrence) and other firms (general deterrence) from engaging in anticompetitive conduct.

For the penalties to fulfil their deterrent purpose, the profit which firms that are considering joining a cartel – or are already part of one – expect to obtain must be lower than the amount of the fine they expect to receive. In other words, a dissuasive fine is one which makes the formation or continuation of a cartel unprofitable, because the conduct would generate more losses than profits for the firms involved. In addition to the illicit profit deriving from the anticompetitive conduct, the other key factor that must be taken into account in determining the amount of dissuasive penalties is the probability of detection and sanction, in other words, the likelihood that competition authorities will discover the cartel and impose the appropriate penalties on the firms involved. The greater the probability of competition authorities detecting and sanctioning a cartel, the greater the anticipated profit must be for companies to decide to participate in the anticompetitive agreement, and therefore, the greater the dissuasive power of a certain amount of penalty will be. From a different point of view, for a given anticipated illicit profit, a lower probability of detection requires imposing a higher fine to achieve the same deterrent objective.

Allain et al. (2013) analysed the internal stability of cartels from a dynamic perspective, considering the stability of a cartel in a hypothetical industry in which the annual probability of detection was λ, and in which, if the cartel is detected, it will be broken up and fine F will be imposed.[1] To introduce a certain instability into the cartel, the model assumes that the profit of not fulfilling agreements is slightly greater than the profit of fulfilling them. In addition, it is assumed that the profit of belonging to a cartel is greater than that associated with a competitive situation. Lastly, it is assumed that it is enough for a single firm within the industry to decide not to participate or to leave the cartel for the others to adopt a competitive strategy going forward. Based on this model, the authors conclude that the sufficient condition for fine F to have a deterrent effect from a dynamic perspective ('dynamic deterrence fine', DDF) is the following:

$$F \geq \frac{\Delta\pi}{\lambda} \equiv DDF$$

where $\Delta\pi$ is the annual illicit profit derived from belonging to the cartel.

Therefore, a fine greater than or equal to the DDF will be sufficient for at least some of the firms in the sector to decide to stop participating in the cartel agreements, thus dismantling the anticompetitive agreement. According to the above expression, a deterrent penalty will be at least equal to the annual illicit profit multiplied by the inverse of the annual probability of detection. For example, for an annual probability of detection of 20% (λ = 0.2), the fine would have to be at least five times ($1/\lambda = 1/0.2 = 5$) the annual illicit profit in order to be deterrent; for a probability of 50% (λ = 0.5), the fine would have to be at least double the annual illicit profit.

The above paragraphs show how important probability of detection is to imposing optimal or dissuasive fines. Therefore, it is a parameter of significant interest for competition authorities. This article seeks to estimate the probability of cartel detection in Spain. The aim is to provide Spanish competition authorities – both the CNMC and autonomous community authorities with decision-making powers – with a numerical benchmark that might be useful with a view to setting dissuasive penalties. Our study will also be useful for anyone trying

[1] Both the probability of detection and the fine are assumed to be constant over time.

to evaluate the deterrent nature, or lack thereof, of the competition penalties imposed in Spain.

Despite the importance of estimating the probability of detection for competition authorities, papers that have attempted to estimate this parameter are relatively scarce. The first article related to the probability of detection was produced by Bryant and Eckard (1991). Using data for 1961 to 1988, these authors estimated that the probability of competition authorities in the United States detecting a price-fixing agreement in a given year was between 13% and 17%. Their article was based on the idea that, if the distribution of the duration of known cartels is characterised by the presence of many cartels with a short duration and few cartels with a long duration, the probability of detection should be high and the number of active cartels low, and vice versa. The article proposes a statistical model which describes the creation, termination/detection, and duration of price-fixing agreements, and uses a maximum likelihood method to estimate the model's parameters. These parameters are then used in turn to obtain an estimate of the number of active cartels and the probability of these being detected at any given time.

Combe et al. (2008) followed the model proposed by Bryant and Eckard. Using data for cartels detected between 1969 and 2007 in the European Union, Combe et al. (2008) estimated that the probability of detection for a cartel in a particular year was between 12.9% and 13.2%. However, these authors pointed out that the probability of detection estimated according to this method was, in reality, the probability of detection conditional on the cartels being detected. In other words, it is the probability of detection estimated based on those cartels which had previously been detected. Therefore, that estimate should be interpreted as the upper limit of the probability of detection for cartelised companies as a whole. Additionally, they concluded that there is a positive relationship between the probability of detection based on the cartels detected, and the probability of detection for cartels as a whole. In other words, when the probability of detection based on the cartels detected increases, so too does the probability of detection for all cartels.

Ormosi (2014) proposed an alternative method for estimating the probability of detection. Given that the above-mentioned articles offered constant probabilities of detection, and could not therefore be used to estimate variation over a period, this author set out to estimate how the probability of detection had varied over time. To this end, he decided to use a method based on capture–recapture analysis, frequently utilised in ecology and epidemiology studies. The simplest approach to this type of analysis estimates the population size of a species by taking two random samples from the same population. The specimens captured in the first sample are marked and then returned to mix with the rest of the population. If the population does not change between the two samples, and the probability of capturing any given individual within the population is constant, then the quotient between the marked elements and the total elements present in the second sample would be an unbiased estimator of the ratio between the marked population and the total population. Furthermore, the proportion of recaptured animals can be used to make inferences regarding parameters of the population, such as its size and the probability of capture and/or survival.

There are two types of capture–recapture models. Some assume that the population does not vary, that is, that the number of individuals does not change with birth, death or migration; others assume that the population varies. There is a significant restriction to the latter models, as estimates are based solely on recaptured individuals, that is, on specimens that have already been marked previously and have been captured again. The models which assume that the population varies use maximum likelihood methods to estimate the probability of capture and survival, but they cannot be used to estimate the size of the population.

Therefore, Ormosi proposed using capture–recapture models in which it is assumed that the population varies to calculate the probability of cartel detection. This author asserts that something similar to what happens with animals also applies to firms. Competition authorities collect samples from the firm population, indicate which companies are participating in a cartel, and the firms ‘return’ to the marketplace (continue operating within it) when the investigation has concluded. Subsequently, another sample of firms is drawn in which some firms are new and others have been ‘captured’ on previous occasions. Thus, the probability of a cartel being detected will be equal to the probability of its being recaptured, whether due to a leniency application, a complaint or an ex officio investigation. The probability of surviving is an apparent probability of survival, as the investigators are not able to differentiate between whether a firm that has only been captured once is not recaptured because it has terminated, because it does not form part of a cartel again or because it becomes part of the population of cartels which are not captured. Ormosi’s model, unlike previous models, is based on an analysis by firm and not by cartel.

As the number of cases on which this method is based is limited, it is a relatively simple model to use and requires a small number of data. Despite its advantages, it continues to suffer from one of the limitations that burdened the Bryant and Eckard model, as the probability obtained based on the detected cartels can only be interpreted as an upper limit of the total probability of detection. By applying this model to the cartels detected by the European Commission, Ormosi concludes that during the 1985–2009 period, the probability of detection is likely to have fluctuated regularly between 10% and 20%, with values outside this interval at isolated times. Another of his conclusions is that collaboration between European and American authorities would have increased the probability of detection more than the introduction of leniency programmes.

Unlike previous papers, Park et al. (2018) estimate the probability of sanction, understood as the probability of detection and sanction, faced by companies that participate in a cartel. The article considers that it is not realistic to assume that any detected cartel will be penalised, as Bryant and Eckard (1991) and Combe et al. (2008) do, as some cartelised companies do not receive a penalty (for example, because they are granted leniency). Furthermore, it considers that Bryant and Eckard do not consider the unobservable cartel population, and criticises, like Ormosi (2014), that the annual probabilities estimated in those articles are constant. In relation to Ormosi's article, Park et al. (2018) consider that it uses two suppositions that are not reasonable. Firstly, capture–recapture models assume that temporary migrations between two states (collusion–competition) do not exist. Secondly, as the results of the article are based on three- or five-year moving averages, the estimate of the annual probability would produce results that could not be accurate due to lack of data. Given that according to these authors, the market would immediately react to changes in competition policy, it would be necessary to estimate the probability of detection and sanction with reference to the shortest possible time period.

Based on the above-mentioned considerations, Park et al. (2018) estimate the probability of sanction using a Bayesian model. They also evaluate the impact of leniency programmes as a tool of competition policy. They establish a Bayesian probability model whose average probability will be the probability of sanction, and this probability would vary over time. Using data from the U.S. Department of Justice, they conclude that the probability of sanction for the 1970–2009 period was between 9% and 23%, and they show that this probability will have increased over the time period analysed. They also conclude that leniency programmes increase the probability of detection.

Lastly, it is worth mentioning the article by Harrington and Wei (2017). Although these authors' aim was not to estimate the probability of detection, they analysed whether probability of detection and cartel duration, estimated from the number of cartels detected, could be considered a reliable approximation of the probability of detection and duration for the whole population of cartels. Therefore, their analysis is relevant for proper interpretation of the results. One of the most important points made by these authors is to highlight that the probabilities of detection calculated to date in other papers do not make it possible to distinguish between a cartel's probability of detection and the probability of a cartel breaking up without the intervention of competition authorities. For this reason, it would not be possible to infer how many cartels avoid detection, because not all of those which have avoided detection would continue operating.

Firstly, the article asserts that if all cartels were created and terminated according to the same process, then the sample of detected cartels would be a representative sample of the cartel population. This would mean that the average duration of the cartels detected would be an unbiased measure of the average duration of all cartels, and the probability of termination (due to detection or because they break up without external intervention) for the detected cartels is also an unbiased measure of the probability of termination for all cartels. They also highlight that, as it is not possible to discern between the probability of cartels being detected and the probability that they will break up on their own, the estimate of a cartel's probability of termination based on its duration must be understood as an upper limit of the probability of a cartel being detected and penalised.

Given that it is not realistic to assume that all cartels follow the same process of creation and termination, the authors analyse the effect of assuming that these processes vary between one cartel and another. The conclusion they reach is that there is a bias when the estimate of the probability of termination based on the cartels detected is used to approximate the probability of termination for the entire cartel population. This bias is linked to the relationship between variation in the probability that they will break up on their own and variation in the probability of detection, both variations referring to that which exists between the different cartels. Thus, if the variation between cartels of the probability that they will break up on their own is large in comparison with the variation in the probability of detection, then the estimate of cartel duration based on those detected would be biased upward. In contrast, if the variation between cartels of the probability that they will break up without outside intervention is small in relation to the variation in the probability of detection, then the estimate of average cartel duration based on those detected is biased downward.

According to the theoretical model constructed, Harrington and Wei (2017) estimated that the average duration of detected cartels might lead to overestimating the average duration of all cartels by up to 10%, or might underestimate it by up to 15%. Lastly, and although this was not the main aim of the article, they calculated that a cartel created between 1960 and 1985 would have a 17% probability of being terminated in a given year, whether due to detection or without outside intervention.

The rest of this paper is arranged as follows: section two describes the model and the data used to estimate the probability of detection; section three describes how the probability of detection was estimated in Spain and shows the results obtained; finally, section four concludes by highlighting the main ideas and suggesting future lines of research.

II. Model and data

The aim of this paper is to obtain a preliminary estimate of the probability of detection in Spain. In order to do so, we will apply the same model proposed by Bryant and Eckard. As explained, this is a preliminary model which was used to estimate the annual probability of detection, although it has some weaknesses highlighted by the subsequent literature. One of these is that the probability obtained is a constant probability, meaning that it is not possible to analyse its variation over time. Additionally, the probability of detection estimated based on the cartels detected should not be used to approximate the overall probability of detection without taking into account the bias that this entails. Lastly, in line with the comments in the previous section, the probability estimated using the Bryant and Eckard model is the probability of termination, without it being possible to distinguish between the probability of detection and that of cartels breaking up on their own. Therefore, the probabilities of detection obtained must rather be understood as an upper limit for the actual probability of detection.

Despite its deficiencies, we have decided to use the Bryant and Eckard model because their work in this area has had the greatest impact to date. Using the same model will enable us to compare our results with those published in several important papers, which provides a useful point of reference. In any case, given that our aim is limited to offering an initial estimate of the probability of cartel detection in Spain, a natural evolution of our work would be to try to improve the estimates using models that do not have the same limitations. Below, we describe the model proposed, as well as the data used to produce the estimates.

i. Description of the model

As stated, the model we have used is that proposed by Bryant and Eckard (1991). These authors put forward a 'birth and death' model to explain the dynamics by which there are a certain number of cartels alive *N(t)* at a given point in time *t*. We consider two processes which determine *N(t)*: one process which describes the formation of cartels, where the probability of a cartel being formed at a given point in time is θ, and one process which describes their termination, where the probability of a cartel terminating at a point in time is λ. The model assumes that the termination of a cartel occurs with its detection and dismantling: when a cartel is detected, a fine is imposed and it terminates.

It is necessary to highlight that, in this model, λ is equal to the probability of detection, conditional on the cartel being detected. According to Combe et al. (2008), the overall probability of detection would be less than λ. If this were true, the probability of detection conditional on the cartel being detected would represent an upper limit to the probability of detection for the total cartel population. Despite this, it seems logical to assume that firms will take λ (the probability of detection conditional on detection of the cartel) into account, as they can estimate it, rather than the overall probability of detection, which they do not know. Therefore, estimating λ remains useful for competition authorities, although it is necessary to interpret the result appropriately.

In the process which describes the emergence of cartels, it is assumed that they form at random and successively. The period between the birth of one cartel $i - 1$ and the emergence of the following cartel *i* is termed A_i. It is assumed that the periods of time which pass until the emergence of a new cartel are distributed exponentially with a mean of $1/\theta$, which is the average time that passes until a new cartel is created.

In the process which describes the termination of cartels, we have already indicated that the model assumes that detection is the sole cause of the cartels' termination. Therefore, the duration of the cartel and the time necessary to detect it are the same. It is assumed that the duration of a cartel L_i is also distributed exponentially with a mean of $1/\lambda$, which is the average duration of the cartels, or equally in this model, the average time it takes to detect them.

Furthermore, it is assumed that the distributions of the cartel emergence and detection times are independent. To accept that the formation and duration of the cartels are distributed independently entails assuming that the detection of a cartel does not increase or decrease the probability that another will emerge, and that the emergence of a new cartel will have no implications for the greater or lesser probability of detection for those already in existence. This supposition seems reasonable, given that cartels are created for a range of reasons that are not necessarily related to the factors which determine their duration.

The independent distribution also implies that a cartel's probability of detection at a given time, assuming that it has not been detected during the previous period, is independent of its duration up to that point. However, it should be clarified that the *cumulative* probability of a cartel being detected increases over time, given that it is equal to the probability that it has not been detected during any of the previous periods.

According to the model used, at time point t there will be $N(t)$ active cartels which could be detected, although as competition authorities have limited resources, only N_{max} cartels can be investigated simultaneously. The model assumes that the creation and termination process for the cartels has reached a steady state. Therefore, the initial conditions (time point T_0 when the cartel creation process began) do not affect the results. Under these conditions, starting from the 'birth and death' processes described above, and applying the maximum likelihood method, it is possible to deduce that the number of active cartels at a given time $N(t)$ follows a Poisson distribution with a mean of θ/λ. As it has been assumed that a steady state has been reached, these two parameters do not vary over time.

If the model is adapted to the available data, estimating its two fundamental parameters will enable us to obtain an approximate value for the probability of emergence, and especially, the probability of cartel detection at a given time.

ii. Data used

For the estimates based on the model described in the previous section, we will be using data from cartel cases investigated and decided by the National Commission for Competition (CNC according to the Spanish name) or the National Commission for Markets and Competition (CNMC) between 2011 and 2018. During this period, 145 cases were investigated and resolved. The necessary data were gathered to identify these cases. These variables were (i) the year the case was decided by the competition authority, (ii) the name of the case, (iii) the reference code assigned to each case by the authorities, (iv) the type of infringement investigated in each case, and (v) whether or not it is a cartel.

The majority of these cases consist in investigations relating to either infringements of article 1 of Act 15/2007, of Defence of Competition (LDC according to the Spanish name), or infringements of article 2 of the LDC. Just three cases simultaneously involved infringements of articles 1 and 2 of the LDC. Given that the model is built to analyse the probability of cartel detection, all of those cases related only to infringements of article 2 of the LDC were discarded.

Once we discarded those cases, we had 122 observations related to infringements of article 1 of the LDC. However, these cases include both cartels and other horizontal agreements between competitors, as well as anticompetitive vertical agreements. As our aim is to estimate the probability of cartel detection, all those cases not related to cartels were also excluded. From 2011 to 2018, 70 cases relating to cartels were investigated and decided by the Spanish competition authority.

For each of the 70 cases used, we obtained the necessary data to estimate the model presented in the previous section, which are the start and end dates of the sanctioned cartels. These dates are the essential variables for calculating the probability of detection, as this is primarily estimated based on the distribution of the durations of the cartels detected. The cases and associated data used to estimate the model are shown in Appendix 1.

The duration of the cartels was computed as the difference in days from the start of the cartel until it terminated. The start date of the cartel corresponds to the date which was confirmed as the start date of the cartel during the investigation. When the cartel is made up of more than one company, the start date may not be the same for all of them, as some may have joined the cartel after it had already formed. In such cases, the earliest date found in the case file was considered the start date. In other words, we used the overall duration of the cartel, rather than the specific duration of the infringement for each one of the companies involved.

In some cases, the start date appears as an exact date (including day, month and year), but when this is not the case, we approximated the start date as the first day of the month, if the month is known, or the first day of the year, if only the year when the cartel was formed is known. Finally, the end date of the cartel is the date given in the case file as the end of the agreements. This date corresponds to that on which the first inspections were carried out at the firms, as it is assumed that on being investigated, the firms stopped engaging in the criminal activity. There may be situations in which the firms continue to participate in the cartel even after being detected by the competition authorities, but this uncommon possibility was not taken into account in the model.

The start date is not known for certain, because it is determined from the evidence gathered by the competition authorities, and there may be cases in which it was not possible to gather the oldest evidence. In addition, the cartels may continue to operate, as we have seen, even after the investigations are initiated. Therefore, the computed durations may be shorter than the actual durations of the infringements.

Lastly, although other articles that use the Bryant and Eckard model (1991) computed two different sets of durations for the cartels, we decided to use a single set of durations. In the other articles, two durations were established to solve the problem related to the lack of precision with regard to knowledge of the start date. Thus, when a case file indicated that the violation had begun in a given year, they calculated one duration with the start date as 1st January, and another duration with the start date as 31st December. In this paper, we decided to use a single set of durations corresponding to a single start date for each cartel. The reason for this is that in our database there are very few instances in which only the start year is known, which would be the case when the differences between the two sets of durations would be more significant. We usually know at least the month and year when the infringement began, so that the greatest difference in duration that might occur would be that existing between the start and end of a month. Therefore, the two measurements of duration would provide very similar estimates, and that would translate into very close estimates for the probabilities of detection. In fact, that is precisely what happens in the paper by Combe et al. (2008), where the two durations they use are so alike that they offer very similar estimates of the probability of detection.

Table 3 summarises the main descriptive statistics for the durations and emergence time in years calculated for the Spanish cartels detected: mean, median, minimum and maximum duration, and standard deviation. Along with these indicators, we have determined the frequency distribution for the duration of Spanish cartels, which is shown in Appendix 2.

Table 3: Main descriptive statistics for the duration and emergence time of cartels detected in Spain (2011–2018)

	Mean	Median	Minimum	Maximum	Standard deviation
Duration (years)	9.4	7.8	0.2	34.0	7.6
Emergence time (years)	0.52	0.17	0.01	4.84	0.91

As the above table shows, the average duration of Spanish cartels is 9.4 years. If we compare the average duration of Spanish cartels with the average duration of American and international cartels, we find that the duration of Spanish cartels is significantly higher. Thus, Bryant and Eckard (1991) estimated that the average duration of cartels in the United States was between 5.2 and 7.3 years, while Combe et al. (2008) estimated that the average duration of European cartels was between 7.5 and 7.8 years. The shortest cartel found in Spain lasted 69 days (the 0.2 years in the table), while the longest cartel operated for 34 years.

Bryant and Eckard (1991) also indicated that a new cartel formed in the United States every 54 days, while Combe et al. (2008) estimated that this happened in Europe every 50 days. This means that the emergence of new cartels would be slower in Spain, as here an average of 190 days pass before a new cartel emerges.

Despite the fact that the average cartel duration is almost two years more than the highest obtained in other papers, there are more observations below the mean than above it, which is reflected in the fact that the median is lower than the mean, and it is in fact equal to the longest mean duration in the other articles published. Therefore, the average duration is significantly influenced by a few extreme values, and this is also reflected in the high standard deviation.

III. Estimating the probability of detection

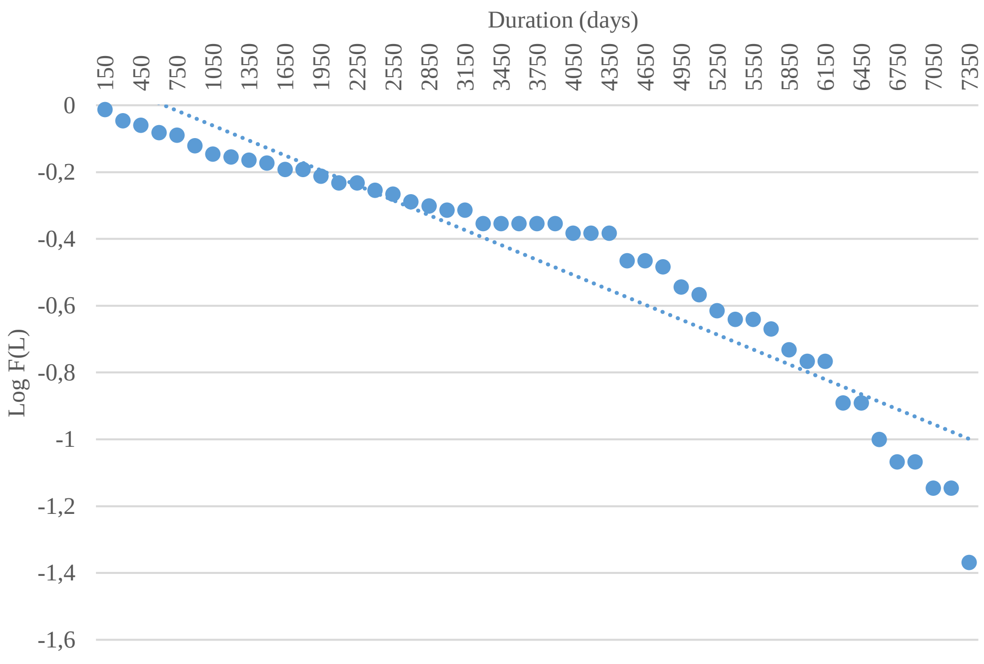
Having described the main characteristics of the data, we can now estimate the annual probability of detection in Spain. The first step requires confirming that the observations required to estimate the theoretical model fit the available data. To do this, we tested whether the durations of the cartels and their emergence times did in fact follow exponential distributions. Once this hypothesis is confirmed, it is possible to make a valid estimate of the probability of detection and the emergence of cartels in Spain.

First of all, we confirmed whether the supposition that cartel duration and emergence times follow an exponential distribution is valid. If cartel duration (random variable L_i) is distributed exponentially with a mean of $1/\lambda$, the distribution function must be $f(L) = 1 - \exp(-\lambda L)$. Using the durations in our database, it is possible to estimate the cumulative distribution function, which is equal to:

$$F(L) = \frac{number\ of\ observations\ \leq L}{total\ number\ of observations}$$

If cartel durations do indeed follow an exponential distribution, when plotting a graph showing the variation in the logarithm of the cumulative distribution function with regard to the durations, the resulting curve should be approximately linear. Figure 3 shows this relationship graphically, with the duration values in days.

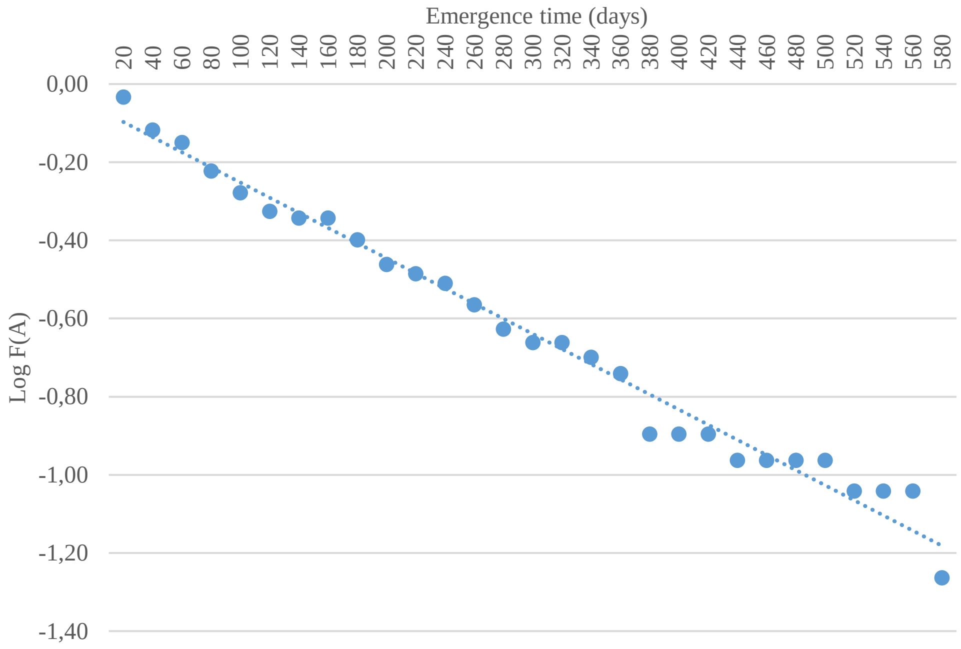
Figure 3: Relationship between cartel duration and the logarithm of the cumulative distribution function for that variable



As the above figure shows, the available data approximately confirm the supposition with regard to the exponential distribution of the cartel durations.

In the case of emergence times for cartels, the same procedure was followed. Figure 4 provides graphic confirmation that this variable also approximately follows an exponential distribution.

Figure 4: Relationship between the emergence time of cartels and the logarithm of the cumulative distribution function for that variable



Although both graphs show a linear relationship between the variables (in days) and the logarithms of the cumulative distribution function, for greater certainty, we run a regression for cartel duration and another for cartel emergence time. The regression of the logarithm of F(L) on cartel duration has an $R^2 = 0.94$; while the regression of the logarithm of F(A) on the data for time elapsed between the creation of different cartels presents an $R^2 = 0.84$. These two indicators quantitatively corroborate the conclusions drawn from the above figures.

The theoretical model, in addition to the exponential distribution of the data, assumes that the process of cartel emergence and detection begins at T_0, which is unknown. To estimate the model, a $[T_1, T_2]$ period is selected, in which the process of cartel emergence and detection will be observed, where $T_2 > T_1 > T_0$[2].

The estimate of the probability of detection will depend on the values of T_1 and T_2, which in turn depend on T_0. Therefore, in order to be able to estimate the probability of detection, it is necessary to define not only the time period of the sample, but also the time that has elapsed since the start of the process. Neither Bryant and Eckard (1991) nor Combe et al. (2008) set a specific T_0, that is, they do not decide when the process began. Rather than

[2] As the cartels which are active at both T_1 and T_2 (that is, those that do not terminate during this interval) will not be observed, the database used is a censored database.

determining the start date, they analyse when the choice of a specific date as a start date no longer influences the estimated probability of detection. Both papers indicate that for start dates prior to 1930, the choice of T_0 ceases to influence the estimated probability of detection, and they therefore conclude in each case that their T_1 (1961 and 1969, respectively) are large enough, and that the process has reached a steady state. Given that the time periods analysed in these articles begin in years significantly earlier than 2011 (our T_1), it is natural to assume that there is even more reason to believe that by the year 2011 the process would also have reached a steady state.

Having verified that the data fit the hypothesis that underpin the theoretical model, the next step was to estimate the probability that a cartel will be detected (λ) and the probability that a new cartel will emerge (θ). We estimated these two parameters using the maximum likelihood method.[3] Table 4 shows the results of the estimate.

Table 4: Estimate of the probability of detection and emergence of cartels

	Probability of detection (λ)	**Probability of a cartel emerging (θ)**
Days	0.00029	0.01
Years	0.107	1.92

The above table shows that the probability of a cartel being detected in Spain in a given year is 10.7%. As we saw earlier, Bryant and Eckard (1991) estimated that the annual probability of detection for cartels in the United States was between 13% and 17%, while Combe et al. (2008) estimated that the annual probability of detection was between 12.9% and 13.2% for European cartels. Ormosi (2014) estimated the annual probability of detection for European cartels, although he used a different model, and concluded that this probability was normally between 10% and 20%, with occasional values outside that interval. Also with a different model to the one we used in this paper, Park et al. (2018) estimated that the probability of a cartel being detected in the United States was between 9% and 23%. Lastly, Harrington and Wei (2017) estimated – although that was not the aim of their paper – that the annual probability of detection in the United States was 17%. As a result, according to

[3] The probability of detection and the probability of emergence are estimated by applying the maximum likelihood method to the following function:

$$V(L_1, \dots, L_n) = \theta^n \lambda^n \exp[-\theta(T_2 - T_1)] \exp[-\lambda \textstyle\sum_{i=1}^{n} L_i] \exp(w).$$

For more details, see the appendix to Bryant and Eckard (1991).

our estimate, the annual probability of detection for cartels in Spain is in the lower range of the estimates obtained in the other articles, although only the conclusions of the first two papers are strictly comparable.

When interpreting these results, several conclusions reached by previous papers must be taken into account. Firstly, as Harrington and Wei (2017) pointed out, the probability of detection estimated is in fact the probability that a cartel will terminate for any reason. According to this, the 10.7% annual probability of detection we have estimated is rather the probability that a cartel will terminate either because it is discovered or because it breaks up without outside intervention. This means that it is an upper limit of the true probability of detection, which would in any event be lower.

Secondly, in their article, Combe et al. (2008) point out that the probability of detection calculated is in fact the probability of detection conditional on the cartel ultimately being detected. Therefore, according to the model proposed by these authors, in this case as well – although for different reasons – the 10.7% probability would be an upper limit of the true value of that probability. In other words, for these authors, the probability of detection for the cartel population as a whole would be lower than estimated.

If the above two remarks are applied simultaneously, it must be concluded that the true probability of detection for the cartel population in Spain as a whole would be significantly lower than the 10.7% estimated. This conclusion is hugely important looking ahead to the possible use Spanish competition authorities might make of this estimate of the probability of detection, as the optimal fine deriving from the value we have estimated should in any event be considered the smallest of the possible dissuasive penalties.

Lastly, another of the conclusions reached in the Harrington and Wei paper (2017) asserted that the average duration of detected cartels might lead to overestimating the average duration of all cartels by up to 10%, or might underestimate it by up to 15%. Given that the probability of detection we have estimated depends solely on cartel duration, this conclusion – should it be confirmed – would mean that the estimated value of the average probability of termination of the cartels detected would underestimate the probability of termination for the entire cartel population by up to 10%, while also possibly overestimating it by up to 15%. Therefore, if we start with a 10.7% probability of cartel termination for Spain estimated from cartels already detected, we should conclude that the probability of termination for a cartel in Spain is rather between 9.1% and 11.7%. This would mean that the estimated probability for the sample of detected cartels would not necessarily be higher than the inferred probability for the total cartel population, contrary to the conclusion reached by Combe et al. (2008) mentioned above.

As pointed out at the beginning of the article, estimating the probability of detection is of great importance for competition authorities, because it is necessary to consider this parameter in order to determine the optimal fine. It must also be considered in ex-post evaluation of the deterrent capability of the penalties imposed. If we were to accept that in Spain the annual probability of cartel termination is 10.7%, and that this is an upper limit for the probability of detection, this would mean that deterrent fines imposed by the Spanish competition authority should be at least nine times the annual illicit profit obtained by the firms that made up the cartel.[4] Therefore, these results have highly significant practical implications for competition enforcement in Spain.

IV. Conclusions and implications for competition authorities

The Bryant and Eckard article (1991) was the first to estimate the probability of cartel detection in the United States. According to their calculations, a cartel had a 13% to 17% probability of being detected by the competition authorities in a given year. Following the model proposed by these authors, Combe et al. (2008) estimated that the probability that the European competition authority would detect a cartel was lower than that estimated by the American authors, between 12.9% and 13.2%.

This article applies the same model to estimate the likelihood that a cartel would be detected in Spain. Therefore, using data of cartel cases between 2011 and 2018 decided by the Spanish competition authority, we have estimated that the annual probability of a cartel being detected in Spain is 10.7%. This probability of detection is therefore at the lower end of the estimates interval. This difference could be explained in part by the characteristics of the cartels analysed in the other two articles, as their estimates are based on larger cartels, in many cases international, while the database used in this article focuses on domestic cartels.

In any event, taking into account what Harrington and Wei (2017) assert in their article, this estimate is not so much the probability of detection as the probability that a cartel will terminate, regardless of the causes. It would therefore represent an upper limit of the real probability of detection. Despite the fact that it is an upper limit, since the real probability of

[4] The deterrent factor is the inverse of the probability of detection, or 1/0.107 = 9.36.

detection is not known, firms that consider forming a cartel will consider this percentage when making decisions. It is therefore a significant variable in any event. Furthermore, applying to our case other results obtained in the same paper by Harrington and Wei, we must conclude that the probability of termination for a cartel in Spain – due to detection or for other reasons – would rather be in the interval between 9.1% to 11.7% for the population as a whole.

Given the importance of this variable for competition authorities, it is necessary to continue this line of research in order to improve estimates of the probability of detection. Firstly, considering that the number of observations included in the database is smaller than the number of observations used in other publications, one way to increase the reliability of the estimates could be to expand the time period analysed, including penalty decisions for cartels prior to 2011. Secondly, it would be advisable to use other methods of estimating this parameter, so that it is possible to compare the results obtained, placing us in a position to evaluate whether our estimates are robust. Lastly, the analysis by Harrington and Wei (2017) would need to be replicated to confirm that their results concerning the bias in extrapolating to the entire population from the results obtained for the sample of cartels are actually applicable to the Spanish case.

V. Bibliography

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VI. Appendices

Appendix 1: Cartel cases used in the estimation of the probability of detection

Year	Case code	Case	End month	Start month
2011	S/0060/08	SINTRABI	31/12/2006	01/01/2002
2011	S/0086/08	PELUQUERIA PROFESIONAL	28/02/2008	01/11/1989
2011	S/0107/08	PLATAFORMA DISTRIBICION MEJILLON EN GALICIA	31/12/2008	01/01/1997
2011	S/0154/09	MONTESA HONDA, S.A.	31/12/2009	01/07/2008
2011	S/0159/09	UNESA Y ASOCIADOS	01/06/2009	01/01/2006
2011	S/0167/09	PRODUCTORES UVA Y MOSTO JEREZ	01/03/2009	01/04/1991
2011	S/0185/09	BOMBAS DE FLUIDOS	03/02/2009	01/11/2004
2011	S/0192/09	ASFALTOS	01/10/2009	01/02/2007
2011	S/0224/10	COLOMER	08/02/2006	01/12/2005
2011	S/0226/10	LICITACIONES CARRETERAS	31/12/2009	01/07/2008
2011	S/0241/10	NAVIERAS CEUTA -2-	01/04/2010	01/02/2008
2011	S/0251/10	ENVASES HORTOFRUTÍCOLAS	31/12/2007	01/01/1999
2011	S/0269/10	TRANSITARIOS -2-	18/11/2008	03/10/2000
2012	S/0179/09	HORMIGON Y PRODUCTOS RELACIONADOS	22/09/2009	01/06/2008
2012	S/0237/10	MOTOCICLETAS	31/10/2010	01/01/2008
2012	S/0244/10	NAVIERAS BALEARES	31/12/2011	01/01/1995
2012	S/0287/10	POSTENSADO Y GEOTECNIA	30/06/2010	01/01/1996
2012	S/0309/10	DEVIR IBERIA	30/09/2010	21/06/2010
2012	S/0317/10	MATERIAL DE ARCHIVO	31/12/2010	01/05/2005
2012	S/0318/10	EXPORTACIÓN SOBRES DE PAPEL	30/04/2011	01/11/1981
2012	S/0331/11	NAVIERAS MARRUECOS	31/12/2010	01/01/2002
2013	S/0293/10	TRANSCONT	31/03/2011	01/01/2007
2013	S/0303/10	DISTRIBUIDORES SANEAMIENTO	05/05/2011	13/02/2008
2013	S/0314/10	PUERTO VALENCIA	31/12/2011	01/01/1998
2013	S/0316/10	SOBRES DE PAPEL	31/12/2010	01/01/1977
2013	S/0329/11	ASFALTOS CANTABRIA	30/04/2011	01/03/1998
2013	S/0342/11	ESPUMA DE POLIURETANO	16/02/2011	23/01/1992
2013	S/0343/11	MANIPULADO DE PAPEL	31/12/2011	01/01/1995
2013	S/0376/11	PANADERIAS PAMPLONA	31/01/2012	01/02/2011
2013	S/0378/11	DESMONTADORAS DE ALGODÓN	01/12/2012	01/01/2004
2013	S/0380/11	COCHES DE ALQUILER	31/10/2011	01/05/2005
2013	S/0383/11	TRANSPORTE SANITARIO CONQUENSE	31/12/2012	01/01/2008
2013	S/0385/11	CAMPEZO CONSTRUCCION	31/12/2009	25/06/2009
2013	S/0397/12	TRANSPORTES MADRID	31/05/2011	31/12/2010
2013	S/0424/12	NOTARIA DE CEUTA	31/12/2012	01/04/2002
2014	S/0404/12	SERVICIOS COMERCIALES AENA	05/09/2012	19/04/1996
2014	S/0423/12	MUNTERS	31/12/2011	01/01/2010
2014	S/0428/12	PALÉS	30/11/2011	01/07/1998
2014	S/0430/12	RECOGIDA DE PAPEL	31/12/2013	01/11/2007

2014	S/0453/12	RODAMIENTOS FERROVIARIOS	31/12/2011	24/06/2004
2015	S/0425/12	INDUSTRIAS LACTEAS 2	31/12/2013	02/01/2000
2015	S/0429/12	RESIDUOS	31/12/2013	01/01/1994
2015	S/0454/12	TRANSPORTE FRIGORÍFICO	31/12/2012	01/04/1993
2015	S/0469/13	FABRICANTES DE PAPEL Y DE CARTÓN ONDULADO	31/12/2013	01/01/2002
2015	S/0471/13	CONCESIONARIOS AUDI/SEAT/VW	01/06/2013	01/05/2006
2015	S/0473/13	POSTES DE HORMIGÓN	11/06/2013	01/07/1985
2015	S/0474/13	PRECIOS COMBUSTIBLES AUTOMOCIÓN	31/01/2013	01/01/2011
2015	S/0481/13	CONTRUCCIONES MODULARES	30/06/2013	01/01/2008
2015	S/0482/13	FABRICANTES AUTOMÓVILES	31/08/2013	01/02/2000
2015	S/0484/13	REDES ABANDERADAS	30/06/2013	04/12/2012
2015	S/0486/13	CONCESIONARIOS TOYOTA	01/06/2013	01/11/2012
2015	S/0487/13	CONCESIONARIOS LAND ROVER	01/06/2013	01/01/2011
2015	S/0488/13	CONCESIONARIOS HYUNDAI	01/06/2013	01/09/2012
2015	S/0489/13	CONCESIONARIOS OPEL	30/06/2013	01/01/2011
2015	S/0517/14	BODEGAS JOSÉ ESTÉVEZ	16/07/2008	09/11/2001
2016	S/0455/12	GRUPOS DE GESTIÓN	06/10/2011	19/06/1999
2016	S/DC/0504/14	AIO	01/01/2014	01/12/1996
2016	S/DC/0505/14	CONCESIONARIOS CHEVROLET	01/01/2012	01/01/2011
2016	S/DC/0506/14	CONCESIONARIOS VOLVO	01/12/2011	01/10/2009
2016	S/DC/0519/14	INFRAESTRUCTURAS FERROVIARIAS	07/10/2014	01/07/1999
2016	S/DC/0525/14	CEMENTOS	31/12/2014	01/01/1999
2016	S/DC/0538/14	SERVICIOS FOTOGRÁFICOS	28/02/2015	01/09/2001
2016	S/DC/0544/14	MUDANZAS INTERNACIONALES	06/11/2014	01/01/1997
2016	S/DC/0555/15	PROSEGUR - LOOMIS	02/03/2015	01/01/2008
2017	S/DC/0512/14	TRANSPORTE BALEAR DE VIAJEROS	31/12/2016	01/10/2004
2017	S/DC/0545/15	HORMIGONES DE ASTURIAS	31/12/2014	01/01/1999
2017	S/DC/0562/15	CABLES BT/MT	30/06/2015	01/06/2002
2018	S/DC/0565/15	LICITACIONES INFORMÁTICAS	27/10/2015	01/01/2005
2018	S/DC/0569/15	BATERIAS DE AUTOMOCION	31/01/2012	01/04/2008
2018	S/DC/0578/16	MENSAJERIA Y PAQUETERIA EMPRESARIAL	31/12/2016	04/01/2005

Appendix 2: Frequency distribution of cartel duration

Interval (years)	Frequency
0–2	13
2–4	10
4–6	6
6–8	6
8–10	4
10–12	3
12–14	9
14–16	4
16–18	8
18–20	3
> 20 years	4
Sample size	70