CEO Overconfidence and Collusion*

Marek Giebel† Catarina Marvão‡ Anja Rösner§ Luís Santos-Pinto ¶
Giancarlo Spagnolo ‖ Cécile Aubert **

May 20, 2026

Abstract

This paper examines how managerial biases shape firms' engagement in illegal strategic behavior. We focus on CEO overconfidence and study its effect on cartel formation and stability. We develop a dynamic model in which overconfident managers overestimate the effectiveness of concealment efforts in reducing detection risk. This belief distortion relaxes both participation and incentive constraints, making collusion more attractive and more sustainable. We test these predictions using firm- and cartel-level data. CEO overconfidence is positively associated with cartel participation, predicts future cartel involvement, and cartel activity declines following the replacement of an overconfident CEO, particularly after forced turnover. Cartels involving overconfident managers also exhibit significantly longer duration and lower hazard rates of breakdown. Competition authorities should thus account for CEO overconfidence to avoid underestimating the persistence of collusion, and also possibly to improve screening for cartel detection.

Keywords: Corporate governance; cartels; managerial incentives; revealed preferences; overconfidence.

*We gratefully acknowledge helpful feedback from the participants at the Irish Academy of Finance (May 2024), CRESSE (July 2024), EARIE (August 2024), the *Workshop on Collusion in Markets* (Tinbergen Institute, December 2024) and UCD Smurfit Seminar Series (March 2025).

†Copenhagen Business School

‡University College Dublin (Smurfit); Stockholm School of Economics (SITE), catarina.marvao@ucd.ie (corresponding author)

§The ROCKWOOL Foundation

¶Faculty of Business and Economics, University of Lausanne

‖University of Rome Tor Vergata; Stockholm School of Economics (SITE); EIEF Rome; CEPR

**Univ. Bordeaux, CNRS, INRAE, BxSE, Toulouse School of Economics, GAEL, U. Grenoble Alpes

"As far as individuals are concerned, I think most antitrust violators probably violate the laws because they do not think they are going to get caught."

— M. L. Denger, "Too Much or Too Little", American Bar Association, Section of Antitrust Law, Antitrust Remedies Forum (2002), p. 6.

1 Introduction

Managerial overconfidence is one of the most extensively documented behavioral traits in corporate decision-making. A large literature shows that overconfident CEOs overestimate returns and underestimate risks (Malmendier and Tate, 2005), leading to systematic distortions in firm strategies. While prior research has largely focused on legal strategic choices, much less is known about how managerial biases shape firms' behavior in high-risk environments where actions expose firms to substantial regulatory penalties.

This paper examines how managerial overconfidence affects firms' engagement in illegal strategic behavior. We focus on collusion as a setting in which beliefs about risk are central. Cartel participation exposes firms and executives to the risk of significant financial penalties, reputational damage, and, in some jurisdictions, criminal sanctions. Engaging in such behavior, therefore, requires beliefs about the risk of being detected, either by authorities, or through other cartel partners. If managers systematically misperceive these risks, firms may engage in collusion even when it would not be optimal under rational expectations.[1]

We develop a dynamic model in which firms decide whether to participate in and sustain collusion under the risk of detection. Managers can exert costly effort to reduce the probability of being detected, such as limiting documentation, structuring communication channels, or reducing traceable evidence, but the effectiveness of this effort is uncertain. Such activities are widely documented in cartel cases and have been formally analyzed in recent theoretical work (e.g., Marx and Mezzetti, 2014; Jensen et al., 2013). Overconfident managers overestimate the effectiveness of their concealment efforts, leading them to underestimate the true probability of detection.

The model shows that this belief distortion lowers *perceived detection-and-concealment cost* (i.e. the perceived detection probability multiplied by the fine, plus concealment costs) and relaxes both the participation constraint and the dynamic incentive constraint sustaining collusion (with or without leniency). As a result, overconfidence increases the likelihood of cartel

[1] For instance, Geis (1968) describes that managers underestimated the detection likelihood in an electrical equipment cartel.

entry and enhances cartel stability. Further, it shows that although overconfidence always lowers the perceived probability of cartel detection, its effect on the true detection probability is ambiguous: when overconfidence increases concealment effort, the true detection probability indeed falls, whereas when overconfidence reduces concealment effort, the true detection probability rises.

The model focuses on managers who overestimate the effectiveness of their own actions in reducing risk. To test its first two predictions, we use option-based measures of CEO overconfidence (Malmendier and Tate, 2005) as an empirical proxy for this belief distortion. This measure is based on delayed option exercise and is commonly interpreted as capturing CEOs' tendency to overestimate future firm performance and to place excessive confidence in their own judgment. Our identifying assumption is that this overconfidence extends beyond expected returns to perceived control over outcomes more generally. In particular, a manager who overestimates his ability to increase firm value may also overestimate his ability to reduce risks through strategic actions. In our setting, this means that overconfident managers may believe they are especially effective at concealing collusive behavior and thereby lowering the probability of detection. This interpretation links the empirical proxy to the mechanism of the model. If overconfident managers perceive concealment as more effective, they will view cartel participation as less risky and therefore more attractive. In that sense, option-based overconfidence serves as a domain-general proxy for distorted beliefs about managerial control, which is the key force emphasized by the model.

In the empirical part of the paper, we classify CEOs as overconfident if they repeatedly delay exercising deeply in-the-money stock options (the *Longholder* measure), and we supplement this with alternative overconfidence proxies for robustness. We document a robust positive association between managerial overconfidence and cartel participation. Overconfidence predicts future cartel involvement, and this relationship persists across a wide range of specifications, including firm controls, year fixed effects, matched samples, and alternative measures of overconfidence. To address identification concerns about observable selection, we employ several complementary strategies. First, we use Granger causality tests, which suggest that overconfidence precedes cartel participation rather than the reverse. Second, we use propensity score matching (e.g. Bos et al., 2018) to compare firms with similar observable characteristics. Third, we implement heteroskedasticity-based (Lewbel) instrumental variables. Fourth, we exploit CEO turnover as a source of within-firm variation: cartel activity declines following the replacement of an overconfident CEO, particularly in cases of forced turnover. Taken together,

these approaches provide consistent evidence supporting a systematic relationship between managerial overconfidence and cartel participation.

We then examine the relation between managerial overconfidence and cartel stability using duration analysis. Cartels involving overconfident managers last significantly longer and exhibit substantially lower hazard rates of breakdown, with baseline estimates indicating reductions in hazard rates of up to 37%. These findings are consistent with the model's prediction that overconfidence relaxes the incentive constraint sustaining collusion.

Our results contribute to several strands of literature. First, we extend the behavioral corporate finance literature on managerial overconfidence. Prior work shows that overconfident CEOs overestimate returns and underestimate risks (Malmendier and Tate, 2005), overinvest and overvalue firms (Heaton, 2002; Adebambo and Yan, 2017), pursue value-destroying mergers (Malmendier and Tate, 2008), underestimate volatility and are less responsive to it (Itzhak et al., 2013; Banerjee et al., 2023), and increase innovation intensity (Galasso and Simcoe, 2011). This literature has largely focused on legal strategic decisions in investment, financing, and innovation contexts (see Malmendier and Tate, 2015 for a review). We show that overconfidence also shapes firms' engagement in illegal coordination. In doing so, we broaden the scope of managerial bias from corporate policy choices to regulatory violations, showing that overconfidence affects not only firm performance but also compliance behavior.

Second, we contribute to the literature on corporate misconduct and governance. A growing body of research links executive traits to fraud and other violations (Schrand and Zechman, 2012). We provide new evidence that CEO characteristics predict cartel participation and persistence. This finding complements work emphasizing the role of shareholder incentives and governance structures in shaping collusive behavior (e.g., Spagnolo, 2000, 2005; Azar et al., 2018; Antón et al., 2023). While some have argued that collusion originates primarily at lower organizational levels, case evidence suggests that senior executives frequently authorize or coordinate cartel agreements (Harrington, 2006; Connor, 2011). Our results support the view that what happens at the very top of the firm is central for understanding collusion.

Third, we contribute to the literature on cartel stability and enforcement. Traditional models of collusion assume rational expectations regarding detection risk and sanctions. Recent theoretical work emphasizes that concealment effort is an endogenous strategic choice and that enforcement tools such as leniency programs may generate unintended responses (Marx and Mezzetti, 2014; Jensen et al., 2013). We complement this strand by introducing behavioral dis-

tortions into detection-avoidance decisions. Our model shows that overconfidence-driven misperceptions of cartel detection risk can sustain collusion, providing a behavioral foundation for persistent cartel activity and recidivism documented in prior empirical work (e.g., Marvão, 2015; Levenstein et al., 2016).

Finally, our findings are relevant to broader questions about deterrence and regulatory design. If overconfident managers systematically underestimate detection risk, policies calibrated under rational deterrence assumptions may be less effective than anticipated. This perspective suggests that enforcement outcomes depend not only on penalties and monitoring technologies, but also on the behavioral characteristics of decision makers. More generally, the paper highlights the importance of integrating behavioral insights into models of corporate governance and regulatory compliance.

The remainder of the paper proceeds as follows. Section 2 develops the theoretical model. Section 3 describes the data and key variables. Section 4 presents the empirical analysis. In particular, section 4.1 focuses on overconfidence and cartel participation, section 4.2 examines overconfidence and cartel duration, and section 4.3 examines the effect of CEO turnover. Finally, Section 5 concludes.

2 Theoretical Framework

2.1 Setup

We consider an infinitely repeated game among N symmetric firms, each run by a risk-neutral manager. In every period, managers decide whether to collude and, conditional on collusion, how much costly concealment effort to exert to reduce the probability of detection. Time is discrete and future payoffs are discounted by $\delta \in (0, 1)$.

We assume collusion resumes after detection and analyze two enforcement regimes, with and without a Leniency Program, which provides fine immunity in exchange for the reporting of the cartel.[2]

2.1.1 Timing and payoffs

Each period unfolds as follows:

[2]We also check the case in which collusion stops after a detection. The effect of overconfidence on both the participation and incentive compatibility constraints is the same.

1. Managers simultaneously decide whether to collude. If at least one refuses, firms compete forever.
2. Conditional on collusion, each manager i, with $i = 1, .., N$, chooses concealment effort $e_i \geq 0$. Concealment efforts are chosen simultaneously and are unobservable.
3. Managers may unilaterally deviate. Under leniency, a deviator may report the cartel and obtain immunity. If a manager deviates, cartel partners detect the deviation with probability 1.
4. If no report is filed, the authority detects and convicts the cartel with probability $\rho \in (0, 1)$.

Per-period profits satisfy $0 \leq \pi^n < \pi^c < \pi^d$, where π^n denotes Nash competition, π^c collusion, and π^d unilateral deviation. Upon detection, each firm pays a fine $F > 0$, except for the leniency applicant.

2.1.2 Detection technology and concealment

The detection probability depends on total concealment effort $x = \sum_i e_i$ via a twice continuously differentiable function $\rho(x) \in (0, 1)$ satisfying

$$\rho'(x) < 0, \qquad \rho''(x) > 0, \qquad \lim_{x \to \infty} \rho(x) = 0. \tag{1}$$

Greater concealment lowers detection probability, with diminishing marginal effectiveness.

Each manager incurs a private monetary concealment cost $\psi(e_i)$, such that concealment cost is therefore strictly increasing and convex in concealment effort:

$$\psi(0) = 0, \qquad \psi'(e_i) > 0, \qquad \psi''(e_i) > 0, \qquad \lim_{e_i \to \infty} \psi'(e_i) = \infty. \tag{2}$$

2.1.3 Overconfidence

Managers may be overconfident about the effectiveness of their own concealment effort. Specifically, manager i perceives the detection probability as

$$\tilde{\rho}_i = \rho\left(\lambda e_i + \sum_{j \neq i} e_j\right), \tag{3}$$

where $\lambda \geq 1$ measures overconfidence, i.e., it captures a manager's overestimation of the marginal effectiveness of his own concealment effort. When $\lambda = 1$, beliefs are unbiased. When $\lambda > 1$,

the manager overestimates the impact of his effort on reducing detection risk, implying $\tilde{\rho}_i < \rho$ whenever $e_i > 0$.

2.2 Beliefs and equilibrium

Managers take others' strategies as given and optimize under their own (possibly biased) beliefs. We assume common knowledge of strategies and of the structure of beliefs, but each manager believes his own perception of detection risk is correct.[3]

This framework allows us to study how overconfidence affects (i) concealment effort, (ii) detection probabilities, (iii) cartel participation, and (iv) cartel sustainability across enforcement regimes.

2.2.1 Concealment effort and detection probabilities

If manager i colludes, his perceived payoff is

$$\pi^c - \tilde{\rho}_i(e_i, e_{-i})F - \psi(e_i) + \delta\tilde{V}_i^c,$$

where $\tilde{\rho}_i = \rho(\lambda e_i + \sum_{j\neq i} e_j)$ is the perceived detection probability, $\psi(e_i)$ is the concealment cost, and $\tilde{V}_i^c$ is the perceived continuation value under collusion. Taking $\tilde{V}_i^c$ as given, manager i chooses effort to minimize his *perceived detection-and-concealment cost* (i.e. the perceived detection probability multiplied by the fine, plus the concealment cost)

$$\min_{e_i \geq 0} \tilde{\Phi}(e_i, e_{-i}) = \tilde{\rho}_i(e_i, e_{-i})F + \psi(e_i). \tag{4}$$

The first-order condition is given by

$$\lambda\rho'\left(\lambda e_i + \sum_{j\neq i} e_j\right)F + \psi'(e_i) = 0. \tag{5}$$

Thus, concealment effort equates the perceived marginal reduction in detection risk to its marginal cost. The second-order condition holds given the assumptions on ρ and ψ.

In a symmetric equilibrium (where all managers are equally overconfident), $e_i = e$ for all i, and effort satisfies

$$\lambda\rho'((N + \lambda - 1)e)F + \psi'(e) = 0. \tag{6}$$

[3] We provide further details and calculations in Appendix A0.

This equation determines the equilibrium concealment effort e^* as a function of model primitives. Appendix A1 proves existence and uniqueness of equilibrium.

Overconfidence affects e^* through the perceived marginal impact of effort on detection. The sign of $\partial e^*/\partial\lambda$ is generally ambiguous and depends on the curvature of $\rho(\cdot)$ (see Appendix A2).

At the symmetric equilibrium, perceived and true detection probabilities are

$$\tilde{\rho}^* = \rho((N+\lambda-1)e^*), \qquad \rho^* = \rho(Ne^*).$$

Proposition 1 (Overconfidence, Concealment Effort, and Detection Probabilities) *Suppose collusion resumes after detection.*

(*i*) *If overconfidence increases equilibrium concealment effort e^*, both perceived and true detection probabilities ($\tilde{\rho}^*$ and ρ^*) decrease in λ.*

(*ii*) *If overconfidence decreases e^*, the perceived detection probability $\tilde{\rho}^*$ decreases in λ, while the true detection probability ρ^* increases.*[4]

Proposition 1 highlights a potential wedge between beliefs and reality. Overconfidence always lowers perceived detection risk. However, true detection risk falls only if concealment effort rises; if effort falls, firms feel safer even as they become easier to detect.

2.2.2 Participation constraint

In a symmetric equilibrium, the perceived continuation value under collusion and the value under competition are

$$\tilde{V}^c = \frac{\pi^c - \tilde{\rho}^* F - \psi(e^*)}{1-\delta}, \qquad V^n = \frac{\pi^n}{1-\delta}.$$

Firms enter a cartel if $\tilde{V}^c \geq V^n$. This participation constraint (PC) determines whether a firm enters a collusive agreement and is equivalent to:

$$\pi^c - \pi^n > \tilde{\rho}^* F + \psi(e^*).$$

Since overconfidence reduces the *perceived detection-and-concealment cost* $\tilde{\rho}^* F + \psi(e^*)$, it increases the net perceived gain from collusion and relaxes the participation constraint.

[4] The proof is presented in Appendix A3.

Proposition 2 (Overconfidence and Cartel Participation) *If collusion resumes after detection, then greater overconfidence increases the incentives to enter a cartel.*[5]

Throughout the analysis, we assume that the participation constraint holds such that firms decide to enter a cartel agreement.

2.2.3 Incentive compatibility constraint

If a manager deviates from collusion, his perceived payoff is

$$\tilde{V}^d = \pi^d - \tilde{\rho}^* F - \psi(e^*) + \delta \frac{\pi^n}{1-\delta}.$$

Collusion is sustainable if $\tilde{V}^c \geq \tilde{V}^d$, which yields the incentive compatibility constraint (ICC):

$$\delta > \delta_1^* \equiv \frac{\pi^d - \pi^c}{\pi^d - \pi^n - \tilde{\rho}^* F - \psi(e^*)}. \tag{7}$$

Overconfidence affects the critical discount factor only through the *perceived detection-and-concealment cost*. Because $\tilde{\rho}^* F + \psi(e^*)$ decreases with overconfidence, the threshold δ_1^* falls, making collusion easier to sustain.

Proposition 3 (Overconfidence and Cartel Sustainability) *If collusion resumes after detection and a leniency program is unavailable, then greater overconfidence increases cartel sustainability.*

A decrease in the equilibrium perceived detection-and-concealment cost raises the denominator in equation (7), which, in turn, lowers the critical discount factor δ_1^*. Consequently, higher overconfidence enhances cartel sustainability.

Overconfidence, therefore, generates a risk-misperception wedge: it robustly strengthens incentives to collude by lowering *perceived detection-and-concealment cost*, while its effect on actual detection depends on how concealment effort responds. This distinction is central for interpreting observed detection rates and enforcement outcomes.

2.2.4 Collusion resumes after detection: leniency program

We now introduce a leniency program. At any time when the cartel is active, a firm may deviate and report it to the competition authority. The first reporting firm receives full immunity (no fine), while the remaining firms pay a fine F.

A deviating firm therefore has an additional option: deviate and report. Under full im-

[5] The proof is presented in Appendix A4.

munity, reporting eliminates the fine and makes concealment unnecessary, so the deviator sets $e^d = 0$. Since $\tilde{\rho}^* F + \psi(e^*) > 0$, deviation with leniency strictly dominates deviation without leniency. The deviation value under leniency is given by

$$\tilde{V}^d_{LP} = \pi^d + \delta V^n,$$

which yields

$$\tilde{V}^d_{LP} = \pi^d + \delta \frac{\pi^n}{1-\delta}. \tag{8}$$

Collusion is sustainable if $\tilde{V}^c \geq \tilde{V}^d_{LP}$. Substituting the continuation values implies the incentive compatibility constraint

$$\pi^c - \tilde{\rho}^* F - \psi(e^*) \geq \pi^d(1-\delta) + \delta\pi^n,$$

which can be written as a threshold condition

$$\delta > \delta^*_2 \equiv \frac{\pi^d - \pi^c + \tilde{\rho}^* F + \psi(e^*)}{\pi^d - \pi^n}. \tag{9}$$

Overconfidence affects the incentive constraint through the *perceived detection-and-concealment cost*, $\tilde{\rho}^* F + \psi(e^*)$. From Proposition 2, this term is decreasing in overconfidence. Hence, greater overconfidence lowers the numerator in equation (9), which, in turn, lowers the critical discount factor δ^*_2, making collusion easier to sustain.

Proposition 4 (Overconfidence and Cartel Sustainability) *If collusion resumes after detection and a leniency program is available, then greater overconfidence increases cartel sustainability.*

Thus, even in the presence of leniency, the pro-collusive effect of overconfidence survives. By lowering firms' *perceived detection-and-concealment cost*, overconfidence increases the perceived net return from adhering to the cartel agreement. Leniency modifies reporting incentives and sanctions but does not overturn this central comparative static in the post-detection regime.

Mechanism and empirical mapping. The model generates two testable implications. First, by lowering *perceived detection-and-concealment cost*, overconfidence relaxes the participation constraint, increasing cartel entry. Second, by relaxing the dynamic incentive constraint, overconfidence increases cartel stability and duration.

3 Data, sample, and key variables

This section describes the data sources, sample construction, and key variables used in the empirical analysis. Our empirical setting combines cartel-level enforcement data with detailed CEO-level compensation, allowing us to link managerial traits to collusive behavior at both the firm and cartel level.

3.1 Data

Our cartel data are drawn from an excerpt of John Connor's *Private International Cartels* dataset.[6] This excerpt covers the years 1984 to 2011 and is limited to publicly reported information on 180 cartels convicted between 1985 and 2011 by the DOJ, involving 470 non-anonymous individual firms.

We merge the cartel data with firm- and CEO-level financial and compensation data from Compustat (including ExecuComp), Thomson Reuters Insider Filings, CRSP, and the Hoberg and Phillips product market database. The Hoberg-Phillips text-based sector classification provides firm-year competitor networks based on product similarity measures derived from 10-K disclosures (Hoberg and Phillips, 2010; Hoberg et al., 2014; Hoberg and Phillips, 2016).

To construct CEO overconfidence measures, we combine Thomson Insider Filings (1998–2013) with ExecuComp data (1998–2016), following Malmendier and Tate (2015). We restrict the sample to publicly traded firms with available sales, SIC codes, and ticker identifiers. Firms are matched across datasets using S&P ticker symbols.[7] After merging all data sources and applying data availability filters, the final sample consists of 11,450 firm-year observations from 2,987 unique firms, of which 76 firms were convicted cartel participants during the sample period.

We further augment the dataset with CEO turnover information from Gentry et al. (2021), supplemented with forced-versus-voluntary classifications from Jenter and Kanaan (2015) and Peters and Wagner (2014). This allows us to analyze changes in collusive behavior following leadership transitions.

[6] Private International Cartels spreadsheet by John M. Connor, Purdue University, Indiana, USA (January 2012). The dataset was modified in several ways: the anonymous firms and groups of firms were dropped to be able to account for different measures of recidivism; some of the variables were resized; where possible, data was checked (and corrected) against the DOJ case documents; the imprisonment variable was updated with John Connor's criminal dataset, obtained in 2016 by one of the authors, and several other variables were dropped due to inconsistent or missing data.

[7] We use the latest available symbol for each firm to reflect mergers and acquisitions. For example, Exxon's US ticker symbol was "XON", but after the 1999 merger with Mobil Oil, it changed to "XOM".

3.2 Sample selection

A central empirical challenge in studying collusion is that only detected and prosecuted cartels are observed. As a result, cartel participation is jointly determined by both collusive behavior and enforcement outcomes. If undetected cartels differ systematically from detected ones, estimates may reflect detection bias rather than underlying collusive propensity.

While selection on unobservables cannot be fully ruled out, we address identification concerns using multiple complementary strategies. These include lag structures, Granger causality tests, propensity score matching, heteroskedasticity-based instruments, and CEO turnover designs that exploit within-firm variation. Taken together, these approaches consistently support a causal interpretation of the relationship between managerial overconfidence and collusion. We discuss this further in section 4.1.3.

3.3 Key variables

Below, we outline the variables used in our main analysis. Definitions of all variables are provided in Table 1 in the Appendix.

3.3.1 Cartel participation and duration

We measure cartel participation using an indicator variable, $\text{CARTEL}_{i,t}$, equal to one if firm i is active in a DOJ-convicted cartel in year t. A firm's cartel participation window spans from the first year of documented involvement to the final enforcement action. Firms involved in multiple cartels are coded as active throughout the combined participation window.[8]

To examine cartel stability, we define cartel duration as the number of years between the cartel's start and termination, measured at the cartel level.

3.3.2 Managerial overconfidence

Our primary explanatory variable is CEO overconfidence, i.e., the overestimation by a CEO of the relative or absolute future performance of a firm related to his own abilities, such as IQ or managerial skills.[9]

[8] Many firms are involved in multiple cartels (known as "repeat offenders" or "serial colluders"), see e.g., Marvão (2015); Levenstein et al. (2016). In these cases, the cartel membership window covers participation in all cartels in which the firm is convicted of participating. For example, if the firm was involved in one cartel between 2006 and 2010 and another between 2008 and 2013, the cartel window of the firm spans from 2006 to 2013.

[9] In general, the literature labels the overestimation of future outcomes in two different ways: "optimism" relates to the overestimation of future outcomes related to exogenous outcomes, such as macroeconomic variables, whereas "overconfidence" (as in Malmendier and Tate, 2005, 2008, 2015) relates to the overestimation of future out-

We follow Malmendier and Tate (2005) and subsequent work in measuring overconfidence using option-based revealed-preference proxies. These measures rely on the premise that CEOs who systematically delay exercising fully vested in-the-money stock options are overconfident, relative to the market's evaluation, about the prospects of their firm. As such, these measures exploit the underdiversification of CEOs.

Our baseline measure, *Longholder*(T), classifies a CEO as overconfident if he repeatedly holds deeply in-the-money stock options until expiration. It focuses on the expiration date of option packages (and not the end of the vesting period). Following Malmendier and Tate's approach, we classify a CEO as overconfident (for all of his years in the sample) if he ever holds an option until the last year of its duration.[10] Therefore, this measure captures a persistent behavioral trait and is time-invariant at the CEO level.

We supplement this proxy with three alternative measures: *Net Buyer*, *Holder 67*, and *Holder 67 Restriction*. These measures capture different dimensions of persistent overconfidence in equity exercise and purchase behavior.

We build these three measures using data from ExecuComp (see Table 2). Data on stock prices come from CRSP, so our sample is restricted to publicly traded firms. In general, *Net Buyer* uses the timing of the acquisition of firm stock, while the other measures use the timing of the exercise of the option. Detailed construction procedures are provided in Appendix C.

In our sample, the options last up to 10 years, and their average duration is 5.3 years. Approximately 80% of the options that are held until their final year are in-the-money, and the average value of in-the-money for the unexercised options is \$5450. This means that the CEO could have profitably exercised these options before their last year. In fact, failure to exercise these options before expiration is difficult to reconcile with any reasonable calibration of the framework in Hall and Murphy (2002).

The ExecuComp data (pre-2006) does not include details about individual option packages. For instance, there is no data on individual grant dates, expiration dates, or strike prices. Therefore, it is not possible to assess the timing of exercise relative to expiration (or grant) dates, such that the "average moneyness" used in *Longholder* is a direct function of stock prices.

comes related to one's abilities. Some authors also define overconfidence as overprecision, i.e., excessive precision of forecasts or knowledge, as reported through surveys (e.g., Itzhak et al., 2013).

[10]The intuition behind the Longholder measure is that a rational, risk-averse, and under-diversified CEO should exercise deep-in-the-money stock options early to reduce exposure to firm-specific risk. CEOs who systematically delay option exercise beyond this benchmark appear to overestimate future firm performance, and are therefore classified as overconfident.

To overcome this issue, Malmendier and Tate (2015) update this measure of overconfidence using data from Thomson Reuters's Insider Filings for the 1996-2012 time period. We follow this approach. In the main analysis, we focus on this updated *Longholder*(T) measure.

Net Buyer exploits the tendency of CEOs to purchase additional firm stock despite already having a high exposure to firm risk. CEOs are classified as overconfident if they were net buyers of firm equity during their first five years in the sample.

Holder 67 targets CEOs who "habitually" exercise options late. If an option is more than 67% in-the-money at some point in the threshold year, the CEO should have exercised at least some portion of the package during or before that year.

Holder 67 Restriction (Holder67(R)). To build this measure, we take the *Holder 67* measure and restrict the sample to CEOs who, at least twice during the sample period, had options valued above the threshold during the fifth year.

In tables 3 and 4, we show that the correlation between the measures is low (4-18%), although there is a nearly full overlap between *Holder67* and *Holder67*(R). Further, across measures, 28%-39% of CEOs in the full sample are classified as overconfident. Among cartel firms, the share ranges from 48% to 64%.[11]

3.3.3 Control variables

Our baseline specifications include firm-level controls commonly used in the corporate finance and misconduct literatures, such as firm size, leverage, profitability, growth opportunities, and industry concentration measures. We further include CEO characteristics such as tenure, age, compensation structure, and equity incentives.

All regressions incorporate an extensive set of fixed effects (sector, year, or sector-year) depending on specification. We do not include firm fixed effects for two reasons. First, our measures of CEO overconfidence capture a persistent managerial trait and are largely time-invariant within firms. Including firm fixed effects would therefore absorb most of the variation in the key explanatory variable. Second, cartel participation exhibits limited within-firm variation, as most firms are never observed in a cartel and only a small subset transitions into or out of collusive activity. As a result, specifications with firm fixed effects are severely underpowered and yield imprecise estimates. We therefore rely on cross-sectional and within-sector-year variation,

[11] We also examine the distribution of overconfident CEOs within cartels. On average, approximately half of the listed firms in each cartel are led by overconfident CEOs.

while controlling for a rich set of firm and CEO characteristics. To complement this approach, we implement CEO turnover designs and lead–lag specifications that exploit within-firm variation and provide additional evidence on the direction of the relationship.

4 Empirical results

In this section, we present the baseline results, examine the direction of the relationship, and discuss potential endogeneity concerns.

4.1 Overconfidence and cartel participation

We begin by examining the relationship between CEO overconfidence and cartel participation using variants of the following specification:

$$\text{CARTEL}_{i,t} = \beta\,\text{overconfidence}_{i,t-1} + \gamma \text{X}_{i,t-1} + \tau_{j,t} + \varepsilon_{i,t}, \tag{10}$$

where $\text{CARTEL}_{i,t}$ is an indicator variable equal to one if firm i is a cartel member in year t, and $\text{overconfidence}_{i,t}$ is an indicator variable equal to one if the CEO of firm i is overconfident in year $t-1$. $\text{X}_{i,t-1}$ is a vector of firm- and CEO-level controls, and $\tau_{j,t}$ denotes sector (SIC)-by-year fixed effects. Standard errors are clustered at the firm level.

Table 5 presents the results using the *Longholder*(T) measure of overconfidence. Specification (1) includes year fixed effects only; specification (2) includes sector fixed effects; specification (3) includes sector-by-year fixed effects; and specification (4) includes both sector and year fixed effects. Panel A excludes CEO characteristics, while Panels B and C progressively add CEO controls, with Panel C using a reduced sample due to data availability.

Across all specifications, CEO overconfidence is positively and significantly associated with cartel participation in the subsequent period. These results suggest that firms led by overconfident CEOs are more likely to engage in collusive behavior.[12]

4.1.1 Time lag

We examine the contemporaneous relationship between overconfidence and cartel participation (untabulated). The results are qualitatively similar but smaller in magnitude. Using a two-year lag yields consistent results, suggesting that the relationship is not sensitive to the specific timing assumption.

[12] In Appendix C, we show the results hold when we replicate the analysis using alternative overconfidence measures. In table 19, the results are broadly consistent across specifications and measures, with the exception of *Net Buyer*, for which estimates are weaker and less stable.

4.1.2 Granger causality

While the baseline results are consistent with the hypothesis that overconfidence influences cartel participation, reverse causality remains a concern. This is because cartel membership may instead affect CEOs' behavioral traits and, in turn, their overconfidence. To shed light on the temporal ordering of the relationship, we examine lead-lag relationships using the following specifications:

$$\text{CARTEL}_{i,t+1} = \beta_1 overconfidence_{i,t} + \beta_2 \text{CARTEL}_{i,t} + \text{X}_{i,t}\gamma + \tau_t + \varepsilon_{i,t}, \tag{11}$$

$$\text{CARTEL}_{i,t-1} = \beta_1 overconfidence_{i,t} + \beta_2 \text{CARTEL}_{i,t} + \text{X}_{i,t}\gamma + \tau_t + \varepsilon_{i,t}. \tag{12}$$

Overconfidence is a highly persistent CEO characteristic and primarily varies through CEO turnover rather than within-CEO changes over time. As such, these specifications should be interpreted as tests of temporal precedence rather than formal Granger causality tests.

If overconfidence reflects a pre-existing managerial trait that shapes firm behaviour, it should be associated with future cartel participation. By contrast, if cartel participation feeds back into CEO traits, one would expect a relationship with past cartel activity.

Table 6 reports the results using the *Longholder*(T) measure.[13] We find that overconfidence predicts future cartel participation, while there is no robust association with past participation. Taken together, these findings are consistent with overconfidence preceding cartel activity, although they should not be interpreted as establishing causality.

4.1.3 Sample and endogeneity concerns

The issue of selection on unobservables is common in settings where variable coding is jointly contingent on both the *presence* and *detection* of the feature of interest (e.g., fraud or insider trading). This selection problem cannot be fully eliminated (e.g. Taylor, 2007; Harrington and Chang, 2009; Miller, 2009)[14] but we address it below. Another potential concern is that our measures of CEO overconfidence are endogenous. Unobserved characteristics—such as managerial ability, corporate culture, or governance structures—may jointly influence both CEO overconfidence and the likelihood of cartel participation, leading to omitted variable bias.

[13] Results using alternative measures are reported in Table 20 and are qualitatively similar.

[14] Two noteworthy exceptions are Hyytinen et al. (2019) and Forsbacka et al. (2023) who use Hidden Markov Models to estimate the probabilities of cartel formation and collapse in the Finnish manufacturing industry (1951-1990), and in the Swedish economy (1947-1993), respectively.

While selection on unobservables cannot be fully ruled out, we address identification concerns using multiple complementary strategies. These include: (i) lag structures; and (ii) Granger causality tests (sections 4.1.1 and 4.1.2 above, respectively); (iii) heteroskedasticity-based instruments; (iv) propensity score matching (PSM) (e.g., Rosenbaum and Rubin, 1983, Li and Prabhala, 2005) as done in, e.g., Bos et al. (2018), to compare firms with similar observable characteristics but different CEO overconfidence status; (v) matched samples based on predicted cartel participation probabilities, allowing comparison between convicted cartel firms and observationally similar non-convicted firms; and (vi) CEO turnover designs that exploit within-firm variation. Taken together, these approaches consistently support the claim of a systematic relationship between managerial overconfidence and collusion.

Heteroskedasticity-based instrumental variables estimation strategy. To address endogeneity concerns, we implement the heteroskedasticity-based identification strategy proposed by Lewbel (2018), which generates internal instruments using model-implied heteroskedasticity.[15] The IV estimates are reported in Table 7. We find that the IV coefficients are broadly consistent with the OLS estimates, although less precisely estimated in some specifications. These results suggest that endogeneity is unlikely to fully explain the baseline findings. Nevertheless, given the nature of the identification strategy, these estimates should be interpreted with caution.

Propensity score matching on overconfidence. CEO overconfidence may be correlated with observable firm, CEO, and market characteristics, such as firm size, sector, or market structure, which themselves affect the likelihood of collusion. To address this concern, we employ propensity score matching (PSM) to compare firms with similar observable characteristics but different CEO overconfidence status. This ensures that differences in collusive behavior between the two groups are not driven by other observable differences.

Using PSM, we estimate the probability that a CEO is classified as overconfident based on observable characteristics. We use these probabilities to match each firm with an overconfident CEO to a statistically similar firm with a non-overconfident CEO, forming "twin" pairs for comparison. To apply PSM, we use the nearest-neighbor matching (NNM) method. NNM is a nonparametric method used to estimate the effect of the overconfidence treatment by pair-

[15] This has been done, e.g., in Forsbacka et al. (2023).

ing each firm with an overconfident CEO with the closest firm without an overconfident CEO, based on a set of covariates.[16]

We first estimate the probability that a firm has an overconfident CEO using a Probit model. The set of covariates includes the same firm- and CEO-level controls as in the baseline regressions. In an extended specification, we additionally incorporate market characteristics from the Hoberg–Phillips database, albeit at the cost of a reduced sample size (Table 8). We then match firms using NNM with a caliper of 0.005, pairing each firm with an overconfident CEO to the closest firm without an overconfident CEO based on propensity scores. This procedure generates a matched sample of firms that are comparable along observable dimensions. To assess the quality of the matching, we conduct standard balancing tests. Table 9 shows that, after matching, differences in covariate means between treated and control groups are not statistically significant, indicating that the matched sample is well balanced.

We re-estimate the baseline regressions using the matched sample. The results, reported in Table 10, are consistent with the baseline findings, indicating that the association between CEO overconfidence and cartel participation is not driven by observable differences across firms.[17]

Matching on collusion. As discussed in Section 3.2, our data capture only detected cartels, while undetected collusion remains unobserved. As a result, firms observed in cartels may differ systematically from other firms, either in their propensity to collude or in their likelihood of detection. To address this issue, we construct a matched sample based on predicted cartel participation probabilities, following Hansen (2008). The goal is to compare firms that participated in detected cartels with observationally similar firms that did not, but are likely to have similar underlying collusive propensities.[18]

The procedure includes three steps. First, we estimate a Probit model of cartel participation using a set of 13 firm-, CEO-, and market-level characteristics. This step is important for determining how similar firms that have not been part of a convicted cartel are to firms that have been part of a cartel. To avoid contamination from the treatment variable (i.e., whether a firm had an overconfident CEO), we estimate this model using only firms that never had an overconfident CEO during the sample period. The estimation results are reported in Table 11. Second,

[16] This enhances the robustness of our analysis by reducing model dependency. Although traditional regression approaches assume a specific functional form for the relationship between overconfidence, collusion, and other covariates, PSM focuses on balancing the distribution of covariates between treated (overconfident CEO firms) and control (non-overconfident CEO firms) groups. This non-parametric approach helps reduce bias from potential misspecification of the functional form.

[17] We provide further details on the PSM procedure in Appendix D1.

[18] See Hansen (2008) for a technical discussion of a similar approach.

we use the estimated coefficients to predict cartel participation probabilities for all firms. For firms with overconfident CEOs, we generate out-of-sample predictions based on the control group.[19] Third, we match cartel firms to non-cartel firms with similar predicted probabilities using NNM. Balancing tests (Table 12) indicate that the matched samples are comparable in observable characteristics.

We then re-estimate the baseline regressions using these matched samples. The results, reported in Table 13, are consistent with the baseline findings. In particular, firms with overconfident CEOs are more likely to engage in collusion, even compared with observationally similar firms with comparable predicted cartel probabilities. These findings further support the robustness of the association between overconfidence and cartel participation.

4.2 Overconfidence and cartel duration

Our theoretical framework predicts that managerial overconfidence relaxes the dynamic incentive constraint sustaining collusion by lowering *perceived detection-and-concealment cost*. A direct empirical implication is that cartels involving overconfident managers should exhibit greater stability and thus, longer duration.

4.2.1 Descriptive evidence

Cartel duration ranges from 0.5 to 22.5 years, with an overall mean of 8.85 years. Table 14 shows that cartels involving overconfident managers last on average 9.96 years, compared to 7.80 years for cartels without overconfident managers. The difference of 2.16 years is statistically significant ($t = 3.63$, $p < 0.001$). The Wilcoxon rank-sum test rejects equality of the duration distributions ($z = 3.27$, $p = 0.001$). Additionally, distributional statistics indicate that the effect is concentrated in the upper tail: the 75th percentile of cartel duration is 13.5 years among overconfident cartels versus 9.5 years among non-overconfident cartels. These patterns indicate that overconfidence is associated with substantially greater cartel persistence, particularly in the upper tail of the duration distribution.

4.2.2 Survival analysis

To formally examine cartel stability, we estimate Cox proportional hazards models of cartel termination. Let $h(t|\mathrm{X})$ denote the hazard rate of cartel breakdown at time t. Our baseline specification is:

$$h(t|\mathrm{X}) = h_0(t) \exp\left(\beta\, Overconfidence_i + \gamma \mathrm{X}_i\right), \tag{13}$$

[19] The levels of the calculated probability for the data (with and without the market-level data) are presented in Appendix D2, in Table 22. Moreover, in Appendix D2, Figure 2, we show the distributions of the probability scores.

where $h_0(t)$ is the baseline hazard, $Overconfidence_i$ is an indicator for managerial overconfidence (at least one overconfident CEO per cartel), and X_i includes cartel- and firm-level controls. Standard errors are clustered at the sector level.

Table 15 reports the results. In the baseline specification (Column 1), the coefficient on overconfidence is negative and statistically significant ($\beta = -0.468$, $p < 0.05$), corresponding to a hazard ratio of 0.63. This implies that cartels involving overconfident managers face approximately a 37% lower risk of termination at any point in time.

Introducing sector and year fixed effects attenuates the magnitude, but the coefficient remains negative. In Column (4), which includes firm controls, the estimate remains statistically significant ($\beta = -0.164$, $p < 0.05$), implying a hazard ratio of 0.85, or a 15% lower breakdown risk. Adding CEO controls further reduces statistical precision, but the coefficient remains negative across all specifications.

Overall, the survival analysis indicates that managerial overconfidence is systematically associated with lower cartel termination risk and, therefore, greater cartel stability. The attenuation of the coefficient after including controls suggests that part of the relationship operates through observable firm and managerial characteristics, but the baseline economic magnitude remains substantial.[20]

4.3 The effect of CEO turnover

Having established that CEO overconfidence precedes cartel participation, we examine whether changes in top management affect collusive behavior. CEO turnover provides a source of within-firm variation that helps isolate the role of managerial traits from time-invariant firm characteristics. We distinguish between voluntary and forced turnover and analyze how changes in CEO overconfidence influence cartel participation.

[20] Robustness tests using alternative duration specifications are presented in Appendix D3. Using log duration as the dependent variable or applying quartile regressions of cartel duration reinforces the described relationship between overconfidence and cartel duration.

4.3.1 Voluntary and forced CEO turnover

We estimate variants of the following specification:

$$\begin{aligned} \text{CARTEL}_{i,t} = {} & \beta_1 \text{ NoOverconfidence}_{i,t-1} \times \text{Turnover}_{i,t-1} \\ & + \beta_2 \text{ Overconfidence}_{i,t-1} \times \text{NoTurnover}_{i,t-1} \\ & + \beta_3 \text{ Overconfidence}_{i,t-1} \times \text{Turnover}_{i,t-1} \\ & + X_{i,t-1}\gamma + \tau_{j,t} + \varepsilon_{i,t}, \end{aligned}$$

where $X_{i,t-1}$ is a vector of firm- and CEO-level controls and $\tau_{j,t}$ denotes sector-by-year fixed effects. The reference group is a non-overconfident CEO with no turnover. We consider three definitions of turnover: any turnover, voluntary turnover, and forced turnover. The latter provides the most informative setting, as it is less likely to be driven by CEO preferences and more likely to reflect exogenous changes in leadership.

Table 16 reports the results. We find that the forced turnover of an overconfident CEO is associated with a significant reduction in cartel participation (column 7). This effect is strongest when an overconfident CEO is replaced by a non-overconfident successor (column 8). These findings provide within-firm evidence consistent with a causal role of managerial overconfidence in cartel participation.

4.3.2 CEO turnover and sales growth

We next examine whether these effects are driven by firm performance by splitting the sample according to sales growth at the time of turnover. If turnover simply reflects poor performance, rather than a change in managerial traits, the effects should vary systematically with firm performance.

The results, reported in Table 17, show that the forced turnover of an overconfident CEO reduces cartel participation regardless of sales growth. However, the effect is stronger when firms experience declining sales. While the smaller sample reduces statistical precision, the overall pattern is consistent with overconfidence playing an independent role beyond firm performance.

4.3.3 CEO turnover conditional on cartel participation

Finally, we condition on prior cartel participation. If turnover reflects internal restructuring following collusion, its impact should be strongest among firms that were previously involved in cartels.

Table 18 confirms this prediction. The forced replacement of an overconfident CEO in a colluding firm significantly reduces the likelihood of future cartel participation. This result strengthens the interpretation that managerial overconfidence sustains collusion rather than merely reflecting underlying firm characteristics.

Overall, the turnover results provide complementary evidence to the baseline findings. Changes in CEO overconfidence within the same firm are associated with systematic changes in cartel participation, particularly in cases of forced turnover. These patterns are difficult to reconcile with purely cross-sectional explanations and support a causal interpretation of the relationship between managerial overconfidence and cartel participation.

5 Conclusion

This paper examines how managerial biases shape firms' engagement in high-risk and illegal strategic behavior, focusing on the role of CEO overconfidence in collusion. We combine a dynamic model of collusion with firm- and cartel-level evidence, from approximately 3,000 publicly listed firms, to examine whether overconfidence at the top of the organization shapes illegal coordination.

In our theoretical framework, overconfident managers overestimate the effectiveness of concealment efforts in reducing detection risk. By lowering perceived detection and concealment costs, this distortion relaxes both participation and incentive-compatibility constraints, making collusion more attractive and more sustainable.

Consistent with these predictions, we document a robust positive association between CEO overconfidence and cartel participation. Overconfidence precedes cartel involvement, and cartel activity declines following the forced replacement of an overconfident CEO —particularly in cases of forced turnover. In addition, cartels involving overconfident managers exhibit greater persistence and lower breakdown hazard rates.

Additional analyses suggest that these patterns are not driven a small subset of dominant overconfident executives. Instead, the results are consistent with a mechanism in which overconfident managers systematically misperceive detection and concealment costs.

Taken together, the findings extend the behavioral corporate finance literature by showing that managerial overconfidence shapes not only standard corporate policies but also illegal coordination. They also contribute to the study of collusion by providing a behavioral foundation for cartel formation and persistence.

More broadly, the results show that firms' responses to regulatory design depend not only on incentives and enforcement intensity, but also on the behavioral characteristics of decision makers. Models of corporate behavior and regulatory compliance that abstract from managerial biases may therefore mischaracterize both firm strategy and policy effectiveness. Incorporating managerial traits into theories of organizational decision-making provides a more complete understanding of how firms operate in high-risk environments.

References

Adebambo, B. and Yan, X. (2017). Investor overconfidence, firm valuation, and corporate decisions. *Management Science*, 64(11):5349–5369.

Antón, M., Ederer, F., Giné, M., and Schmalz, M. (2023). Common ownership, competition, and top management incentives. *Journal of Political Economy*, 131(5):1294–1355.

Azar, J., Schmalz, M. C., and Tecu, I. (2018). Anticompetitive effects of common ownership. *The Journal of Finance*, 73(4):1513–1565.

Banerjee, S., Huang, S., Nanda, V., and Xiao, S. (2023). Managerial overconfidence and market feedback effects. *Management Science*, 69(12):7285–7305.

Bos, I., Davies, S., Harrington, J. E., and Ormosi, P. (2018). Does enforcement deter cartels? a tale of two tails. *Industrial Journal of Industrial Organization*, 59(C):372–405.

Connor, J. (2011). Problems with prison in international cartel cases. *Antitrust Bulletin*, 56(2):311–344.

Forsbacka, T., Le Coq, C., and Marvão, C. (2023). Cartel birth and death dynamics: Empirical evidence. *International Journal of Industrial Organization*, 89:102932.

Galasso, A. and Simcoe, T. S. (2011). Ceo overconfidence and innovation. *Management Science*, 57(8):1469–1484.

Geis, G. (1968). The Heavy Electrical Equipment Antitrust Cases of 1961. In *White-Collar Criminal*, pages 3–19. Routledge.

Gentry, R. J., Harrison, J. S., Quigley, T. J., and Boivie, S. (2021). A database of CEO turnover and dismissal in S&P 1500 firms, 2000–2018. *Strategic Management Journal*, 42(5):968–991.

Hall, B. J. and Murphy, K. J. (2002). Stock options for undiversified executives. *Journal of Accounting and Economics*, 33(1):3–42.

Hansen, B. B. (2008). The prognostic analogue of the propensity score. *Biometrika*, 95(2):481–488.

Harrington, J. and Chang, M.-H. (2009). Modelling the birth and death of cartels with an application to evaluating antitrust policy. *Journal of the European Economic Association*, 7:1400–1435.

Harrington, J. E. (2006). How do cartels operate? *Foundations and Trends in Microeconomics*, 2:1–105.

Heaton, J. B. (2002). Managerial optimism and corporate finance. *Financial Management*, 31(2):33–45.

Heifetz, A., Shannon, C., and Spiegel, Y. (2007a). The dynamic evolution of preferences. *Economic Theory*, 32(2):251–286.

Heifetz, A., Shannon, C., and Spiegel, Y. (2007b). What to maximize if you must. *Journal of Economic Theory*, 133:31–57.

Hoberg, G. and Phillips, G. (2010). Product market synergies and competition in mergers and acquisitions: A text-based analysis. *Review of Financial Studies*, 23(10):3773–3811.

Hoberg, G. and Phillips, G. (2016). Text-based network industries and endogenous product differentiation. *Journal of Political Economy*, 124(5):1423–1465.

Hoberg, G., Phillips, G., and Prabhala, N. (2014). Product market threats, payouts, and financial flexibility. *The Journal of Finance*, 69(1):293–324.

Hyytinen, A., Steen, F., and Toivanen, O. (2019). An anatomy of cartel contracts. *Economic Journal*, 129(621):2155–2191.

Itzhak, B.-D., Graham, J., and Harvey, C. (2013). Managerial miscalibration. *Quarterly Journal of Economics*, 128:1547–1584.

Jensen, S., Kvaloy, O., Olsen, T. E., and Sorgard, L. (2013). Crime and punishment: When tougher antitrust enforcement leads to higher overcharge. *NHH Dept. of Economics Discussion Paper No. 04/2013*.

Jenter, D. and Kanaan, F. (2015). CEO turnover and relative performance evaluation. *The Journal of Finance*, 70(5):2155–2184.

Levenstein, M. C., Marvão, C., and Suslow, V. Y. (2016). Preventing cartel recidivism. *Antitrust Magazine*, 30(3):157–171.

Lewbel, A. (2018). Identification and estimation using heteroscedasticity without instruments: The binary endogenous regressor case. *Economics Letters*, 165:10–12.

Li, K. and Prabhala, N. (2005). Self-Selection Models in Corporate Finance. *Robert H. Smith School Research Paper*, 06-020.

Malmendier, U. and Tate, G. (2005). CEO overconfidence and corporate investment. *The Journal of Finance*, 6:2661–2700.

Malmendier, U. and Tate, G. (2008). Who makes acquisitions? CEO overconfidence and the market's reaction. *Journal of Financial Economics*, 89:20–43.

Malmendier, U. and Tate, G. (2015). Behavioral CEOs: The role of managerial overconfidence. *Journal of Economic Perspectives*, 29(4):37–60.

Marvão, C. (2015). The EU Leniency Programme and Recidivism. *Review of Industrial Organization*, 49(1):1–27.

Marvão, C. (2015). The EU leniency programme and recidivism. *Review of Industrial Organization*, 49(1):1–27.

Marx, L. M. and Mezzetti, C. (2014). Effects of antitrust leniency on concealment effort by colluding firms. *The Journal of Antitrust Enforcement*, 2:305–332.

Miller, N. H. (2009). Strategic leniency and cartel enforcement. *American Economic Review*, 99(3):750–68.

Peters, F. S. and Wagner, A. F. (2014). The executive turnover risk premium. *The Journal of Finance*, 69(4):1529–1563.

Rosenbaum, P. R. and Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70:41–55.

Schrand, C. M. and Zechman, S. L. (2012). Executive overconfidence and the slippery slope to financial misreporting. *Journal of Accounting and Economics*, 53(1-2):311–329.

Spagnolo, G. (2000). Stock-related compensation and product-market competition. *The RAND Journal of Economics*, 31(1):22–42.

Spagnolo, G. (2005). Managerial incentives and collusive behavior. *European Economic Review*, 49(6):1501–1523.

Squintani, F. (2006). Equilibrium and mistaken self-perception. *Economic Theory*, 27(3):615–641.

Taylor, J. (2007). Cartel code attributes and cartel performance: An industry-level analysis of the national industrial recovery act. *The Journal of Law and Economics*, 50:597–624.

Appendix A: Theoretical Framework, Proofs, and Additional Notes

A0: Beliefs, Information, and Behavioral Foundations

Belief Structure

To compute equilibrium under biased perceptions, we impose a standard "agree-to-disagree" structure.

(i) Each manager correctly anticipates rivals' strategies.

(ii) Each manager believes that his own perception of detection risk is correct.

(iii) Managers understand that rivals may hold biased perceptions, and this disagreement is common knowledge.

Thus, managers agree on the strategic environment and on the mapping from actions to true detection probabilities, but disagree about the effectiveness of their own concealment effort. Each manager optimizes given his own perceived detection probability, as given by equation (3), while recognizing that others may use $\lambda > 1$.

This formulation follows the approach developed in dynamic games with heterogeneous but commonly known belief distortions (e.g., Heifetz et al., 2007a,b; Squintani, 2006). It ensures that equilibrium strategies are well-defined even when beliefs differ.

Behavioral Foundations

The belief specification is consistent with evidence from psychology and managerial decision-making showing that individuals:

- overestimate the impact of their own actions on outcomes,
- recognize biases in others more readily than in themselves ("blind-spot bias"),
- and exhibit persistent overconfidence in strategic and financial environments.

In our model, these features generate a wedge between perceived and true enforcement risk. This wedge drives the comparative statics in the main text.

A1: Concealment Effort – Existence, Uniqueness, and Comparative Statics

Existence and Uniqueness of Equilibrium Effort

Manager i minimizes *perceived detection-and-concealment cost* as derived from equation (4)

$$\tilde{\Phi}_i(e_i, e_{-i}) = \rho\left(\lambda e_i + \sum_{j \neq i} e_j\right) F + \psi(e_i).$$

The first-order condition is shown in equation (5). The second-order condition is

$$\lambda^2 \rho''\left(\lambda e_i + \sum_{j \neq i} e_j\right) F + \psi''(e_i) > 0,$$

which holds under the assumptions on ρ and ψ, given by equations (1) and (2). Hence, each manager's problem is strictly convex.

In a symmetric equilibrium $e_i = e$ for all i, and effort satisfies

$$\lambda \rho'((N + \lambda - 1)e)F + \psi'(e) = 0.$$

Lemma 1 (Existence and uniqueness of e^*) *Equation (4) admits a unique solution $e^* > 0$.*

Define the function:

$$Z(e) = \lambda \rho'\big((N + \lambda - 1)e\big)F + \psi'(e).$$

First note that Z is continuous on $[0, \infty)$ because it is a composition of twice continuously differentiable functions.

Step 1: Sign of $Z(0)$ and behavior at infinity.

At $e = 0$, using $\psi(0) = 0$ and $\psi'(0) = 0$,

$$Z(0) = \lambda \rho'\big((N + \lambda - 1) \cdot 0\big)F = \lambda \rho'\big(0\big)F.$$

By assumption, $\rho'(0) < 0$, hence

$$Z(0) < 0.$$

As $e \to \infty$, we have $\rho((N+\lambda-1)e) \to 0$ and $\rho'((N+\lambda-1)e) \to 0$, while by strict convexity and $\psi'(0) = 0$ we have $\psi'(e) \to \infty$. Therefore

$$Z(e) = \lambda\rho'((N+\lambda-1)e)F + \psi'(e) \longrightarrow +\infty,$$

as $e \to \infty$. In particular, there exists $E > 0$ such that $Z(e) > 0$ for all $e \geq E$.

By continuity of Z and the facts that $Z(0) < 0$ and $Z(e) > 0$ for large e, the Intermediate Value Theorem implies that there exists at least one $e^* > 0$ such that $Z(e^*) = 0$.

Step 2: Monotonicity and uniqueness. Differentiate $Z(e)$ with respect to e:

$$Z'(e) = \lambda(N+\lambda-1)\rho''((N+\lambda-1)e)F + \psi''(e)$$

. The first term in $Z'(e)$ is strictly positive for all $e > 0$ since $\rho'' > 0$ and $N + \lambda - 1 > 0$. The second term in $Z'(e)$ is also strictly positive for all $e > 0$ because $\psi''(e) > 0$.

Therefore, we have $Z'(e) > 0$ for all $e \geq 0$, so Z is strictly increasing on $[0, \infty)$. Hence Z can cross zero at most once. Together with existence from Step 1, this implies that there is a unique $e^* > 0$ satisfying $Z(e^*) = 0$.

A2. Comparative Statics with Respect to Overconfidence

Define

$$G(e, \lambda) = \lambda\rho'((N+\lambda-1)e)F + \psi'(e).$$

At equilibrium, $G(e^*, \lambda) = 0$.

Applying the implicit function theorem,

$$\frac{\partial e^*}{\partial \lambda} = -\frac{\partial G/\partial \lambda}{\partial G/\partial e}.$$

The denominator is

$$\frac{\partial G}{\partial e} = \lambda(N+\lambda-1)\rho''((N+\lambda-1)e^*)F + \psi''(e^*),$$

which is strictly positive under equations (1) and (2).

The numerator is

$$\frac{\partial G}{\partial \lambda} = \rho'((N+\lambda-1)e^*)F + \lambda e^* \rho''((N+\lambda-1)e^*)F.$$

Hence,

$$\frac{\partial e^*}{\partial \lambda} = -\frac{\rho'((N+\lambda-1)e^*) + \lambda e^* \rho''((N+\lambda-1)e^*)}{\lambda(N+\lambda-1)\rho''((N+\lambda-1)e^*))F + \psi''(e^*)}F.$$

Since the denominator is positive, the sign of $\partial e^*/\partial \lambda$ is determined by

$$\rho'((N+\lambda-1)e^*) + \lambda e^* \rho''((N+\lambda-1)e^*).$$

Because $\rho' < 0$ and $\rho'' > 0$, the sign is generally ambiguous.

A3. Proof of Proposition 1

At the symmetric equilibrium,

$$\tilde{\rho}^* = \rho((N+\lambda-1)e^*), \qquad \rho^* = \rho(Ne^*).$$

The impact of overconfidence, λ, on the perceived cartel detection probability, $\tilde{\rho}^*$, is given by

$$\frac{\partial \tilde{\rho}^*}{\partial \lambda} = \rho'((N+\lambda-1)e^*)\left[e^* + (N+\lambda-1)\frac{\partial e^*}{\partial \lambda}\right].$$

Substituting

$$\frac{\partial e^*}{\partial \lambda} = -\frac{\rho'((N+\lambda-1)e^*) + \lambda e^* \rho''((N+\lambda-1)e^*)}{\lambda(N+\lambda-1)\rho''((N+\lambda-1)e^*))F + \psi''(e^*)}F,$$

we obtain

$$\begin{aligned}\frac{\partial \tilde{\rho}^*}{\partial \lambda} &= \rho'((N+\lambda-1)e^*)\left[e^* - (N+\lambda-1)\frac{\rho'((N+\lambda-1)e^*) + \lambda e^* \rho''((N+\lambda-1)e^*)}{\lambda(N+\lambda-1)\rho''((N+\lambda-1)e^*))F + \psi''(e^*)}F\right] \\ &= \rho'((N+\lambda-1)e^*)\frac{e^*\psi''(e^*) - (N+\lambda-1)F\rho'\left((N+\lambda-1)e^*\right)}{\psi''(e^*) + \lambda(N+\lambda-1)F\rho''\left((N+\lambda-1)e^*\right)} < 0,\end{aligned}$$

since $\rho' < 0$, $\rho'' > 0$, and $\psi'' > 0$.

At equilibrium, the impact of overconfidence on the true cartel detection probability, $\rho^* = \rho(Ne^*)$, is given by

$$\frac{\partial \rho^*}{\partial \lambda} = \rho'(Ne^*)N\frac{\partial e^*}{\partial \lambda}.$$

Since $\rho' < 0$, true cartel detection probability always decreases in λ if

$$\frac{\partial e^*}{\partial \lambda} > 0.$$

In particular, if $\partial e^*/\partial \lambda > 0$, both perceived and true detection probabilities decrease in overconfidence. If $\partial e^*/\partial \lambda < 0$, perceived detection probability falls while true detection probability increases in overconfidence.

A4. Proof of Proposition 2

Manager i's equilibrium *perceived detection-and-concealment cost* as a function of overconfidence λ is given by

$$\begin{aligned}\tilde{\Phi}^*(\lambda) &= \tilde{\Phi}(\lambda, e^*(\lambda)) \\ &= \tilde{\rho}^* F + \psi(e^*(\lambda)) \\ &= \rho((N + \lambda - 1)e^*(\lambda))F + \psi(e^*(\lambda)).\end{aligned}$$

To prove the proposition, we need to show that, at equilibrium, the *perceived detection-and-concealment cost* is decreasing in overconfidence. Taking the derivative of $\tilde{\Phi}^*(\lambda)$ with respect to λ we obtain

$$\frac{d\tilde{\Phi}^*(\lambda)}{d\lambda} = e^*(\lambda)\tilde{\rho}' F + \frac{\partial \tilde{\Phi}(e^*)}{\partial e^*}\frac{\partial e^*}{\partial \lambda},$$

where $\tilde{\rho}' = \rho'((N + \lambda - 1)e^*(\lambda))$. Using the Envelope Theorem, we have

$$\frac{d\tilde{\Phi}^*(\lambda)}{d\lambda} = e^*(\lambda)\tilde{\rho}' F < 0.$$

Hence, manager i's equilibrium *perceived detection-and-concealment cost* is decreasing in overconfidence. Consequently, higher overconfidence makes cartel participation more desirable as it lowers the left-hand side of the inequality $\tilde{V}^c > V^n$, which is equivalent to $\pi^c - \pi^n > \tilde{\rho}^* F + \psi(e^*(\lambda))$.

Appendix B

Table 1: Summary statistics items

Variable	Mean	Std. Dev.	Min	Max
Cartel variable				
CARTEL	0.015	0.122	0	1
CDuration (years)	8.666	5.264	0.5	22.5
Overconfidence measures				
Longholder (T)	0.372	0.483	0	1
Holder67	0.279	0.448	0	1
Holder67(R)	0.279	0.448	0	1
Netbuyer	0.287	0.452	0	1
Firm control variables				
Cash over total assets	0.154	0.181	-0.002	0.995
Sales over total assets	1.086	0.863	0.000	41.916
Capital intensity over total assets	20.396	640.054	-107.004	52448.277
Return on assets	0.039	0.137	-3.145	4.826
Cashflow over total assets	33.635	1,707.770	-78,768.000	129,757.992
Dividends over total assets	0.014	0.049	-0.154	2.650
Leverages over stockholder's equity	4,206.549	12,259.575	2.014	391,673.938
Market share	0.151	0.212	0	1
HHI	0.232	0.194	0.010	1.032
Markups	0.158	3.090	-309.405	0.952
CEO turnover	0.152	0.359	0	1
CEO control variables				
Log(CEO age)	3.984	0.140	3.296	4.489
Log(CEO tenure)	8.143	0.950	0.693	10.191
Chair	0.229	0.420	0	1
Founder	0.024	0.152	0	1

Table 2: Compustat ExecuComp items used to calculate the four overconfidence measures, as in Malmendier and Tate (2005).

Compustat variable	item	Proxy for:
[A] total assets	6	book value assets
[C] capital expenditures[*]	128	investment
[E] earnings before extraordinary items[*]	18	cash flow
[D] depreciation	14	
[CE] common equity	60	
[K] property, plants, and equipment	8	proxy for capital
[L] total liabilities	181	
[P] fiscal-year closing price	199	
[PV] preferred stock par value	130	
[PL] preferred stock liquidating value	10	[*]
[PR preferred stock redemption value	56	
[BS] balance sheet deferred taxes and investment tax credit	35	
[S] common shares outstanding	25	
[SE] stockholders' equity	216	
.		
[ME] Market equity=[S]*[P]	.	.
[BE] book equity=[SE or CE]+[PS or A] -[L] -[PL or PR or PV] +[BS]	.	.
[MA] Market value assets=[A]+[ME]-[BE]	.	.
Q=[MA]/[A]	.	.

Normalized beginning-of-the year capital. Given that our sample is not limited to manufacturing firms. Also normalized by assets (as robustness). Cash flow trimmed at the 1% level.

Table 3: Correlation matrix

	Compustat data; N=22,329			
	Longh(T)	Holder67	Holder67(R)	NetBuyer
Holder67		100%		
Holder67(R)		99.97%	100%	
Netbuyer		5.42%	5.43%	100%
	Matched data; N=11,060			
	Longh(T)	Holder67	Holder67(R)	NetBuyer
Longholder(T)	100%			
Holder67	17.63%	100%		
Holder67(R)	17.63%	100%	100%	
Netbuyer	10.77%	4.41%	4.41%	100%

Table 4: Overconfidence measures

	[1]	[2]	[3]	[4]	[5]	[6]	[7]=[3]-[5]
	full sample		in cartel		not in cartel		overconfidence
	overconfident=1	ov.=0	ov.=1	ov.=0	ov.=1	ov.=0	wedge
Longholder(T)	8,816	13,749	302	170	8514	13579	
	39%	61%	64%	36%	39%	62%	25%
Netbuyer	14,233	36,298	405	442	13828	35856	
	28%	72%	48%	52%	28%	72%	20%
Holder67	6,112	16,098	27	28	6085	16070	
	28%	73%	49%	51%	28%	73%	22%
Holder67(R)	6107	16101	22	29	6085	16072	
	27%	73%	43%	57%	28%	73%	16%

Table 5: Baseline estimations. This table presents results on the relation between cartel membership and overconfidence measures, using variants on the regression specification: $\text{CARTEL}_{i,t} = \beta\, overconfidence_{i,t-1} + \gamma \text{X}_{i,t-1} + \tau_{j,t} + \varepsilon_{i,t}$

	CARTEL_t			
	[1]	[2]	[3]	[4]
	Panel A			
$\text{Longholder(T)}_{t-1}$	0.041***	0.043***	0.040***	0.041***
	(0.012)	(0.012)	(0.012)	(0.012)
N	9,460	9,460	9,460	9,460
R-squared	0.019	0.036	0.050	0.037
	Panel B			
$\text{Longholder(T)}_{t-1}$	0.046***	0.048***	0.044***	0.046***
	(0.012)	(0.012)	(0.012)	(0.012)
log(CEO age)	0.090*	0.094**	0.096**	0.094**
	(0.047)	(0.047)	(0.048)	(0.047)
log(CEO tenure)	-0.014**	-0.015**	-0.014**	-0.014**
	(0.006)	(0.006)	(0.006)	(0.006)
N	9,460	9,460	9,460	9,460
R-squared	0.022	0.039	0.053	0.040
	Panel C			
$\text{Longholder(T)}_{t-1}$	0.030**	0.030**	0.026**	0.029**
	(0.012)	(0.012)	(0.012)	(0.012)
log(CEO age)	0.092*	0.101**	0.101**	0.098**
	(0.050)	(0.049)	(0.051)	(0.050)
log(CEO tenure)	-0.008	-0.009	-0.007	-0.008
	(0.006)	(0.006)	(0.006)	(0.006)
chair	0.010	0.008	0.006	0.008
	(0.010)	(0.010)	(0.010)	(0.010)
founder	-0.038***	-0.034**	-0.035**	-0.033**
	(0.011)	(0.014)	(0.016)	(0.014)
N	5,818	5,818	5,818	5,818
R-squared	0.018	0.040	0.066	0.042
firm controls	yes	yes	yes	yes
year FE	yes			yes
sector FE		yes		yes
year-sector FE			yes	

Table 6: Mechanism test: Causal direction. This table presents evidence on the lead-lag relation between cartel membership and overconfidence. The specification mirrors that of Table 5, but uses future CARTEL and prior CARTEL as the dependent variables.

	CARTEL_{t+1}	CARTEL_{t-1}
	[1]	[2]
Longholder(T)	0.005**	0.004
	(0.002)	(0.002)
CARTEL_t	0.885***	0.905***
	(0.005)	(0.005)
N	7,670	7,030
R-squared	0.809	0.819
CEO controls	yes	yes
firm controls	yes	yes
year-sector controls	yes	yes

Table 7: Lewbel test

	(1)	(2)	(3)	(4)
	OLS	IV(Lewbel)	OLS	IV(Lewbel)
$\text{Longholder(T)}_{t-1}$	0.041***	0.197**	0.041***	0.085**
	(0.012)	(0.088)	(0.012)	(0.039)
N	9460	9460	9460	9460
R-squared	0.019	-0.096	0.037	0.028
Hansen J statistic	.	18.762	.	30.803
p-value	.	0.6004	.	0.4252
firm controls	yes	yes	yes	yes
year FE	yes	yes	yes	yes
sector FE	no	no	yes	yes

Note. The Lewbel-generated instruments in column (2) include years 7 to 21; as well as the lagged values of the following ratios: cash/total assets, sales/total assets, capital intensity/total assets, ROA, cash flow/total assets, dividends/total assets, leverage/shareholder equity.
The Lewbel-generated instruments in column (4) include the same as in column (2), as well as industries 2 to 10.

Table 8: Propensity score matching: Probit estimation to calculate propensity scores

Outcome	(1) Longholder[T]	(2) Longholder[T]
Cash over total assets	-0.472***	-0.471**
	(0.126)	(0.196)
Sales over total assets	0.034	0.029
	(0.023)	(0.039)
Capital intensity over total assets	-0.000	-0.000
	(0.000)	(0.000)
Return on assets	1.899***	1.720***
	(0.216)	(0.383)
Cashflow over total assets	0.000	0.000
	(0.000)	(0.000)
Dividends over total assets	-0.553	-0.755**
	(0.390)	(0.380)
Leverages over stockholder's equity	0.000**	0.000
	(0.000)	(0.000)
log(CEO age)	0.245**	0.445**
	(0.124)	(0.177)
log(CEO tenure)	0.154***	0.173***
	(0.020)	(0.029)
Chair	0.040	-0.081
	(0.037)	(0.061)
Founder	0.106	0.877**
	(0.109)	(0.400)
Market share		0.606***
		(0.136)
HHI		-0.648***
		(0.152)
Markup		0.141
		(0.231)
Sector FE	Yes	Yes
Year FE	Yes	Yes
Observations	6937	2423

Note. This table shows the estimation results of Probit regressions to determine the probability of overconfidence. The outcome 'Longholder[T]' is described in Section 3.3. Controls are applied as described in Section 3.3 firm controls in columns (1) and (2) include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. In column (2), we add variables covering the firm market share, industry HHI, and markup. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 9: Mean comparison of firms with overconfident CEOs (treatment) and those with non-overconfident CEOs (control)

	Mean		Difference	p-value
	Treatment	Control	(2)-(1)	(1)=(2)
Panel: Main data				
Cash over total assets	0.143	0.140	-0.003	0.459
Sales over total assets	1.136	1.125	-0.011	0.619
Capital intensity over total assets	6.441	16.048	9.607	0.254
Return on assets	0.061	0.060	-0.001	0.808
Cashflow over total assets	13.492	-5.801	-19.293	0.404
Dividends over total assets	0.014	0.013	-0.000	0.810
Leverages over stockholder's equity	4243.539	4563.879	320.340	0.187
log(CEO age)	3.982	3.984	0.002	0.566
log(CEO tenure)	8.191	8.211	0.020	0.422
Chair	0.361	0.362	0.001	0.952
Founder	0.027	0.026	-0.001	0.857
Panel: With HobergPhilips data				
Cash over total assets	0.125	0.126	0.001	0.909
Sales over total assets	1.064	1.067	0.003	0.916
Capital intensity over total assets	10.457	23.020	12.562	0.380
Return on assets	0.070	0.069	-0.001	0.565
Cashflow over total assets	21.266	-16.131	-37.397	0.343
Dividends over total assets	0.016	0.016	-0.000	0.818
Leverages over stockholder's equity	6589.404	6394.946	-194.458	0.626
log(CEO age)	3.988	3.989	0.001	0.821
log(CEO tenure)	8.124	8.157	0.032	0.290
Chair	0.410	0.405	-0.005	0.841
Founder	0.004	0.005	0.001	0.705
Market share	0.187	0.177	-0.010	0.229
HHI	0.250	0.248	-0.002	0.798
Markup	0.197	0.194	-0.003	0.505

Note. The table shows the comparison of the propensity score weighted means for the treatment and control group. The treatment group is formed of firms that have overconfident CEOs while the control group consists of firms without overconfident CEO.

Table 10: Main results after propensity score matching

	(1)	(2)
	CARTEL$_t$	
Longholder[T]$_t$	0.010***	0.011**
	(0.003)	(0.006)
Firm controls	Yes	Yes
CEO controls	Yes	Yes
Sector FE	Yes	Yes
Year FE	Yes	Yes
HobergPhilips controls	No	Yes
Observations	4772	2798

Note. This table shows the estimation results of a linear regression model of equation (10). The measure of interest 'Longholder[T]' is described in Section 3.3. The outcome is an indicator 'Cartel' that takes the value one if the firm is part of a collusive agreement at time t and zero in any period before and after the collusion period. Controls are applied as described in Section 3.3. The firm controls in columns (1) and (2) include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. In column (2), we add variables covering the firm market share, industry HHI, and markup. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 11: Probit estimations to calculate the prognostic score of a firm to be part of a cartel or not

Outcome	(1) CARTEL$_t$	(2) CARTEL$_t$
Cash over total assets	-1.592**	-1.675***
	(0.652)	(0.642)
Sales over total assets	-0.603***	-0.647***
	(0.213)	(0.223)
Capital intensity over total assets	6.663***	6.726***
	(1.497)	(1.517)
Return on assets	-4.539*	-4.438*
	(2.498)	(2.483)
Cashflow over total assets	4.007	4.071
	(2.640)	(2.643)
Dividends over total assets	0.539	1.631
	(4.882)	(4.736)
Leverages over stockholder's equity	0.027	0.027
	(0.026)	(0.026)
log(CEO age)	1.801***	1.804**
	(0.697)	(0.709)
log(CEO tenure)	-0.214*	-0.210*
	(0.112)	(0.113)
Chairman	0.077	0.084
	(0.152)	(0.150)
Market share		-0.235
		(0.358)
HHI		0.034
		(0.406)
Markup		-0.424
		(0.668)
Constant	-8.652***	-8.551***
	(2.924)	(2.958)
Pseudo R-squared	0.164	0.165
Observations	1352	1349

Note. This table shows the estimation results of Probit regressions to determine the probability of cartel participation. The regressions are performed for observations for which the measure of interest 'Longholder[T]' as described in Section 3.3 never exceeds zero (i.e., the control population). The outcome is an indicator 'Cartel' that takes the value one if the firm is part of a collusive agreement at time t and zero in any period before and after the collusion period. Controls are applied as described in Section 3.3. The firm controls in columns (1) and (2) include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. In column (2), we add variables covering the firm market share, industry HHI, and markup. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 12: Mean comparison of firms part of a cartel (treatment) and those that are not part of a cartel (control)

	Mean		Difference	p-value
	Treatment	Control	(2)-(1)	(1)=(2)
Panel: Main data				
Cash over total assets	0.082	0.084	0.002	0.882
Sales over total assets	0.801	0.880	0.079	0.230
Capital intensity over total assets	0.066	0.059	-0.006	0.296
Return on assets	0.038	0.018	-0.020	0.111
Cashflow over total assets	0.038	0.023	-0.015	0.202
Dividends over total assets	0.015	0.014	-0.001	0.823
Leverages over stockholder's equity	1.365	1.425	0.060	0.881
log(CEO age)	4.013	4.016	0.003	0.863
log(CEO tenure)	1.491	1.364	-0.127	0.278
Chairman	0.713	0.730	0.017	0.805
Panel: With HobergPhilips data				
Cash over total assets	0.088	0.089	0.001	0.969
Sales over total assets	0.978	0.866	-0.113	0.139
Capital intensity over total assets	0.057	0.056	-0.001	0.830
Return on assets	0.022	0.018	-0.004	0.786
Cashflow over total assets	0.022	0.023	0.000	0.994
Dividends over total assets	0.012	0.014	0.002	0.412
Leverages over stockholder's equity	1.316	1.405	0.088	0.828
log(CEO age)	4.023	4.007	-0.015	0.355
log(CEO tenure)	1.546	1.289	-0.256	0.025
Chairman	0.746	0.746	0.000	0.998
Market share	0.226	0.182	-0.044	0.241
HHI	0.252	0.258	0.005	0.874
Markup	0.174	0.157	-0.017	0.342

Note. The table shows the comparison of the propensity score weighted means for the treatment and control group. The treatment group is formed of firms that participate in collusion, while the control group consists of firms that did not participate in collusion.

Table 13: Sample restriction based on minimum probability to be part of collusion at some time

	(1)	(2)	(3)	(4)
Outcome	$CARTEL_t$			
Observations:	Only matching		Complete firm-years	
Longholder[T]	0.180***	0.202***	0.060**	0.059**
	(0.064)	(0.065)	(0.026)	(0.026)
Variables included in the matching approach				
Firm controls	Yes	Yes	Yes	Yes
CEO controls	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
HobergPhilips controls	No	Yes	No	Yes
R-squared	0.032	0.040	0.008	0.008
Observations	828	794	3900	3891

Note. This table shows the estimation results of a linear regression model of equation (10). The measure of interest 'Longholder[T]' is described in Section 3.3. The outcome is an indicator 'Cartel' that takes the value one if the firm is part of a collusive agreement at time t and zero in any period before and after the collusion period. Controls are applied as described in Section 3.3. The firm controls include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 14: Cartel duration by managerial overconfidence

	Non-Overconfident (0)	Overconfident (1)	Difference (0) − (1)
Observations	170	162	
Mean Duration (years)	7.80	9.96	-2.16***
Median Duration (years)	7.50	8.50	
Std. Dev.	4.76	6.01	
25th Percentile	4.50	4.50	
75th Percentile	9.50	13.50	
90th Percentile	13.50	21.50	
t-statistic (mean diff.)			-3.63
p-value (t-test)			0.0003
Wilcoxon z-statistic			-3.27
p-value (rank-sum)			0.0011

Notes: Cartel duration is measured as the number of years between cartel start and termination. The difference column reports mean differences between non-overconfident and overconfident cartels. *** denotes significance at the 1% level.

Table 15: Managerial overconfidence and cartel duration: cox proportional hazards models

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Log-Hazard Coefficients						
Overconfidence	-0.468**	-0.213	-0.190	-0.164**	-0.401***	-0.139
	(0.184)	(0.136)	(0.118)	(0.078)	(0.096)	(0.087)
Panel B: Hazard Ratios (exp(β))						
Overconfidence	0.63	0.81	0.83	0.85	0.87	0.87
Sector FE	No	Yes	Yes	Yes	No	Yes
Year FE	No	No	Yes	Yes	Yes	Yes
Firm Controls	No	No	No	Yes	Yes	Yes
CEO Controls	No	No	No	No	Yes	Yes
Observations	229	229	229	229	229	229

Notes: The table reports Cox proportional hazards models of cartel termination. The dependent variable is the hazard rate of cartel breakdown. Standard errors (in parentheses) are clustered at the sector level. Hazard ratios are reported in Panel B for ease of interpretation. A hazard ratio below one implies a lower risk of cartel termination. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 16: The impact of CEO turnover and overconfidence on cartel formation - considering the overconfidence of the next CEO

Outcome	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	CARTEL$_t$								
Turnover type	Any turnover ($t-1$)			Voluntary turnover ($t-1$)			Forced turnover ($t-1$)		
		Next CEO overconfident (t)			Next CEO overconfident (t)			Next CEO overconfident (t)	
		No	Yes		No	Yes		No	Yes
Longholder (T)									
No Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.021*	0.010	0.036	0.020	0.006	0.039	0.021	0.020	0.006
	(0.012)	(0.011)	(0.030)	(0.014)	(0.013)	(0.034)	(0.026)	(0.028)	(0.028)
Overconfidence$_{t-1}$ × No Turnover$_{t-1}$	0.018	-0.009*	0.010	0.016	-0.010**	0.009	0.014	-0.013***	-0.000
	(0.012)	(0.006)	(0.009)	(0.011)	(0.005)	(0.008)	(0.011)	(0.004)	(0.014)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.007	-0.015***	-0.006	-0.005	-0.016***	-0.004	-0.018*	-0.011	-0.032
	(0.013)	(0.006)	(0.018)	(0.014)	(0.006)	(0.020)	(0.011)	(0.008)	(0.026)
Comparison of coefficients									
No O × T vs. O × No T (p-value)	0.861	0.111	0.458	0.858	0.207	0.443	0.807	0.244	0.826
No O × T vs. O × T (p-value)	0.133	0.042	0.279	0.241	0.103	0.327	0.148	0.257	0.289
O × No T vs. O × T (p-value)	0.046	0.438	0.409	0.100	0.376	0.551	0.018	0.883	0.166
R-squared	0.097	0.156	0.076	0.096	0.156	0.076	0.095	0.156	0.075
Observations	3163	2104	1426	3163	2104	1426	3163	2104	1426

Note. This table shows the estimation results of a linear regression model of equation (10). The measure of interest 'Longholder[T]' is described in Section 3.3. The outcome is an indicator 'Cartel' that takes the value one if the firm is part of a collusive agreement at time t and zero in any period before and after the collusion period. Controls are applied as described in Section 3.3. The firm controls include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 17: The impact of CEO turnover and overconfidence on cartel formation - considering the change in sales before the turnover event

Outcome	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	CARTEL$_t$								
Turnover type	Any turnover ($t-1$)			Voluntary turnover ($t-1$)			Forced turnover ($t-1$)		
		Sales growth ($t-2$)			Sales growth ($t-2$)			Sales growth ($t-2$)	
		Negative	Positive		Negative	Positive		Negative	Positive
Longholder (T)									
No Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.014	-0.010	0.029*	0.010	-0.019	0.024	0.027	0.014	0.049
	(0.011)	(0.011)	(0.017)	(0.013)	(0.013)	(0.019)	(0.030)	(0.015)	(0.051)
Overconfidence$_{t-1}$ × No Turnover$_{t-1}$	0.020	0.028	0.020*	0.018	0.025	0.018	0.017	0.026	0.017
	(0.013)	(0.021)	(0.012)	(0.013)	(0.021)	(0.012)	(0.013)	(0.020)	(0.012)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.001	-0.016	0.006	0.002	-0.009	0.007	-0.018	-0.030	-0.011
	(0.015)	(0.015)	(0.020)	(0.017)	(0.014)	(0.022)	(0.013)	(0.023)	(0.013)
Comparison of coefficients									
No O × T vs. O × No T (p-value)	0.746	0.048	0.665	0.668	0.036	0.815	0.762	0.486	0.536
No O × T vs. O × T (p-value)	0.432	0.686	0.397	0.714	0.516	0.589	0.135	0.099	0.223
O × No T vs. O × T (p-value)	0.172	0.018	0.463	0.324	0.036	0.588	0.023	0.027	0.036
R-squared	0.084	0.095	0.092	0.084	0.094	0.091	0.084	0.093	0.091
Observations	2648	829	1819	2648	829	1819	2648	829	1819

Note. This table shows the estimation results of a linear regression model of equation (10). The measure of interest 'Longholder[T]' is described in Section 3.3. The outcome is an indicator 'Cartel' that takes the value one if the firm is part of a collusive agreement at time t and zero in any period before and after the collusion period. Controls are applied as described in Section 3.3. The firm controls include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 18: The impact of CEO turnover and overconfidence on cartel formation - considering cartel participation in the last year

Outcome	(1)	(2) $CARTEL_t$	(3)
Turnover type	Any turnover $(t-1)$	Voluntary turnover $(t-1)$	Forced turnover $(t-1)$
Longholder(T)			
$Overconfidence_{t-1}$	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
$Turnover_{t-1}$	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)
$CARTEL_{t-1}$	0.873***	0.876***	0.888***
	(0.039)	(0.039)	(0.036)
$Overconfidence_{t-1} \times Turnover_{t-1}$	-0.003**	-0.004**	0.001
	(0.002)	(0.002)	(0.002)
$Overconfidence_{t-1} \times CARTEL_{t-1}$	-0.088	-0.120*	-0.108*
	(0.064)	(0.067)	(0.059)
$Turnover_{t-1} \times CARTEL_{t-1}$	0.118***	0.115***	0.103***
	(0.039)	(0.038)	(0.040)
$Overconfidence_{t-1} \times Turnover_{t-1} \times CARTEL_{t-1}$	-0.301*	-0.119	-0.883***
	(0.175)	(0.175)	(0.062)
Sum of coefficients of interaction term ($CARTEL_{t-1}$ yes)	0.598***	0.749***	0.000
	(0.156)	(0.155)	(0.005)
Sum of coefficients of interaction term ($CARTEL_{t-1}$ no)	-0.003***	-0.004***	0.000
	(0.001)	(0.001)	(0.002)
Comparison of 'Sum of coefficients of interaction term' with each other (p-value)	0.000	0.000	0.980
R-squared	0.749	0.746	0.756
Observations	6727	6727	6727

Note. This table shows the estimation results of a linear regression model of equation (10). The measure of interest 'Longholder[T]' is described in Section 3.3. The outcome is an indicator 'CARTEL' that takes the value one if the firm is part of a collusive agreement at time t and zero in any period before and after the collusion period. Controls are applied as described in Section 3.3. The firm controls include the lagged variables for cash scaled by assets, sales scaled by assets, capital intensity scaled by assets, return on assets, cash flow scaled by assets, dividend payments scaled by assets as well as leverage. CEO controls include the logarithm of age and tenure. Moreover, each regression includes a set of sector and year-fixed effects. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Appendix C: Alternative *Overconfidence* measures

Net Buyer

Net Buyer exploits the tendency of CEOs to purchase additional firm stock despite already having a high exposure to firm risk. Specifically, we consider the subsample of CEOs who remain in their positions for at least 10 years.

CEOs are classified as overconfident if they were net buyers of firm equity during their first five years in the sample, i.e., if they bought stock on net in more years than they sold on net during their first five sample years. As such, we exclude the first five years of the CEOs' tenure, as in Malmendier and Tate (2005). By using disjoint subsamples of CEO years to establish overconfidence and to measure its potential effects on investment, we can reduce endogeneity issues.

Holder 67

Holder 67 considers the status of each option package in the sample at the end of the vesting period. To maintain comparability across packages with different vesting periods, we examine the first year in which all packages in the sample are at least partially exercisable and compute the percentage in-the-money for each package. Risk aversion and underdiversification predict that CEOs should exercise options immediately after the vesting period if the amount in the money is beyond a rational benchmark.

We set 67% in-the-money in 2007 as our threshold to maximize the sample size. If an option is more than 67% in-the-money at some point in 2007, the CEO should have exercised at least some portion of the package during or before that year. This threshold corresponds to a risk aversion of 3 in a constant relative risk aversion (CRRA) utility specification and to a 66% share of wealth in company equity.

Therefore, this measure targets CEOs who "habitually" exercise options late.

Holder 67 Restriction

To build this measure, we take the *Holder 67* measure and restrict the sample to CEOs who, at least twice during the sample period, had options valued above the threshold during the fifth year. This restriction guarantees that every CEO in the subsample had the opportunity to be classified as overconfident and, thus, limits the degree of unobserved overconfidence in the control group.

Overall, the two *Holder 67* measures place no restriction on how long the CEO must hold

the option beyond the fifth year and, thus, can capture short-term delays in option exercise, rather than an "habitual" tendency to hold too much risk (*a fixed overconfidence effect*).

Table 19: This table presents results on the relation between cartel membership and overconfidence measures, using variants on the regression specification, in an analogous way to table 5: $\text{CARTEL}_{i,t} = \beta\, overconfidence_{i,t-1} + \mu_i + \tau_{j,t} + \varepsilon_{i,t}$

	CARTEL_t					
Panel A	[1]	[2]	[3]	[4]	[5]	[6]
Holder67_lag	0.008**	0.008**	0.008**	0.008**	0.008***	0.008**
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
N	17,173	17,173	12,081	12,081	12,081	12,081
R-squared	0.031	0.016	0.036	0.017	0.137	0.046
Panel B	[1]	[2]	[3]	[4]	[5]	[6]
Holder67(R)_lag	0.008**	0.008**	0.008**	0.008**	0.008***	0.008**
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
N	17,173	17,173	12,081	12,081	12,081	12,081
R-squared	0.031	0.016	0.036	0.017	0.137	0.046
Panel C	[1]	[2]	[3]	[4]	[5]	[6]
Netbuyer_lag	0.002	0.010***	0.003	0.010***	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
N	39,091	39,086	24,883	24,878	24,878	24,878
R-squared	0.029	0.024	0.031	0.024	0.078	0.042
CEO controls	no	no	yes	yes	yes	yes
firm controls	yes	yes	yes	yes	yes	yes
year FE	yes		yes			yes
sector FE		yes		yes		yes
year-sector FE					yes	

Table 20: Mechanism test: Causal direction

This table presents evidence on the lead-lag relation between cartel membership and overconfidence, for the *Net Buyer* measure. The specification mirrors that of Table 19, but uses future CARTEL and prior CARTEL as the dependent variables.

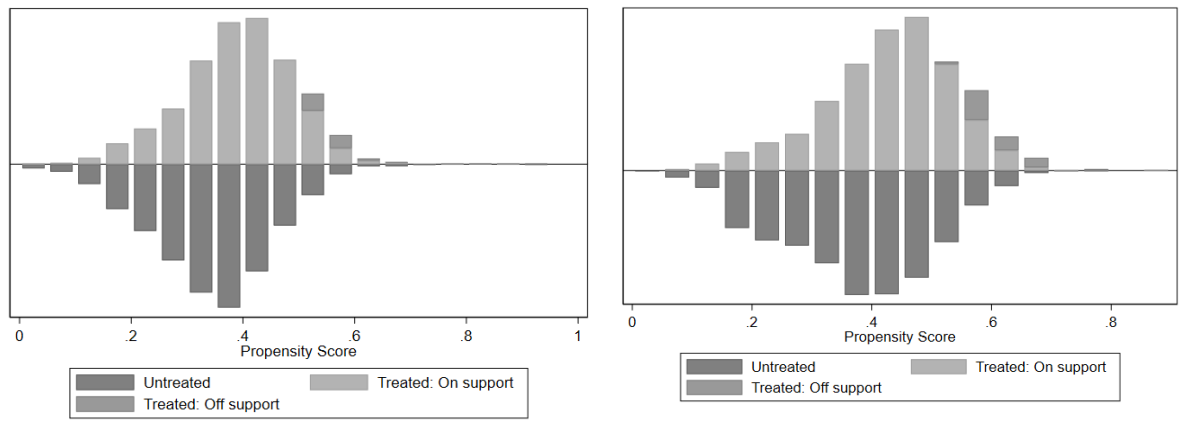
	CARTEL_{t+1}	CARTEL_{t-1}
	[1]	[2]
Netbuyer	0.00144*	0.00013
	(0.001)	(0.001)
CARTEL_t	0.87245***	0.92668***
	(0.016)	(0.013)
CEO controls	yes	yes
firm controls	yes	yes
year-sector controls	yes	yes
N	24,600	25,127
R-squared	0.828	0.823

Appendix D1: Propensity Score Matching procedure

To further evaluate the propensity score matching procedure, we present histograms of the propensity score matches for the treated and untreated groups. Figure 1 shows the histograms for the overconfidence measure *Longholder*(T) for our main variable of interest, the cartel outcome. The left panel shows the histogram for our baseline data, while the right panel includes the additional covariates from the Hoberg and Philips data (market share, HHI, and markups). The x-axis represents the propensity scores, which indicate the probability of being in the treated group (i.e., having an overconfident CEO) based on observable characteristics. The y-axis represents the frequency of observations. The dark gray bars represent the "Untreated" medium-gray bars represent the "Treated: On support" group, indicating treated observations with that have suitable matches in the untreated group. The light gray bars represent the "Treated: Off support" group, indicating treated observations that do not have suitable matches in the untreated group. There is a significant overlap between the treated (on support) and the untreated group for the cartel outcome in the *Longholder*(T) measure.

Figure 1: Propensity score matching for Longholder[T]_lag

(a) Main data **(b) With HobergPhilips data**



Note. This figure shows the propensity scores for the measure Longholder[T]_lag. The x-axis shows the propensity scores, which indicate the probability of being in the treated group (having an overconfident CEO) based on observable characteristics. The y-axis represents the frequency of observations. The dark gray bars represent the "Untreated" group. The medium-gray bars represent the "Treated: On support" group, indicating treated observations with suitable matches in the untreated group. The light gray bars represent the "Treated: Off support" group, indicating treated observations that do not have suitable matches in the untreated group. The left panel shows the propensity scores for the main data including firm and CEO characteristics, while the right panel includes the HobergPhilips data (including controls market shares, HHI and markups).

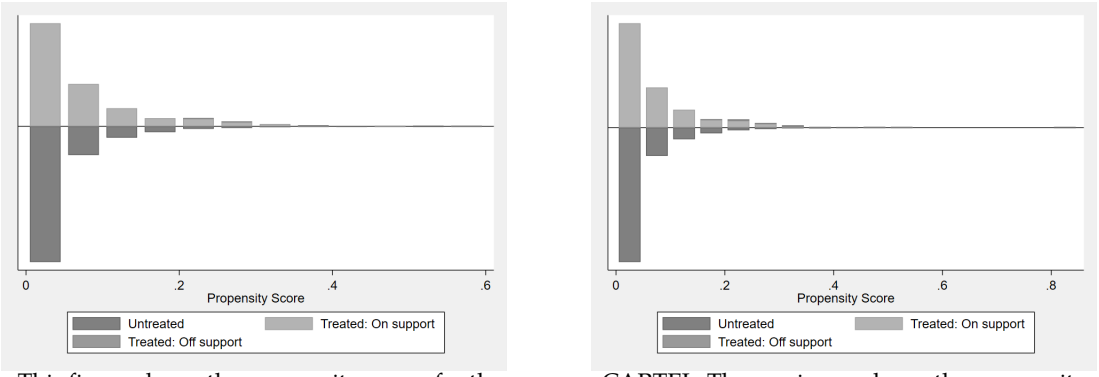
Table 21: Summary statistics of the propensity score

	mean	sd	p10	p25	p50	p75	p90	count
Propensity score (Main data)	0.361	0.110	0.214	0.292	0.367	0.434	0.497	6937
Propensity score (Main data) (Longholder[T] =0)	0.342	0.109	0.197	0.273	0.348	0.415	0.477	4431
Propensity score (Main data) (Longholder[T] =1)	0.395	0.102	0.260	0.333	0.400	0.465	0.520	2506
Propensity score (With HobergPhilips data)	0.399	0.124	0.217	0.318	0.409	0.487	0.552	3781
Propensity score (With HobergPhilips data) (Longholder[T] =0)	0.373	0.124	0.199	0.283	0.380	0.463	0.529	2273
Propensity score (With HobergPhilips data) (Longholder[T] =1)	0.438	0.114	0.286	0.371	0.447	0.516	0.578	1508

Appendix D2: Prognostic Score Matching procedure, with firm controls

Figure 2: Prognostic scores for CARTEL

(a) Main data **(b) With HobergPhilips data**



Note. This figure shows the propensity scores for the measure CARTEL. The x-axis reprshows the propensity scores, which indicate the probability of being in the treated group (i.e., having an overconfident CEO) based on observable characteristics. The y-axis represents the frequency of observations. The dark gray bars represent the "Untreated" group. The medium gray bars represent the "Treated: On support" group, indicating treated observations with suitable matches in the untreated group. The light gray bars represent the "Treated: Off support" group, indicating treated observations that do not have suitable matches in the untreated group. The left panel shows the propensity scores for the main data, including firm and CEO characteristics, while the right panel includes the HobergPhilips data (including controls, market shares, HHI, and markups).

Table 22: Summary statistics of the prognostic score

	mean	sd	p10	p25	p50	p75	p90	count
Propensity score (Main data)	0.048	0.067	0.002	0.008	0.023	0.058	0.120	5845
Propensity score (Main data) (cartel =0)	0.046	0.065	0.002	0.008	0.022	0.055	0.117	5426
Propensity score (Main data) (cartel =1)	0.072	0.082	0.005	0.015	0.044	0.095	0.191	419
Propensity score (With HobergPhilips data)	0.048	0.067	0.002	0.008	0.024	0.059	0.122	5661
Propensity score (With HobergPhilips data) (cartel =0)	0.046	0.065	0.002	0.008	0.022	0.056	0.118	5251
Propensity score (With HobergPhilips data) (cartel =1)	0.070	0.079	0.004	0.015	0.045	0.088	0.184	410

Appendix D3: Alternative duration specifications

Table 23 reports OLS regressions using log duration as the dependent variable. In the baseline specification without fixed effects, managerial overconfidence is associated with a statistically significant increase in log duration (Column (1): $\beta = 0.233$, $p < 0.01$), implying approximately 26% longer cartel duration.[21]

Introducing sector and year fixed effects attenuates the estimate (Columns (2)–(4)), though the coefficient remains positive throughout. When we include CEO characteristics alongside year fixed effects and firm controls (Column (5)), the association strengthens again and is statistically significant ($\beta = 0.294$, $p < 0.01$). In the most saturated specification with sector and year fixed effects, firm controls, and CEO controls (Column (6)), the coefficient remains positive but is estimated less precisely.

Overall, the log-duration evidence corroborates the survival analysis: overconfidence is consistently associated with longer cartel duration, and the magnitude is economically meaningful. The sensitivity of statistical significance to the inclusion of fixed effects and controls suggests that part of the relationship operates through observable industry, time, and managerial characteristics, consistent with the mechanism emphasized in the theory.

Table 23: Managerial overconfidence and cartel duration: log-duration OLS

	(1)	(2)	(3)	(4)	(5)	(6)
Overconfidence	0.233***	0.133	0.131	0.165	0.294***	0.160
	(0.074)	(0.094)	(0.098)	(0.105)	(0.096)	(0.108)
Sector FE	No	Yes	Yes	Yes	No	Yes
Year FE	No	No	Yes	Yes	Yes	Yes
Firm Controls	No	No	No	Yes	Yes	Yes
CEO Controls	No	No	No	No	Yes	Yes
Observations	332	229	229	229	229	229
R-squared	0.030	0.240	0.250	0.401	0.228	0.408

Notes: The dependent variable is ln(*Duration*), where duration is measured in years from cartel start to termination. Overconfidence equals one if the cartel involves an overconfident manager. Heteroskedasticity-robust standard errors are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 24 reports quantile regressions of cartel duration at the 25th, 50th, and 75th percentiles. In the baseline specification (Columns (1)–(3)), overconfidence is associated with a statistically significant increase in duration at the median and, especially, in the upper part

[21] The percentage effect is computed as $\exp(\beta) - 1$.

of the distribution. Specifically, the estimated effect is close to zero at the 25th percentile, approximately one additional year at the median ($p < 0.10$), and about four additional years at the 75th percentile ($p < 0.01$).

Once we introduce sector and year fixed effects and firm controls (Columns (4)–(6)), the estimates remain positive but are less precisely estimated. In specifications that include year fixed effects alongside firm and CEO controls (Columns (7)–(9)), the median effect is again positive and statistically significant ($\hat{\beta} = 2.667$, $p < 0.01$). Overall, the quantile results suggest that the relationship between overconfidence and cartel duration is concentrated in the middle-to-upper part of the duration distribution, consistent with the view that overconfidence is particularly relevant for sustaining long-lived cartels.

Finally, we test the proportional hazards assumption using Schoenfeld residuals. We fail to reject the proportionality assumption, supporting the validity of the Cox specification.

Table 24: Managerial Overconfidence and Cartel Duration: Quantile Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Baseline			Sector & Year FE + Firm Controls			Year FE + Firm & CEO Controls		
	Q25	Q50	Q75	Q25	Q50	Q75	Q25	Q50	Q75
Overconfidence	0.000	1.000*	4.000***	1.267	0.947	1.260	1.630	2.667***	1.833
	(0.603)	(0.592)	(1.223)	(0.961)	(0.666)	(1.588)	(1.011)	(0.756)	(1.601)
Observations	332	332	332	229	229	229	229	229	229

Notes: The table reports quantile regressions of cartel duration (in years) at the 25th, 50th (median), and 75th percentiles. Overconfidence equals one if the cartel involves an overconfident manager. Standard errors are in parentheses. Columns (1)–(3) include no additional controls. Columns (4)–(6) include sector and year fixed effects and firm controls. Columns (7)–(9) include year fixed effects, firm controls, and CEO controls. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.