



Who Blows the Whistle on Cartels? Finding the Leniency Applicant at the European Commission

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Abstract

Competition authorities need a better understanding of the determinants of cartel self-reporting in order to increase cartel members' incentives to apply for the benefit from leniency programs and thus improve the effectiveness of anti-cartel policy. Using information on 683 firm groups that participated in 132 cartels that were penalized by the European Commission between 1996 and 2020, we estimate which type of cartel member is most likely to be the first or subsequent leniency applicant. Our results emphasize the role of firm groups as a driver to self-report: The higher is the proportion of firms that are part of the same group (relative to the size of the cartel), the greater is the likelihood of applying for leniency. Fines also incentivize cartelists—with the exceptions of ringleaders—to self-report. While ringleaders or instigators tend to avoid being first confessors, they appear to be more likely to self-report than are others only after someone else has revealed the cartel. Finally, cartels that do bid-rigging are less likely to be uncovered by a leniency application.

Keywords Cartels · European Commission · Leniency Programs

JEL Classification D22 · K21 · L4

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1 Introduction

Cartels comprise one of the most damaging restraints on competition for consumers and the economy in general. However, the highly covert and secret nature of these anticompetitive practices makes their detection, investigation, and prosecution very difficult for the authorities concerned (Werden, 2009). Modern anti-cartel enforcement has introduced mechanisms that are aimed at changing the structure of incentives that are at the heart of cartel behavior.

Leniency programs are an effective mechanism to fight cartels. In addition to the ability of leniency programs to obtain evidence of cartels that were previously hidden from the antitrust authorities, leniency programs also provide advantages in terms of saving resources that would normally be used to detect and prove the existence of cartels.¹

The success that has been achieved by these programs in identifying cartels—as well as their potential deterrent effects against the creation of new ones—has promoted their rapid implementation in most jurisdictions around the world and increased the effectiveness of antitrust policies (Borrell et al., 2014). According to Ordóñez-de-Haro et al. (2018), the introduction of the leniency program in 1996 was the main turning point of the European Commission's anti-cartel policy that led to a significant improvement in its effectiveness and the expansion of the EU cartel policy domain. The subsequent versions of the program in 2002 and 2006 have sought to increase the effectiveness of the EC competition policy to combat cartels.

The academic literature has focused on explaining the keys to the success of leniency programs, as well as their potential drawbacks. Indeed, there is an extensive theoretical as well as empirical and experimental economic literature on the mechanisms that underlie their operation (see Marvão & Spagnolo, 2015, 2018, for a review of this topic).

We are particularly interested in analyzing which variables drive cartels members to apply for the benefits of the leniency program.² A better understanding of these variables would provide competition authorities with relevant information to target their investigations on those companies that—if they were involved in a cartel—are more likely to apply for leniency. Greater scrutiny and pressure on these types of firms would most likely increase the effectiveness of the leniency programs by encouraging confessions.

Our study is closely related to the studies of Brenner (2011), Marvão (2014), Koh and Jeong (2014), Hoang et al. (2014), Kim and Kim (2016), and Rosenboom

¹ It is worth highlighting that when a company applies to the leniency program, it is acknowledging its liability as a participant in the cartel and, at the same time, providing solid evidence of the involvement of other companies. This decreases the likelihood of successful appeals against the competition authorities' penalty decision (Motta, 2009).

² It is important to notice that we do not focus on the characteristics of the firms that deviate from a cartel agreement but only on the characteristics of the firms from cartels that end up in a leniency process. A firm that deviates from the cartel agreement does not automatically self-report the cartel under the leniency program – although theoretically, under certain conditions, doing so is a dominant strategy (see Harrington & Chang, 2015).

(2020). In a seminal paper on this topic, Brenner (2011) analyzes 39 cartel cases over the period 1996–2004 in which the EC's 1996 leniency program was applied. His estimation results support that—at the firm level—large multinational firms are more likely to reveal the cartel and cooperate with the competition authority because they have more legal resources.

Marvão (2014) analyzes the characteristics of the firms that obtained immunity from fines under the leniency programs and the characteristics of the cartels in which they participated. She uses data from 63 cartel cases (81 cartels) that were penalized by the EC in the period 1998–2011 and data from 799 US cartels that were penalized in the period 1984–2009. Her empirical results show that the firms that qualify for full immunity from fines under the EC leniency program are usually repeat or multiple offenders, while in the US case it is the cartel leaders who are most likely to apply for and obtain full immunity.³

Hoang et al. (2014) consider 442 firm groups that participated in 76 cartels that were penalized by the EC in the period 2000–2011 under the 1996 and the 2002 EC leniency programs.⁴ A 'firm group' or 'single economic entity' is defined as an economic entity that is formed from a set of firms that are either companies controlled by the same firm, or the controlling firm itself.⁵ The authors analyze the determinants—at the cartel level and at the firm group level—of self-reporting under the EC leniency program. Their results show that the probability of becoming the chief witness increases with: the amount of the expected basic fine; the number of countries within one firm group; and the firm groups with the largest market shares in the cartel. However, this probability decreases with the number of firms within one group, which might be counter-intuitive. They also find that in those cases where the 2002 Leniency Notice was applied, recidivist groups are more likely to be the chief witnesses.

Koh and Jeong (2014) and Kim and Kim (2016) analyze the factors that induce applications to the leniency program for penalized cartels in South Korea. The former analyze cartel-level characteristics over the period 2005–2012 and find that the number of leniency applications increased during the early years—2008–2009—of the global financial crisis, in cartels with a smaller number of members. The latter authors consider the period 2005 to 2009 and analyze, in addition to cartel-level characteristics, cartel member-level variables that would explain a higher number of leniency applications. The study finds that firms that belonged to large Korean business conglomerates (known as 'chaebols') are more likely to be the first to apply for leniency to the authorities. They also point out that the statistical significance of the explanatory variables changes if the first or the second leniency applicant is considered.

³ As recognised by the author, this is a surprising result since the US Department of Justice guidelines state that the leader cannot receive immunity from fines.

⁴ Because of the small number of cartel cases that occurred under the 2006 EC Leniency Notice available at that time (four cases), they excluded it from their empirical analysis.

⁵ For instance, a parent company and its subsidiaries are considered a single economic entity or firm group. These subsidiaries do not enjoy real economic independence from their parent company.

Finally, Rosenboom (2020) analyzes which factors—at both the cartel and cartel-member level—determine the likelihood of a cartel member’s applying for the Dutch leniency program. Her sample includes 366 firms that were involved in 63 cartels that were penalized by the Dutch authority during the period 2002–2017. She finds that individual cartel members that faced a higher base fine, or were part of a listed company, were more likely to apply for leniency. Furthermore, cartels that were discovered through a leniency application, were active in the construction or manufacturing sectors, or involved more than one type of infringement were more likely to self-report.

The present paper contributes to this empirical literature in several ways: First, our data set comprises 132 cartels that were penalized by the EC between 1996 and 2020 (in which the leniency program was applied). Unlike previous studies, our sample allows us to assess the effects of the three versions of the EC leniency program—1996, 2002, and 2006—on the likelihood that a cartel was uncovered by a self-reporting firm, as well as on the likelihood that a cartel member applied for leniency.

Second, we follow Hoang et al. (2014) when considering a firm group instead of a firm as a decision-making unit. We should not ignore the fact that where various firms that belong to the same group are involved in a cartel infringement, one leniency application is usually made on behalf of all of them, and all of the firms benefit from immunity or fine reductions based on that leniency application. The sample contains a total of 683 firm groups, which include 1,568 firms.

Third, we explore the determinants of self-reporting, in line with previous studies (e.g. Hoang et al., 2014). The larger and enriched database allows us to include a more comprehensive set of explanatory variables than previous studies. Our findings provide valuable information on the factors that make a firm group more likely to be the first applicant for leniency. We also obtain new significant evidence on some variables for which previous studies reported counterintuitive results or simply non-significant results.

Furthermore, we undertake two additional levels of analysis: i) a preliminary analysis at the cartel level to explore what factors make a cartel more likely to be uncovered via a leniency application; and ii) a follow-up analysis of the drivers of self-reporting for subsequent confessors—those firm groups that apply subsequently for leniency but were not the first confessors—which was not explored in previous related studies on the EC leniency program.⁶ These additional analyses further contribute to determine what factors influence firm groups to cooperate or not with the EC under the leniency program. None of the previous studies has addressed these three levels of analysis simultaneously.

Our results underline the role that both firm groups and fines play in the likelihood to self-report. In fact, the former is the most relevant driver of being first confessor: The higher is the number of firms that belong to a particular group relative to the total number of firms in the cartel, the higher is its probability to self-report.

⁶ As far as we know, Kim & Kim (2016) are the only ones to explore this issue for the Korean leniency program.

Moreover, another relevant result shows that ringleaders or instigators are less likely to be the first to self-report their cartels; but once another cartel member has already self-reported the cartel, then the leaders are more likely to cooperate with the EC under the scope of the leniency program.

Last but not least, the findings at the cartel level highlight the challenges that face the EC Leniency Program with respect to certain types of infringements. We show that cartels that involve bid-rigging practices are less likely to be uncovered as a result of a leniency application that is made to the Commission.

2 Dataset

The present paper is built upon an own-elaborated database that contains a detailed compilation of information on all cartels (and firms) that were penalized by the European Commission in the period 1962–2020. It is based on Ordóñez-de-Haro et al. (2018) but updated to 2020.

These authors show that the introduction of the leniency program was a critical juncture that allowed authorities to identify cartels more effectively and to provide evidence for penalizing collusion much more easily than before. For this reason, we focus only on cartels that were discovered after the entry into force of the first EU Leniency Program (1996). This is a cornerstone of our analysis because it enables us to consider cartels that were uncovered following a leniency application and also those that were uncovered as a result of a third-party complaint or an investigation started by the EC's own initiative.⁷ But the key is that all of the cartel prosecutions that are included in our database fell within the scope of one of the three European Commission's Leniency Notices: 1996, 2002, or 2006. This dataset provides us with information as to which firms decided to apply for leniency and when, which is critical for the construction of our dependent variables.

The first step in our empirical strategy is to obtain information about what drives the firms to report their cartel activity to the antitrust authority. The dataset contains information about those variables that we expect—based both on the academic literature and on the incentives that are generated by the anti-cartel legislation itself—to influence each cartel member's decision to blow the whistle.

The dataset includes the fine amount that was imposed at the cartel and firm group level before leniency reductions. This will serve as a proxy for a cartel's and each firm group's expected fines. If cartel members are rational, they will weigh the expected costs and benefits of reporting cartel conduct versus non-reporting (see Hoang et al., 2014; Rosenboom, 2020). Based on the information that has been provided by the EC on the method for setting fines and its implementation,⁸ a cartel

⁷ Some cartel cases do not include a detailed description of dates, penalties, and similar, and so it is impossible to include them in the database. Please see Online Annex 1 for a description of cartel cases included in this previous version: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4503090

⁸ The EC has published a series of fining guidelines that explain the successive steps and criteria that would be taken to set fines – most recently in 2006.

member could be expected to estimate the expected level of fines if detected and penalized by the EC without reporting. Fine exemption or reductions under the EC leniency program reduce the expected fine. This would suggest that higher fines before leniency reductions (as a proxy for expected fines) increase a cartel member's incentives to self-report and thus the probability that a cartel is uncovered by a leniency application. We express all fines in equivalent 2015 prices.

The dataset also contains information about: cartel duration and the duration of firm groups' participation in the cartel (in months); the number of firms and countries (total and by firm groups within each cartel); a "frequency" of firm groups (the proportion of firms that belong to the same firm group relative to the total number of firms that participated in each cartel); binary variables that represent the nature of the cartel infringements (price fixing, market sharing/quota arrangements, market foreclosure, limit production, restriction in variables other than production, exchange of information, and bid rigging); and a "cartel stability" variable (that takes value 1 if all of the same firms remain in the cartel for the entire cartelized period).

We also include a diversity measure that is based on the Shannon index.⁹ We need to consider the varying upper and lower bounds of the Shannon index to obtain a measure of diversity that is generally applicable for comparisons across different cartels, if the number of firms varies.

To eliminate the effect of cartel size, we define the standardized Shannon index to be $\bar{H} = \frac{H - H_{\min}}{H_{\max} - H_{\min}} \in [0, 1]$.¹⁰ For example, consider a n -firm cartel. If one firm group's relative frequency is $\frac{(n-1)}{n}$ —all of the firms but one belong to the same firm group¹¹—then the standardized index score will be 0. If the relative frequency of each of the n firms is $\frac{1}{n}$ —no firms belong to the same firm group—then the score will be 1. This variable measures the diversity of firm groups within cartels and allows us to control for the concentration of firms within cartels: the firms that belong to the same 'group'.

Moreover, we collect the aggravating and attenuating circumstances—which were included in the 1998 and 2006 EC Fining Guidelines—in the EC's cartel decisions. We consider three dummy variables: "ringleader", which takes the value 1 if the EC stated that a firm group played the role of leader or instigator in the cartel; "limit participation", which takes the value 1 when the Commission stated that a firm group had a minor or passive role in the cartel; and "recidivist", which takes the value 1 if the Commission established that a firm group was a recidivist or repeat offender. These cartel roles are not necessarily mutually exclusive. These variables

⁹ The Shannon index is a statistic index that measures the diversity of species in a community (in biology). The higher is the value of H , the greater is the diversity of species in a particular community. It is obtained as $H = -\sum_{i=1}^N f q_i * \ln(f q_i)$, where $f q_i$ is the relative frequency of the number of firms that belong to the same group i within the cartel.

¹⁰ H is the Shannon index; $H_{\max} = \ln(n)$ and $H_{\min} = \ln(n) - \left(\frac{n-1}{n}\right)\ln(n-1)$ are the upper and lower bound, respectively, for the Shannon index; and n is the number of firms that participated in the cartel.

¹¹ Notice that in this context, a firm group's relative frequency never reaches the value 1 because collusion requires at least two firm groups.

will allow us to test whether the role that is played by a firm group has an impact on its likelihood to self-report.

We develop two levels of analysis: a general analysis at cartel level; and a detailed analysis of incentives by firm group or single economic entity. For this reason, we include tables of descriptive statistics at these two levels (see Tables 1, 2, and 3). Table 1 shows the descriptive statistics for the final sample at the cartel level. In total, the dataset includes 132 cartels. It should be clarified that some EC decisions in cartel cases may include more than one cartel.¹² The first case that we consider is IV/F-3/33.708—British Sugar plc (decision year, 1998); and the last are two cartels that are included in AT.40299—Closure Systems case (decision year, 2020). All of the cartels that are included in the database are in Online Annex 1.

A general overview of the database shows that 74% of the detected cartels were uncovered and penalized following a leniency application. Unlike closely related previous studies that, due to data availability, focused on cartels under the 1996 and/or 2002 EC leniency programs (Brenner, 2011; Marvão, 2014; Hoang et al., 2014), our data set allows us to include also the 2006 EC leniency program in our empirical analysis. The sample contains 52 cartels that fell under the scope of the 2006 EC Leniency Notice (more than 39% of the cartels considered), which include 232 firm groups. With regard to the type of infringements found, price fixing is the most usual infringement (86%) followed by market sharing/quota allocation (58%). Some 12% of the cartels in the sample involve bid rigging. Note that one cartel could include more than one infringement.

Table 2 shows the descriptive statistics for the same sample but at the firm group level. Preliminary analysis showed that the decision of a cartelist to self-report, and its consequences—e.g., fine reduction and total fine—were highly correlated with those of other firms within the same group. This shows that the correct layer of analysis should be the groups, instead of individual firms. A total of 683 firm groups formed part of the 132 cartels included in the final sample. These firm groups include 1,568 firms; 17% of the firm groups were first confessors.

Table 3 also includes average data for the main variables by Leniency Program. The proportion of cartels that were uncovered via leniency application were more varied, with 53% related to the 1996 program, 68% for the 2002 program and 98% for the 2006 program.

Of all detected cartels in the sample, 46% were initiated after the first EC leniency program. This information will help us to test potential variances in behavior among cartelists—depending on whether they were established with the knowledge that leniency programs were in place or not. The most relevant results show higher fines and lower cartel duration over time.¹³ Another fact is how the number of firms and countries diminish after considering firm groups: Although each cartel contains

¹² For example, the “Vitamins” case (Case number 37512) includes 12 cartels, although four of them were time-barred, and they were finally excluded from our empirical analysis. See Online Annex 1.

¹³ In fact, t-tests to compare both fines and cartel duration by programs have been applied. Results show that all are statistically different, with the exception of fines in Program 2002 to 2006 and duration in Program 1996 to 2002.

Table 1 Descriptive statistics—cartel level (N = 132 cartels)

	Mean	Median	St.Dev	Min	Max
Initiated by leniency	0.742	–	0.439	0	1
Born before 1996	0.477	–	0.501	0	1
Dead before 1996	0.053	–	0.225	0	1
1996 Leniency Program	0.394	–	0.49	0	1
2002 Leniency Program	0.212	–	0.41	0	1
2006 Leniency Program	0.394	–	0.49	0	1
Fine (in million euros at constant 2015 prices)	382	178	722	0.828	7,005
Cartel duration (in months)	79.528	61.462	67.175	2.762	419.047
Number of firm groups	5.18	4	3.09	2	17
Number of countries (firm group)	3.515	3	1.793	1	12
Cartel stability	0.303	–	0.461	0	1
Price fixing	0.864	–	0.344	0	1
Market sharing	0.583	–	0.495	0	1
Market foreclosure	0.015	–	0.123	0	1
Limit production	0.076	–	0.266	0	1
Other restrictions	0.015	–	0.123	0	1
Information exchange	0.455	–	0.5	0	1
Bid-rigging	0.121	–	0.328	0	1
% Recidivism	0.07	0	0.15	0	0.66
Standardized Shannon Index	0.65	0.63	0.26	0	1

Source: Authors' elaboration from the European Commission publicly available cartel decisions

on average 12.7 firms, cartels contain on average only seven firm groups. This is an indicator of the relevance of the involvement of companies that belong to the same group in the cartels.

3 The Drivers of Leniency Applications

This section reviews some of the most relevant factors that incentivize companies that have participated in cartels to apply for leniency under the EC's leniency program, which then leads to the estimations in Sect. 5.

3.1 European Commission's Leniency Notices

The first EC Leniency Program (1996)¹⁴ contained a gradation in the potential reduction of the penalty that would be applied to the cooperating company—depending essentially on the time at which the company provided the decisive information.

¹⁴ OJ C 207, 18.7.1996.

Table 2 Descriptive statistics—by firm groups (N=683 firm groups)

	Mean	Median	St.Dev	Min	Max
First confessor	0.176	0	0.381	0	1
Subsequent confessor	0.501	1	0.5	0	1
Initiated by leniency	0.719	1	0.45	0	1
Born before 1996	0.539	1	0.499	0	1
Dead before 1996	0.072	0	0.258	0	1
Program 1996	0.4	0	0.49	0	1
Program 2002	0.26	0	0.439	0	1
Program 2006	0.34	0	0.474	0	1
Fine (in million euros at constant 2015 prices)	74	23.1	150	0.001	1,676
Cartel duration (in months)	73.653	57	60.882	1.4	419
N. of firms	12.7	10	7.8	2	31
Number of firm groups	7	6	3.966	2	17
N. of countries	5.2	5	2.7	1	13
Number of countries (firm group)	4.2	4	2.1	1	12
Ringleader	0.059	0	0.235	0	1
Recidivist	0.069	0	0.253	0	1
Limit participation	0.092	0	0.29	0	1
Frequency	0.192	0.154	0.131	0.032	0.75

Source: Authors' elaboration from the European Commission publicly available cartel cases

This first Leniency Communication did not specify many details that were relevant to a potential applicant, which allowed the Commission discretion in its decisions but generated legal uncertainty for companies (Borrell et al., 2015).

In order to address the problems that were identified in the previous Notice, the Commission issued a Second Notice in February 2002.¹⁵ This clarified the conditions that would have to be met for full immunity from penalty payments to be granted during the first undertaking to provide evidence. Among other changes it also opened up the possibility that companies that had played the role of ringleaders, instigators, or leaders in the cartel could access the benefits that were associated with the program, as long as they had not coerced other companies to participate in the infringement (Arp & Swaak, 2003; Borrell et al., 2015).

Finally, the second revision of the EU leniency program was published in December 2006.¹⁶ This revision introduced modifications—such as the marker system—that aimed at increasing the effectiveness of the program by facilitating and encouraging greater competition among cartel members to be the first to apply for leniency (Borrell et al., 2015; Sandhu, 2007). Moreover, companies that coerce other cartel members could qualify for reductions in the fines through the leniency program.

¹⁵ OJ C 45, 19.2.2002.

¹⁶ OJ C 298/17, 8.12.2006.

Table 3 Average data by firm groups and EU Leniency Program

	Total	1996 Program	2002 Program	2006 Program
Cartels included	132	52	28	52
Firm groups	683	273	178	232
First confessor	0.176	0.154	0.14	0.228
Subsequent confessor	0.501	0.553	0.461	0.47
Born before 1996	0.539	0.949	0.579	0
Dead before 1996	0.072	0.179	0	0
Fine (in million euros at constant 2015 prices)	74 (150)	39 (60)	84 (140)	110 (220)
Cartel duration (in months)	73.6 (60.8)	84.5 (64.9)	78.8 (61)	56.9 (51.71)
N. of firms	12.7 (7.8)	10.2 (7.2)	16.9 (8.3)	12.3 (6.8)
Number of firm groups	7 (3.9)	7.5 (4.2)	7.6 (3.3)	5.8 (3.9)
N. of countries	5.2 (2.7)	4.6 (2.7)	6.6 (2.5)	4.8 (2.4)
N. of countries (firm groups)	4.2 (2.1)	4.3 (.2.2)	5.1 (2.4)	3.5 (1.3)
Ringleader	0.059	0.114	0.039	0.009
Recidivist	0.069	0.044	0.157	0.03
Limit participation	0.092	0.081	0.073	0.121
Frequency	0.19 (0.13)	0.18 (0.12)	0.157 (0.108)	0.223 (0.142)
Standardized Shannon index	0.65	0.80	0.59	0.53

Source: Authors' elaboration from the European Commission publicly available cartel cases. Standard deviation in parentheses

Marvão (2014)'s study considered controls for the different EC leniency programs of 1996 and 2002. She shows that the predicted probability of immunity in inactive cartels—those that were reported after they were terminated—is lowest under the 1996 leniency program. On the other hand, the opposite is true for cartels that were still active at the time of reporting. Due to data availability, Hoang et al. (2014) also limit their study to the 1996 and 2002 leniency programs. Their results support the hypothesis that the 2002 revision of the leniency program substantially increases the likelihood of a repeat offender to become a chief witness.

We contribute to this strand of the literature by providing an empirical analysis of the three EC leniency programs of 1996, 2002, and 2006. This analysis allows us to examine the validity of previous results and to provide further insights as to the impact of the different versions of the EC leniency program.

3.2 Cultural Factors

Sociological and/or cultural disparities between cartel participants that would undermine their necessary mutual trust could contribute to a cartel's destabilization and breakdown. In fact, a number of studies point to the cultural ties between firms within a cartel as one of the factors to be considered as a variable that influences its

cohesion (Podolny & Morton, 1999; Van Driel, 2000; Levenstein & Suslow, 2006; Stephan, 2010; Brenner, 2011; Hoang et al., 2014).

Brenner (2011) considers two cultural aspects—uncertainty avoidance and individualism—and estimates their effect on the propensity of firms to report a cartel to the authority. However, in his estimates he finds no statistically significant effect of culture. Hoang et al. (2014) consider the number of countries to which firms within a group belong (belonging to the same legal entity) to proxy for possible differences in cultural habits. They find that the probability of applying for leniency increases with the number of different origin countries within one group. Bertrand and Lumineau (2016), in a study of a sample of 41 cartels that were penalized by the EC in the period 2001–2011, suggest that cartels with smaller cultural differences would be less sensitive to the destabilizing effects that were generated by the introduction of the leniency program.

In our study we collect information on the number of different countries to which cartel members belong. This variable may be indicative of the degree of cultural differences between partners in their respective cartel. Each firm group is assigned to the country where the parent firm has its registered head office.

3.3 Cartel Structure and Cartel Activity

There are several internal factors that are specific to the cartel that influence firms' incentives and ability to create and maintain different collusive agreements over time. The most relevant variable in the academic literature on leniency programs is the duration of the cartel (Borrell et al, 2018; Brenner, 2011). According to the theoretical results by Harrington and Chang (2009), the program should have a positive effect on the duration of cartels in the short run and a negative effect in the long run if it is effective and sufficiently dissuasive.

Borrell et al. (2018) empirically show that, due to the introduction of the leniency program in the EU and Spain, the duration of cartels in the short run doubles, while it halves in the long run. Studies that have analyzed incentives to apply for leniency and cartel duration indicate that the longer the duration of the cartel, the greater the likelihood of applying for leniency (Brenner, 2011; Marvão, 2014; Kim & Kim, 2016; Rosenboom, 2020). These results imply that—given that the older is the cartel, the higher is the expected fine—the greater also is the probability of breaking the cartel agreement.

The nature of the infringement (price-fixing, market sharing/quota arrangements, exchange of information, bid-rigging, etc.) can be a significant driver for a cartel to be uncovered through a leniency application. Koh and Jeong (2014) consider bid-rigging as a determinant of leniency applications—although its impact is not statistically significant. Kim and Kim (2016) divide their sample into two groups: the non-bidding cartel sample, and the bidding cartel sample. Their results indicate that in bidding cartels most of the differences at the cartel level lose statistical significance, while most of the variables at the firm level have a strong impact on the probability to confess. Rosenboom (2020) considers several types of infringement. She finds that being involved in information exchange decreases the probability that a firm

will apply for leniency, while being involved in fixing other terms, such as agreeing not to grant discounts, increases that probability.

Luz and Spagnolo (2017) draw attention to the risk of undermining the effectiveness of leniency programs against bid rigging in public procurement because of the interaction with legislation and enforcement around corruption. In the case of the European Union, they point out that if just one of the countries affected by the cartel does not provide leniency for the corruption offense, it reduces cartel members' incentives to blow the whistle.

As was pointed out above, our empirical analysis also considers several types of infringement—including bid-rigging—that could potentially affect the probability that a cartel is uncovered by a leniency application. As far as we know, this is the first study to analyze these effects under the EC leniency programs.

With regard to the cartel structure, the number of participants in the cartel also affects the probability to self-report. Theoretical predictions that are offered by dynamic models (Ivaldi et al., 2003), as well as experimental evidence (Horstmann et al., 2018) with respect to tacit collusion, point out that agreements become more difficult to sustain when the number of participants is larger. Nevertheless, the empirical evidence supports a negative relationship: The larger is the number of firms, the lower are the cartelists' incentives to apply for leniency (see Marvão, 2014; Koh & Jeong, 2014; Kim & Kim, 2016 or Rosenboom, 2020).

Marvão (2014) suggests that this relationship might be due to the greater difficulty that a potential leniency applicant would encounter in obtaining sufficient evidence of the involvement of all participants. Koh and Jeong (2014) and Kim and Kim (2016) argue that cartels with a large number of members would be more complex in terms of organization, and level of consensus of the agreements reached for their operation, which would reduce incentives to apply for leniency. Moreover, Koh and Jeong (2014) add that, since the total profits of a cartel are comparatively higher when more firms are involved, members would have less incentive to admit their existence to the authorities. Rosenboom (2020) argues that a greater number of members do not make a cartel more complex, but it does increase the joint market share that is cartelized, which increases the stability of the cartel.

The market share and certain structural asymmetries among cartel participants also affect firms' decision to apply for leniency. Both variables show a positive correlation with the probability of being a confessor (see Kim & Kim, 2016; Grout & Sondereffet, 2005; Davies & Olczak, 2008). A proxy for this variable, which is employed by Brenner (2011) and Kim and Kim (2016), is whether a firm belongs to a multinational organization. The major problem in the study of the cartels that are penalized by the European Commission is that information on firms' market shares is labelled as confidential and thus is not available in most cartel decisions. Hoang et al. (2014) also point out this problem and run a separate regression for a smaller sample with cartel cases that contain this information. They find a significant positive effect on the probability of being the chief witness for the group with the highest market share within the cartel.

Inelastic demand markets, stable markets (Levenstein & Suslow, 2006; Marvão, 2014), or the sector in which they operate (Antonielli & Mariniello, 2014; Levenstein et al., 2015) also affects cartels' stability.

Finally, the share of each firm group in a cartel must be considered. We hypothesize that the larger is the number of firms that are involved in a cartel that belong to the same group, the greater is the loss that is associated with the fine for that firm group and the greater is the likelihood that it will apply for leniency. For this reason, we consider two variables that were previously described: the relative frequency of each firm group within the cartel, and the standardized Shannon index.

3.4 Behavioral Factors Specific to each Cartel Member

A cartel is necessarily an “illegal joint venture” of firms where each participant may play a particular role in the organization and operation of the cartel. Specific behavioral characteristics of each cartel member may affect its incentives to apply for leniency. The first is the duration of the firm’s participation (or firm group) in the cartel. Since the expected penalty of each firm or firm group increases proportionally with the length of participation in a cartel, its incentives to apply for leniency should also increase. However, none of the studies that include each firm’s individual duration in the cartel as an explanatory variable obtains statistically significant estimators (Brenner, 2011; Hoang et al., 2014).

Another interesting question is whether the leniency application is more likely to take place once the applicant or another member has left the cartel: whether cartels that have exhibited some signs of internal instability or even collapsed are more likely to lead to a leniency application. The firm that leaves the cartel becomes a market rival and may accelerate the race to be the first to apply for leniency. Gärtner and Zhou (2012) found evidence that, once the cartel collapses, leniency applications tend to be delayed. Kim and Kim (2016) find that firms that exit from the cartel are more likely to apply for leniency. We control for the entry or exit of firm groups in the cartel through the variable “cartel stability”.

Finally, the behavior or role that is played in the functioning and organization of the cartel is a relevant factor in this relationship. We consider three main types: ring-leaders or cartel leaders; repeat offenders or recidivists; and cartel members with a minor or passive role in the cartel.

The academic literature has focused on analyzing the effect of discriminatory programs (those that exclude ringleaders from benefiting) versus non-discriminatory leniency programs. Theoretical and empirical papers question the effectiveness of eliminating the possibility for ringleaders to benefit from the leniency program, as ringleader leniency may have the effects of destabilizing existing cartels and deterring future cartels (see Herre et al., 2012; Bigoni et al., 2012; Hesch, 2012; Bos & Wandschneider, 2013; Chen et al., 2015; and Clemens & Rau, 2019). The 2002 Notice allowed instigators, ringleaders, or leaders in a cartel to access the benefits of the leniency program—including the possibility for them to benefit from full exemption from any fine. However, Hoang et al. (2014) find no evidence that ringleaders or instigators are leniency seekers and exclude this behavior as an explanatory variable.

The European Commission’s penalties policy considers recidivism as one of the aggravating factors to increase penalties. In fact, the penalties double. At the same time, however, EC Leniency Notices allow repeat offenders to benefit from all of

the potential benefits of the program—including full exemption from the penalty—under the same conditions as other non-recidivist cartel members. Marvão (2016) shows that repeat offenders appear to receive larger reductions in the fines from the Commission, which suggests that companies may have learned “the rules of the game” by repeatedly colluding and betraying the cartel—not only to reduce their penalties, but also to harm their former cartel accomplices, and now rivals. Hoang et al (2014) found mixed results about recidivist cartel members and likelihood to apply for leniency under the EC Leniency Notices.

With regard to the firms that play a minor or passive role in the cartel, the Commission recognizes this role as a mitigating factor that could reduce the amount of the penalty. As far as we know, there is no empirical paper that considers the effect of this behavior on the probability of applying for the benefits of the leniency program.

Table 4 shows a summary of variables that were mentioned above that might explain cartel behavior (or a cartel member’s behavior), including the relevant references and expected sign in relation to the probability to self-report.

4 Methodology

In all of the analyses that we conducted, the dependent variable of interest is binary: i) cartels that are uncovered by leniency application or not; and ii) cartelists that decide whether to self-report or not. Hence, we use logit and probit models to undertake the analyses of observed outcomes (McFadden, 1974).

We conduct three separate modelling exercises: The first model examines which type of detected cartels are more likely to be uncovered by a leniency application (in total 74% of detected cartels, as was highlighted in Table 1). A second model explains what makes a cartelist more likely to be the first applicant that seeks the benefit of the EC leniency program. Finally, a third model explores the determinants behind subsequent applicants to self-report (excluding the first applicants from the dataset).

For a given dependent binary variable Y , probit and logit regressions model the probability of the dependent variable taking value 1, as follows:

$$P(Y = 1|X_1, \dots, X_k) = \beta_0 + \sum_{k=1}^K \beta_k X_k + \varepsilon_{it}, \quad (1)$$

where X_k is the set of k explanatory variables and β_k are parameters to be estimated. The logit model assumes that the error term ε_{it} follows a logistic distribution, whereas the probit model assumes a normal distribution.

The following sections provide the details of the model specifications for the various analyses that we performed—estimations at the cartel and firm group levels—including descriptions of the explanatory variables. In all cases, we implement and report a similar empirical strategy to specify the model. In order to substantiate the robustness of the results, we report a wide range of model specifications that we tested, where in each case we estimate both probit and logit versions of the models

Table 4 Drivers of the leniency applications

Drivers of leniency applications	Previous studies	Expected sign (*)
<i>EC Leniency program</i>		
1996 Leniency Notice	Marvão (2014) and Hoang et al. (2014)	-/+
2002 Leniency Notice	Marvão (2014) and Hoang et al. (2014)	+
2006 Leniency Notice		+
<i>Sociological and/or cultural disparities</i>		
	Podolny and Morton (1999) and Van Driel, (2000), Levenstein and Suslow (2006), Stephan (2010), Brenner (2011), Hoang et al. (2014), and Bertrand and Lumineau (2016)	+
<i>Cartel structure and cartel activity</i>		
Cartel duration	Brenner (2011), Marvão (2014), Kim and Kim (2016), Rosenboom (2020)	+
Type of infringement (<i>Bid rigging</i>)	Koh and Jeong (2014), Kim and Kim (2016), Luz and Spagnolo (2017) and Rosenboom (2020)	-
Number of cartel members	Marvão (2014), Koh and Jeong (2014), Kim and Kim (2016), Rosenboom (2020)	-
Market share and relative participation in the cartel	Grout & Sondereffet (2005) and Davies and Olczak (2008), Brenner (2011) (proxy), Hoang et al. (2014) and Kim and Kim (2016) (proxy)	+
<i>Behavioral factors</i>		
Cartel member duration	Brenner (2011) and Hoang et al. (2014)	+
Ringleader or instigator		-/+
Recidivist		+
Minor or passive role	Marvão (2016) and Hoang et al. (2014)	-/+

(*) The expected sign relates to the probability to self-report

Source: own elaboration

(we present the latter in the Online Annex 2). Errors were clustered accordingly for each data context—at the cartel level, clustered by case; and at the firm group level, clustered by cartel—and further sensitivity tests were performed on clustering.

4.1 The Model at the Cartel Level: What Factors Make Cartels More Likely to be Uncovered Through Leniency Applications?

Prior to analyzing the determinants of self-reporting (see 4.2 below), this initial analysis first explores the data at the aggregated cartel level. The aim is to investigate the following question: Which cartel characteristics correlate with the probability that a cartel investigation is opened as a result of a leniency application (as opposed to a competition authority's uncovering the cartel beforehand via its own investigation)?¹⁷

At this level of analysis, the dependent variable is a dummy variable that takes the value 1 if a particular cartel member's leniency application causes investigation into a cartel to be opened, and 0 otherwise (if the authority uncovered the cartel through own investigation). Following Eq. (1), for this analysis the model is specified as follows (note that the equation below corresponds with model 2 in Table 5 below, whereas other models include only a subset of these variables):

$$\begin{aligned}
 P(Y = 1 | X_1, \dots, X_k) = & \beta_0 + \beta_{bornbef96} D_{bornbef96} + \beta_{deadbef96} D_{deadbef96} \\
 & + \beta_{prog02} D_{prog02} + \beta_{prog06} D_{prog06} + \beta_{fine} Fine_j \\
 & + \beta_{fine^2} Fine_j^2 + \beta_{dur} Dur_j + \beta_{dur^2} Dur_j^2 \\
 & + \beta_{Ncountries} N.ofcountries_j + \beta_{stab} D_{Stability_j} \\
 & + \beta_{SHI} SHI_j + \beta_{\%Recidivism} \%Recidivism_j \\
 & + \sum_{m=1}^5 \beta_{infr_m} Infringement_{mj} + \beta_{fine_shi} Fine_j * SHI_j + \epsilon_{jt}
 \end{aligned} \tag{2}$$

All variables are measured at the aggregated level of the cartel (for cartels j , where $j = 1, \dots, 132$).¹⁸ Variables $D_{bornbef96}$ and $D_{deadbef96}$ are dummy variables for those cartels that started and died before 1996, respectively, when the leniency program was not available. D_{prog02} , D_{prog06} are dummy variables for the leniency programs from 2002 and 2006 respectively (the base category is the program from 1996). These act as control variables for any otherwise unexplained effects that are related to the various leniency programs that were established by the EC. β_{fine} is the total fine that was imposed on the cartel j (the sum of the fines that were imposed on all of the undertakings involved in that cartel), which are calculated before leniency

¹⁷ There are three ways that a cartel investigation may be opened: following a cartel member's leniency application; following a third-party complaint; or following a European Commission investigation that is started on its own initiative (*ex-officio*).

¹⁸ The subscript j is used to avoid confusion with the upcoming set of models, where some of the same variable names are used at the firm group level (with subscript i).

was applied. We also consider its squared term. As previously mentioned, these act as a proxy for the expected fine.

The variable Dur_j represents the duration of the cartel (months). $N.ofcountries_j$ is the number of different countries to which the firms that were involved in cartel j belonged. The stability of the cartel is represented by $D_{Stability_j}$. The concentration of firm groups and individual firms within the cartel is proxied by SHI_j , the standardized Shannon index that was previously described. $\%Recidivism_j$ is the share of recidivists (number of recidivists/number of cartel members) in cartel j . Five binary variables ($m=1, \dots, 5$) that control for the nature of infringement are under $Infringement_{mj}$. β_0 is the constant, which represents the overall tendency (*ceteris paribus*) to initiate the leniency procedure within the cartel. Finally, the logit model assumes that the error term ε_{jt} is logistically distributed, and the probit model assumes a normal distribution. Results of the estimation of Eq. (2) and variations will be shown in Sect. 5, in Table 5.

4.2 The Model at the Firm Group level: What Factors Make a Firm Group More Likely to be the First Applicant for Leniency?

The second part of the empirical work—and the most relevant—explores the determinants of the likelihood of a firm group to self-report the cartel. We investigate what factors influence firms to cooperate or not with the EC under the leniency program. Since some firms form part of groups, decisions to self-report will also affect the groups and not just the firm. Therefore, the decision-maker is assumed to be the group, which in some cases will comprise only one firm.

The dependent variable now takes the value 1 if the firm group was observed to be the first applicant for leniency, and 0 otherwise. In this case, the relevant set of independent variables (X_k) describe the group i and its involvement in the cartel, where some cartel characteristics are included as control variables. The general model is specified as follows (note that not all variables feature in each model, as is outlined in the results in Tables 6 and 7, which include multiple specifications):

$$\begin{aligned}
 P(Y = 1|X_1, \dots, X_k) = & \beta_0 + \beta_{bornbef96}D_{bornbef96} + \beta_{deadbef96}D_{deadbef96} + \beta_{prog02}D_{prog02} \\
 & + \beta_{prog06}D_{prog06} + \beta_{fine}[(1 + \beta_{Rlead_fine} * Ringleader)Fine] + \beta_{fine^2}Fine^2_i + \beta_{dur}Dur_i \\
 & + \beta_{dur^2}Dur_i^2 + \beta_{freq}Frequency_i + \beta_{Rlead}D_{Ringleader} + \beta_{stab}D_{Stability_j} + \sum_{m=1}^5 \beta_{infr_m}D_{infringement_{mj}} \quad (3) \\
 & + \beta_{rec96}D_{Recidivism96} + \beta_{rec02}D_{Recidivism02} + \beta_{rec06}D_{Recidivism06} + \beta_{Nfirms}N.offirms_j \\
 & + \beta_{Ncountries}N.ofcountries_j + \varepsilon_{it}
 \end{aligned}$$

All of the variables are similar to those that were explained before (Eq. (2)), although some are measured at the level of the firm group (i) instead of at the cartel level (j). In addition, the frequency of the firm group within the cartel is called *Frequency*; notice that it shows a high correlation with the covariate

Table 5 Cartel level results—Explaining leniency initiation. Probit

	Model (1)	Model (2)	Model (3)	Model (4)
Born before 1996	.9312 (0.59)	.8134 (0.58)	.8134 (0.58)	.9978** (0.44)
Dead before 1996	-1.581** (0.72)	-1.436** (0.71)	-1.436** (0.69)	-1.641** (0.69)
Program_2002	.6312 (0.53)	.8332 (0.57)	.8332 (0.53)	.7331 (0.56)
Program_2006	3.59*** (0.73)	3.655*** (0.73)	3.655*** (0.68)	3.542*** (0.71)
Fine	1.45e-09* (0.00)	-2.68e-09 (0.00)	-2.68e-09 (0.00)	-2.59e-09 (0.00)
Cartel duration	-.0003522 (0.01)	.0000341 (0.01)	.0000341 (0.01)	
Cartel stability	.4975 (0.36)	.3795 (0.38)	.3795 (0.38)	.3218 (0.37)
N. of countries	.07405 (0.08)	.07342 (0.08)	.07342 (0.09)	.09594 (0.09)
Standardized Shannon index	.04364 (0.77)	-.8997 (0.84)	-.8997 (0.75)	-1.191 (0.84)
% Recidivism	-.08116 (1.06)	-.4304 (1.11)	-.4304 (1.06)	-.4674 (1.10)
Price fixing	.4131 (0.53)	.506 (0.60)	.506 (0.59)	.3602 (0.57)
Market sharing	-.2422 (0.41)	-.2751 (0.41)	-.2751 (0.40)	-.2346 (0.41)
Limit production	-.3708 (0.63)	-.6592 (0.73)	-.6592 (0.72)	-.6907 (0.76)
Information exchange	-.5651 (0.41)	-.5479 (0.43)	-.5479 (0.38)	-.6288 (0.41)
Bid-rigging	-1.733*** (0.65)	-1.893*** (0.62)	-1.893*** (0.58)	-1.719*** (0.57)
Fine^2	-2.31e-19** (0.00)	-1.68e-19 (0.00)	-1.68e-19 (0.00)	-1.70e-19 (0.00)
Duration^2	.0000164 (0.00)	.0000148 (0.00)	.0000148 (0.00)	
Fine*Standardized Shannon index		6.52e-09* (0.00)	6.52e-09* (0.00)	6.48e-09* (0.00)
Sample			Without clustered errors	Without duration
Observations	132	132	132	132
Pseudo R ²	0.440	0.473	0.473	0.464

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; the dependent variable takes the value 1 if a particular cartel member's leniency application causes an investigation into a cartel to be opened, and 0 otherwise; estimated models correspond to Eq. (2); errors are clustered by case

number of firms, and we should not include both simultaneously in the estimations. $D_{Ringleader}$ is a binary variable that takes the value 1 if the firm group played the role of ringleader or instigator in the cartel.¹⁹ $D_{Recidivism}$ is split into three dummy variables that indicate whether the firm group's role could fall within the description of Recidivism, in each of the Leniency programs (1996, 2002, and 2006). The inclusion of the "Ringleader" variable is unique to our dataset; and, as will be outlined below, the results will provide a novel interpretation of its effect on the probability of being the first leniency applicant.

It is important to notice that we do not include market share as an explanatory variable, as this is expected to be highly correlated with the expected fine, which has been included in other works. While market share data are more difficult to obtain (the data are not readily available from most of the Commission's published decisions), the expected fine will take into account market share and any other effects, and is ultimately a proxy for the potential risk that is perceived by the group. Hence, even if we had a good estimate of market share, we believe it is more appropriate to leave it outside the model due to its likely correlation with the expected fine.

5 Results

This section presents the results of the estimated models: We consider separately the estimation of Eqs. (2) and (3). Under each subsection, we include several models. This allows us to show the effect of different specifications: e.g., inclusion or removal of key variables and interactions. We discuss our preferred model specification in each case. All results showed are marginal coefficients.

5.1 Analysis at the Cartel Level

First, we focus on the analysis of the factors that might explain what makes a cartel more likely to be uncovered thanks to the EC leniency programs. We summarize the results from Eq. (2) in Table 5. Online Table A.2 shows the logit results.

The objective of this preliminary modelling is to observe any tendencies in the process of uncovering cartels, prior to the central analysis of firm groups' decisions

¹⁹ It should be noticed that our results on cartel ringleaders – as with any other study that is based on the information that is available from the EC's decisions – may be subject to some selection bias since the categorization as ringleader depends on when the EC felt sufficiently convinced so as to name a ringleader explicitly. Therefore, possibly the number of ringleaders may be higher than is contained in EC cartel decisions. While bearing in mind that problem, we implicitly assume – in line with previous empirical studies that consider cartel ringleaders (Davies & De, 2013; Marvão, 2014; Hoang et al., 2014; and Hüscherlath & Smuda, 2016) – that a firm group is non-ringleader when the EC report does not confirm the ringleader status. The potential effect of this data issue is recommended as an area for further research.

to self-report or not. Model 1 represents the basic model form without considering covariates interactions, while models 3 and 4 are sensitivity tests with respect to the use of clustering in the errors and the inclusion of duration (to test results against a potential endogeneity issue). Model 2 has the best model fit, and the results are generally robust across models. Since Model 2 also presents the most comprehensive set of variables, this is our preferred specification and is the focus of the discussion below.

First, the estimated coefficients on the control variables show that the share of cartels that were uncovered through a self-initiated leniency application is higher under the 2006 Leniency Program than under the first 1996 Leniency Program. This result could simply be due to nearly all cartel cases under the 2006 leniency program being uncovered as a result of a leniency application (see Table 3)—or to the fact that there have just been more cases post 2006—and does not necessarily mean that self-reporting has increased over time. Also those cartels that ceased to exist before 1996 were less likely to be initiated by a self-reporting firm.

The total fine that was imposed on firm groups that were involved in the cartel appears to be positive and significant under the most parsimonious model (Model 1): The higher is the overall expected fine, the greater is the possibility that a cartelized participant would self-report. However, models 2 to 4 suggest that the effect of the total fine may not be homogeneous. On the one hand, the negative coefficient for the squared fine implies a non-linear relationship, although the magnitude is very small and in some cases not significant. On the other hand, there is a significant interaction between total fine and the Shannon index, which we will discuss below. The coefficient on the standardized Shannon index is not statistically significant. However, the interaction between the index and the fine is positive and significant at the 90% level; this suggests that there may be a higher probability of leniency initiation when both expected fines and diversity within the cartel are high.

The duration of the cartel, the number of countries, and cartel stability do not significantly correlate with the cartel's being uncovered as a result of a leniency application.

Finally, differences in the nature of infringement may also influence how a cartel is uncovered. Cartels that do bid-rigging are associated with a negative effect on the probability of leniency initiation. According to the argument by Luz and Spagnolo (2017), the lack (even absence) of legal harmonization and coordination in the European Union between the leniency program legislation and legal provisions against corruption crimes would reduce the effectiveness of the EC leniency program in uncovering cartels that involve this type of anticompetitive practice.

5.2 Analysis at the Firm Group Level

Now we seek to identify which are the more important drivers for firm groups to be the first to self-report their cartels by applying for the benefits of the leniency

Table 6 (continued)

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
	(4.9e-6)	(4.7e-6)	(4.8e-6)	(4.5e-6)	(7.8e-6)	
Fine*Ringleader		-1.5e-8**	-1.4e-8**	-1.5e-8**	-1.5e-8**	-1.6e-8**
		(7.7e-9)	(6.8e-9)	(7.3e-9)	(7.1e-9)	(7.4e-9)
Recidivism_prog96		-0.4200	-0.4518	-0.4325	-0.4325	-0.3575
		(0.66)	(0.68)	(0.66)	(0.60)	(0.62)
Recidivism_prog02		0.5874**	0.5605**	0.6271**	0.6271**	0.5963**
		(0.26)	(0.26)	(0.26)	(0.32)	(0.25)
Recidivism_prog06		0.0806	0.1881	0.0610	0.0610	0.0336
		(0.64)	(0.65)	(0.66)	(0.58)	(0.66)
N. of firms			-0.0307***			
			(0.01)			
N. of countries				-0.061***	-0.061**	-0.059***
				0.02	0.029	0.019
Sample					Without clustered errors	Without duration
Observations	683	683	683	683	683	683
Pseudo R^2	0.075	0.087	0.074	0.094	0.094	0.091

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; the dependent variable takes the value 1 if the firm group was observed to be the first applicant for leniency, and 0 otherwise; estimated models correspond to Eq. (3); errors are clustered by cartel

programs.²⁰ We summarize the results of the model at the firm group level in Table 6; these results correspond to Eq. (3) that we previously described. The choice of probit or logit does not alter the findings (see Table A.3 in Online Annex 2).

The model shows that several variables do seem to have an influence on the observed outcome: that a firm group was the first to apply for leniency. Similar to the previous analysis, Model 1 takes the basic form without considering covariate interactions; models 2–4 include additional variables in an incremental fashion. Models 5 and 6 are sensitivity tests with respect to the use of clustering in the errors and the inclusion of duration (to test results against a potential endogeneity issue). Model 4 is arguably the one that best describes the data, and overall the results are robust to changes in the model specification. For this reason, this is our preferred specification, and the discussion focuses on it.

An important driver that underlies self-reporting is the variable “Frequency”. It shows a positive sign and high statistical significance in all models. This result supports the hypothesis that the larger is the proportion of firms within one group (relative to the size of the cartel), the greater is the potential loss from the fines and, therefore, the greater is the likelihood of applying for leniency. This result contrasts

²⁰ It should be acknowledged that groups can choose to self-report, but they will not always know whether they will be the first to do so (there are instances of applications arriving very close to one another, in which event the outcome of being first may have an element of luck).

Table 7 Model for other confessors (exclude first confessors). Probit

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Born before 1996	-0.4607 (0.34)	-0.4531 (0.35)	-0.3758 (0.34)	-0.4531** (0.23)	-0.3903 (0.34)
Dead before 1996	-0.8440* (0.47)	-0.8433* (0.46)	-1.0117** (0.46)	-0.8433*** (0.26)	-0.8950* (0.46)
Program 2002	-0.7138*** (0.26)	-0.7669*** (0.26)	-0.5266** (0.22)	-0.7669*** (0.18)	-0.7643*** (0.26)
Program_2006	-0.8082** (0.36)	-0.8437** (0.37)	-0.5749* (0.35)	-0.8437*** (0.25)	-0.8237** (0.36)
Fine	1.1e-9 (1.2e-9)	1.1e-9 (1.2e-9)	1.6e-9 (1.2e-9)	1.1e-9 (9.5e-10)	1.2e-9 (1.2e-9)
Firm group duration	0.0024 (0.00)	0.0018 (0.00)	0.0046 (0.00)	0.0018 (0.00)	
Cartel stability	-0.0550 (0.26)	-0.0948 (0.27)	-0.0230 (0.24)	-0.0948 (0.18)	-0.1323 (0.27)
Frequency	3.1541*** (0.83)	3.1785*** (0.84)		3.1785*** (0.64)	3.1547*** (0.83)
Ringleader	0.8459*** (0.22)	0.5716* (0.31)	0.5935** (0.28)	0.5716 (0.42)	0.5992** (0.30)
Limit participation	-0.3072 (0.25)	-0.3156 (0.25)	-0.3510 (0.25)	-0.3156* (0.19)	-0.3276 (0.25)
Recidivism	0.1813 (0.21)				
Price fixing	0.2585 (0.32)	0.2381 (0.32)	0.2915 (0.30)	0.2381 (0.24)	0.2395 (0.32)
Market sharing	0.1461 (0.23)	0.1350 (0.23)	0.1168 (0.22)	0.1350 (0.14)	0.1570 (0.22)
Market foreclosure	-0.6101 (0.89)	-0.4977 (0.95)	-0.7132 (0.99)	-0.4977 (0.59)	-0.4511 (0.92)
Limit production	-0.1956 (0.30)	-0.2141 (0.30)	-0.4566 (0.32)	-0.2141 (0.20)	-0.2196 (0.30)
Other restrictions	-0.9288 (0.82)	-0.6560 (0.75)	-0.4037 (0.63)	-0.6560 (0.67)	-0.6624 (0.75)
Information exchange	0.2310 (0.20)	0.2141 (0.20)	0.1225 (0.19)	0.2141 (0.14)	0.2016 (0.20)
Bid-rigging	-0.1086 (0.26)	-0.0937 (0.26)	0.0329 (0.22)	-0.0937 (0.19)	-0.0697 (0.26)
Fine^2	-5.3e-19 (8.4e-19)	-5.1e-19 (8.6e-19)	-8.4e-19 (8.4e-19)	-5.1e-19 (6.7e-19)	-5.6e-19 (8.6e-19)
Firm group duration^2	-5.9e-6 (1e-5)	-3.1e-6 (1e-5)	-1e-5 (1e-5)	-3.1e-6 (9.4e-6)	
Fine*Ringleader		3.4e-9 (2.8e-9)	2.9e-9 (2.3e-9)	3.4e-9 (2.9e-9)	3.2e-9 (2.7e-9)

Table 7 (continued)

	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Recidivism_prog96		-0.5081 (0.41)	-0.4980 (0.42)	-0.5081 (0.46)	-0.5058 (0.42)
Recidivism_prog02		0.3970* (0.22)	0.4233* (0.23)	0.3970 (0.35)	0.3696 (0.22)
N. of firms			-0.0550*** (0.01)		
Sample	563	558	558	558	558
Observations				Without clustered errors	Without duration errors
Pseudo R^2	0.143	0.145	0.160	0.145	0.144

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; the dependent variable takes the value 1 if the firm group was observed to be the second or later applicant for leniency, and 0 otherwise; estimated models follow the structure of Eq. (3); errors are clustered by cartel

with that obtained by Hoang et al. (2014), who find a (small but) significant negative effect of the number of firms within one group.

Also, a related finding is that a larger number of firms in the cartel is associated with a lower probability that one particular firm group will disclose the cartel (see model 3, where Frequency variable is not included due to high correlation). This result finds support from the study of Marvão (2014) on penalized cartels by the EC, and from other studies on cartels that were penalized by other authorities (Koh & Jeong, 2014; Kim & Kim, 2016; and Rosenboom, 2020). One potential explanation is the ‘peer-effect’: an increasing number of participants can act as a deterrent to uncover everybody else. Another potential explanation is that, when many firms are involved, the risk is spread and the share of the penalty becomes smaller. This would reduce the incentives for any of the involved firms to trigger a leniency process. Furthermore, the greater is the number of firms that are involved in a cartel, the greater is the fear of betraying the cartel since the greater is the number of cartel members betrayed, the greater is the likelihood of more widespread and severe retaliations from them.²¹

The monetary incentive to apply for leniency—the fine—shows a positive and marginally significant coefficient: A higher fine acts as an incentive to self-report.²² This result is in line with the findings of Hoang et al. (2014) and Rosenboom (2020),

²¹ Jaspers (2020) – in a qualitative study that was based on a series of interviews with business and legal professionals – highlights the fact that one of the most important reasons that discourages applications for the leniency program is the fear of future retaliations in the market from other participants in the cartel.

²² We acknowledge that there is a possibility that the positive relation between total fines and self-reporting is also partly driven by reverse causality: if self-reports generate better evidence, which leads to higher fines. While we cannot rule this out, if reverse causality was indeed a driver we would expect to see a similar ‘fine effect’ on the regression on second and subsequent confessors (since they also self-reported). However, as the results in Table 7 will show, this is not the case since the fine is not significant for other confessors. Nevertheless, this remains an interesting question for further research.

who report a small but significant positive effect of the fine level on the likelihood of applying for leniency. But, importantly, we also hypothesized that the incentive of the fine is not homogenous across all firm groups. Consequently, we allowed this coefficient to vary for certain groups and found that, for cartel leaders, the fine has a negative coefficient and is statistically significant (models 2–6). This has important implications for the design of leniency programs. It can reflect the fact that cartel leaders are aware that they have fewer possibilities of receiving fine reductions and hence do not have a monetary incentive to self-report. Furthermore, since leaders are usually large companies with substantial resources and market power, it could also show that they are less sensitive to potential fines.

In general, the results show that monetary incentives (fines and concentration within the cartel) are generally working. The result that ringleaders do not seem to have incentives to disclose the cartel (Model 1), because they may believe that they will not get a fine reduction,²³ clearly contrasts with the positive relationship that was obtained by Marvão (2014) for US cartels.²⁴ Her result is surprising because the US Department of Justice guidelines state that the leader cannot receive immunity from fines. This prevents the cartel leaders and instigators to benefit from leniency at the expense of others.

However, for everyone else (except leaders), it seems that the higher is the expected fine, the more likely is the firm to self-report. Therefore, for everyone else, it is the “most guilty” firms—those who are aware of their potential higher fine if uncovered—who will self-report. This is desirable only if the fine reductions under the leniency program do not end up penalizing the smaller and perhaps defenseless ones. If that would be the case, leniency programs should instead try to incentivize the less powerful groups to self-report.

The groups’ duration within the cartel is not significant in all models. However the significance of the squared term in models 1, 2, and 4 shows that this effect could be largely driven by groups that have been within a cartel for a very long time: These long-standing groups have a greater probability to self-report. One potential explanation could be related to the monetary incentive in a way that was not picked up by the total fine: Firm groups can anticipate that longer association within a cartel is likely to increase the fine (but also the profits, as García, 2018, states).²⁵ Most dummy variables for the nature of infringements are insignificant; but some specifications show a positive coefficient for the practice of “market sharing”.

²³ This result could suggest that these groups might have generally exercised aggressive leadership, which would increase the likelihood that the Commission would exclude them from the benefits of the program. See Davies and De (2013) for an explanation of the different roles that are played by ringleaders.

²⁴ Hoang et al. (2014) exclude ringleader status from the set of explanatory variables in their model because they do not find evidence that former ringleaders ever became the chief witness.

²⁵ Note that although correlation between duration and fine was low, we conducted a sensitivity test of the model excluding duration. This provides reassurance that results are robust to the exclusion of duration.

Finally, repeat-offenders—recidivist cartel members—are more likely to be the first to apply for leniency under the 2002 Leniency Program than under the other two programs. This latter result is consistent with the findings of Hoang et al. (2014): They indicate that the changes that were incorporated into the second EC Leniency Notice—which clarified the conditions under which immunity from fines would be granted to the first company to provide evidence—significantly increased the incentives of repeat offenders to self-report when compared with the incentives under the 1996 Leniency Notice. Our results also indicate that the 2006 Leniency Notice does not entail a higher probability of recidivists to be the first to self-report, as compared to the probability under the 2002 Leniency Notice.

As was previously mentioned, previous related empirical studies support some of our findings. Nevertheless, significant differences also exist between our analysis and previous works: First, the empirical strategy in most of previous related studies—except that of Hoang et al. (2014)—is at the firm level and not at the firm group level. This means that they do not consider that in many cartels there are more than one firm that belong to the same group or parent company. They could be then ignoring the fact that when various firms that belong to the same group are involved in a cartel infringement, one leniency application is usually made on behalf of all of them.

Second, we use different specifications and include additional explanatory variables such as ‘leading role’ or previously unexplored interaction terms. Third, our more updated and comprehensive database allows us to test not only factors that were previously considered by earlier research on cartels penalized by the EC but also to examine factors that were not reported in earlier studies. This is the case, for example, of the effect of the 2006 EC leniency program or the type of infringements in which the cartel was involved.

Furthermore, we obtain new significant evidence on some variables—such as the number of firms within one group or the role of ringleaders—for which previous studies reported counterintuitive or non-significant results.

5.3 Analysis of Subsequent Leniency Applicants

In this third level of analysis, we explore the outcomes of the remaining groups that chose to apply for leniency (but who turned out not to do so in the first place). Note, however, that it is not possible to know whether a second leniency applicant knew about another member’s previous application—in some cases they would have been aware, but not necessarily.

We would expect that the likelihood to apply for leniency for the remaining groups to be more random than for those who were the first. However, it would still make sense to see monetary incentives playing a role.

Table 7 shows the results of this analysis.

Model 1 takes the basic form without considering covariate interactions. Model 3, with the number of firms instead of Frequency as a covariate, is our preferred specification. This model has the best fit and the widest set of variables with theoretically plausible results.

As in previous estimations for first confessors, Model 2 shows that the variable “Frequency” is still a key driver of being a self-reporter. It shows a positive sign and high statistical significance, in line with expectations. A related finding (given the correlation between both variables) is that the larger is the number of firms within the cartel, the lower is the likelihood of applying for leniency once the cartel have been disclosed (see Model 3).

Somewhat surprisingly, the expected fine is not significant. However, it is possible that part of the monetary incentive is better captured through the ‘frequency’ variable. Estimations also show that those firm groups that participated in cartels that died before 1996 Leniency Program and also those that participated in cartels that fell under the 2002 and 2006 Programs were less likely to be a second or subsequent self-reporter.

This third modelling exercise interestingly shows that the coefficient of ringleader changes sign as compared to the estimations on first confessors, which suggests that leaders and instigators are more likely to self-report than are others (*ceteris paribus*) once the cartel have been uncovered. This contrasts with our previous findings, which showed how leaders tend to hide and were not sensitive to monetary incentives. This model therefore greatly complements those findings and allow us to see the broader picture: Leaders and instigators are more likely to cooperate only once someone else has self-reported the cartel to the authority; the earlier self-reporter presumably is trying to obtain some form of leniency.

6 Conclusions

When mutual mistrust is established among the members of a cartel, this mistrust is incompatible with a cartel’s stability and survival. Therefore, if the necessary incentives are generated to promote distrust among cartelists, destabilization and, most likely, prosecution of the cartel will be accelerated.

The leniency program should be understood as a complement rather than a substitute for other tools that the competition authorities already had to fight against cartels. Therefore, it is essential to find initiatives that achieve *ex officio* investigations to boost the effectiveness of the leniency program and vice versa. One of these initiatives is to create a profile of the cartels and companies with the greatest potential to apply for leniency. In this way, proactive policies would focus on those markets and companies that meet the profile to stimulate their destabilization through the leniency program.

The present work addresses several important questions, such as which types of cartels are more likely to begin the process of leniency, and which types of cartel members are more likely to be the first or subsequent applicants to seek the benefit of the EC leniency program (and the determinants behind self-reporting). Our models build and expand upon the previous literature: by using an extended database (with novel variables and covering a wider and more recent timeframe); by undertaking three distinct but complementary analyses; and by exploring new hypotheses and model specifications that enriched the findings.

We use a detailed compilation of information on 132 cartels (683 firm groups or single economic entities, which include 1568 firms overall) that were penalized by the EC in the period 1996–2020. All of these cartel prosecutions fell within the scope of one of the three European Commission’s Leniency Notices: 1996, 2002, or 2006. This dataset provides information on which firms decided to apply for leniency and when. To the best of our knowledge, this is the largest and most comprehensive dataset that has been explored in this way in the context of the EC.

A preliminary analysis at the cartel level revealed some interesting results: for example, that cartels that died before any leniency program was in place have been less likely to be uncovered by a self-reporting firm. Moreover, the higher are the fines, the higher is the probability of leniency initiation; the impact of fines is stronger when there is also greater diversity of firm groups within a cartel. We also find that bid-rigging cartels are less likely to be uncovered through a leniency application, which might suggest that incentives are not working as well in those cases. This is a worrying finding since these cartels are linked to corruption and misuse of public funds.

Complementing past studies, we analyzed what drives firm groups to disclose their cartels by applying for leniency. The frequency of firm groups within the cartel turns out to be the most relevant covariate. The results show that the incentives of group firms to be the first confessor depend on their own ‘weight’ within the cartel (which is expected to be linked to their expected monetary consequences). In addition, the expected fine is also positively associated with a higher probability to self-report, which further emphasizes the importance of monetary consequences in general.

Another important finding concerns the role of ringleaders: They are less likely to self-report in the first place; but once someone else has uncovered the cartel, their probability to self-report subsequently is higher than for other groups.

Overall, our findings emphasize the need (and the potential) to continue fighting against cartels through improvements in the incentives to self-report.

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Declarations

Competing interests The authors declare no competing interests.

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