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Article

SHORT AND LONG RUN EFFECTS OF LENIENCY PROGRAMS ON CARTEL STABILITY AND PROSECUTION[##]

Joan-Ramon Borrell[*], Carmen García[**], Juan Luis Jiménez[***] & José Manuel Ordóñez-de-Haro[#]

ABSTRACT

This study investigates the effects of leniency programs on cartel duration, cartel fines, and the length of investigations, providing empirical insights that contribute to the ongoing debate regarding their theoretical and empirical implications. The introduction of leniency programs in two different jurisdictions (EU and Spain) at different times and the exogeneity of the introduction date enable us to identify their impact using difference-in-differences estimations. We empirically show that leniency programs, by destabilizing existing cartels, allow for the detection of the longer-lasting ones in the short run. In the long run, our results suggest that destabilization effects prevail, and leniency programs discourage the creation of new cartels. Specifically, our findings indicate that the duration of detected cartels almost doubles in the short run and nearly halves in the long run. Finally, our study reveals that the introduction of leniency programs results in a significant increase in the average fines per cartel case, both before and after taking into account the fine reductions resulting from these programs. This suggests that leniency programs contribute to stronger sanctions against cartels, enhancing their general deterrent effect. However, our findings also indicate that leniency programs lengthen the average duration of

[*] Corresponding author: Universitat de Barcelona, Dep. d'Econometria, Estadística i Economia Aplicada- Institut d'Economia Aplicada (IREA) - Grup de Governs i Mercats (GiM), 1-11 John M. Keynes Street, Spain; and, University of Navarra, IESE Business School, Public-Private Sector Research Center. jrborrell@ub.edu

[**] Universidad de Las Palmas de Gran Canaria. Facultad de Economía, Empresa y Turismo. Grupo de Investigaciãn en Análisis de Políticas Públicas. Despacho D.2-02. 35017. Las Palmas de Gran Canaria. carmen.garciagalindo@ulpgc.es

[***] Universidad de Las Palmas de Gran Canaria. Facultad de Economía, Empresa y Turismo. Grupo de Investigaciãn en Análisis de Políticas Públicas. Despacho D.2-12. 35017. Las Palmas de Gran Canaria. juanluis.jimenez@ulpgc.es

[#] Universidad de Málaga, Dep. de Teoría e Historia Econãmica, Pl. El Ejido, s/n. 29013. Málaga. jmoh@uma.es

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cartel investigations, which may hinder the ability of competition authorities to proactively pursue other cases.

KEYWORDS: Antitrust, Competition Policy, Cartels, Leniency programs,

JEL: D7, K2, L4

I. INTRODUCTION

The apparent success of leniency programs to uncover cartels, as well as their potential deterrent effects against the creation of new ones, has promoted their rapid establishment and implementation around the world (Borrell, Jiménez and García, 2014). There is a wide economic literature on the mechanism that underlies the programs' functioning and the role they play in different fields.[1] According to the seminal theoretical studies by Motta and Polo (2003) and Spagnolo (2004), leniency programs have, in principle, destabilization effects in the fight against cartels.[2] Nevertheless, Spagnolo (2004) raises concerns that leniency programs may facilitate collusion if final expected fines turn smaller by applying into the program and obtaining amnesty.[3]

There has been growing interest in studying how leniency programs impact the duration and stability of cartels. Many empirical studies have been driven by theoretical contributions from Harrington and Chang (2009, 2015). They develop a dynamic model that endogenizes both the population of cartels and the population of discovered cartels and identify how these two populations are related to assess the efficacy of the antitrust innovation. According to their findings, an efficacious antitrust innovation that increases the probability of detection causes the least stable cartels to collapse immediately[4] and the subsequent discovery of cartels arises from a pool of the surviving, more stable, and therefore longer-lasting cartels. Thus, the implementation of an effective detection policy results in a short-term increase in the average duration of discovered cartels. In the long run, the average duration of uncovered cartels decreases due to the overall improvement in deterring cartel practices. However, they note that this long run effect may not apply to leniency policies, which can have perverse effects that promote cartel formation and undermine their destabilizing effects.

Most empirical studies rely on comparisons before and after the policy change (Hinloopen et al., 2023). Miller (2009) and Brenner (2009) are two seminal papers on this topic. The former concludes that the number of cartel discoveries peaks after the introduction of the US leniency program, and then falls to the pre-entrance period. The latter studies the impact of the first EU leniency program and finds no evidence of an increase in the number or duration of cartels detected following its introduction.[5]

Levenstein and Suslow (2011), by using an international cartels prosecuted by the US-DoJ or the EC, provide descriptive statistical support that cartels broken up immediately after the introduction of the leniency program are lasting longer than those uncovered since then.

[1] Marvão and Spagnolo (2015, 2018) and Hinloopen et al. (2023) provide a comprehensive review of the literature in this research area.

[2] Many other theoretical contributions by Fees and Walzl (2004), Motchenkova (2004), Chen and Harrington (2007), Harrington and Chang (2009) and Sauvagnat (2015) also yield to the same general conclusion: leniency programs hinder collusion. Experimental studies also find that leniency programs reduce cartel formation (see, among others, Apesteguia et al., 2007; Hinloopen and Soetevent, 2008; Bigoni et al., 2012; and Dijkstra et al., 2020).

[3] These concerns could be more acute where, as Harrington (2008) pointed out, the authorities focus their efforts and limited resources on leniency proceedings whilst reducing the resources available for their *ex officio* investigations or where, as Chen and Harrington (2007) show, leniency programs only facilitate the discovery of the less stable cartels while make the coordination of the more stable cartels easier.

[4] It is assumed that these are very unlikely to be discovered due to their exit from the cartel population.

[5] De (2010) also finds no significant results for the duration of EC cartels detected under the EU leniency program.

However, they are not able to test these predictions formally. Zhou (2015) also analyses cartel cases sanctioned by the EC and the US-DoJ. Specifically, he distinguishes between cartels born before the program's implementation and collapsed after (short-run impact) and those that were formed and broken under the program's existence (long-run impact). His empirical findings are consistent with Harrington and Chang's theoretical results but are subject to certain limitations that may impact their reliability.[6,7] Hellwig and Hüschelrath (2018) conclude that cartels initiated under the EC leniency program have a shorter expected duration than those started before the leniency program was implemented.[8]

Regarding the potential benefits or costs of leniency programs in the process of cartel prosecution, Brenner (2009) uses investigation duration and total fines as proxies for the costs of cartel prosecution and the information disclosed to competition authorities. His OLS regression results show that under the 1996 EU leniency program, fines increase, and investigation duration decreases by 1.5 years. Vanhaverbeke and Buts (2020) build on Brenner's work, examining the impact of all three versions of the EU leniency program. Their study confirms Brenner's findings on fines but contradicts them on investigation duration, with no statistically significant differences between the effects of the three program versions.

As we have detailed, the empirical literature provides mixed and inconclusive evidence on the destabilization and deterrent effects of leniency programs on cartels. In contrast to most previous studies, which estimate the program's impact on cartels using the Cox proportional hazard model, we employ for the first time a causal analysis (difference-in-differences).[9] This approach provides a more robust analysis by defining clear control and treatment groups. We compare partially treated cartel cases (resulting from an unexpected change in competition policy) and fully treated cases (cartels born under the program) to a control group of cases not potentially affected by the leniency policy. This approach enables us to identify and quantify the impact of leniency programs on cartel duration, fines, and investigation duration more accurately.

Our objective is to, not only analyze the short-term and long-term causal impact of the leniency policy, but also to take advantage of the explanatory power of considering two differentiated temporal and geographical scopes of the implementation of the leniency program. Specifically, we examine the impact of leniency on a broad set of cartel cases sanctioned by the European Commission (EC) and the Spanish Competition Authority from 1969 and 1995, respectively, until 2018. The leniency program was introduced at different times: in 1996 in the EU (and revised later in 2002 and 2006) and in 2008 in Spain. The Spanish leniency program was inspired by the EU leniency program and, therefore, does not substantially differ from it.

The key identifying assumption in our analysis is that the exact moment at which leniency programs are introduced is largely exogenous as it depends on political developments at the EU and Spanish level. The differences in the timing of policy adoption allow us to distinguish between changes in the mean of cartel duration, cartel fines, and investigation duration across

[6] However, the lack of data on cartel cases born and dead after the 2002 EC leniency notice makes it difficult to study the long-run effect of this revision. Zhou uses US-DoJ cases data as a proxy for these EC cartel cases. It is important to note that Zhou (2015) does not use a treatment group and a control group, but only analyze cartels that were affected by the leniency program.

[7] Choi and Hahn (2014) also found that the introduction of the leniency program in Korea had a short-run effect, reducing the hazard rate and resulting in longer cartel duration. However, in the long run, it increased the rate of cartel dissolution, leading to a reduction in cartel duration. Similar results were found by Feinberg et al. (2016) for Korean cartels, although they found a smaller and mixed impact on cartel stability in the long term.

[8] Nkosi and Boshoff (2022) reach the same conclusion using cartels in South Africa.

[9] Jochem et al. (2020) also use this technique to evaluate only the impact of the 2002 reform of the EU leniency program by assigning treatment status to self-reported cartels and comparing them to those directly detected by the EC or non-self-reported cartels (control group), both before and after the reform came into effect. As pointed out by Hinloopen et al. (2023), this is an assignment procedure that is highly likely to be non-random and, as such, violates the other-things-equal condition.

jurisdictions (EU versus Spain) and across time (before versus after). Cartels affecting trade between Member States have had access to the EU leniency policy since 1996,[10] while those affecting only the Spanish national market have had access to the Spanish leniency program since 2008.[11] Once these permanent effects across jurisdictions and time effects are controlled for, we estimate the impact of the difference-in-differences effect of the introduction of leniency programs.

The contributions of this paper are manifold. First, the study examines the EU's leniency program, including revisions in 2002 and 2006, as well as the program implemented in Spain in 2008. We exploit the exogenous policy's geographic and temporal differences. Second, the analysis allows for heterogeneous effects of the program, distinguishing between partially and fully treated observations in terms of short and long-run impact. Finally, the paper defines the control and treatment groups with respect to cases uncovered by leniency applications, those that benefited from the program regardless of how they were discovered, and those affected by the policy even if they do not fall into the previous categories. Program evaluation techniques such as the difference-in-differences estimator are used since we always work with a treatment and a control group. The latter group comprises not only the old cartel cases in that jurisdiction but also includes those cases from the other jurisdiction considered. We test the parallel trend assumptions that are crucial to identify causal treatment effects.

Our results show that leniency programs have a clear and sharp effect on cartel stability. The average estimate shows that the duration of discovered cartels approximately doubles in the short run (around 98%) and halves in the long run (around 57%). According to Harrington and Chang's (2009) theory, leniency programs, by destabilizing existing cartels, allow for the detection of the longer-lasting ones in the short run. In the long run, our results suggest that destabilization effects prevail, and leniency programs discourage the creation of new cartels.[12]

In terms of the impact of leniency programs on cartel prosecution, our findings suggest a substantial increase in the average fines imposed in cartel cases. This indicates that leniency programs contribute to stronger sanctions against cartels, enhancing their general deterrent effect.[13] Brenner's interpretation suggests that leniency programs encourage firms to provide more evidence to authorities. We also find weak evidence that investigations took longer after leniency programs were introduced, likely due to the increased volume of evidence. Our findings underscore the effectiveness of leniency programs in curbing cartel behavior and the importance of considering other factors that may affect their efficiency.

The paper organizes as follows. After this introduction, section 2 shows the data collected for this paper on cartel cases sanctioned by the EC and the Spanish Competition Authority. It also details the method of the diff-in-diff program evaluation techniques used in the paper and defines the groups of control cartels and the leniency treated cartels. Section 3 shows the results of the program evaluation exercise and offers the magnitudes of the impact of leniency programs on cartel duration, the amount of the fines and investigation duration. Finally, section 4 offers

[10] Article 101 of the TFEU (ex 81 TEC) applies to cartels which "may affect trade between Member States". The significant effect on trade between Member States triggers the application of EU competition law, while national law applies otherwise. Additionally, National Competition Authorities (NCAs) cannot use the EU Leniency Program for their cartel proceedings. The EU Leniency Program can only be applied by and is binding only on the EC (Gauer and Jaspers, 2006; Carames, 2021).

[11] Before 2008, cartels operating in Spain that did not affect trade among Member States had no interest in applying to the EC Leniency Program because they had low expectations that European Commission would pursue the case. However, after 2008, cartels that did not affect trade among Member States but did affect the Spanish national market became interested in applying to the new Spanish Leniency Program (See Schroeder and Heinz, 2006 for a discussion of legal puzzles in the application of leniency programs by the EC and NCAs).

[12] We are not able, however, to tackle the pending question of whether leniency promotes the stability of hard-core cartels which remain still undetected.

[13] According to Veljanovski (2022), this result could also be explained by a tightening of the sanctions imposed on cartels by competent authorities to counteract any adverse impact that the leniency program may have on overall deterrence.

concluding remarks, policy implications, and a discussion of the pending questions for further research.

II. DATA AND METHODS

We have collected the detailed information of all cartel decisions taken by the European Commission and Spanish Competition Authority. The database contains cartels sanctioned by EC between 1969 and 2018, and by the Spanish Competition Authority between 1995 and 2018.[14] In total there have been 243 cartel cases (151 cases in EU and 92 cases in Spain), narrowed to 227 if we exclude the 16 cases involving only business associations but not actual firms (8 EU cases, and other 8 Spanish cases). Our analysis will be at each cartel case level, which usually sanctions one cartel.[15]

In our sample, leniency policy spans for approximately 23 years in the EU (between 1996 and 2018) and 11 years in Spain (between 2008 and 2018). There have been 104 European cartel cases that fell within the scope of implementation of the leniency program since its introduction in 1996 (75 cartel cases initiated following a leniency application), and 27 Spanish cartel cases since its introduction in 2008 (23 cases initiated following a leniency application).[16]

Table 1 shows the basic descriptive statistics of the data collected by jurisdiction (EU/Spain), and by the no leniency/leniency split. The figures of the cases under the EU or Spanish leniency programs consider all cartels that benefited from them. A description of the variables can be found in the annex, and more in detail in Ordóñez-de-Haro, Borrell and Jiménez (2018).

Differences outlined in Table 1 might stem from changes in the type of sanctioned cartel cases whenever the leniency program was applied, but the leniency program may not have caused those differences. We need an identification strategy that allows us to separate and quantify the causal effect of the leniency program on cartel duration, fines, and the duration of cartel investigations. Previous empirical papers lack completely a clear identification strategy. We propose and apply a strategy based on the staggered adoption of leniency programs in the EU and Spain to obtain causal impacts from the introduction of leniency programs on cartel duration, fines and the length of cartel investigation.

A. The Identification Strategy of the Leniency Programs' Effects

Our main identification source comes from the fact that the date of implementation of the program is exogenous, and that it has been introduced in two jurisdictions affecting different type of cartels (those affecting trade among Member States and those in Spain not affecting trade among EU Member States) at distinct points of time. We use a difference-in-differences approach in which we compare the cartel cases in the treatment group to those in the control group, both groups being composed of European and Spanish cartel cases.

However, we need to be more specific about our sample of interest given that there are three issues which had not been taken into account in previous empirical papers studying the impact of leniency programs. First, cartel members can benefit from the leniency program if they provide the competition authority with evidence which allows it to initiate an investigation and to

[14] We will call European or EU cases to the cartels uncovered and sanctioned by the European Commission, and Spanish cases or cases in Spain to refer to the cartel uncovered and sanctioned by the Spanish Competition Authority. See web annex 5 for all cartel cases included in the database, available at https://doi.org/10.6084/m9.figshare.25586958.v1

[15] There are a few decisions in which more than one cartel is sanctioned: usually because during the investigation closely related cartels were found, some of them were alive simultaneously affecting different but close products, or different moments of time also simultaneously or closely sequentially. Cartels are so closely related that we treat the duration of the cartel case as the dates within which any of those interrelated cartels were active, and the sum of fines to all cartels in such case decision, and the duration of the whole investigation to those closely related cartels sanctioned in the same decision.

[16] Cartel cases that fell within the scope of application of the leniency program includes those initiated following a leniency application, made before the competition authority had taken any investigative steps, or following a competition authority's investigation on its own-initiative or on the basis of a complaint.

Table 1. Average statistics by leniency program and jurisdiction

Variables	EU (1969–2018)				Spain (19959–2018)			
	No leniency		Leniency programs 1996, 2002 & 2006		No leniency		Leniency program 2008	
Number of cases (all)	47		104		65		27	
Number of cases (associations only excluded)	39		104		57		27	
Basic amount of fines	125.7	(300.3)	412.4	(794.2)	21.4	(33.8)	26.6	(32.2)
Final fine	74.3	(204.0)	264.7	(459.7)**	17.2	(25.6)	24.4	(31.2)
Average (percentage) of fine reduction by leniency	0.0	(0.0)	0.3	(0.2)***	0.0	(0.0)	0.7	(0.3)***
Final fine per firm	15.7	(65.3)	21.9	(30.2)	2.1	(3.5)	1.6	(1.8)
Final fine per consolidated firm	21.8	(98.1)	43.3	(75.5)	2.5	(4.4)	2.6	(3.3)
Max cartel duration (years)	7.7	(6.2)	7.8	(6.0)	7.5	(6.8)	11.2	(7.8)**
Duration of investigation	3.5	(2.0)	4.5	(1.6)***	2.8	(1.0)	2.5	(0.5)
Average number of firms	10.9	(10.4)	12.6	(9.7)	13.5	(12.1)	17.4	(20.2)
Average number of consolidated firms	10.0	(9.5)	6.4	(3.6)***	11.9	(10.7)	13.0	(16.5)
Average number of countries	4.7	(4.1)	5.1	(2.8)	1.2	(0.5)	2.4	(1.7)***
Average number of countries (parent firms)	4.7	(4.2)	3.9	(2.0)	1.2	(0.5)	2.3	(1.7)***
Cartel Stability	0.1	(0.2)	0.2	(0.1)	0.1	(0.3)	0.0	(0.0)*
Cases stem from a leniency application	0.0	(0.0)	0.72	(0.5)***	0.02	(0.1)	0.81	(0.4)***
Cases stem from the EC's own initiative	0.72	(0.5)	0.21	(0.4)***	0.47	(0.5)	0.15	(0.4)***
Cases stem from a notification	0.05	(0.2)	0.0	(0.0)**	0.0	(0.0)	0.0	(0.0)
Cases stem from a complaint	0.23	(0.4)	0.07	(0.3)***	0.51	(0.5)	0.04	(0.2)***

Note 1: Fines in constant millions of euro 2010 (GDP World Bank deflator). Standard deviation within brackets. Cartel cases with sanctions only to business associations (not individual firm sanctions) excluded: 8 cases out of 151 excluded in the EU, and 8 cases out of 92 excluded in Spain. Note 2: *, ** and *** indicates that mean t-tests between leniency/no leniency split shows statistical significance at 10%, 5%, 1%, respectively. Source: Authors elaboration from the European Commission and the Spanish Competition Authority publicly available information on cartel cases.

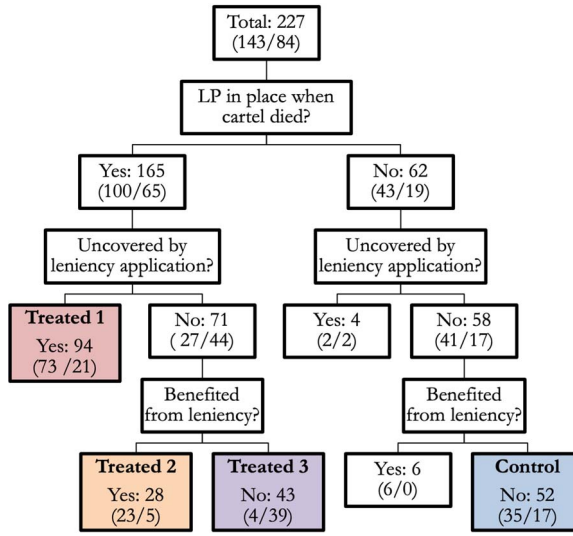

Figure 1. Sample split EU/Spain. Definition of treated and control group. Note: LP refers to leniency program. Source: Authors' elaboration from the publicly available case files.

uncover their cartel. But even if the cartel's discovery would have resulted from the competition authority's ex-officio investigation, cartel members could also benefit from the leniency program if they cooperate under the terms of the program.

Secondly, these previous scenarios can occur even if the cartel ceased to be active before the leniency program came into force, as was the case in ten cartel instances.

Finally, apart from falling or not within the scope of implementation of the program, an additional distinction needs to be made among cartel cases in our sample: some cartels were alive before the date of the entry into force of the leniency program and died after that date (partial treatment) and some others were born and broken with the program already in force (full treatment).

Figure 1 summarizes all the possible treatment options (cartel cases potentially affected by leniency), and the control group (cartel cases not potentially affected by the leniency policy).[17]

Our control group comprised of those cartels that were born and died before 1996 for the European cases, and before 2008 for the Spanish cases. The control group is not affected by the treatment in any sense:[18] cartel members could not apply to any leniency program while they were alive, and they did neither benefit from it afterwards (depicted as Control in Figure 1).

Our treatment group will be different, depending on the outcome of interest. When studying the effect of the leniency programs on cartel duration, our first treatment group will be formed by those cartel cases that were uncovered as a result of the leniency applications from some of their members (treated 1: ***cartels uncovered by leniency application***).

The second treatment group will consider all the cartel cases for which the leniency program was available while they were active, regardless of whether they fell or not within the scope of

[17] The division of European and Spanish cases is specified in brackets. The first figure corresponds to EU and the second one to Spain.

[18] Note that, in this case, in which cartel cases died before the leniency programs were implemented, the cartels uncovered by leniency application (4 cases in total) or that benefited from leniency (6 cases in total) are excluded from our sample of interest, since they are not an appropriate control nor a properly treated case (died before the leniency program entered into force).

Table 2. Classification of partial and full treatment

	Control		**Partial treatment**		**Full treatment**	
	Born (Before)	**Died** (Before)	**Born** (Before)	**Died** (In/After)	**Born** (In/After)	**Died** (In/After)
1996 EU leniency	1996	1996	1996	1996	1996	1996
2002 EU leniency	1996	1996	2002	2002	2002	2002
2006 EU leniency	1996	1996	2006	2006	2006	2006
2008 Spanish leniency	2008	2008	2008	2008	2008	2008

application of the program: cartels alive while the leniency program was into force (treated 1, treated 2, and treated 3: ***all treated cartels***).

The reason for this distinction is the following: when studying cartel duration, we are firstly interested in those cases that internally broke up because some cartel member applied for leniency disclosing the existence of the cartel to the competent authority, that is, those in which some member applied for leniency and then the cartel got uncovered as a result of its application. This will give us the comparison between those cartel cases in which their members made direct use of the program and broke up (treated 1) and the control group (control).

Additionally, we are also interested in studying the effect of the existence of the program on the duration of all cartel cases discovered. Regardless of whether the members of the cartel did or did not apply for a lenient treatment, the entry in force of the program could have had some deterrence effect on existing and future cartels (maybe new cartels formed are shorter-lived), and in that case the treatment group of interest are all the cartel cases that coexisted with the leniency program already in force during some period of their lifespan, that is, all cartels treated by the policy (treated 1, treated 2, and treated 3).

However, when analyzing the effect of the policy on fines and on the duration of the investigation, our treatment group is composed by those cartel cases for which the leniency program was available while cartels were still alive, and that additionally applied for leniency and obtained some benefit from the program (treated 1 and treated 2 in the previous figure). Those are all the cartels coexisting with the leniency program to which the program was implemented and that obtained some fine reduction (treated 1 and treated 2: ***benefited from leniency***).[19]

As mentioned above, there is a second distinction we make in our treatment group among those cartel cases that died after the corresponding leniency program entered into force in each jurisdiction: EU or Spain. The classification comes from the date of formation: if the cartel was born before the date of the entry in force of the leniency program (and died after), we consider this observation had a *partial* treatment. On the other hand, if the cartel both was formed and died after the program had entered into force then it had *full* treatment (See Table 2).

It should be clarified that these treatment variables corresponding to EU overlap. The reason is that, since 1996 EU Leniency considers all those cartel cases born and dead after 1996 (full treatment), it also includes those cases affected by the versions of the program implemented afterwards.

With respect to partial treatment, we could also have a similar case: for instance, two different cartel cases may have been formed in 1994 but one could have died in 1999 (partial

[19] This group excludes also dead cartels in which some of their members obtained immunity or fine reductions under the leniency program although these cartels were no longer alive when the program came into force. In those cases, leniency applicants revealed the existence, or cooperate if cartels were already uncovered, of a dead cartel that was active before the leniency program came into force, cartels whose lifespan was prior to the entry into force of the leniency program.

treatment under 1996 EU Leniency) and the other one in 2004 (partial leniency under 2002 EU Leniency). We assign partial treatment status in both stories. Thus, the effects obtained refer to the total effect of the leniency program from that moment onwards, and not to the effect of the version of the program implemented in any given year. However, a cartel formed in 2000 which died in 2004 would be a cartel fully treated under the 1996 EU Leniency Program, but also partially treated under the 2002 EU Leniency Program.

In the estimations we include both treatments simultaneously in the regressions. So, the estimated parameter of treatment dummy offers the marginal effect of each type of treatment (full or partial), given that in a few cases both treatments may have had an impact on the studied outcomes (cartel duration, fines, and years of investigation).

In so doing, we are then obtaining conditional effects taking into account that a few cartels had the impact of full treatment under the previous leniency program, but also the impact of the partial treatment under the subsequent EU leniency program. We also run separate regressions for each type of treatment (full or partial) and the results were very similar to those including both treatments simultaneously.

In the non-parametric matching estimations, the effect of each type of treatment has to be estimated separately by construction. So, in this case, we cannot obtain the conditional estimates given the impact of the previous and subsequent EU leniency programs. Finally, for rendering unbiased and consistent estimates of the impact of the treatment, difference-in-differences estimation requires that the outcomes under study should follow parallel trends before any treatment in the two jurisdictions under study.

Given that we are analyzing two different jurisdictions, we check the parallel trend assumption[20]. Figure 2 depicts cartel duration by jurisdiction and by year of investigation and shows that the duration of cartels evolves similarly in both jurisdictions before the policy is implemented.

Figures 2.1 and 2.2 in the web annex 2 of the paper depict the average amount of basic fines and final fines per cartel case, respectively, by jurisdiction and by year of investigation, and show that although the amounts are different in both jurisdictions they evolve similarly before the policy is implemented.[21]

Results of the estimations testing the parallel trend assumption are correct: it holds when analyzing the impact of leniency programs on cartel duration, basic amount of fines and final fines. However, it does not hold when studying the number of years of investigation.[22]

B. Estimation Models and Procedures

B. Survival Analysis

In order to analyze the impact of the leniency programs on cartel duration, we compare the duration of the cartels in the treatment group against those in the control group. A limitation of working with cartel cases is that we can only work with discovered cartels, and results may not be inferred to the whole population.

However, Harrington and Chang (2009) develop a model of cartel creation and dissolution that allows inferring the impact of the competition policy on the population of cartels by measuring the impact on the duration of discovered cartels. According to it, if the probability of discovering and convicting cartel members increases due to a change in the policy, then the

[20] We control for other explanatory variables to take into account possible differences across jurisdictions as some variables present statistically significant differences while others do not. This issue is explained in section 2.2. In addition, we double check whether our controls variables in most regressions are clean controls: do have common pre-trends in one and the other jurisdiction. Results are available upon request (they have been not included due to space problems).

[21] Web annex 2 available at https://doi.org/10.6084/m9.figshare.25586958.v1

[22] These results are available upon request. They have not been included due to space problems. See also Figure 2.3 in the web annex 2 of the paper.

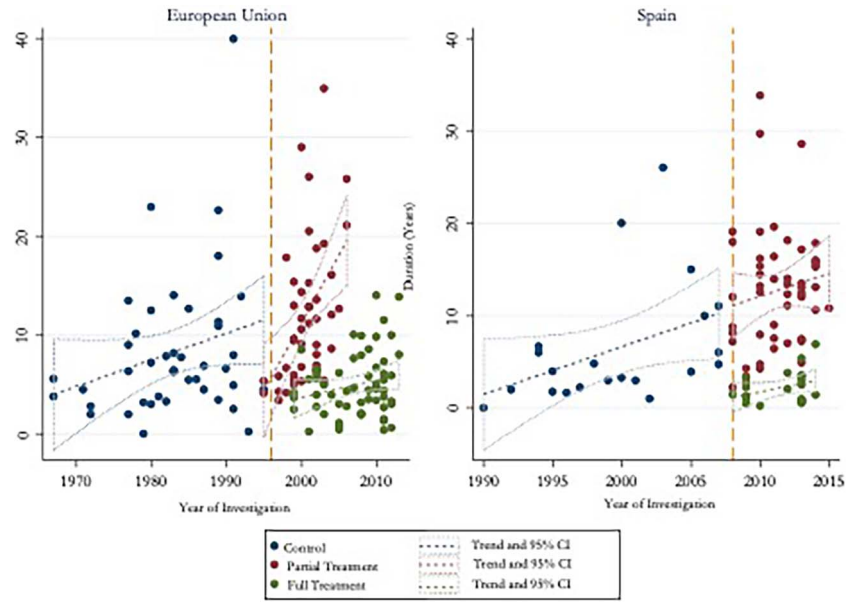

Figure 2. Cartel duration and trends by jurisdiction.

least stable cartels collapse immediately. Thus, the surviving cartels have longer durations, and this turns into a rise in average duration of discovered cartels in the short run. In the long run, average duration of observed discovered cartels could go up or down, since less stable cartels do not form in first place (thus, a rise in duration of discovered cartels would be found in the data) but the formerly stable cartels break up earlier (in this case, a decrease in duration of uncovered cartels should be observed).[23]

We distinguish between the short run and long run impact of the leniency program on cartel duration in the sense of those cartels that were formed before the date of the entry into force of the program and died after (partial treatment or short run effect) versus those cases that were formed when the leniency program was already in force (full treatment or long run effect).

For our purpose, we estimate the Cox proportional hazard model for survival analysis.[24] The purpose of the model is to examine how specific factors influence the rate of an event happening.[25] In this case, the event is cartel death. The regression estimated is the following one:

$$h_i(t) = h_0(t)\exp\left(\beta_1 treatment_i + \beta_2 spain_i + \beta_3 lncountry_i + \beta_4 lnfirm_i + \beta_5 stability_i + \varepsilon_t + \eta_s + u_i\right) \quad (1)$$

[23] Harrington and Wei (2017) give the conditions under which the duration of detected cartel would be an unbiased measure of the duration of the cartel population.

[24] Brenner (2009), De (2010), and Zhou (2015) also use this methodology, with the main difference that we study the cases of EU and Spain, which allows for a diff-in-diff approach. This gives us the opportunity to improve the comparison group by not only using the previous cases of the corresponding jurisdiction but also the ones in the other jurisdiction, and the treated group receives the treatment in different periods of time.

[25] The Cox proportional hazard model assumes that the effects of the predictor variables upon survival are constant over time and are additive. If the coefficient is positive, or equivalently the hazard ratio is greater than one (exponential of the coefficient), it indicates that, as the value of the covariate increases, the event hazard increases and thus the length of survival decreases. In other words, a hazard ratio above one indicates that it is positively associated with the event probability, and thus, negatively associated with the length of survival.

where: $treatment_i$ is a binary variable that either denotes partial treatment or full treatment and takes value 1 if the cartel case was affected by any leniency program; $spain_i$ is a binary variable that takes value 1 for Spanish cases; $lncountry_i$ is the logarithm of the number of countries to which belong the firms involved in the cartel case; $lnfirm_i$ is the logarithm of the number of firms involved in the cartel case; $stability_i$ is a binary variable that takes value 1 if all firms entered and exited the cartel at the same time; ε denotes time fixed effects; η denotes industry fixed effects; and u_i is the error term.

The time fixed effects correspond to two dummy variables: one of them takes value 1 if the year of the decision is between 1996 and 2007 (both inclusive) and the other one takes value 1 if the year of the decision is after 2007. An alternative specification considers investigation year, instead of decision year, as time fixed effects. These variables control for any possible changes in average discovered cartel duration not related to the leniency enforcement that happened simultaneous either in Spain or in the European Union in three periods: before the entry into force of the leniency program in the EU (1995 and before), in the period in which the only leniency program enforced was the one in the EU (1996–2007), and in the period in which both programs were enforced (2008 and after).[26] The industry fixed effects are captured with inclusion of NACE Rev.2 classification sector dummies.[27]

B. OLS Estimations

We also estimate an OLS approximation to the impact of the leniency program on the log of duration to check whether the functional form of the Cox proportional hazard model for survival analysis has any impact of the results. We will see below that results of both the Cox model and the OLS approximation are very similar.

Additionally, we are interested in studying the effect of the leniency program on the basic amount of fines and final fines imposed to the discovered cartels, and on the duration of the investigation. Following Brenner (2009), if more information is disclosed due to the cooperation with the authority, then the basic amount of fines per case (fine prior to the application of the leniency scheme) should be larger than the basic amount of fines per case imposed before the introduction of the leniency program. The effect on the final fines of the treated group could be either positive or negative, depending on the reduction. However, Brenner (2009) finds that the fine reductions do not fully compensate for the increase of basic amount of fines. With respect to the duration of the investigation, it should decrease given that the costs of obtaining relevant information are lower. We should also consider that the information disclosed could make the analysis of the case more complex. The latter could be also explained by the greater body of evidence that must be assessed before a decision is taken by the competition authority.

The regression estimated, by OLS, is the following one:

$$y_i = \beta_0 + \beta_1 \cdot treatment_i + \beta_2 \cdot Spain_i + \beta_3 \cdot lnCountry_i + \beta_4 \cdot lnFirm_i + \beta_5 \cdot lnDuration_i + \varepsilon_t + \eta_s + u_i \quad (2)$$

where: *yi* is the logarithm of the outcome of interest (basic amount of fines, final fine or years of investigation); *lnDurationi* is the logarithm of the maximum duration of the cartel case; and the rest of the variables are defined as above.

An important methodological issue arises at this point. To study cartel fines, we have to control for cartel duration, since it is relevant to determine the fine imposed by the authority. However, leniency program may have an impact on cartel duration. Therefore, we also estimate a reduced form equation without duration as explanatory variable to see the impact of leniency

[26] A binary variable for each year which would control all average changes orthogonal to the leniency program that simultaneously affect the EU and Spain cannot be used because the number of observations is not big enough.

[27] NACE is the French acronym for the European Classification of Economic Activity.

on fines via both channels altogether: the direct effect of leniency on fines and the indirect effect of leniency on fines through changes in cartel duration.

B. Matching Estimator

Finally, matching techniques are used to overcome the potential problem of cartels comparability (Bos et al., 2018). The methodology used in this case is the non-parametric nearest neighbor matching method. Following Imbens and Wooldridge (2009), let *Yi* denote the outcome of interest, let *Xi* be the observable characteristics on which we are matching and let Ci be the treatment variable. Given a sample {*Yi, Xi, Ci*}*i* = *1N*, let *ℓ1 (i)* be the nearest neighbor to *i*, that is:

$$\ell_1(i) = j, for\ j \in \{1, ..., N\}, if\ C_j \neq C_i, and\ \left\|X_j - X_i\right\| = \min_{k:C_k \neq C_i} \|X_k - X_i\| \qquad (3)$$

where the metric used is the Mahalanobis metric, which is based on the inverse of the full sample variance–covariance matrix and is the most common in the literature. The observable characteristics used for the matching are the control variables used in the OLS specification.

We exploit the variation across groups of units that receive treatment at different times. Goodman-Bacon (2021) show that the difference-in-differences estimation of the effect of the treatment applied to different units at different times is "a weighted average of all possible 2×2 DD estimators that compare timing groups to each other".[28]

In our case, we compare the cases treated by leniency at the EU jurisdiction with the control cases both in the EU and Spain for which cartels were alive only before the introduction of the leniency policy. We also compare the cases treated by the leniency policy at two different times, using the later-treated group (Spain) as a control before its treatment begins, and then the earlier-treated group (EU) as a control after its treatment begins.

According to Goodman-Bacon (2021), when treatment effects do not change over time, the difference-in-differences estimator yields a variance-weighted average of cross-group treatment effects and all weights are positive. We find no heterogeneity of treatment effects over time (similar average effects in the staggered effect of the treatment first in the EU and then, later on, in Spain).

Sloczynski (2022) shows that difference-in-differences regression model is expected to provide a reasonable approximation to Average Treatment Effect (ATE) in which we are interested if both groups, treated and control, are of similar size even when treatment on the treated (ATT) differs from the effect of treatment on the untreated (ATU). In our dataset, we have a quite similar number of control cartels cases with respect to the number of cartels cases treated in each treatment: partial or full treatment. So diff-in-diff is offering non-biased estimates of ATE, the average treatment on the treated (ATT) and the untreated (ATU).

C. Data

Table 4 shows the descriptive statistics of the data we are going to use to identify and quantify the impact of the leniency policy on cartel duration: the ***control group*** and the group of ***all treated cartels*** (treated 1, treated 2, and treated 3 in Figure 1) that were alive while the program was available whether their members had applied or benefited from it or not.[29] There are 52 cartels in the control group, 67% corresponding to the EU and 33% to Spain.

[28] Other papers that also point to this issue are the following: De Chaisemartin and D'Haultfoeuille (2020), Sun and Abraham (2021), Borusyak and Haravel (2017), and Athey and Imbens (2022).

[29] In the web annex 1, we show the descriptive statistics for the control group, the group of cartel cases uncovered by leniency application (treated 1 in Figure 1), and for the group of cartel cases that benefited from leniency and that were alive when the program was available (treated 1 and 2 in Figure 1). Web annex 1 available at https://doi.org/10.6084/m9.figshare.25586958.v1

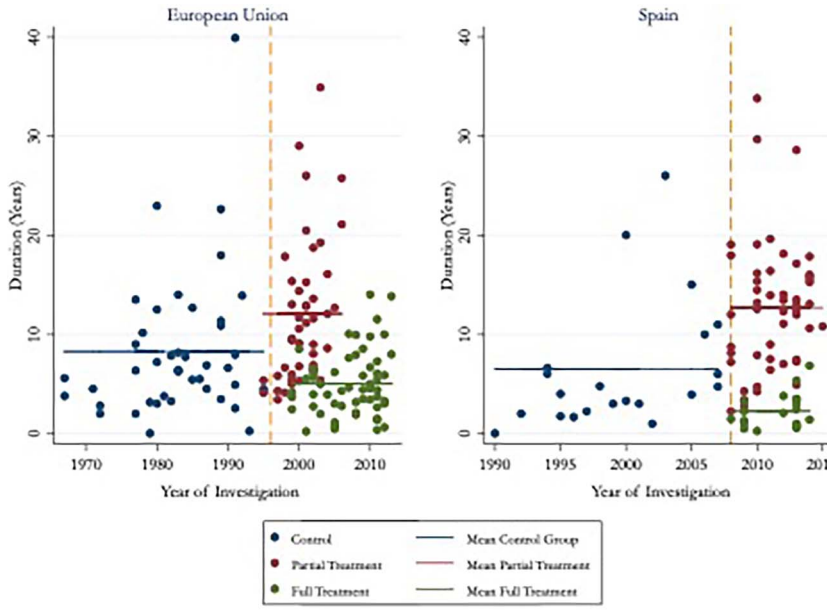

Figure 3. Discovered cartel duration by jurisdiction. Source: Authors' elaboration from the publicly available case files.

III. RESULTS

In this section we present the results of the Cox regression for cartel duration, the OLS results for cartel duration, basic amount of fines, final fines, and number of years of investigation, and the ATT results for fines and the duration of the investigation, after applying matching techniques.

A. Effects on Cartel Stability

We start by analysing the impact of leniency programs on the duration of discovered cartels. Figure 3 shows the mean statistics of cartel duration by jurisdiction across time. It is clear that discovered cartel mean duration per cartel case is larger for the cartel cases created before the leniency program entered into effect and were broken up after it (partial treatment), and that mean cartel duration per cartel case is smaller for cartel cases created after the leniency program entered into effect (full treatment). Regression analysis will show whether these mean differences are statistically significant, and what are the short- and long-term effects of leniency programs on discovered cartel stability.

A. Survival Analysis

Table 3 presents the results (expressed as hazard ratio) for the Cox regression estimation. Results show that those cartel cases that were partially treated by the leniency program and were uncovered by the leniency program enforcement (treated 1), experiment a 69% smaller in the hazard of failure (short run effect in column 2: estimated coefficient minus 1). This means that the duration of these cartel cases is significantly higher than those in the control group.

When all cartels partially treated are considered (treated 1, treated 2, and treated 3), meaning all the cartel cases affected by the existence of the program, had they applied for the program or not, the decrease in the probability of dying is 67% (short run effect in column 5: estimate coefficient of 0.33 minus 1).

Table 3. Cartel duration (Cox regression) hazard ratio

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Partial treatment	**0.44*****	**0.31*****	**0.25*****	**0.39*****	**0.33*****	**0.27*****
	(0.09)	(0.06)	(0.04)	(0.06)	(0.02)	(0.04)
Full treatment	**3.64*****	**4.05*****	**3.46*****	**4.61*****	**4.90*****	**4.28*****
	(0.63)	(0.42)	(0.61)	(0.60)	(0.68)	(0.71)
Log N. countries	0.82*	0.74***	0.75***	0.91	0.88*	0.90*
	(0.08)	(0.08)	(0.07)	(0.06)	(0.06)	(0.06)
Log N. firms	1.19**	1.18	1.21*	1.08	1.05	1.06
	(0.09)	(0.15)	(0.13)	(0.11)	(0.12)	(0.1)
Stability	1.43	1.13	1.15	1.49**	1.35*	1.33*
	(0.42)	(0.35)	(0.32)	(0.26)	(0.23)	(0.20)
After fixed effects	No	Investigation year	Decision year	No	Investigation year	Decision year
Industry fixed effects	No	Yes	Yes	No	Yes	Yes
Spain fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	143	143	143	210	210	210
Pseudo R^2	0.043	0.063	0.065	0.059	0.074	0.076
Sample	Uncovered by leniency	Uncovered by leniency	Uncovered by leniency	All treated cartels	All treated cartels	All treated cartels

All leniency programs (EU96, EU02, EU06 & SP08) Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Standard errors in parentheses. Relevant coefficients are in bold. Note on sample: *Uncovered by leniency* refers to cartel cases subject to treated 1 in Figure 1, while *all treated cartels* refer to cartel cases subject to treated 1, 2, and 3 in Figure 1.

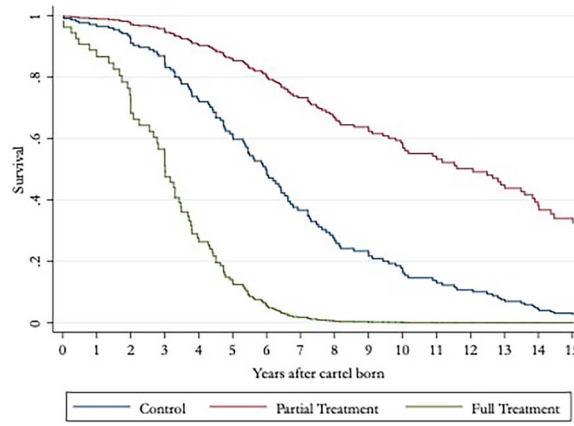

Figure 4. Survival estimations. Cox proportional hazards regression. Source: Authors' elaboration from estimations included in Table 3.

Thus, results show a short-run effect (partial treatment) of leniency program: the detected cartel cases have longer duration than the ones in the control group (hazard ratio lower than one). This result is consistent with the one outlined theoretically by Harrington and Chang (2009), and also found empirically by Zhou (2015). These authors conclude that the average duration of discovered cartels rises in the short run, in response to a more effective competition policy. The reason is that if the policy is efficacious, then its adoption will immediately cause the marginally stable cartels to collapse, and they will exit the cartel population.

Table 3 also shows that those cartel cases that were fully treated by the leniency program and were uncovered by the program, experiment a 305% (column 2, estimated coefficient of 4.05 minus 1) and a 390% (column 5, estimated coefficient of 4.90 minus 1) increase in the hazard of failure (baseline hazard is when coefficient equals 1). This means that the duration of these cartel cases is significantly shorter than those in the control group.

The hazard ratio can be interpreted as follows: the probability of dying of those cartel cases that were born and died under the leniency program is around four times higher (4.05, column 2, to 4.90, column 5) than the one of the cartel cases in the control group. Therefore, the duration of the treated cases is lower than the duration of the cartel cases that were born and died before the leniency program came into force and did not benefit from that program afterwards.

Following the previous discussion regarding Goodman-Bacon (2021), we have also estimated the treatment effect separately for the EU and Spain, although they should be carefully interpreted, given that the number of observations in each group is low, especially in the case of full treatment in Spain. Results are presented in Table 3.1 in the web annex 3 of the paper,[30] which show no heterogeneity of treatment effects over time nor across jurisdiction (similar average effects in the staggered effect of the treatment first in the EU and then, later on, in Spain).

Going back to the case in which EU and Spain are treated jointly, Figure 4 shows the survival probabilities of cartels at different duration time, at the average value of the other covariates, and for the three groups of cartel cases: partially treated and fully treated cartel cases that got uncovered by leniency (treated 1), and the control group.

The figure shows the survival rates for the cartel cases that were partially treated (leniency introduced after the cartel was born and was in force when the cartel died) is always larger

[30] Web annex 3 availabe at https://doi.org/10.6084/m9.figshare.25586958.v1

than the control group and, both are larger than the ones in the fully treated group (leniency introduced before the cartel was born).

At the duration of 4 years, survival is around 70% for the control group. For the partially treated cartel cases survival increases up to around 95% (those cartels were very stable while at year 4 of their live, most likely reaching that age before the leniency program came into force, and those cartels broke down once the program entered into force), and for the full treated cartels survival goes down to around 20% (those cartels are less stable at year 4 of their life which occurs while the leniency program had already entered into force).

Harrington and Chang (2009) find that the effect of the leniency program on cartel duration in the long run is ambiguous, it could go either up or down. On the one hand, those cartels at the margin that are less stable will not form under this policy, which entails a rise in the observed durations. On the other hand, the formerly stable long-running cartels break up earlier, reducing observed cartels durations. Our results are consistent with the second explanation: the long run effect of the leniency program is a decrease in cartels duration because formerly stable long-running cartels break up earlier, which is a clear destabilization effect. Although equal or more stable cartels are formed, those finally end breaking up earlier due to the leniency policy that makes them less stable.

Another question is whether the leniency program brings shorter or less stable cartels into light or whether it does really deter collusion by means of the formation of shorter cartels or the formation of fewer cartels. Harrington and Chang (2009) claim that in response to a policy that alters the likelihood of detection and conviction, the effect of the rate of cartels can be inferred by observing the duration of discovered cartels in the short run. If average cartel duration goes up, then the policy has caused the probability that firms are discovered and convicted to rise and thus we can conclude that it will result in fewer cartels forming in the new steady state. Our results prove this last point: fewer cartels are formed in the new steady state.

A. OLS Estimations[31]

Table 4 shows the results using an OLS regression of log of cartel duration. As shown in the table, results hold. The average length of detected cartels that break up temporarily (short run) increases directly after introducing a leniency program (average estimate of around 98%).[32] In the long run, the average length of detected cartels that break up after introducing the leniency policy decreases (average estimate of around 57%).[33] Given the mean duration of cartels in the control group is 7.0 years, duration of the discovered cartels goes up, on average, in 6.8 years in the partial treatment cases, and, on average, goes down by 4.0 years in the full treatment cartel cases.

We also compute all the estimations restricting the sample in the partial treatment group to those cartels with duration of 22 years or less in the EU, and 10 years or less in Spain. These durations are the maximum durations that cartels born and died after leniency (fully treated cartels) can last given that leniency was introduced in the EU in 1996 (2018–1996 = 22), and in Spain in 2008 (2018–2008 = 10 years). Results, not shown for the sake of simplicity, hold even under this constraint in the sample. The larger average length of discovered cartels partially treated by the leniency policy is not driven by the left uncensored (uncensored date of birth) potential life span of the discovered cartels before the introduction of leniency.

[31] Most results presented in this subsection are replicated in Annex 3 considering the implementation of the leniency program separately in EU and in Spain. Results hold, although results are weaker in Spain due to the low number of treated observations. In the case of full treatment, we have not been able to estimate the effect in Spain for most of the outcomes.

[32] The average effect has been obtained using the coefficients of the six models estimated, and according to the coefficient interpretation in the case of log-linear models.

[33] Average estimates of columns 2, 3, 5, and 6: estimates including time fixed effects computed using investigation or decision year.

Table 4. Log of Cartel duration

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Partial Treatment	**0.74*****	**0.64*****	**0.81****	**0.80*****	**0.55*****	**0.71****
	(0.13)	(0.15)	(0.27)	(0.12)	(0.16)	(0.31)
Full Treatment	**−0.69*****	**−0.90*****	**−0.74****	**−0.78*****	**−0.92*****	**−0.80*****
	(0.12)	(0.11)	(0.30)	(0.10)	(0.09)	(0.19)
Log N. Countries	0.02	−0.01	−0.02	0.03	0.03	0.01
	(0.06)	(0.09)	(0.09)	(0.05)	(0.07)	(0.08)
Log N. Firms	0.13*	0.24*	0.20	0.08	0.13	0.10
	(0.06)	(0.11)	(0.12)	(0.07)	(0.10)	(0.10)
Stability	−0.38*	−0.18	−0.23**	−0.39	−0.27	−0.30
	(0.19)	(0.14)	(0.10)	(0.23)	(0.20)	(0.18)
After fixed effects	No	Investigation Year	Decision Year	No	Investigation Year	Decision Year
Industry fixed effects	No	Yes	Yes	No	Yes	Yes
Spain fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	146	146	146	217	217	217
R^2	0.269	0.365	0.358	0.384	0.443	0.439
Sample	Uncovered by leniency	Uncovered by leniency	Uncovered by leniency	All treated cartels	All treated cartels	All treated cartels

OLS regression. All leniency programs (EU96, EU02, EU06 & SP08) Note: * $p<0.10$, ** $p<0.05$, ***$p<0.01$. Standard errors in parentheses. Relevant coefficients are in bold. Note on sample: *Uncovered by leniency* refers to cartels treated 1 in Figure 1, while *all treated cartels* refer to cartels treated 1, 2 and 3 in Figure 1.

B. Effects on Cartel Prosecution

Leniency programs may entail both benefits and costs for cartel prosecution. Leniency programs provide more evidence about illegal activity, which could lead to a shorter prosecution process and higher fines (Brenner, 2009). However, they may also make prosecution less effective in terms of punishment and deterrence of this anticompetitive practice since reductions and exemptions in fines under the program could reduce the final sanction (Spagnolo, 2004). Additionally, the analysis of all the evidence provided may require lengthening the duration of the investigation, which could increase the program's overall prosecution costs (Ordóñez-de-Haro et al. 2018; Vanhaverbeke and Buts, 2020). We will now empirically examine the effects that leniency programs have on fines imposed in cartel cases, both before and after the program's fine reductions, as well as on the duration of the investigation.

B. Cartel Fines

Table 5 shows that we also find a significant effect of the leniency program on basic amount of fines per cartel case.[34] Basic amount of fines is the fine before discounting the benefits of cooperation under the leniency program. Both partial and full treatment result in higher fines: by 95% to 99% in the case of cartels under partial treatment that apply for leniency (both uncovered or not by leniency applications) when controlling for cartel duration; by 129% to 200% in the case of cartels under full treatment that apply for leniency or cooperate when controlling for cartel duration.[35]

When not controlling for cartel duration, the effect of partial treatment is higher due to larger cartel duration of discovered cartels under leniency (136% to 200% in columns 5 and 6 which include time fixed effects) while the effect of full treatment is lower due to shorter cartel duration of discovered cartels under leniency (43% to 84% in columns 5 and 6 which include time fixed effects). Table 4.1 in the web annex 4 of the paper shows the results of the effect of the leniency program on final fines.[36]

These results may be driven by two effects: (1) competition authorities may access to full detailed information about the cartel activity through the leniency program, helping the authorities to charge a larger fine thanks to the program; (2) it might also be explained by a tightening of the sanctions imposed on cartels by competent authorities to counteract any adverse impact that the leniency program may have on overall deterrence (Veljanovski, 2022).

We double check the robustness of the results of the estimation of the impact of the leniency policy on fines using matching techniques. OLS estimates offer the impact for the cases at the mean of the covariate characteristics of the cartel cases, while local comparisons using matching techniques allow us to estimate the impact comparing cases of similar characteristics locally in the treatments and control groups. So, we can control more accurately for the differences in the characteristics of the cartel cases in the treatments and control groups.

Using local matching comparison techniques, we obtain again a strong and significant positive impact of leniency program (either partial or full treatment) on basic amount of fines and final fines.

Comparing among groups of homogenous cartel cases the impact of partial and full treatment on fines is estimated to be much larger than the estimated using OLS techniques that compare the "average cartel case": basic amount of fines and final fines are between 6 and 15 times larger

[34] Most results presented in this subsection are replicated in Annex 3 considering the implementation of the leniency program separately in EU and in Spain. Results hold, although results are weaker in Spain due to the low number of treated observations. In the case of full treatment, we have not been able to estimate the effect in Spain for most of the outcomes.

[35] Average estimates of columns 2, 3, 5 and 6: estimates including time fixed effects computed using investigation or decision year.

[36] Web annex 4 available at https://doi.org/10.6084/m9.figshare.25586958.v1

Table 5. Log of basic amount of fines (deflated)

Variables	**Full model**			**Reduced form**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Partial treatment	**1.30****	**0.67****	**0.69***	**1.81*****	**0.86*****	**1.10****
	(0.45)	(0.25)	(0.33)	(0.47)	(0.17)	(0.37)
Full treatment	**1.44*****	**0.83*****	**1.10*****	**1.05*****	**0.36***	**0.61****
	(0.25)	(0.10)	(0.11)	(0.28)	(0.19)	(0.27)
Log N. countries	0.50*	0.39***	0.57***	0.54*	0.42***	0.60***
	(0.27)	(0.10)	(0.13)	(0.26)	(0.06)	(0.08)
Log N. firms	0.13	0.49***	0.30**	0.21	0.61***	0.39***
	(0.26)	(0.12)	(0.10)	(0.26)	(0.16)	(0.12)
Log duration	0.63***	0.50**	0.60***			
	(0.14)	(0.17)	(0.10)			
After fixed effects	No	Investigation year	Decision year	No	Investigation year	Decision year
Industry fixed effects	No	Yes	Yes	No	Yes	Yes
Spain fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	118	118	118	118	118	118
R^2	0.594	0.748	0.754	0.536	0.721	0.714
Sample	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency

All leniency programs (EU96, EU02, EU06 & SP08) Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Standard errors in parentheses. Relevant coefficients are in bold. Note on sample: *Cartels benefiting from leniency* refers to cartel cases subject to treated 1 and treated 2 in Figure 1: cartel cases for which some members got immunity and/or fine reductions under the leniency program and that were alive when the program was available. This group excludes dead cartels in which some of their members obtained immunity or fine reductions under the leniency program although these cartels were no longer alive when the program came into force. In those cases, leniency applicants revealed the existence, or cooperate if it had been revealed, of a dead cartel that was active before the leniency program came into force, cartels whose lifespan was prior to the entry into force of the leniency program.

Table 6. Log of basic amount of fines (deflated)

Estimator	Partial treatment (1)	Full treatment (2)	Partial treatment (3)	Full treatment (4)
ATT (m=1)	**2.55*****	**2.58*****	**3.48*****	**3.09*****
	(0.52)	(0.36)	(0.60)	(0.42)
ATT (m=5)	**2.41*****	**2.81*****	**3.17****	**3.11*****
	(0.45)	(0.41)	(0.40)	(0.39)
After fixed effects	Investigation Year	Investigation Year	Decision Year	Decision Year
Industry fixed effects	Yes	Yes	Yes	Yes
Spain fixed effects	Yes	Yes	Yes	Yes
Observations	109	65	109	65
Sample	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency

All leniency programs (EU96, EU02, EU06 & SP08). Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Standard errors in parentheses. Relevant coefficients are in bold. Note on sample: *Cartels benefiting from leniency* refers to treated 1 and treated 2 in Figure 1: cartel cases for which some members got immunity and/or fine reductions under the leniency program and that were alive when the program was available. Note on controls: Matching cartels according to the number of countries of origin of the firms per cartel, the log of the number firms per cartel, the log of cartel duration, a dummy for Spain, industry fixed effects dummies, and the period after the introduction of leniency fixed effects dummies.

in the treated cartel cases compared with the control non-treated cartel cases (as the estimates are in logs, we obtain the marginal effects by taking the exponent of the coefficient minus 1). By construction, matching techniques requires to estimate the partial treatment and the full treatment effects separately (see Table 6 for basic amount of fines and Table 4.2 in the web annex of the paper for final fines).[37]

B. Duration of the Investigation

Finally, we find not so conclusive results with respect to the impact of the leniency policy on the duration of the investigation[38] in the OLS regressions, presented in Table 7. Partial treatment appears to have no impact on the length of the investigation. By contrast, full treatment appears to increase the years of the investigation significantly (by 13% in column 3 and by 29% in column 2 which include time fixed effects). Table 7 offers the results including only the cartel cases that benefited from leniency in the treatment groups (treated 1 and treated 2: ***cartels benefiting from leniency***). We obtained very similar results when estimating the OLS regressions including all cartels affected by the leniency policy in the treatment groups (treated 1, treated 2, and treated 3: ***all treated cartels***). Reduced form estimations that do not include cartel duration as covariate (which may be affected by the leniency policy) render also very similar results.

Using local matching techniques, we are also able to identify and quantify the impact of leniency program on the duration of cartel investigations: partial and full treatment make cartel investigation lengthier: around 28% larger in the partial treatment cases and around 57% larger in the full treatment cases.[39] Given that the average years of investigation is 3.5 years for the

[37] Web annex 4 available at https://doi.org/10.6084/m9.figshare.25586958.v1

[38] Most results presented in this subsection are replicated in Annex 3 considering the implementation of the leniency program separately in EU and in Spain. Results hold, although results are weaker in Spain due to the low number of treated observations. In the case of full treatment, we have not been able to estimate the effect in Spain for most of the outcomes.

[39] Average Treatment on the Treated (ATT) effect estimates for $m = 5$.

Table 7. Log of years of investigation

Variables	**(1)**	**(2)**	**(3)**
Partial Treatment	0.04	-0.02	-0.13
	(0.07)	(0.09)	(0.08)
Full Treatment	**0.28*****	**0.29*****	**0.13****
	(0.06)	(0.09)	(0.06)
Log N. Countries	0.10**	0.13**	0.12**
	(0.04)	(0.05)	(0.05)
Log N. Firms	0.05	0.04	0.05
	(0.04)	(0.06)	(0.06)
Log Duration	0.01	0.01	0.01
	(0.04)	(0.04)	(0.04)
After fixed effects	No	Investigation year	Decision year
Industry fixed effects	No	Yes	Yes
Spain fixed effect	Yes	Yes	Yes
Observations	170	170	170
R^2	0.210	0.250	0.258
Sample	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency

All leniency programs (EU96, EU02, EU06 & SP08). Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Standard errors in parentheses. Relevant coefficients are in bold. Note on sample: *Cartels benefiting from leniency* refers to treated 1 and treated 2 in Figure 1: cartel cases for which some members got immunity and/or fine reductions under the leniency program and that were alive when the program was available.

Table 8. Log of years of investigation

Estimator	**Partial treatment (1)**	**Full treatment (2)**	**Partial treatment (3)**	**Full treatment (4)**
ATT ($m = 1$)	**0.24**	**0.58****	**0.22**	**0.46*****
	(0.15)	(0.20)	(0.14)	(0.16)
ATT ($m = 5$)	**0.25***	**0.45*****	**0.24***	**0.45*****
	(0.14)	(0.16)	(0.13)	(0.15)
After fixed effects	Investigation Year	Investigation Year	Decision Year	Decision Year
Industry fixed effects	Yes	Yes	Yes	Yes
Spain fixed effects	Yes	Yes	Yes	Yes
Observations	153	108	153	108
Sample	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency	Cartels benefiting from leniency

All leniency programs (EU96, EU02, EU06 & SP08). Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Standard errors in parentheses. Relevant coefficients are in bold. Note on sample: *Cartels benefiting from leniency* refers to treated 1 and treated 2 in Figure 1: cartel cases for which some members got immunity and/or fine reductions under the leniency program and that were alive when the program was available. Note on controls: Matching cartels according to the number of countries of origin of the firms per cartel, the log of the number firms per cartel, the log of cartel duration, a dummy for Spain, industry fixed effects dummies, and the period after the introduction of leniency fixed effects dummies.

observations in the control group, this means an increase of the duration of the investigation or 1 year in the partial treatment cases, and 2 years in the full treatment cases (see Table 8).

This result is consistent with the theory that leniency programs provide competition authorities with much more detailed information about cartel conspiracies. This information allows

authorities to conduct thorough investigations, which result in more evidence and charges being brought forward in their decisions. However, including this additional evidence and charges is time-consuming and lengthens the duration of the investigation. At the same time, the literature has highlighted that leniency policies may hinder the ability of competition authorities to pursue other cases proactively, as a result of the additional time and resources required to investigate cases under the leniency programs.[40]

IV. CONCLUDING REMARKS

This study contributes to the literature by providing further causal empirical insights into the impact of leniency programs on cartel stability and prosecution. Specifically, our focus is on the effects of leniency programs that have been implemented in the European Union and Spain, aiming to identify and quantify empirically their causal impact on three key outcomes: the duration of cartels, the amount of cartel fines, and the duration of investigations. To conduct our analysis, we use a dataset that included all cartel cases sanctioned by the European Commission and the Spanish Competition Authority from their beginnings until 2018.

Our empirical strategy considers a control group of cartels (born and dead before the introduction of the leniency programs), a partially treated group (born before the introduction of the leniency programs but dead in that year or after) and a fully treated group (born and dead in, or after, the year of the introduction of leniency programs). We consider several models to estimate the effects of leniency programs on the three key outcomes. We also employ a difference-in-differences approach to identify the effect of interest on cartel duration and fines, taking advantage of the exogeneity of the date of introduction and the fact that the leniency programs were implemented in the two jurisdictions affecting different types of cartels (those affecting trade among EU Member State and those only affecting the Spanish national market) at different moments in time.

Regarding the cartel destabilization effects of leniency programs, our Cox proportional hazard regression results indicate a short-run effect of leniency programs. Cartels that were partially affected by the policy change exhibit longer durations when discovered under leniency policy than those in the control group. In the long run, the average duration of cartels discovered under the leniency policy is smaller than in the control group. The probability of a cartel dying that was born and died under the existence of the leniency program is significantly higher than that of the cartels in the control group. Additionally, employing OLS techniques, we find that existing cartels discovered just after the introduction of leniency have an average duration that is nearly double that of control cartel cases (a 98% increase): the leniency program can facilitate the discovery of longer-lasting existing cartels that were previously concealed. While new cartels formed and discovered after the introduction of leniency have an average duration that is nearly halved the duration of control cartel cases (a 57% decrease). These empirical findings are consistent with the theory proposed by Harrington and Chang (2009) on the short and long-term effects of antitrust innovations that enhance the likelihood of detecting and convicting cartels. The successful implementation of leniency programs in the EU and Spain has avoided the theoretically feasible outcome of failure in the deterrence effect, which previous empirical literature has not rejected.

[40] Many authors have alerted competition authorities that they should not make cartel detection's success depend on the results obtained with the leniency program, concentrating their limited resources on this detection method while other methods take up a marginal role. This strategy may end up reducing the effectiveness of the fight against cartels, either by increasing the stability of the cartels, or by generating a sense of security in those cartel operated sectors if the authorities focused only on leniency proceedings, and conversely reducing the *ex officio* investigations (see, among others, Friederiszick and Maier-Rigaud, 2008; Hammond, 2008; Harrington and Chang, 2015; Schinkel et al. 2020).

Concerning the impact of leniency programs on cartel prosecution, we find a significant effect on fines. Fines per cartel case increase substantially—by half, double or even triple using OLS techniques, and by 6 to 11 times using local matching techniques. These results suggest that leniency programs enhance cartel prosecution by increasing the severity of sanctions, likely due to the greater evidence obtained, thus strengthening their deterrent effect. However, we find that leniency programs may increase the cost of prosecuting cartels by extending the investigation period, possibly due to the need for authorities to analyze a larger evidence pool. Using local matching techniques, the investigation time in cartel cases under leniency programs could potentially increase by 1 to 2 years. This effect may negatively impact competition authorities with limited resources, as they would need additional time and resources to investigate cases under leniency programs.

Further research is needed to assess the potential loss of efficacy in leniency programs if authorities solely rely on them. Additionally, the 2014 Directive's private claims for damages may not fully protect whistleblower companies, potentially decreasing their willingness to cooperate.

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Annex 1: Description of Variables.

From the publicly available case files, we have computed the following information. Monetary values are deflated based on the year 2010 (World Bank prices database)

i) *Basic amount of fines*$_i$ (euro): it is the total basic amount of fines of the case *i* before leniency application. This information is not always available in the publicly available case files, which implies we have a smaller number of observations than number of cartel decisions.
ii) *Final fine*$_i$: the sum of fines imposed on all the undertakings involved in the cartel case *i*. It differs from the basic amount of fine because in the final fine it is taken into account aggravating and/or attenuation circumstances that increase or reduce the final fine with respect to the basic amount of fine. The data is offered before and after leniency.
iii) *Average (percentage) of fine reduction by leniency*$_i$: average of the percentage reductions granted to leniency applicants per case in the final fine.
iv) *Final fine per firm*$_i$*:* the ratio between the final official fine and the total number of firms participating in the cartel *i*.
v) *Final fine per consolidated firm*$_i$*:* the ratio between the final official fine and the total number of firms participating in the cartel *i*. All the subsidiaries and the parent company belonging to the same consolidated group (*holdings*) are counted only once.
vi) *Maximum duration*$_i$: maximum number of years the cartel *i* was functioning according to the final decision.
vii) *Duration of the investigation*$_i$: the number of years between the starting date of the Commission's investigation and the date of its final decision in each cartel case.
viii) *Average number of firms*$_i$: it is the average number of firms that participate in the cartel during its existence.
ix) *Average number of consolidated firms*$_i$: this is the number of cartel participants but all the subsidiaries and the parent company belonging to the same consolidated group (*holdings*) are counted only once.
x) *Number of countries*$_i$: this is the number of different countries from which cartel participants belonged to. Each company is assigned to the country where it has its registered head office.
xi) *Number of countries (parents)*$_i$*:* this variable is similar to the previous one but discounting the effect of parent and subsidiaries, where they exist. We account for only one country in which the parent firm has its head office.
xii) *Stability*$_i$*:* binary variable that takes value 1 when there was no entry or exit of cartel's members throughout the life of the cartel.
xiii) *Case stems from . . .*$_i$: binary variables which take value 1 for each way a case *i* starts with: a leniency application from one cartelist (post-1996 leniency notice), a notification (in the pre-2004 authorization regime), a Commission's own-initiative investigation (*ex officio*), or a Commission's investigation following a third-party complaint.