Semi-Parametric Analysis of International Hard-Core Cartels Duration: The Role of Clemency, Agency, and Firms

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Abstract

We examine big International Hard Core Cartels with the aim to disentangle the factors associated with the duration of these collusive agreements. We utilize a database of cartels that were convicted between 2012 and 2018 (with at least one conviction issued by a competition authority) to analyze how the duration of cartels can be correlated with factors such as the number of conspirators, the enactment of a leniency law, and the utilization of leniency programs. The results from the proportional Cox model indicate that collusive agreements tend to last shorter when a Leniency Program is available, which is consistent with a dissuasion effect. However, those cartels applying to the leniency program tend to be involved in longer cartels than those that do not apply to the program. Furthermore, and maybe surprising, we do not find a negative relation between cartel duration and the number of participants. As the number of companies involved in anti competitive practices increases, the duration of the agreement also tends to rise. Finally, a higher level of effectiveness by the regulatory authority appears to be correlated with shorter durations of cartels.

Keyword: Collusion, Duration, Leniency Programs, Proportional Cox.
JEL classification: L13, L22, L41

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1 Introduction

Within the expansive scope of competition policy control, one of the most significant areas pertains to the detection and prevention of cartels. The timely identification and dissuasion of this anticompetitive conduct by competition agencies holds direct consequences for consumer welfare and enhances exchange conditions within markets (OECD, 2020). According to Mario Monti (Swedish Competition Authority, 2001), the impact of cartels on the economy and consumer welfare is substantial and has been underestimated over time. According to a report by the OECD (2000), the average price increase due to price-fixing is approximately 10%, accompanied by a 20% reduction in produced quantities. Hence, empirical analysis of the characteristics of collusive agreements becomes pertinent, specifically concerning determinants that correlate with the duration of these illicit activities.

In this paper we analyze the duration of cartels and the factors that are linked to the reduction or extension of the duration of cartels. This enables competition agencies and policymakers to establish identification mechanisms and regulatory changes that can influence the reduce of cartel life or enhance the avenues for timely identification.

We use a database compiled by OECD that we complement with other sources of information. The main database was compiled by OECD of 200 International Hard Core Cartels identified by competition agencies globally. It includes cases in around 50 countries in different regions where authorities have issued decisions against these agreements during the period 2012 and 2018. We add information about local authorities (like budget, ranking) and indicating whether colluding firms have benefited from the Leniency Program during the investigation.

We employ a semi-parametric Proportional Hazard model, specifically the Cox model, to estimate the probability of a cartel's survival in a given year. We control for a set of attributes, including whether the country had a Leniency Program at the time the companies initiated the cartel, whether colluding firms (at least one) benefited from leniency measures from antitrust authorities, and the number of conspirators in the cartel. Additionally, we account for the amount of the sanction, whether a union or association sponsored the cartel, the industry and country in which the cartel operates, whether firms engaged in bid-rigging processes, and attributes associated with the performance of competition authorities (such as budget, ranking, and whether the authority intervened to halt the illegal activity). Given the nature of our study, our results are interpreted as correlations.

We find that cartels tend to have shorter durations when a Leniency Law is in effect in the specific jurisdiction at the moment of the cartel's formation, even if the cartels do not apply for leniency. Unconditional estimations show that the duration of cartels lasts, on average, half the time when a Leniency Law is active, compared to those cartels formed when a Leniency Program does not exist. In the Cox model, we estimate that the survival rate of cartels decreases by 80% when a Leniency Program is available (even when not

solicited), in comparison to those cartels formed when a Leniency Program does not exist.

This result is consistent with alternative (not mutually exclusive) scenarios. First, authorities may be discovering more illegal cartels, but detecting a higher proportion of shorter-duration cartels. Additionally, in line with predictions from theoretical models, Leniency Programs have a dissuasive effect on both cartel formation and duration. As a result, the evidence supports a situation where longer cartels are not formed due to the anticipation of being unveiled sooner than expected. Alternatively, all cartels may experience shorter durations, as the stability of cartels is influenced by the existence of Leniency Programs. This latter statement is linked to our next result.

Members of cartels that have applied to Leniency Programs tend to be associated with cartels that have longer durations. Unconditional estimations reveal that cartels applying for leniency benefits last 25% longer. In the Cox model, we estimate that the survival rate of cartels increases by 45% for those cartels that eventually apply for leniency benefits.

In other words, the likelihood of surviving for an additional year is higher for cartels in which at least one member eventually applies for leniency benefits. This result raises the question of whether colluders anticipate investigations and the possibility of some participants deviating from the illegal agreement. If penalties are not sufficiently severe, certain firms might choose to engage in profitable illegal activities even while expecting eventual detection. In such cases, applying to the leniency program becomes a first-mover advantage for colluders, with the added consideration that the cartels should anticipate a longer period of colluding benefits.

An intriguing finding emerges from our analysis: cartels with a larger number of participants tend to display a higher survival probability and, consequently, longer durations. This runs counter to prevailing theoretical literature, which often emphasizes the escalation of coordination and monitoring costs as the number of participants increases. This theoretical expectation poses challenges when interpreting our empirical results. A plausible explanation could be that markets with a greater number of participants inherently possess attributes that facilitate simpler coordination or monitoring mechanisms.

We also find that agents with a better Horizontal CPL Index (reflecting more efficiency) tend to unveil cartels that last longer. Similarly, agencies with higher budget tends to find cartels with longer duration. Finally, we find no statistical significance results in several other dimensions explored like cartels associated with bid-rigging, cartels that were sponsored by an association (Union or similar), the amount of the sanction to the cartel.

This work contributes by investigating the duration of collusive agreements and the factors associated with them, particularly focusing on the efficacy of competition agencies in identifying such behaviors and the characteristics of the markets. In the next section, we review the related literature, integrating our contributions into each strand of research

The paper is organizes as follows. The second section of this work will delve into a literature review. The third section describes the empirical strategy. The forth section describes the data. The fifth section presents the results. The sixth section concludes.

2 Literature

There are few studies that have theoretically addressed the determinants that influence the duration of collusive agreements. Much of the literature has focused on establishing the conditions that allow for greater or lesser stability of cartels. For example, evaluating effective punishment mechanisms to discipline members within the cartel, identifying how the number of participants affects the formation and stability of the agreement, studying the differences between explicit and tacit agreements, among others.

On the other hand, empirical studies have delved more deeply into the variables that influence the duration of cartels. In general, most of these studies have used duration models to establish the relationships that affect the survival of collusive agreements.

In this section, a compilation of theoretical and empirical literature will be presented, associated with the variables that this research proposes as relevant to understanding the duration of collusive agreements, such as the leniency program, number of companies, and detection by competition agencies.

2.1 Leniency

The leniency program, also known as indulgence or amnesty, is a highly effective tool for competition authorities to uncover collusive agreements and deter their formation. This program offers total or partial amnesty of sanctions for whistleblowers who provide relevant information for investigating and detecting cartels.

According to research by De (2010), the leniency program has several important effects on market cartels, including:

- The "protection against punishment" effect (Spagnolo, 2004) or the "whistleblower amnesty" effect (Harrington, 2008) works by simply violating the compatibility restriction of incentives that generates an increase in the reward for cheating, since companies have the opportunity to deviate from the agreement and report to competition agencies simultaneously.
- On the other hand, Ellis and Wilson (2001) show that leniency can have a destabilizing effect as it may prompt self-reporting in situations where companies seek to increase the future cost of rivals through higher penalties. According to Brenner (2009), self-reporting may be prompted when: 1) the probability of detection

increases exogenously; and, 2) a cartel that is stable in the absence of a leniency policy can become unstable after it is introduced into the competition legal framework. In this context, informing is more profitable than simply stopping colluding or cheating and not reporting. It reduces expected fines in case of conviction and increases the costs of rivals through fines and compliance measures.

- The "whistleblower threat" effect (Spagnolo, 2000) shows that the threat of self-reporting to punish a deviating company can also become credible and sustain collusion.
- The "cartel amnesty" effect (Motta and Polo (2003) and Harrington (2008)) suggests that the expected gains from collusion will increase due to the reduction of the expected sanction under a leniency program.
- The "race to the courthouse" effect (Harrington, 2008) occurs when the probability of detection varies over time. The probability of paying sanctions is higher because cartel companies in collapse will request leniency.

Research by Harrington and Chang (2009) shows that the introduction of amnesty programs will cause a greater number of cartels to collapse in the short term, particularly those that are less stable. Additionally, empirical works applying duration models to cartels identified in the United States and Europe (Levenstein and Suslow (2011), De (2010), Abrantes-Metz et al. (2013), Hellwig and Hüschelrath (2017), Zimmerman and Connor (2005)) have found that the leniency policy's introduction reduces the probability of survival of cartels and destabilizes collusion.

2.2 Number of Firms

The number of companies is a significant factor that influences the formation and stability of collusive agreements. Theoretical and experimental work, such as that of (Huck et al. (2004) y Fouraker and Siegel (1963)), has shown that it becomes increasingly challenging to sustain agreements as the number of companies involved increases. This is due to coordination problems, incentives to deviate, imperfect monitoring, punishment mechanisms, and ineffective communication capacity among members.

Further research by Allen and Mills (1989), Hay and Kelley (1974) y Dolbear et al. (1968) found that cartels with many companies generate coordination problems that destabilize the agreement. Regarding the ability to detect deviation and punishment mechanisms, Stigler (1964) and Dolbear et al. (1968) conclude that when there are more companies in the agreement, it is difficult to detect deviation from the actions of all members. On the other hand, imposing punishments or rewards is not effective since price changes resulting from deviation would have little effect on the market.

Regarding monitoring and communication, Fonseca and Normann (2012) establish that in the absence of interaction between companies, prices decrease when there are more participants. Garrod and Olczak (2018) affirm that tacit monitoring is effective when there is a small number of cartel members since deviation by small companies can be difficult to detect, something that was also observed by Compte et al. (2002). For Garrod and Olczak (2018) and Fonseca and Normann (2012), monitoring and communication between actors are crucial for agreements to be more stable even with a larger number of participants. Escrihuela-Villar and Guillén (2011) mention that, under certain parameters, the critical discount factor above which joint profit maximization is sustained may decrease with the number of cartel companies when not all companies in the market participate in the agreement.

Hay and Kelley (1974) identified that in the United States of America, 79% of collusive agreements involved between 2 to 10 competitors, demonstrating that agreements can be functional even with more than 2 members. Abrantes-Metz et al. (2013) and De (2010) used duration models to identify the effect of the number of companies on the survival of the agreement. The results obtained were that a greater number of companies was associated with longer durations of agreements. In summary, the number of companies involved in a collusive agreement has a significant impact on its formation and stability. Although it becomes more challenging to sustain agreements with a larger number of participants, monitoring and communication can help to increase stability. The optimal number of participants for a successful collusive agreement depends on various factors, such as coordination problems and the effectiveness of monitoring and communication mechanisms.

2.3 Competition agency, sanction, budget

Firms that are part of cartels face at least three external threats: antitrust authority investigations, competition from marginal companies, and changes in the market environment (von Auer and Pham (2019)).

The stability of a collusive agreement depends on the sanctions that competition authorities impose on companies for coordinating their strategies in the market. Therefore, these costs are internalized in the profits of these firms(Bryant and Eckard (1991), Combe et al. (2007), and Evenett et al. (2001)). Competition agencies that are most efficient in investigations can destabilize agreements and discourage their formation by imposing penalties (both criminal and monetary).

Researchers such as von Auer and Pham (2019), Combe et al. (2007), and Armoogum (2016) have modeled the influence of competition agencies on collusive agreements. Their findings indicate that a more aggressive antitrust policy reduces the size of the cartel and increases the number of marginal companies, despite a consequent additional social cost. Antitrust policies also reduce the stability of cartels, and cartels with a larger number of

companies are more likely to be detected. Leniency programs provide effective evidence for sanctioning collusive agreements, and as the authority gains experience, both the probability of detection and conviction increase. However, budgetary and legal limitations can affect the probability of detection, as identified by Chen and Rey (2013).

Therefore, the sanctions imposed by competition agencies tend to discourage the formation and destabilize collusive agreements. As such, the probability of detection, which is interrelated with the experience and budget of antitrust authorities, is a relevant point in the life cycle of these criminal organizations and is related to the duration of these acts.

3 Empirical Estrategy

The methodology employed in this study is based on duration models[1]. These models enable the analysis of how various characteristics influence the survival time of individuals or firms facing a given event. In essence, survival analysis involves observing individuals starting in an initial state and tracking their exit from that state.

The aim of this study is to estimate the probability of a cartel collapsing or dissolving as a function of variables that affect the agreement's stability. To achieve this, the study will employ duration models to analyze the data.

3.1 Función de Hazard

One of the most relevant aspects of this empirical strategy is the use Hazard Function, which allows approximate the probability of leaving the initial state in a short period of time, conditioned on having survived up to that moment.

If we denote $T \geq 0$ as the duration, which is the time period until a certain event occurs[2], and which has some distribution in the population, the hazard function for T is defined as follows:

$$\lambda(t) = \lim_{dt \to 0} \frac{P(t \leq T < t + dt | T \geq t)}{dt} \tag{1}$$

For each t, $\lambda(t)$ is interpreted as the probability of leaving a state in a short time interval t, conditional on that state remaining the same at time t. The previous equation can be expressed as follows:

[1]The methodological description is based on chapter 20 of the book by Wooldridge (2010). A more in-depth review of duration models can be found in the book by Cleves et al. (2010).

[2]For this research, T would be the time measured in years from the creation of the cartel until the agreement expired.

$$f(t) = \lambda(t)e^{-\int_0^t \lambda(s)ds} \tag{2}$$

The hazard functions provide a convenient definition of dependence on the duration of a phenomenon. There is positive dependence on the duration at some point, say t, if $d\lambda(t)/dt > 0$ for all $t > 0$. This means that the probability of leaving the initial state increases the longer one stays in the initial state. On the other hand, there is negative dependence at a point t if $d\lambda(t)/dt < 0$ for all $t > 0$. This indicates that the probability of leaving the initial state decreases the longer one stays in the initial state.

One extension of these models are hazard functions conditioned on a set of covariates x that do not vary over time, with the most commonly used model being the Proportional Hazard (PH):

$$ln\lambda(t;x) = x\beta + ln\ \lambda_0(t) \tag{3}$$

In the above equation, $\lambda_0(t) > 0$ is a base hazard, while the vector β measures the semi-elasticity of the hazard with respect to the covariate x_j. The expression $x\beta$ is called the Hazard ratio, if β is greater than zero, or equivalently, if the Hazard ratio is greater than 1, it indicates that as the value of the i-th covariate increases, the hazard event, which for our case is the death of the cartel, increases, and consequently, the length of survival decreases.

3.2 Censoring and Heterogeneity

3.2.1 Censoring

Survival analysis data is often incomplete an are usually subject to right censoring. Right censoring occurs when a participant is evaluated for a period, but the exact date of transition from the initial state to the final state is unknown.

In related works, such as that of De (2010), it was established that data is censored when the European Commission cannot identify the specific date of the agreement's disintegration. As a result, the author proposed a model that considers right censoring on the date of the decision made. In Levenstein and Suslow (2011), cartels may collapse due to two causes: intervention by competition agencies or natural death. The authors treat cartels that died due to the alternative cause as censored when estimating models. They consider the date of natural death as censoring for models that evaluate the duration of cartels identified by competition agencies and vice versa for the opposite case.

Hellwig and Hüschelrath (2017) determined that cartels detected by agencies would experience natural death later if they had not intervened, but an agency's death can never

occur after natural death. Therefore, the authors used censoring in modeling when the death of a collusive agreement was caused by the competition agency.

Similar to Abrantes-Metz et al. (2013), this work assumes that there is no censoring in their survival evaluation. There are two reasons for this: Firstly, complete periods of the initial and final state are available for all observations, meaning that the beginning and end of collusive agreements are always observed. Secondly, while other authors suggest that death caused by competition agencies can be considered as censored, the detection by antitrust authorities does not limit the duration of collusive agreements. It is an intrinsic part of the survival of cartels, who from the beginning of the conduct, must internalize that competition agencies seek the necessary mechanisms for their identification and sanction.

3.2.2 Heterogeneity

When modeling the probability of survival, it's essential to consider the impact of unobserved heterogeneity, which refers to differences between individuals that aren't captured by the included variables. This can result in different hazards even for individuals with the same covariate values, leading to confounding with the baseline hazard (Cameron and Trivedi, 2005).

To address this issue, mixed models can be used if three criteria are met: 1) heterogeneity is independent of observed covariates, event start time, and censoring time; 2) heterogeneity follows a known distribution up to an infinite number of parameters; and 3) heterogeneity enters multiplicatively into the hazard function. Parametric models, such as Weibull, Gompertz, Lognormal, and Exponential, are commonly used to incorporate unobserved heterogeneity (Cameron and Trivedi, 2005).

For the specific case of modeling the survival of collusive agreements, Abrantes-Metz et al. (2013) recognized the need to account for unobserved heterogeneity since the controlled covariates could only explain a portion of the duration variability. In their model, the unobserved factor is assumed to be constant throughout the cartel's life, and the covariates are also constant over time. The authors allowed for controlling a fixed (although imperfect) heterogeneity of other omitted factors in each model specification. Similarly, Levenstein and Suslow (2011) extended the Weibull Proportional Hazard model to a mixed model, incorporating a specific effect of the subject that is unobservable independently of additional time.

Although Hellwig and Hüschelrath (2017) acknowledges the possibility of unobserved heterogeneity, they don't provide any indication that it influences the hazard in their estimation of a mixed Proportional Hazard model at the firm level. They also report that for modeling at the cartel level, the direction of the effects found initially remains the same for most variables.

To rule out unobserved heterogeneity, a parametric specification using a Gompertz distribution was proposed for model A2 (section 5). The likelihood ratio test showed that the null hypothesis of no presence of heterogeneity is accepted, indicating that the semi-parametric model is a consistent approximation to evaluate the influence of covariates on the duration of collusive agreements.

4 Data Description

In 2018, the OECD compiled a database containing approximately 200 cases related to International Hard Core Cartels that were identified from 2012 to 2018 in around 50 countries. According to the OECD, "the included cartels are those in which competition authorities have issued decisions against these agreements (...)" This information includes data on the amounts of fines, geographical extent of agreements, industries where illicit acts were carried out, duration of the cartel, number of participants, whether the agreement was supported by associations or whether they were practices carried out in tenders, among other variables. The database corresponds to a collection developed by Professor John Connor, which the OECD acquired in 2017.

For this study, we utilized only 176 effective cases from the database, as there were 15 investigations that did not have the duration of the illicit act, which made them unusable in the proposed modeling. Additionally, there are 40 cases that are duplicated among various authorities because they were cartels whose damage extension was in more than two jurisdictions. Therefore, we grouped these cases and called them "Multi-agency Collaboration". [3]

Furthermore, we collected other relevant variables that could help us to study the determinants of the duration of cartels.

In the following sections, we will provide a description of the variables used in this research.

- Duration: a continuous variable indicating the length of the anticompetitive agreements in years (including fractions), as identified by competition authorities. The minimum duration is 0 years, and the maximum is 28.
- Leniency Policy: a dummy variable that takes the value of 1 if a leniency policy was in place at the start of the collusive agreement, and 0 otherwise.
- Leniency Applied: this variable takes the value of 1 if any company involved in the collusive agreement applied leniency to the competition authority, and 0 otherwise.

[3] The case *"1119"* was also renamed because the conduct was reported to have been identified in the United States when it was actually in the United Kingdom. The names of the geographic extension of the conduct were added in six cases that were not identified in the database.

The data were collected from public information sources, reports from multilateral organizations, and specialized magazines.

- Number of Firms: the number of firms that participated in the collusive agreement, ranging from a minimum of 2 to a maximum of 38.

- Budget: the budget assigned (in millions of USD) to antitrust authorities for the year 2014-2015, as compiled from public sources, reports from competition agencies, and the Global Competition Review's Enforcement Rating (with a logarithmic transformation).

  It should be noted that most of the data correspond to this frequency, but some are available only for the years 2012, 2013, 2016, and 2017. In this case, it is assumed that the budgets did not significantly change in the medium term and that they are representative of the years in which the collusive behaviors were identified.

- Horizontal CPL Index: a continuous variable ranging from 0 to 6, based on the OECD's questionnaire responses from 49 competition authorities in 2013. The higher the index, the greater the efficiency of the competition agency in controlling collusive agreements.

- GCR Ranking: the performance rating (average 2010-2014) assigned by the Global Competition Review to various competition agencies. This variable takes the value of 2 to 5, with 5 denoting "Elite" institutions, 4 indicating "Very Good" performance, 3 indicating "Good" performance, and 2 representing "Fair".

- Sanction: the fine (in millions of USD) imposed by the antitrust agency.

- Bid Rigging: a variable that indicates whether the collusive agreement (1) took place in a tender or (0) involved practices such as price fixing or market allocation.

- Death Antitrust Intervention: a dummy variable that takes the value of 1 if the competition agency discovered the collusive agreement at least one year before its termination. This implies that the antitrust authority initiated a sanctioning procedure that led to a series of investigations and information gathering, which either incentivized the end of the agreement or terminated it after imposing a fine. If the variable is 0, it is assumed that the cartel ended naturally, i.e., the competition agency took more than two years to identify the behavior.

- Association: this variable takes the value of 1 if the collusive agreement was sponsored by an association (only 14 cartels in the database have this feature) and 0 otherwise.

- Industry: a variable indicating the economic sector in which the anticompetitive behavior occurred, as detailed in Table 1.

- Geography: refers to the region in which the collusion occurred, with categories including North America, South America, Europe, Asia, and Other Regions. The

latter includes 12 cases identified among Oceania, Africa, Multi-Agency Collaboration, and the Middle East.

Table 1 presents a summary of the descriptive statistics for the variables used in this study.

Table 1: Descriptive statistics

	Observations	Mean	Standard deviation	Min	Max
Duration	176	5.82	4.97	0	28
Leniency Policy	176	.77	.41	0	1
Leniency Application	165	.41	.49	0	1
Leniency Policy X Leniency Application	165	.26	.44	0	1
Number of Firms	168	7.27	6.75	2	38
Ln Budget	162	3.11	1.06	.009	4.76
Horizontal CPL Index	149	5.89	.39	3.42	6
GCR Ranking	133	3.69	.71	2.16	4.94
Sanction	175	60.06	159.18	.001	1165.85
Bid Rigging	176	.47	.50	0	1
Death Antitrust Intervention	176	.38	.48	0	1
Association	176	.07	.27	0	1
Industry					
Accommodation and Food services	171	.005	.07	0	1
Administrative and Support Services	171	.01	.13	0	1
Agriculture and Fishing	171	.01	.13	0	1
Construction	171	.04	.21	0	1
Finance and Insurance	171	.02	.16	0	1
Information	171	.02	.16	0	1
Manufacturing	171	.55	.49	0	1
Mining and Oil	171	.01	.10	0	1
Other Services	171	.02	.15	0	1
Professional, Scientific, and Technical	171	.07	.26	0	1
Real State	171	.005	.07	0	1
Retail Trade	171	.02	.15	0	1
Transportation and Warehousing	171	.08	.28	0	1
Utilities	171	.017	.13	0	1
Wholesale Trade	171	.052	.22	0	1
Region					
Agency-North America	176	.04	.20	0	1
Agency-South America	176	.08	.28	0	1
Agency-Asia	176	.13	.34	0	1
Agency-Europe	176	.625	.48	0	1
Agency-Otras Regions	176	.06	.24	0	1
Multi-Agency	176	.04	.20	0	1

Source: Own elaboration based on information from the OECD (2012-2018)

Before reviewing the results of the Cox Proportional Hazard regression, it is informative to perform some unconditional estimations. Table 2 presents the average duration of cartels in different situations. On average, cartels last for 6.09 years. When classifying them,

Table 2: Duration per Leniency Application and Leniency Policy

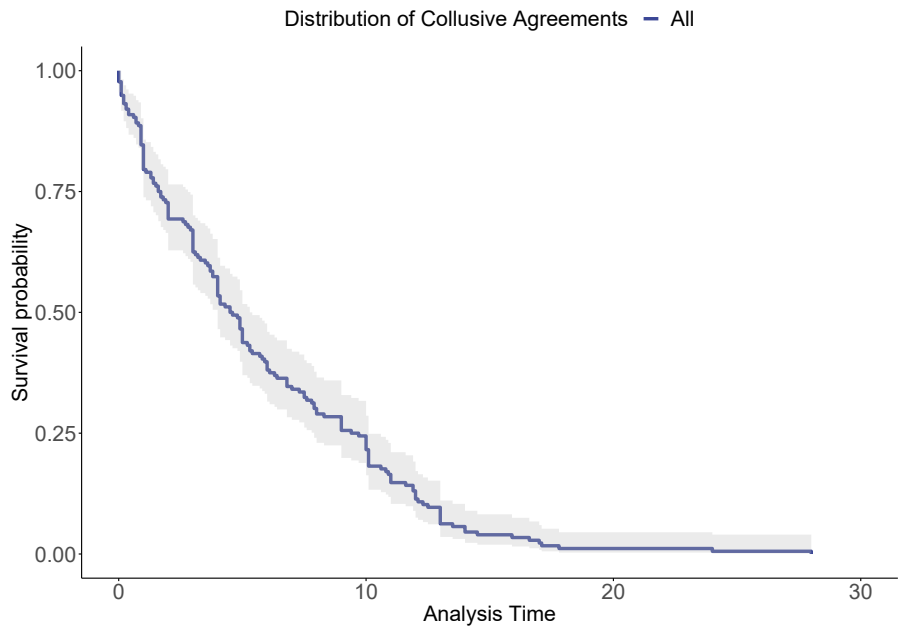
	No Leniency Law	Leniency Law Active	Total
Apply to Leniency Program	9.64	4.23	5.07
Do not apply to Leniency Program	11.58	5.35	7.55
Total	10.83	4.62	6.09

Source: Own elaboration based on information from the OECD (2012-2018)

cartels last on average 10.83 years when there is no leniency law at the moment of cartel formation. Cartels last 4.62 years when a Leniency Law is active at the moment of cartel formation, regardless of whether companies apply to the cartel.

We can also perform non-parametric estimations using the Kaplan-Meier method and visualize the relationship between the duration of the collusion agreement and the probability of survival. Figure 1 displays the distribution associated with international cartel cases.

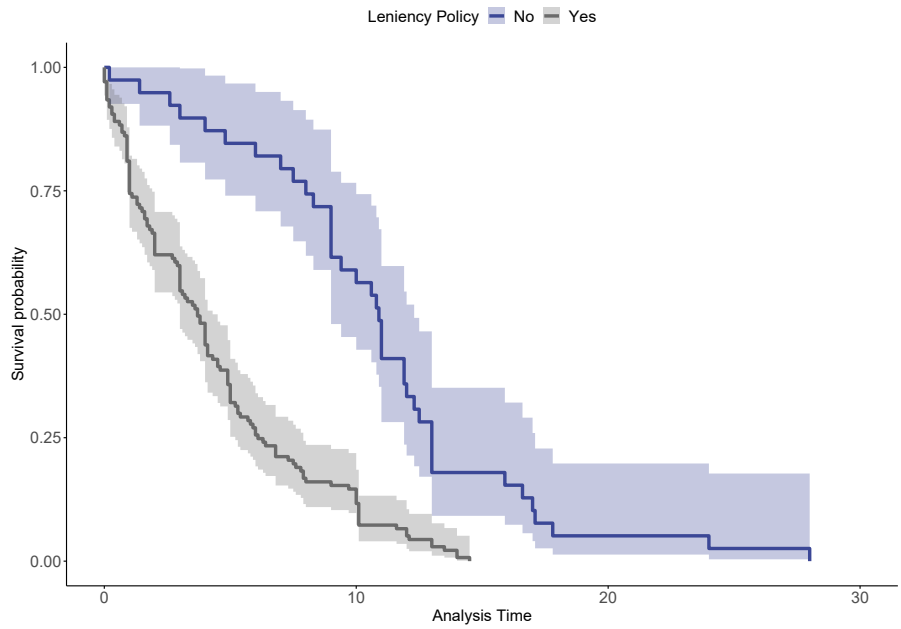
Figure 1: Kaplan-Meier probability of survival



The Kaplan Meier method is useful for comparing different groups. Figure 2 presents estimates for varying survival and duration patterns, distinguishing between cartels that originated during a period when a Leniency Policy was in effect and those that emerged in times when such a policy did not exist. The results show that when a Leniency Policy is accessible (even without being actively sought), cartels tend to exhibit both a lower probability of survival and shorter duration.

Another relevant aspect concerns the distribution of durations in cases where companies

Figure 2: Kaplan-Meier probability of survival, Leniency Policy



Own elaboration based on information from the OECD (2012-2018)

actively submit leniency agreements to competition agencies. Figure 3 presents these estimations, indicating that firms seeking leniency benefits often associate with cartels of longer durations and higher probabilities of survival, as opposed to cartels where no firm participates in the leniency program. It's important to note that certain cartels might have formed before the introduction of Leniency Programs, yet they subsequently apply for leniency benefits after the law's enactment and the program's activation.

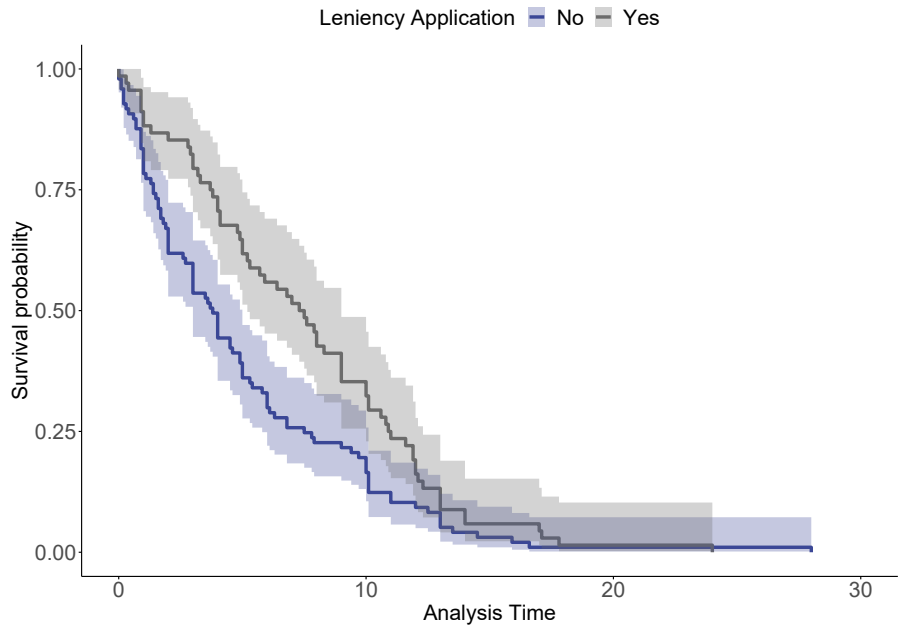
Lastly, Figure 4 delves into the analysis of survival distribution and duration in relation to the number of companies participating in cartels. The findings indicate that cartels with more participants tend to exhibit higher survival rates and longer durations.

In the Annex section, other survival distributions for variables collected in this study, such as Bidding, Geographic scope, Budget, and Horizontal ICP index, were graphed. They exhibit some similarities regarding the results evident in semi-parametric modeling.

5 Results

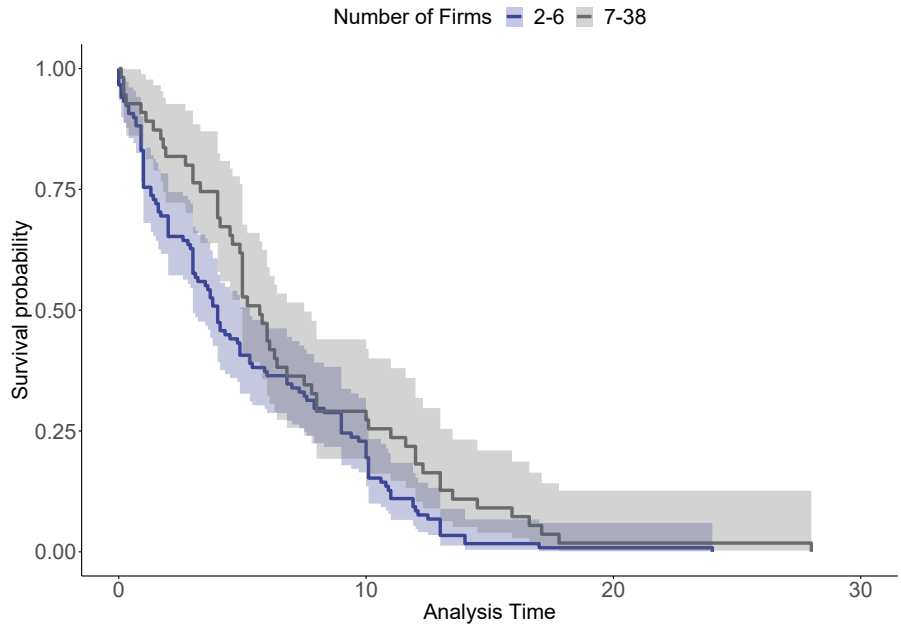
Something important to consider when evaluating the results of the modeling carried out in this section is that the sample of cartel cases used may be biased, as we only have information on collusive agreements that have been revealed by competition agencies. Therefore, it is likely that the identified duration is overestimated compared to the true distribution in the total population of collusive agreements. One explanation for this circumstance is that competition agencies are less likely to capture very short-lived cartels,

Figure 3: Kaplan-Meier probability of survival, Leniency Application



Own elaboration based on information from the OECD (2012-2018)

Figure 4: Kaplan-Meier probability of survival, Number of Firms



Own elaboration based on information from the OECD (2012-2018)

which can form and disappear without attracting attention (Levenstein and Suslow, 2011).

Additionally, it is important to note that the results obtained and the interpretations made do not constitute a causal analysis and are not necessarily replicable for collusive agreements that do not fall into the category of International Hard Core Cartels.

The duration of collusive agreements was estimated using different specifications of the Cox Proportional model. Model A1 used the following explanatory variables: Leniency Application, Leniency Policy, Number of Firms (linear and quadratic terms), Budget (in logs), and Horizontal CPL Index. On the other hand, Model A2 added variables such as Sanction, Bid Rigging, Death Antitrust Intervention, and Association, as well as controls by industries and regions. Meanwhile, Model A3 was analogous to Model A1 but used the GCR Ranking as a measure of the performance of the competition authorities that identified the agreements. Model A4 incorporated controls for regions and industries in Model A3, as well as variables such as Sanction, Bid Rigging, Death Antitrust Intervention, and Association. Finally, the models called B maintained the same variables as their counterpart A, but added an interaction between Leniency Policy and Leniency Application. The latter was disregarded in these models given the high correlation between them.

Table 3 displays the results obtained from the estimation of the semi-parametric models for each of the proposed specifications.[4] The coefficients associated with each explanatory variable regarding the duration of the cartel are presented, not the Hazard Ratio. Therefore, coefficients must be interpreted in the following was: coefficients with a positive sign would indicate that the survival of a collusive agreement decreases when the explanatory variable increases by one unit. The opposite occurs if the coefficient is negative, that is, the probability of survival increases with the explanatory variable.

It should be noted that while other similar works have used other explanatory variables such as market shares, the size of colluding companies, economic cycles, industries where the conduct was developed, interest rates, exchange rates, among others, it was not possible to collect this data for each of the cases evaluated since, in some competition agencies, the complete resolutions of the imposed sanctions are not publicly available.

Therefore, the primary purpose of this study is to show the relationships between the duration and the identified agreements in several competition agencies worldwide. Additionally, while empirical duration works have found that the variables described above could influence the probability of survival, it is considered that they are probably not correlated with the covariates used in the eight mentioned specifications.

[4]Only the significant industries are shown. The complete table with all variables can be consulted in the appendix section.

Table 3: Proportional Cox Models

	Model A1	Model A2	Model A3	Model A4	Model B1	Model B2	Model B3	Model B4
Leniency								
Leniency Policy	1.385***	1.685***	1.516***	2.244***	1.661***	2.049***	1.665***	2.675***
	(5.71)	(5.57)	(5.49)	(6.09)	(6.33)	(6.40)	(5.80)	(6.83)
Leniency Application	-0.356*	-0.476**	-0.179	-0.528**				
	(-1.79)	(-2.10)	(-0.90)	(-2.08)				
Leniency (Policy & Application)					-0.494**	-0.655**	-0.295	-0.810***
					(-2.05)	(-2.43)	(-1.32)	(-2.82)
Firms								
Number of Firms	-0.0762*	-0.0802*	-0.103**	-0.0982**	-0.0732*	-0.0767*	-0.102**	-0.0976**
	(-1.81)	(-1.85)	(-2.30)	(-2.06)	(-1.74)	(-1.79)	(-2.30)	(-2.09)
Number of Firms (Square)	0.00133	0.00194	0.00257*	0.00317**	0.00119	0.00180	0.00250*	0.00317**
	(0.95)	(1.41)	(1.74)	(2.08)	(0.85)	(1.31)	(1.71)	(2.13)
Agency								
Budget (log)	-0.349***	-0.0994			-0.373***	-0.121		
	(-4.13)	(-0.70)			(-4.27)	(-0.86)		
Horizontal CPL Index	-0.426**	-0.944***			-0.389*	-0.927***		
	(-1.97)	(-2.83)			(-1.80)	(-2.78)		
GCR Ranking			-0.383***	-0.116			-0.396***	-0.107
			(-2.67)	(-0.63)			(-2.75)	(-0.58)
Sanction		-0.000282		0.000368		-0.000469		0.000266
		(-0.27)		(0.35)		(-0.43)		(0.24)
Characteristic								
Bid Rigging		0.218		0.136		0.254		0.154
		(0.95)		(0.56)		(1.09)		(0.64)
Death Antitrust Intervention		-0.187		-0.198		-0.163		-0.257
		(-0.71)		(-0.77)		(-0.62)		(-1.00)
Association		-0.117		-0.402		-0.119		-0.436
		(-0.28)		(-0.67)		(-0.29)		(-0.72)
Industry								
Accommodation and Restaurants		2.360**		2.607**		2.268**		2.493**
		(2.12)		(2.27)		(2.03)		(2.17)
Real State		2.224*		1.666		2.182*		1.639
		(1.85)		(1.39)		(1.81)		(1.37)
Regions								
Agency-South America		0.803		0.651		0.799		0.840
		(1.17)		(0.91)		(1.16)		(1.15)
Agency-Asia		0.639		0.340		0.653		0.384
		(1.14)		(0.56)		(1.15)		(0.62)
Agency-Europe		1.801***		1.886***		1.855***		2.087***
		(2.79)		(3.10)		(2.84)		(3.34)
Agency-Other Regions		1.813**		2.473***		1.842**		2.578***
		(2.47)		(2.99)		(2.48)		(3.09)
Observations	129	129	115	115	129	129	115	115
Pseudo R^2	0.061	0.099	0.056	0.109	0.062	0.101	0.057	0.113

t statistic in parenthesis

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Own elaboration based on information from the OECD (2012-2018)

Next, we will provide a description of the results obtained through the Cox Proportional model for each variable.

5.1 Leniency

The evidence suggests that cartels that engage in illegal activities after leniency policies are implemented tend to be associated with lower survival probability than those established before this policy. The associated coefficients in the proposed models are positive and significant, supporting this conclusion. The survival probability is 85% lower for those cartels initiated when a Leniency Program was active.

This result is consistent with empirical studies conducted by De (2010), Hellwig and Hüschelrath (2017), Abrantes-Metz et al. (2013), and Levenstein and Suslow (2011). They also confirm that leniency programs have been effective in destabilizing hard-core cartels and justifying their incorporation into competition regulations.

There are multiple explanations consistent with this empirical result. First, the number of cartels detected increased after the Leniency Program is active, with a higher proportion of shorter cartels. Additionally, we might expect that cartels are on average shorter, as they are less stable. Finally, some cartels might not form.

Regarding collusive agreements detected through leniency programs, the results show that the coefficients are negative and statistically significant, except for model A3. This implies that cartels with longer durations and higher probabilities of survival are the ones that apply to benefit from Leniency Programs. The survival probability increases by 45%, depending on the model specifications, for cartels whose companies will eventually apply for the benefit.

The interpretation of this result can go either way: Cartels last longer because they can apply for leniency benefits, or they apply for leniency benefits because they last longer. The question that arises is why shorter cartels do not find it worthy to apply to the Leniency Program as often.

The results of the regression are consistent with theoretical-empirical evidence that firms present leniency commitments to obtain partial or total exoneration from fines and increase the costs of competitors who have to assume a sanction for the illegal act (Harrington and Chang, 2009). The informant has short- and medium-term advantages over other companies. Therefore, it is presumable that organizations that have lasted longer are in a position where the agreement has collapsed or is about to collapse (due to coordination failures among members, deviations from the agreement, revenge motivation, among others), and as a consequence of these scenarios, the best strategy they can take is to present information to the competition agency.

Models B show that the interaction between leniency policy and presented leniency main-

tains a negative and significant coefficient, except for specification B3. The results suggest that the survival probability of collusive agreements is increased by approximately 70% when cartels are formed after the introduction of leniency programs in each jurisdiction and a leniency request is made. Therefore, leniency programs are related to the identification of longer-lasting cartels.

In conclusion, leniency policies have a destabilizing effect on collusive agreements, increasing the number of detected cartels and decreasing their survival time. However, based on information on international hard-core cartels, leniency also allows for the identification of more stable cartels.

5.2 Number of Firms

When analyzing the number of conspirators linear and quadratic terms are incorporated. The linear term is negative and statistically significant in all specifications. The quadratic term is positive and statistically significant for specifications A3, A4, B3, and B4.

The results show that the duration of cartels do not decrease with the number of participants in the cartel. This suggests that an increase of one company in the number of cartel participants increases the survival probability by 8% (a result close to the 16% quantified by Hellwig and Hüschelrath (2017)). However, there is a positive quadratic effect that indicates that as the number of companies in the agreement increases, the survival probability of the cartel increases until is reaches a number between 15 to 30 companies (depending on the model specification).

As detailed in the literature review, the theoretical convention indicates that as the number of members in a cartel increases, these organizations become less stable due to coordination difficulties, monitoring problems, and incentives to deviate (both due to the fall in collusive benefits and the increase in benefits of deviation).

Even through descriptive statistics, this can be seen. In the international cartel database, 28% of the cases identified by competition authorities had up to three conspiring companies, while the remaining 72% were collusive agreements with more than four companies.

Expanding this range, 28% of cartels had between 10 to 38 companies colluding in the market. It should be noted that when referring to the number of companies, it is referring to the total number of companies that participated in the illicit act, which means that there may have been firms that entered or exited during the life of the agreement.

From this, three conclusions can be drawn:

- The theory of agreement stability and the number of companies may be more associated with tacit than explicit collusion. This could explain the results obtained in the modeling, given that most of the cases identified by competition agencies are

explicit agreements, for which legal evidence can be obtained through the collection of documents such as text messages, emails, contracts, among others, to sanction this practice. In contrast, identifying tacit collusion can be an economic and legal challenge for a judge to determine the sanction for such conduct. Therefore, if tacit agreements were to be identified, there is a possibility that they would be stable to the extent that there are few companies involved.

- One reasonable explanation for this phenomenon is that those agreements that have maintained a large number of firms, and whose organizational structure is highly sophisticated, allows for monitoring of member behavior as well as establishing the necessary mechanisms to discipline any deviation. Although there is no public data on the exact characterization of the conduct, such as price fixing, market allocation, customer or supplier allocation, among others, it could be the case that, unlike pure price coordination, the other behaviors may be more stable due to allocation.

- It is presumable that in the scenario where there is a high number of firms and they will obtain a lower benefit from the collusive distribution of profits, the state of pure competition would reduce their profits. Therefore, maintaining the agreement would be a better strategy than competing.

5.3 Budget, CPL Index and GCR Ranking

This research has made a relevant contribution by incorporating variables associated with competition agencies into the modeling of duration. To this end, the models A1, A2, B1, and B2 include the Budget and Horizontal CPL Index variables. These variables enable the measurement of the performance of competition agencies that detect collusive agreements and observe whether there is a relationship between them concerning the duration of cartels.

The "Horizontal CPL Index", which measures the efficiency and tools available to competition authorities for detecting and sanctioning horizontal agreements (such as price fixing, market allocation, and bid rigging), has a Cox Proportional model's coefficient that is significant for all specifications. This indicates that competition authorities with higher scores can identify longer-lasting cartels. An increase of 1 unit in this variable increases the probability that the agency will identify agreements with a higher survival rate by approximately 32% to 62% (or decreases the hazard).

The results suggest that there is a negative relationship between the budget of competition institutions and the duration of agreements. An increase of 1% in the budget reduces the hazard by 20%, meaning that competition agencies with more economic resources can detect cartels with longer durations. However, the results were only statistically significant for specifications A1 and B1. The loss of power may be related to correlations regarding the geographic location of the authorities that identified the agreements.

It is essential to understand that investments that competition authorities make

are relevant to identifying these behaviors, which require tools to locate them since they are secret. For example, investments in electronic equipment for raids, forensic laboratories, IT infrastructure, or personnel training. Agencies that make greater investments can detect more sophisticated cartels.

Finally, the GCR Ranking variable supports the same conclusion as models A1, A2, B1, and B2. Competition agencies identify longer-lasting cartels (on average, by 21%) with each additional point in the score awarded to their detection performance and efficiency. The results are only significant for specifications that do not include regions and industries, which may be related to regional variables capturing asymmetries in the performance, budget, among others, of competition authorities.

5.4 Sanction, Bid Rigging, Death Antitrust Intervention, Association

In terms of the impact of monetary sanctions imposed by competition authorities on cartel duration, it was found that the coefficients are negative for A2 and B2 specifications, while they are positive for A4 and B4 specifications; however, none of these coefficients were statistically significant.

Similarly, for the Bid Rigging variable, the coefficient associated with the survival probability is not significant across all four specifications, indicating no significant difference in duration between this type of agreement and others such as price fixing or market sharing.

As for the Death Antitrust Intervention and Association variables, the results do not demonstrate statistical significance and maintain a negative coefficient across all specifications.

5.5 Region and Industry

With regards to the geographic location where the agreements were detected, it is worth mentioning that in Europe and Other Regions, cartels pose a higher risk (with a positive coefficient and statistical significance) than those agreements detected in North America (the base case), across all specifications. The average duration of agreements detected in North America is around 2.2 years, while in Europe and Other Regions, the average duration is 5.11 and 3.81 years, respectively.

Lastly, for the cases of Asia and South America, the null hypothesis is accepted that there is no significant difference in the duration of agreements between these regions and those discovered in North America. It should be noted that although the Collaboration-Multiagency variable was mentioned in the data description, no results were obtained as the Budget, GCR Ranking, and CPL-Horizontal Index variables are linked to a single authority. Therefore, these observations were not included in the Cox proportional hazards model analysis.

In terms of industry controls where anticompetitive behavior occurred, only two out of the 14 were significant - namely Accommodation and Food Services, as well as Real Estate. Both industries had a positive coefficient, indicating an increased risk compared to the base case of the Manufacturing industry.

6 Conclusion

In this document, we have explored the duration of international hard-core cartels across different countries. This exploration enables us to observe how specific characteristics relate to the probability of the collapse of these illegal acts. Some of our findings are consistent with other empirical studies.

One notable discovery in our research is the identification of a direct correlation between the leniency regime and the destabilization of cartels. On average, this correlation leads to a decrease in their survival time. Furthermore, these leniency programs have facilitated the detection of longer collusive agreements.

Regarding the impact on the number of firms involved, we have identified that as the number of participants increases, the survival probability actually increases. This suggests that collusive agreements can remain stable even when there is a high number of participants. This stability could stem from the fact that the state of collusion is more advantageous than competition. In response, organizations might employ sophisticated mechanisms to avoid deception and sustain the agreement for an extended period.

Our research incorporates controls related to the performance of competition agencies, including CPL indices, agency budgets, and rankings published by Global Competition Review. These variables relate to the probability of detecting and deterring cartels. The results indicate that authorities equipped with more resources and better performance are more capable of sanctioning and uncovering collusive agreements with longer durations.

Finally, with respect to the other incorporated variables—such as Sanction, Bid Rigging, Agency Death, and Association—none of them demonstrated significance in the proposed models. Similarly, concerning controls based on industries and regions, only the Accommodation and Real Estate sectors showed significant results within the former category. In the case of the latter variable, the survival probability decreases in the regions of Europe and Other Regions compared to agreements detected in North America.

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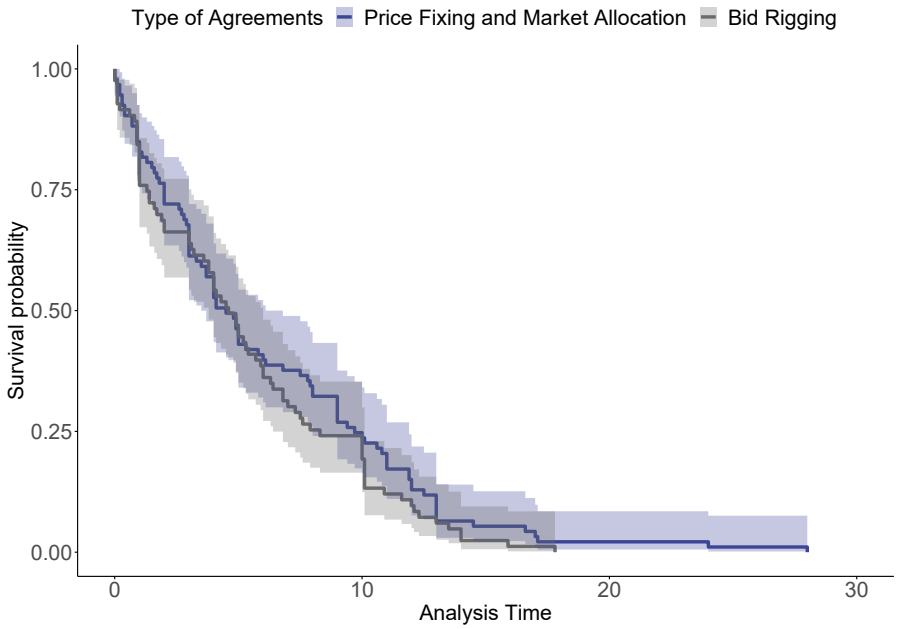
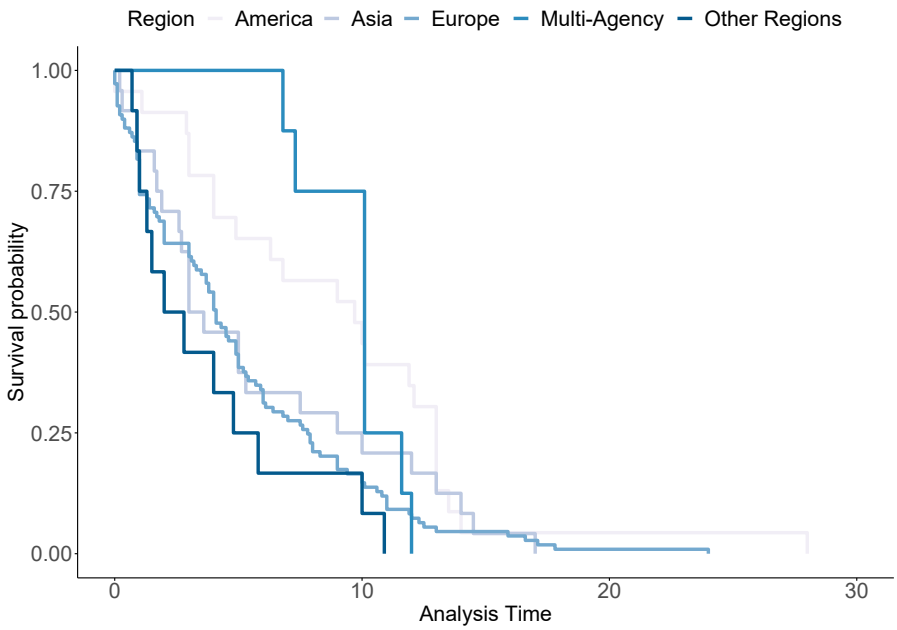
7 Anexo

Figure 5: Kaplan-Meier probability of survival,Bid Rigging



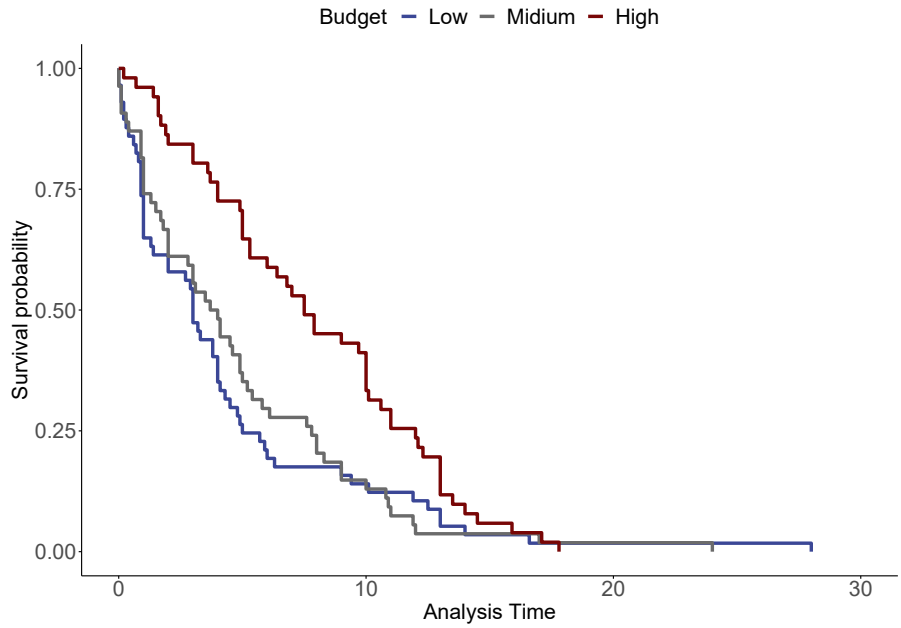
Own elaboration based on information from the OECD (2012-2018)

Figure 6: Kaplan-Meier probability of survival, Regions



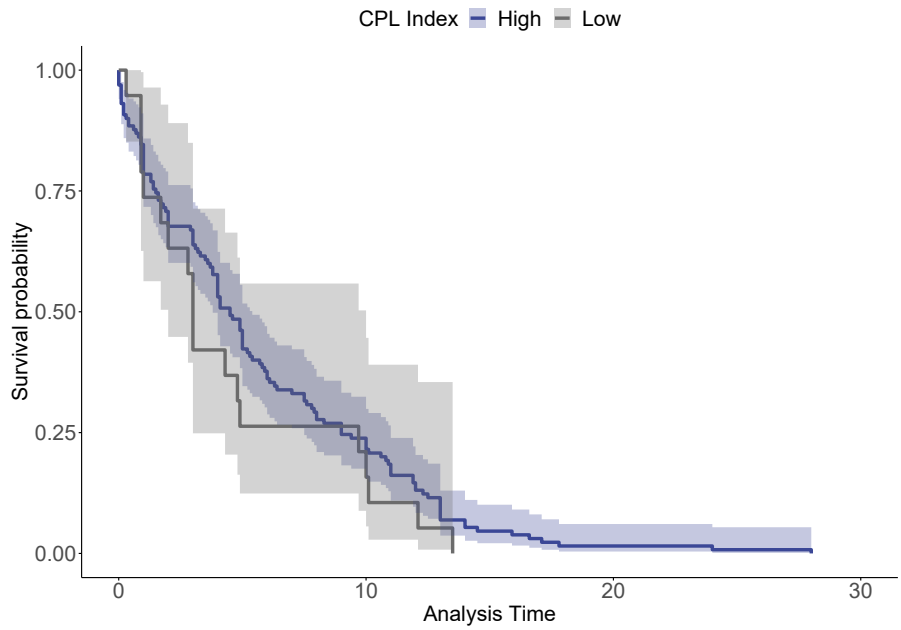
Own elaboration based on information from the OECD (2012-2018)

Figure 7: Kaplan-Meier probability of survival, Budget



Own elaboration based on information from the OECD (2012-2018)

Figure 8: Kaplan-Meier probability of survival, CPL Index



Own elaboration based on information from the OECD (2012-2018)

Table 4: Proportional Cox Models

	Model A1	Model A2	Model A3	Model A4	Model B1	Model B2	Model B3	Model B4
Leniency								
Leniency Policy	-0.356*	-0.476**	-0.179	-0.528**				
	(-1.79)	(-2.10)	(-0.90)	(-2.08)				
Leniency Application	1.385***	1.685***	1.516***	2.244***	1.661***	2.049***	1.665***	2.675***
	(5.71)	(5.57)	(5.49)	(6.09)	(6.33)	(6.40)	(5.80)	(6.83)
Leniency Policy X Leniency Application					-0.494**	-0.655**	-0.295	-0.810***
					(-2.05)	(-2.43)	(-1.32)	(-2.82)
Firms								
Number of Firms	-0.0762*	-0.0802*	-0.103**	-0.0982**	-0.0732*	-0.0767*	-0.102**	-0.0976**
	(-1.81)	(-1.85)	(-2.30)	(-2.06)	(-1.74)	(-1.79)	(-2.30)	(-2.09)
Number of Firms Sq	0.00133	0.00194	0.00257*	0.00317**	0.00119	0.00180	0.00250*	0.00317**
	(0.95)	(1.41)	(1.74)	(2.08)	(0.85)	(1.31)	(1.71)	(2.13)
Agency								
Ln Budget	-0.349***	-0.0994			-0.373***	-0.121		
	(-4.13)	(-0.70)			(-4.27)	(-0.86)		
Horizontal CPL Index	-0.426**	-0.944***			-0.389*	-0.927***		
	(-1.97)	(-2.83)			(-1.80)	(-2.78)		
GCR Ranking			-0.383***	-0.116			-0.396***	-0.107
			(-2.67)	(-0.63)			(-2.75)	(-0.58)
Sanction		-0.000282		0.000368		-0.000469		0.000266
		(-0.27)		(0.35)		(-0.43)		(0.24)
Characteristic								

Bid Rigging	0.218	0.136	0.254	0.154
	(0.95)	(0.56)	(1.09)	(0.64)
Death Antitrust Intervention	-0.187	-0.198	-0.163	-0.257
	(-0.71)	(-0.77)	(-0.62)	(-1.00)
Association	-0.117	-0.402	-0.119	-0.436
	(-0.28)	(-0.67)	(-0.29)	(-0.72)
Industry				
Accommodation and Food Services	2.360**	2.607**	2.268**	2.493**
	(2.12)	(2.27)	(2.03)	(2.17)
Administrative and Waste Management	0.635	0.304	0.712	0.422
	(0.84)	(0.29)	(0.94)	(0.40)
Agriculture and Fishing	0.974	0.0328	0.932	-0.131
	(1.53)	(0.03)	(1.46)	(-0.12)
Construction	0.515	0.619	0.540	0.681
	(1.10)	(1.29)	(1.15)	(1.41)
Finance and Insurance	0.157	0.519	0.274	0.638
	(0.28)	(0.69)	(0.48)	(0.86)
Information	0.292	0.840	0.298	0.868
	(0.54)	(1.32)	(0.55)	(1.36)
Mining and Oil	-0.925	-0.601	-0.769	-0.470
	(-0.84)	(-0.54)	(-0.71)	(-0.43)
Other Services	0.238	0.0335	0.193	-0.107
	(0.39)	(0.05)	(0.31)	(-0.16)
Professional, Scientific, and Technical	0.00101	0.0974	-0.0499	0.00462
	(0.00)	(0.23)	(-0.13)	(0.01)
Real Estate	2.224*	1.666	2.182*	1.639

		(1.85)		(1.39)		(1.81)		(1.37)
Retail Trade		1.340		-0.261		1.344		-0.402
		(1.63)		(-0.39)		(1.64)		(-0.59)
Transportation and Warehousing		-0.324		-0.367		-0.407		-0.459
		(-0.87)		(-1.06)		(-1.08)		(-1.31)
Utilities		0.942		1.000		0.907		0.924
		(1.23)		(1.25)		(1.18)		(1.16)
Wholesale Trade		-0.0307		-0.740		-0.111		-0.923
		(-0.06)		(-0.72)		(-0.22)		(-0.90)
Región								
Agency- South America		0.803		0.651		0.799		0.840
		(1.17)		(0.91)		(1.16)		(1.15)
Agency-Asia		0.639		0.340		0.653		0.384
		(1.14)		(0.56)		(1.15)		(0.62)
Agency-Europe		1.801***		1.886***		1.855***		2.087***
		(2.79)		(3.10)		(2.84)		(3.34)
Agency-Other Regions		1.813**		2.473***		1.842**		2.578***
		(2.47)		(2.99)		(2.48)		(3.09)
Observations	129	129	115	115	129	129	115	115
Pseudo R^2	0.061	0.099	0.056	0.109	0.062	0.101	0.057	0.113

t statistic in parenthesis
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Own elaboration based on information from the OECD (2012-2018)