CEO Overconfidence and Collusion*

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Abstract

We explore whether there is a relationship between CEO overconfidence and collusion. Overconfidence may make managers compete more if they expect to be able to outperform competitors, or it may push them to collude if they expect the cartel to be stable and not to be caught/ convicted. These contrasting theoretical hypotheses make empirical analysis crucial.
We document that: (1) there is a positive and highly significant relationship between overconfidence and collusion, and (2) overconfidence Granger causes cartel participation (and not the other way around). We then discuss some possible mechanisms underlying this relationship. These findings are highly policy-relevant. They confirm that cartel enforcement should focus on the top layer of firm management and on shareholders who provide their incentives. They also suggest that CEO overconfidence could possibly be used as a screen to detect cartels.

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

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1 Introduction

Overconfidence is a behavioral bias that usually refers to underestimating failure (e.g. Malmendier and Tate, 2005). In situations in which an accurate perceived risk assessment is usually necessary, overconfidence is viewed as detrimental to effective judgment. This applies to top managers, where it has been shown that overconfident managers tend to underestimate risk. Overconfidence has been shown to have a huge impact on CEO behaviour in contexts such as acquisitions (e.g., Malmendier and Tate, 2008), innovation (e.g., Galasso and Simcoe, 2011), and corporate investment (e.g., Malmendier and Tate, 2005).

CEOs have an influential role in the firm's behavior, although this can be through indirect channels (e.g., Yu (2023)). In the context of cartels, Harrington (2006b) and Connor (2011) describe how, in convicted cartels in the US, decisions are typically taken by very top managers, though implemented by intermediate management, suggesting that the principle of the cartel may be established by the CEO.[1]

This paper is dedicated to establishing an empirical relationship between overconfidence and collusion. The decision for or against a cartel agreement is related to future perceptions of risk. If a firm engages in a collusive agreement, several possibilities have to be taken into account, e.g., the detection probability, reputational loss, and fines. Not participating in a cartel can also be related to risk, as stronger competition could decrease the profits of the firm and rewards for the manager. A manager whose decision is biased by overconfidence might underestimate the risks in both situations.

To examine the relationship between CEO overconfidence and collusion, we fol-

[1] In fact, lower-level managers may not be aware of the cartel agreement and may destabilize it (unknowingly). For example, Harrington (2006a) describes how, in the lysine cartel, a salesman was fired for lowering prices below those agreed by the cartel.

low the literature and classify a manager as overconfident if she recurrently delays exercising fully vested in-the-money stock options (Malmendier and Tate, 2005, 2015). Accordingly, we define four different measures of overconfidence that exploit the underdiversification of CEOs.

Our results show a positive and highly statistically significant relationship between overconfidence and collusive behavior for all measures. To find the true direction of the effect, we test for Granger causality and show that overconfidence affects collusion and not vice versa. This means that convicted colluding managers are, on average, more overconfident than other managers.

We contribute to the literature in two main ways. First, by establishing an empirical relationship between overconfidence and collusion. In other words, by showing that the effects of overconfidence on the profitability of cartels and on the probability of not being caught by the antitrust authority dominates that on the stronger preferences for competition.

Second, we contribute by showing that the individual characteristics of CEOs are a clear predictor of cartel formation, suggesting that cartel formation is a decision taken, or at least encouraged, at the very top of the governance structure.

Our findings confirm that firm governance, i.e. shareholder-CEO relationships and CEO incentives, are a crucial determinant of collusive behavior, as argued in early theoretical work such as Spagnolo (2000, 2004, 2005), and in recent empirical work such as Azar et al. (2018); Bloomfield et al. (2023); Ha et al. (2024) and Antón et al. (2023).

The fact that Gonzalez et al. (2019) and Marvão and Spagnolo (2024) find little evidence that managers of convicted cartel firms are held accountable by either corporate governance or the legal system suggests that the problem remains as urgent as it was

at the time of Buccirossi and Spagnolo (2008).

Different implications arise from our results. First, firms can take the overconfidence bias into account in the hiring strategy, especially if/when collusion is undesirable. Second, competition authorities can use the relationship to detect cartels. As managers involved in collusion are more overconfident, it might be a first step to screening firms with managers who are above industry-average overconfident. In addition, overconfident managers underestimate the risk of detection. Thus, there might be a higher likelihood of finding evidence as more overconfident managers are less careful.

The paper is structured as follows: in the next section, we present a review of the literature. In Section 3, data, sample, and key variables are explained. Section 4 discusses the empirical analysis, including baseline and more sophisticated results. Section 5 discusses potential channels and mechanisms concerning the general association and direction of the effect. Section 6 concludes.

2 Literature Review

Our work contributes mainly to two strands of literature. First, we contribute to the literature on the role of personal managerial characteristics in corporate decision-making, particularly regarding “unjustified" beliefs based on available information (Baker and Wurgler, 2006). Malmendier and Tate (2005) and Malmendier and Nagel (2005) find that CEOs tend to overestimate the success of their corporate decisions, while Itzhak et al. (2013) show that CEOs underestimate the variance of stock market returns and other financial signals. The overconfidence of CEOs also increases the likelihood of making value-destroying mergers, especially when these are diversified (Malmendier and Tate, 2008). In addition, Malmendier and Tate (2005) show that the level of edu-

cation and the educational background of CEOs directly affect firm strategic decisions.

While a broad literature has examined overconfidence in poor business decisions (e.g. Heaton 2002; Malmendier and Tate; Malmendier and Tate 2005; 2008; Pikulina et al. 2017), few empirical studies have directly examined its relationship with crime. Schrand and Zechman (2012) propose that overconfident financial managers may tend to fraudulent practices when faced with persistent earnings' shortfalls. Gervais and Odean (2001) establishes a link between overconfidence and criminal decision-making, suggesting that perceived criminal ability and a self-serving bias in evaluating the threat of sanctions contribute to criminal behaviour in overconfident individuals.

As such, managerial overconfidence is linked to risk, given that overconfident managers underestimate the risk of, for example, failure (e.g. McCannon et al. 2016). This may occur, for example, because their internal risk calculation focuses primarily on factors and variables within their control rather than those outside their control (Tor 2002).

The discussion of overconfidence related to crime and risk has direct implications for the relationship between overconfidence and collusion. First, risk is directly related to overconfidence, and collusion is risky with regard to cartel stability, detection, and possible fines (civil and criminal) and reputational loss. Second, overconfidence is related to criminal behavior, as cartels are subject to criminal penalties in several jurisdictions like the US.

Recent work has focused on the effect of overconfidence on preferences for competition. For example, Camerer and Lovallo (1999) and more recently Schüssler (2018) show experimentally that overconfidence leads to excessive entry/competition. Reuben et al. (2024) show that when overconfident MBA students have a stronger than aver-

age preference for competition, they tend to perform worse than their peers in terms of long term income.

Anecdotal evidence suggests that colluding managers are more overconfident than non-colluding managers because they seem extremely overconfident in believing they will never be exposed (Geis, 2017). However, if overconfident managers expect to outperform their competitors, it is also plausible that they may prefer to compete rather than collude.

Second, we contribute to the literature on corporate governance and collusive behavior (Buccirossi and Spagnolo (2008) survey the early literature). Some observers have argued that responsibility for cartel formation lies in lower ranking price-setting managers, and that "compliance programs" that "educate" these managers could be a solution to the problem. However, Harrington (2006b) and Connor (2011) describe how, in convicted cartels in the US, decisions are typically taken by very top managers, though implemented by intermediate management.

The literature has also suggested that shareholder-CEO relationships, and CEO incentives, are a crucial determinant of collusive behavior. This is argued in early theoretical work such as Spagnolo (2000, 2004, 2005), and in recent empirical work such as Azar et al. (2018); Bloomfield et al. (2023); Ha et al. (2024) and Antón et al. (2023).

Finally, Gonzalez et al. (2019) and Marvão and Spagnolo (2024) find little evidence that managers of convicted cartel firms are held accountable by either corporate governance or the legal system. Gonzalez et al. (2019) study convicted (listed) cartel firms in the US between 1990 and 2014, finding that their CEOs are given greater job security and receive large bonuses, while rarely facing individual prosecution. Marvão and Spagnolo (2024) examine the consequences of cartel detection for the career of CEOs

in the US and the EU and find that only 4% of all CEOs in EC cartel firms (1998-2020) are explicitly fired as a result of cartel participation, and that 30% of CEOs indicted by the DOJ (1985-2011) are fired. Most often, CEOs remain in place or take on other high-level positions in the firm, such as board chairmanships. Together, this may suggest that the problem remains as urgent as it was at the time of Buccirossi and Spagnolo (2008).

3 Data, Sample and Key variables

3.1 Data

The cartel data used in the empirical analysis is an excerpt from John Connor's Private International Cartels dataset.[2] This excerpt covers the years of 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.

The financial and compensation data used in this study come from four sources: Compustat's ExecuComp Annual and Quarterly Industrial Files; Thomson Reuters Insider Filings; and the Hoberg and Phillips Data Library. The Hoberg and Phillips Data Library provides a text-based network industry classification, giving each firm a list of firm-year specific competitors, with associated similarity scores. The scores are based on the cosine similarity between two firms' product disclosures.[3]

We use two data sources to build our overconfidence measures. First, we use data

[2]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 and several other variables were dropped due to inconsistent or missing data.

[3]See: Hoberg and Phillips (2010, 2016), and Hoberg et al. (2014).

from Thompson for the period 1998 to 2013 (to match the same time period as in Malmendier and Tate (2015)). Second, we use data from Compustat for the period 1998 to 2016. We remove all observations with missing data on sales, ticker symbols, or SIC codes. We match this set with the cartel dataset, using the ticker symbols of the firms.[4] Our final sample consists of 11,450 firm-year observations from 2987 unique firms, of which 76 firms were cartel members at some point during our sample period.

We further add data on the position and post-cartel career path of the managers convicted by the US DOJ and of the CEOs of the firms convicted by the US DOJ. These data were obtained from *Bloomberg*, Who's Who in Finance and Industry and other online sources.

3.2 Sample Selection

One concern with the data is the possibility of sample selection bias. Since cartels are prohibited by the Sherman Act, they are secret, so the available data include only cartel members that were prosecuted and convicted. This problem of selection on the unobservables cannot be overcome in our setting, but its existence is acknowledged in the interpretation of the results.

To the extent that undetected cartels exist, and differ from detected cartels along relevant dimensions, our results may be biased (e.g., if overconfidence plays a role in the detection of the cartel). This problem is not unique to our study; an analogous concern applies to all studies where variable codings are jointly contingent upon both the presence and *detection* of the feature of interest.[5]

[4]Where possible, we use the US ticker symbols developed by Standard & Poor's (S&P) to identify each firm. 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".

[5]Common examples include fraud/financial misreporting (e.g., AAER issuances); insider trading; etc.

3.3 Variables

Below, we outline the variables used in our main analyses. Definitions for all variables can be found in Table 1 in the Appendix.

3.3.1 Cartel Membership

We measure cartel membership with a dummy variable equal to one for all firm-years identified as part of a cartel membership window. A firm's cartel membership window spans from the first year for which the firm was successfully prosecuted for antitrust violations to the year of the final antitrust enforcement action.[6] We refer to this measure as CARTEL.

We further construct the indicator variable, BUST, to reflect the transitions of the firms from cartel members to non-cartel members (that is, when the final enforcement actions are successfully brought against the firms).[7] BUST takes a value of one if $\text{CARTEL}_{i,t-1} = 1$ and $\text{CARTEL}_{i,t} = 0$.

3.3.2 Managerial overconfidence

The literature defines overconfidence as optimism, i.e., the overestimation of a firm's relative or absolute performance (e.g. Malmendier and Tate (2005, 2008)).[8]

We follow the approach in Malmendier and Tate (2005) which develops four option-

[6] Many firms are involved in multiple cartels (known as "repeat offenders" or "serial colluders"), see e.g. Marvão (2015); Levenstein et al. (2015). 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.

[7] It is conceivable that cartels manage to sustain even after cartel member firms are caught, convicted and fined. To the extent that regulatory interventions are ineffective, it would reduce the power of our tests.

[8] Some authors instead define overconfidence as over precision, i.e., the excessive precision of one's benefits, as reported through surveys (e.g. Itzhak et al. (2013)).

based measures of overconfidence. These measures are based on the premise that CEOs who recurrently 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.

We construct four measures of overconfidence: [1] *Longholder* (using both data from Compustat Execucomp and from Thomson), [2] *Net Buyer*, [3] *Holder 67*, and [4] *Holder 67 Restriction*. We build measures [2] to [4] using data from ExecuComp (see table 2). Data on stock prices comes from CRSP, such that our sample is restricted to publicly traded firms.

Net Buyer uses the timing of the acquisition of firm stock, whereas the other measures use the timing of option exercise. We discuss these in further detail below.

[1] Longholder

Longholder focuses on the expiration date of option packages (and not the end of the vesting period). 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. Therefore, this measure captures **habitual failure to diversify**, or a **personality**, and not a time-varying, overconfidence effect.

In our sample, options last up to 10 years and their average duration is 5.3 years. Around 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 the 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. 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. In the main analysis, we use the updated *Longholder* measure. In *Appendix B*, we show how the results for the longholder measure from ExecuComp for comparison purposes (particularly with older studies), but we do not discuss these in the paper.

[2] Net Buyer

Net Buyer exploits the tendency of CEOs to purchase additional firm stock despite having an already high exposure to firm risk. Specifically, we consider the subsample of CEOs who keep their position as CEO for at least 10 years in our sample.

CEOs are classified as being 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.

We exclude the first five years of the CEOs' tenure. By using disjoint subsamples of CEO years to establish overconfidence and to measure its potential effects on investment, we can reduce endogeneity issues.

[3] Holder 67

Holder 67 considers the status of each option package in the sample at the end of the vesting period. To keep comparability across packages with different lengths of vest-

ing periods, we examine the first year in which all the 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 take 67% in-the-money during the year of 2007 as our threshold. 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 three in a constant relative risk-aversion (CRRA) utility specification and to a percentage of wealth in company equity equal to 66.

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

[4] 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 that were 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*). However, this also restricts considerably the sample of overconfident CEOs.

Table 3 describes the share of overconfident CEOs for the full sample and within the cartel sample, for each of the four measures. On average, 28% to 39% of CEOs

are overconfident, depending on the specific overconfidence measure. However, for within the cartel sample, 48% to 64% of CEOs are overconfident.

4 Empirical Analysis

4.1 Baseline Results

We begin our analysis by examining the relationship between overconfidence and cartel membership. We do so with variants of the following regression specification:

$$\text{CARTEL}_{i,t} = \beta\, overconfidence_{i,t} + \mu_i + \tau_{j,t} + \varepsilon_{i,t}, \tag{1}$$

where $overconfidence_{i,t}$ is an indicator variable equal to one if the CEO in firm i is overconfident in year t, $\text{CARTEL}_{i,t}$ is an indicator variable equal to one if firm i is a cartel member in year t, and μ and τ are firm and/or CEO, and SIC-year fixed effects. Across our first set of tests, specifications differ with respect to the measure of overconfidence (*Holder67*, *Holder67 Restriction*, *Longholder* and *Net Buyer*), the fixed effect structure and the use of different control variables.

Pooled results for the entire sample are presented in Table 4. In each panel, the dependent variable is each of the overconfidence measures. Across all panels, the fixed effects are consistent: in the first specification, we include only firm and year fixed effects; the second specification uses instead firm and sector fixed effects; and in the third to sixth specifications, we add CEO controls and variations of firm, year, sector and year-sector fixed effects.

We find that overconfident CEOs are significantly more likely to be part of a cartel in the following period. Except for the *Net Buyer* measure, the results hold in the

cross-section, as well as within-firm and sector-year, and are robust to the inclusion of a variety of controls. This implies support for the hypothesis that overconfident managers are more likely to engage in collusive behavior.

4.1.1 Time lag

In untabulated results, we examine the contemporaneous relationship between overconfidence and collusion. The results are similar to those described in table 4, but are, in general, of a smaller magnitude. This is particularly true for the two *Holder67* measures which capture short-term overconfidence.

4.1.2 Granger Causality

We develop our baseline estimations under the hypothesis that overconfidence affects cartel membership. Another possibility is that cartel membership instead affects the behavioral traits of CEOs and thus overconfidence. We assess this possibility by examining the lead-lag relations between cartel membership and overconfidence. We do so with variants on the following regression specifications:

$$\text{CARTEL}i, t+1 = \beta_1 overconfidence_{i,t} + \beta_2 \text{CARTEL}i, t + \mu_i + \tau_t + \varepsilon_{i,t}, \quad (2)$$

$$\text{CARTEL}i, t-1 = \beta_1 overconfidence_{i,t} + \beta_2 \text{CARTEL}i, t + \mu_i + \tau_t + \varepsilon_{i,t}. \quad (3)$$

If cartel membership pushes CEOs to be more overconfident, we would expect $overconfidence_t$ to be associated with CARTEL_{t-1}; if overconfidence pushes firms to collude, we would expect $overconfidence_t$ to be associated with $\text{CARTEL}t+1$. In Table 5 we present the results for the *Netbuyer* measure. We find that overconfidence explains future cartel participation, but not past cartel participation. These patterns hold with

or without controlling for contemporaneous overconfidence. Thus, overconfidence appears to "Granger cause" collusion and not the other way around.

4.1.3 Sector concentration

Table 6 [TBW]

4.2 Within-cartel overconfidence heterogeneity

[TBW]

4.3 Propensity Score Matching

Next, we apply a matching approach to find comparable "twins" among the firms with more or less overconfident CEOs. This approach allows us to compare the overconfidence of these pairs, which are as similar as possible regarding observable characteristics. To achieve this, we employ the nearest neighbor matching (NNM) method. NNM is a non-parametric method used to estimate the treatment effect of a particular variable — in this case, CEO overconfidence — by pairing each treated unit (firm with an overconfident CEO) with the closest untreated unit (firm with a less overconfident CEO) based on a set of covariates.

The proximity is measured using a propensity score, which represents the probability of a unit receiving the treatment given its observed characteristics. By matching firms based on their propensity scores, we ensure that the comparison between treated and untreated firms is made between units that are similar in terms of the covariates included in the propensity score model.

First, we estimate the propensity scores for all firms using a logistic regression model. The model includes the same CEO and firm controls of the baseline model

to capture all observable covariates that could influence the likelihood of a CEO being overconfident. Using the estimated propensity scores, we pair each treated firm (with an overconfident CEO) with the untreated firm (with a less overconfident CEO) with the closest propensity score and a maximal distance of 0.005. This one-to-one matching ensures that each treated firm has a comparable counterpart, creating pairs of firms that are similar in observable characteristics (the "twins").

After matching, we re-estimate our baseline estimates using the matched sample. This helps us assess whether the significant differences in overconfidence between the two types of firms persist even after controlling for observable characteristics. The results presented in the Appendix, Table 11 indicate that the significant differences in overconfidence between firms with more or less overconfident CEOs persist even after matching. Thus, the results remain consistent with our baseline estimates, showing the robustness of our findings.

To further evaluate the propensity score matching procedure, we show histograms of the propensity score matches for the treated and untreated groups. Figure 1 shows the histograms for the overconfidence measure *NetBuyer* respectively for each cartel outcome. The overconfidence measure $Longholder(T)$ is represented in Figure 2 in a similar manner. The x-axis represents 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 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 *NetBuyer* treatment, as well as for the cartel and cartel start outcomes in the *Longholder*(T) measure. This suggests that the matching works well for these outcomes. However, there are regions of poor matching for the treated groups (off-support). This means there is a treated observation without a corresponding untreated observation with a similar propensity score. This suggests potential issues with matching in these regions, and these off-support treated observations need to be excluded from the analysis to maintain the integrity of the matching process. The results of the estimation calculated without those observations remain similar to before and can be found in the Appendix, Table 12.

4.4 Propensity Score Matching Algorithm

[TBW]

5 Mechanism

In this paper, we are interested in empirically examining *whether overconfidence affects collusion*. In the previous sections we show that: (1) CEO overconfidence is structurally associated with collusive behavior, (2) convicted colluding managers are, on average, more overconfident than other managers, and (3) overconfidence granger causes collusion.

In this section, we discuss the different possible mechanisms driving the relationship.

The first result is in line with Geis (2017) who find that overconfident CEOs are overconfident about the likelihood of being caught. However, if overconfident managers expect to outperform their competitors, they may prefer to compete rather than

collude.

Two hypotheses arise regarding the direction of the effect. One hypothesis is that: (i) more overconfident managers are more likely to collude because they underestimate the risk of detection and the potential penalties and / or deviation from the cartel. A second hypothesis is that: (ii) colluding, which tends to lead to increased profits, may increase managerial overconfidence. This effect may become stronger as the duration of the cartel increases. Our third result shows that (i) dominates (ii).

Given these three results, we should also see a change in overconfidence over time during the cartel period. Therefore, we examine the effect of changes in CEO (in section 5.1) and the changes in overconfidence level (in section 5.2). Thus, we hypothesize that *managerial overconfidence in colluding firms (only) increases significantly during the cartel period.*

5.1 Changes in CEO

We test for the effect of CEO changes using variants on the following regression specification:

$$\text{CARTEL}_{i,t} = \beta \Delta \text{CEO}_{i,t-1} \times overconfidence_{i,t-1} + \mu_i + \tau_{j,t} + \varepsilon_{i,t}. \tag{4}$$

Thus, we interact a variable that measures CEO turnover with an overconfidence measure. We apply two versions of the CEO turnover variable. First, any turnover (voluntary and involuntary), and second, forced turnover. In the next step, we then extend the specification by considering the role of firm performance. Namely, we account for firms that have positive or negative sales growth at the time of the turnover event. This allows us to disentangle whether the potential change in cartelization is related to over-

confidence and CEO turnover or the change in firm performance.

The results of this exercise are shown in Table 7. We calculate the value of the added parts of the interaction term. This allows us to compare this with the individual coefficients of the turnover and overconfidence variable.

For the *Holder 67* variables in panels A and B, the coefficients are not statistically significant on conventional levels. However, the effects point towards a rather negative impact of CEO turnover on collusion.

Next, for the *NetBuyer* variable, the interaction term is negative and statistically significantly different from zero for the forced turnover events. The comparison with the isolated turnover and overconfidence variables implies that the effect is indeed higher in absolute terms when the old CEO was overconfident, and there was a turnover event.

Overall, we show that the forced turnover of an overconfident CEO makes collusion less likely. The effect might be attributed to changes in strategy, since it does not differ remarkably for the situation with a preceding decrease or increase in sales.

5.2 Change in overconfidence

We test for the effect of changes in overconfidence due to CEO changes using variants on the following regression specification:

$$\text{CARTEL}_{i,t} = \beta \Delta \text{CEO}_{i,t-1} \times overconfidence_{i,t-1} + \mu_i + \tau_{j,t} + \varepsilon_{i,t}. \tag{5}$$

We proceed similarly as described in Section 5.1 and interact the overconfidence measures with a set of CEO turnover indicators. However, in this part of the analysis, we want to shed light on whether collusion could be driven by a change in the overconfidence of the old and new CEO. Therefore, we first perform the regressions

to obtain baseline results. This is followed by restricting the post-turnover samples to either overconfident or not overconfident CEOs.

We present the results of this procedure in Table 8. The baseline estimates are similar to those presented previously. We, again, observe an insignificant effect for the *Holder 67* measures and also no effect, which is statistically significant on conventional levels for the *NetBuyer* measure when any turnover is considered. This pattern also does not change considerably if we consider whether the incoming CEO is overconfident or not.

When analyzing forced turnover, there is evidence of an effect on collusion that remains negative, as described above. Distinguishing between whether the new CEO is overconfident or not, we find that the effects do not differ to a large extent from each other. However, it seems that the effect of the lower likelihood of collusion is driven by the intersection of the overconfidence of the old CEO and forced turnover in the case that the new CEO is not overconfident (column 5). However, when the new CEO is overconfident, the negative effect is largely explained by the turnover event that might imply a strategy change to the firm (column 6).

5.3 Change in overconfidence, given cartel participation

The positive (interaction) effect described above is examined regardless of whether the firms participated in a (convicted) cartel. Two hypotheses are feasible. If firms are not in the cartel, they may fire the CEO for low performance, etc. However, if firms were in a cartel and fired the CEO, they may be trying to “clean up" the firm. In table 9, we try to disentangle this effect.

TBW

6 Conclusion

This paper analyses a potential relationship between overconfidence and collusion. Although there is already a broad literature on overconfidence in different contexts (e.g., Fischhoff et al. 1977, Lichtenstein et al. 1982, Lundeberg et al. 1994, Gervais and Odean 2001, Heaton 2002, Malmendier and Tate; Malmendier and Tate 2005; 2008, Pan and Statman 2012, Burks et al. 2013, Schrand and Zechman 2012, Pikulina et al. 2017), there is no clear evidence of the relationship between overconfidence and collusion.

To establish this relationship, we combine information on cartels, financial, compensation, position, and post-cartel career path data. With a sample of 11,450 firm-year observations from about 3000 firms, of which 76 have been convicted for collusion, we constructed four different measures for overconfidence.

We begin the analysis by showing that there is indeed a relationship between overconfidence and collusion. In the next step, we can confirm that the relationship is positive, since we find that overconfident managers are more likely to engage in collusive behavior. However, we also find that collusion is positively correlated with overconfidence. Thus, the next step implies diving deeper into the analysis to find the true direction of the effect. We distinguish the effect by testing the Granger causality. These results support the notion that overconfidence affects collusion and not vice versa.

The results have several implications. First, firms can consider the overconfidence bias in their hiring strategy, especially when collusion is undesirable. Second, competition authorities can use this relationship to detect cartels. Since managers who collude are more overconfident, a first step might be to screen firms with overconfident managers above the industry average. Third, they highlight the importance of CEOs

in firms' cartel participation decision, confirming once more the importance of focusing on corporate governance variables, shareholders and CEO incentives, in the fight against cartels.

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Appendix

Table 1: Summary statistics items

[TBW]

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: Overconfidence measures

	full sample		within cartel	
	overconfident=1	ov.=0	overconfident=1	ov.=0
Longholder(T)	8257	13059	302	170
	38.7%	61.3%	64.0%	36.0%
Netbuyer	14237	36297	411	447
	28.2%	71.8%	47.9%	52.1%
Holder67	6110	16098	27	28
	27.5%	72.5%	49.1%	50.9%
Holder67(R)	6107	16101	27	28
	27.5%	72.5%	49.1%	50.9%

Table 4: This table presents results on the relation between cartel membership and overconfidence measures, using variants on the regression specification: $\text{CARTEL}_{i,t} = \beta\, overconfidence_{i,t-1} + \mu_i + \tau_{j,t} + \varepsilon_{i,t}$

Panel A	[1]	[2]	[3]	[4]	[5]	[6]
Holder67_lag	0.007***	0.004**	0.005**	0.003*	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
logage			0.011*	0.021***	0.006	0.008
			(0.006)	(0.008)	(0.005)	(0.006)
logtenure			0.002*	0.001	0.001	0.001
			(0.001)	(0.001)	(0.001)	(0.001)
N	22,096	22,096	12,771	12,771	12,771	12,771
R-squared	0.027	0.013	0.032	0.014	0.111	0.040
Panel B	[1]	[2]	[3]	[4]	[5]	[6]
Holder67(R)_lag	0.007***	0.004**	0.005**	0.004**	0.004**	0.004**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
logage			0.011*	0.008	0.006	0.008
			(0.006)	(0.006)	(0.005)	(0.006)
logtenure			0.002*	0.001*	0.001	0.001*
			(0.001)	(0.001)	(0.001)	(0.001)
N	22,096	22,096	12,771	12,771	12,771	12,771
R-squared	0.027	0.013	0.032	0.040	0.111	0.040
Panel C	[1]	[2]	[3]	[4]	[5]	[6]
	N0	N1	N2	N3	N4	N5
Netbuyer_lag	0.002	0.010***	0.000	0.000	-0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
logage			0.022***	0.019**	0.016**	0.019**
			(0.008)	(0.008)	(0.008)	(0.008)
logtenure			-0.001	-0.002	-0.002	-0.002
			(0.002)	(0.002)	(0.002)	(0.002)
N	47,413	47,408	24,915	24,911	24,911	24,911
R-squared	0.019	0.020	0.028	0.040	0.082	0.040
Panel D	[1]	[2]	[3]	[4]	[5]	[6]
Longholder(T)_lag	0.041***	0.045***	0.045***	0.047***	0.044***	0.046***
	(0.013)	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)
logage			0.109**	0.105**	0.106**	0.106**
			(0.046)	(0.046)	(0.046)	(0.046)
logtenure			-0.014**	-0.014**	-0.013**	-0.013**
			(0.006)	(0.006)	(0.006)	(0.006)
N	9,681	9,681	8,674	8,674	8,674	8,674
R-squared	0.010	0.027	0.018	0.036	0.052	0.037
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 5: 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 4, but uses future CARTEL and prior CARTEL as the dependent variables.

	$CARTEL_{t+1}$	$CARTEL_{t-1}$	$CARTEL_{t+1}$	$CARTEL_{t-1}$	$CARTEL_{t+1}$	$CARTEL_{t-1}$
netbuyer	0.002***	0.001	0.002***	0.001	0.002***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$CARTEL_t$	0.910***	0.948***	0.911***	0.949***	0.908***	0.946***
	(0.010)	(0.008)	(0.011)	(0.009)	(0.012)	(0.010)
N	47,409	47,408	39,133	39,139	34,788	35,094
R-squared	0.866	0.866	0.867	0.867	0.862	0.856
CEO controls	no	no	no	no	yes	yes
firm controls	no	no	yes	yes	yes	yes
sector controls	yes	yes	yes	yes	yes	yes

Table 6: This table presents results on the relation between cartel membership and overconfidence, split by industry concentration.

	Concentrated		Non-concentrated	
Panel A	[1]	[2]	[3]	[4]
Holder67_lag	0.009*	0.009*	0.006	0.005
	(0.005)	(0.005)	(0.004)	(0.004)
N	8728.000	8728.000	7417.000	7417.000
R-squared	0.032	0.040	0.034	0.048
Panel B	[1]	[2]	[3]	[4]
Holder67(R)_lag	0.009*	0.009*	0.006	0.006
	(0.005)	(0.005)	(0.004)	(0.004)
N	8728.000	8728.000	7417.000	7417.000
R-squared	0.032	0.014	0.034	0.019
Panel C	[1]	[2]	[3]	[4]
NetBuyer_lag	-0.000	0.005**	0.004	0.016***
	(0.002)	(0.002)	(0.004)	(0.005)
N	18850.000	18846.000	16076.000	16076.000
Panel D	[1]	[2]	[3]	[4]
Longholder(T)_lag	0.062***	0.065***	0.004	0.005
	(0.017)	(0.017)	(0.013)	(0.013)
N	5559.000	5559.000	3115.000	3115.000
R-squared	0.037	0.058	0.012	0.030
concentration	high	high	low	low
CEO controls	yes	yes	yes	yes
firm controls	yes	yes	yes	yes
year FE	yes		yes	
sector FE		yes		yes

Table 7: 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)
	Cartel (t)					
Turnover type	Any turnover ($t-1$)			Forced turnover ($t-1$)		
		Sales growth ($t-2$)			Sales growth ($t-2$)	
		Negative	Positive		Negative	Positive
Panel A: Holder 67						
Overconfidence$_{t-1}$	-0.000	-0.002	0.000	-0.000	-0.002	0.001
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Turnover$_{t-1}$	-0.001	-0.002	-0.000	-0.001	-0.002	-0.001
	(0.001)	(0.003)	(0.000)	(0.001)	(0.002)	(0.001)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.004	0.002	0.006	-0.001	-0.000	-0.001
	(0.004)	(0.002)	(0.007)	(0.001)	(0.003)	(0.001)
Sum of coefficients of interaction term	0.003	-0.003	0.005	-0.002	-0.004	-0.001
	(0.004)	(0.003)	(0.006)	(0.002)	(0.005)	(0.001)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.360	0.805	0.350	0.575	0.548	0.594
Sum vs. Overconfidence (p-value)	0.447	0.664	0.429	0.144	0.594	0.172
R-squared	0.014	0.035	0.013	0.014	0.035	0.012
Observations	7087	1992	5095	7087	1992	5095
Panel B: Holder 67 restricted						
Overconfidence$_{t-1}$	-0.000	-0.002	0.000	-0.000	-0.002	0.001
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Turnover$_{t-1}$	-0.001	-0.002	-0.000	-0.001	-0.002	-0.001
	(0.001)	(0.003)	(0.000)	(0.001)	(0.002)	(0.001)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.004	0.002	0.006	-0.001	-0.000	-0.001
	(0.004)	(0.002)	(0.007)	(0.001)	(0.003)	(0.001)
Sum of coefficients of interaction term	0.003	-0.003	0.005	-0.002	-0.004	-0.001
	(0.004)	(0.003)	(0.006)	(0.002)	(0.005)	(0.001)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.360	0.805	0.350	0.575	0.548	0.594
Sum vs. Overconfidence (p-value)	0.447	0.664	0.429	0.144	0.594	0.172
R-squared	0.014	0.035	0.013	0.014	0.035	0.012
Observations	7087	1992	5095	7087	1992	5095
Panel C: Netbuyer						
Overconfidence$_{t-1}$	-0.001	0.005	-0.003	-0.001	0.004	-0.003
	(0.003)	(0.006)	(0.003)	(0.002)	(0.005)	(0.003)
Turnover$_{t-1}$	-0.001	-0.007**	0.002	-0.000	-0.005	0.004
	(0.003)	(0.003)	(0.004)	(0.006)	(0.004)	(0.010)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.005	-0.010	-0.004	-0.018**	-0.020*	-0.020*
	(0.008)	(0.012)	(0.009)	(0.007)	(0.011)	(0.011)
Sum of coefficients of interaction term	-0.007	-0.012	-0.005	-0.019***	-0.021***	-0.019***
	(0.006)	(0.008)	(0.006)	(0.005)	(0.008)	(0.005)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.377	0.540	0.408	0.007	0.038	0.040
Sum vs. Overconfidence (p-value)	0.369	0.131	0.785	0.000	0.015	0.001
R-squared	0.047	0.056	0.048	0.047	0.056	0.049
Observations	11044	2933	8111	11044	2933	8111
Panel D: Longholder (T)						
Overconfidence$_{t-1}$	0.020	0.028	0.020*	0.017	0.026	0.017
	(0.013)	(0.021)	(0.012)	(0.013)	(0.020)	(0.012)
Turnover$_{t-1}$	0.014	-0.010	0.029*	0.027	0.014	0.049
	(0.011)	(0.011)	(0.017)	(0.030)	(0.015)	(0.051)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.035*	-0.034	-0.043*	-0.062*	-0.070**	-0.076
	(0.019)	(0.023)	(0.026)	(0.033)	(0.034)	(0.049)
Sum of coefficients of interaction term	-0.001	-0.016	0.006	-0.018	-0.030	-0.011
	(0.015)	(0.015)	(0.020)	(0.013)	(0.023)	(0.013)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.432	0.686	0.397	0.135	0.099	0.223
Sum vs. Overconfidence (p-value)	0.172	0.018	0.463	0.023	0.027	0.036
R-squared	0.084	0.095	0.092	0.084	0.093	0.091
Observations	2648	829	1819	2648	829	1819

Note. 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 8: The impact of CEO turnover and overconfidence on cartel formation - considering the overconfidence of the next CEO

Outcome	(1)	(2)	(3)	(4)	(5)	(6)
	Cartel (t)					
Turnover type	Any turnover ($t-1$)			Forced turnover ($t-1$)		
		Next CEO overconfident (t)			Next CEO overconfident (t)	
		No	Yes		No	Yes
Panel A: Holder 67						
Overconfidence$_{t-1}$	0.000	-0.001	0.001*	0.001	-0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Turnover$_{t-1}$	-0.001	-0.001	-0.000	-0.001	-0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.003	0.002	0.003	-0.001	0.001	-0.002
	(0.004)	(0.002)	(0.004)	(0.001)	(0.001)	(0.002)
Sum of coefficients of interaction term	0.002	-0.000	0.004	-0.002	-0.001	-0.001
	(0.004)	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.361	0.324	0.298	0.536	0.878	0.652
Sum vs. Overconfidence (p-value)	0.598	0.322	0.589	0.057	0.932	0.115
R-squared	0.012	0.021	0.020	0.012	0.021	0.019
Observations	7866	5186	3034	7866	5186	3034
Panel B: Holder 67 restricted						
Overconfidence$_{t-1}$	0.000	-0.001	0.001*	0.001	-0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Turnover$_{t-1}$	-0.001	-0.001	-0.000	-0.001	-0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.003	0.002	0.003	-0.001	0.001	-0.002
	(0.004)	(0.002)	(0.004)	(0.001)	(0.001)	(0.002)
Sum of coefficients of interaction term	0.002	-0.000	0.004	-0.002	-0.001	-0.001
	(0.004)	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.361	0.325	0.298	0.536	0.877	0.652
Sum vs. Overconfidence (p-value)	0.598	0.323	0.588	0.057	0.929	0.115
R-squared	0.012	0.021	0.020	0.012	0.021	0.019
Observations	7866	5188	3032	7866	5188	3032
Panel C: Netbuyer						
Overconfidence$_{t-1}$	-0.001	-0.000	-0.001	-0.001	0.000	-0.002
	(0.003)	(0.003)	(0.006)	(0.002)	(0.002)	(0.005)
Turnover$_{t-1}$	-0.001	-0.001	0.000	-0.000	0.004	-0.017***
	(0.003)	(0.002)	(0.009)	(0.005)	(0.007)	(0.006)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.003	0.002	-0.008	-0.016***	-0.016**	0.002
	(0.007)	(0.008)	(0.013)	(0.006)	(0.007)	(0.008)
Sum of coefficients of interaction term	-0.005	0.000	-0.008	-0.017***	-0.012***	-0.017***
	(0.004)	(0.007)	(0.007)	(0.004)	(0.004)	(0.006)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.497	0.869	0.427	0.005	0.026	0.971
Sum vs. Overconfidence (p-value)	0.418	0.944	0.318	0.000	0.001	0.018
R-squared	0.044	0.042	0.077	0.045	0.042	0.077
Observations	13617	9691	3926	13617	9691	3926
Panel D: Longholder (T)						
Overconfidence$_{t-1}$	0.018	-0.009*	0.010	0.014	-0.013***	-0.000
	(0.012)	(0.006)	(0.009)	(0.011)	(0.004)	(0.014)
Turnover$_{t-1}$	0.021*	0.010	0.036	0.021	0.020	0.006
	(0.012)	(0.011)	(0.030)	(0.026)	(0.028)	(0.028)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.045**	-0.016	-0.052	-0.053*	-0.019	-0.038
	(0.018)	(0.014)	(0.036)	(0.029)	(0.028)	(0.036)
Sum of coefficients of interaction term	-0.007	-0.015***	-0.006	-0.018*	-0.011	-0.032
	(0.013)	(0.006)	(0.018)	(0.011)	(0.008)	(0.026)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.133	0.042	0.279	0.148	0.257	0.289
Sum vs. Overconfidence (p-value)	0.046	0.438	0.409	0.018	0.883	0.166
R-squared	0.097	0.156	0.076	0.095	0.156	0.075
Observations	3163	2104	1426	3163	2104	1426

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

Outcome	(1)	(2)	(3)	(4)	(5)	(6)
	Cartel (t)					
Turnover type	Any turnover ($t-1$)			Forced turnover ($t-1$)		
		In cartel ($t-1$)			In cartel ($t-1$)	
		No	Yes		No	Yes
Panel A: Holder 67						
Overconfidence$_{t-1}$	0.000	-0.000	-	0.001	-0.000	-
	(0.001)	(0.000)	-	(0.001)	(0.000)	-
Turnover$_{t-1}$	-0.001	-0.000	-	-0.001	-0.000	-
	(0.001)	(0.000)	-	(0.001)	(0.000)	-
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.003	0.000	-	-0.001	0.000	-
	(0.004)	(0.000)	-	(0.001)	(0.000)	-
Sum of coefficients of interaction term	0.002	-0.000	-	-0.002	-0.000	-
	(0.004)	(0.001)	-	(0.001)	(0.001)	-
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.361	0.362	-	0.536	0.633	-
Sum vs. Overconfidence (p-value)	0.598	0.912	-	0.057	0.889	-
R-squared	0.012	0.005	-	0.012	0.005	-
Observations	7866	7846	20	7866	7846	20
Panel B: Holder 67 restricted						
Overconfidence$_{t-1}$	0.000	-0.000	-	0.001	-0.000	-
	(0.001)	(0.000)	-	(0.001)	(0.000)	-
Turnover$_{t-1}$	0.003	0.000	-	-0.001	0.000	-
	(0.004)	(0.000)	-	(0.001)	(0.000)	-
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	0.003	0.002	-	-0.001	0.001	-
	(0.004)	(0.002)	-	(0.001)	(0.001)	-
Sum of coefficients of interaction term	0.002	-0.000	-	-0.002	-0.000	-
	(0.002)	(0.000)	-	(0.001)	(0.000)	-
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.361	0.362	-	0.536	0.632	-
Sum vs. Overconfidence (p-value)	0.598	0.923	-	0.057	0.888	-
R-squared	0.012	0.005	-	0.012	0.005	-
Observations	7866	7846	20	7866	7846	20
Panel C: Netbuyer						
Overconfidence$_{t-1}$	-0.001	0.001	-0.013	-0.001	0.000	-0.011
	(0.003)	(0.001)	(0.063)	(0.002)	(0.001)	(0.061)
Turnover$_{t-1}$	-0.001	-0.001**	-0.035	-0.000	-0.000	-0.515
	(0.003)	(0.000)	(0.170)	(0.005)	(0.000)	(0.386)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.003	-0.001*	0.027	-0.016***	-0.002*	-0.130
	(0.007)	(0.001)	(0.216)	(0.006)	(0.001)	(0.404)
Sum of coefficients of interaction term	-0.005	-0.002**	-0.021	-0.017***	-0.002**	-0.656***
	(0.004)	(0.001)	(0.135)	(0.004)	(0.001)	(0.202)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.497	0.059	0.947	0.005	0.032	0.727
Sum vs. Overconfidence (p-value)	0.418	0.006	0.953	0.000	0.017	0.001
R-squared	0.044	0.010	0.452	0.045	0.010	0.478
Observations	13617	13459	158	13617	13459	158
Panel D: Longholder (T)						
Overconfidence$_{t-1}$	0.018	0.001	-0.012	0.014	0.001	0.007
	(0.012)	(0.002)	(0.060)	(0.011)	(0.002)	(0.053)
Turnover$_{t-1}$	0.021*	-0.002	0.007	0.021	-0.000	-0.319
	(0.012)	(0.001)	(0.115)	(0.026)	(0.002)	(0.363)
Overconfidence$_{t-1}$ × Turnover$_{t-1}$	-0.045**	-0.003	-0.246	-0.053*	-0.002	-0.557
	(0.018)	(0.002)	(0.324)	(0.029)	(0.003)	(0.362)
Sum of coefficients of interaction term	-0.007	-0.003**	-0.251	-0.018**	-0.002	-0.869***
	(0.013)	(0.002)	(0.30)	(0.011)	(0.002)	(0.127)
Comparison of 'Sum of coefficients of interaction term' with individual coefficients of interaction term						
Sum vs. Turnover (p-value)	0.133	0.214	0.436	0.148	0.439	0.128
Sum vs. Overconfidence (p-value)	0.046	0.036	0.444	0.018	0.222	0.000
R-squared	0.097	0.018	0.751	0.095	0.018	0.788
Observations	3163	3076	87	3163	3076	87

Note. 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 10: The impact of CEO turnover and overconfidence on cartel formation - considering cartel participation in the last year

	(1)	(2)
Outcome	Cartel (t)	
Turnover type	Any turnover $(t-1)$	Forced turnover $(t-1)$
Panel A: Netbuyer		
$\text{Overconfidence}_{t-1}$	-0.000	-0.001
	(0.001)	(0.001)
Turnover_{t-1}	-0.001**	-0.000
	(0.000)	(0.001)
$\text{Overconfidence}_{t-1} \times \text{Turnover}_{t-1}$	-0.001	-0.002**
	(0.001)	(0.001)
Cartel_{t-1}	0.777***	0.791***
	(0.043)	(0.042)
$\text{Overconfidence}_{t-1} \times \text{Cartel}_{t-1}$	0.074	0.053
	(0.059)	(0.056)
$\text{Turnover}_{t-1} \times \text{Cartel}_{t-1}$	0.077	-0.298
	(0.137)	(0.352)
$\text{Overconfidence}_{t-1} \times \text{Turnover}_{t-1} \times \text{Cartel}_{t-1}$	-0.203	-0.542
	(0.200)	(0.353)
Sum of coefficients of interaction term (Cartel_{t-1} yes)	0.722***	0.001
	(0.138)	(0.002)
Sum of coefficients of interaction term (Cartel_{t-1} no)	-0.003***	-0.003***
	(0.001)	(0.001)
Comparison of 'Sum of coefficients of interaction term' with each other (p-value)	0.000	0.086
R-squared	0.728	0.733
Observations	13617	13617

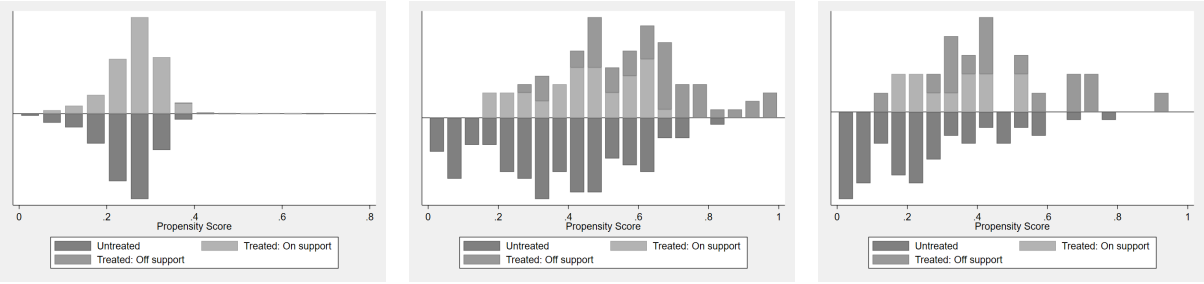
Note. Standard errors clustered at the firm level are in parentheses. Significance: * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 11: Propensity score matching

	(1) Cartel	(2) Cartel start	(3) Cartel end
Panel A: Netbuyer_lag			
Overconfidence	0.010***	-0.023	0.000
	(0.003)	(0.060)	(0.159)
Firm controls	Yes	Yes	Yes
CEO controls	Yes	Yes	Yes
FE Industry	Yes	Yes	Yes
FE Year	No	No	No
R-squared	0.002	0.002	0.000
Observations	6728	86	24
Panel B: Longholder[T]_lag			
Overconfidence	0.045***	0.009***	-
	(0.005)	(0.002)	-
Firm controls	Yes	Yes	-
CEO controls	Yes	Yes	-
FE Industry	Yes	Yes	-
FE Year	Yes	Yes	-
R-squared	0.010	0.002	-
Observations	7920	7332	-

Note. This table shows the estimation results of a linear regression model of equation (1). The measure of interest 'netbuyer' and 'Longholder[T]' are described in Section 3.3. The first 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 (columns 1). The outcome in column (2) is an indicator 'Cartel start' that takes the value one for a firm that is part of a collusive agreement at the point in time when the collusive agreement started. For column (3), the outcome is an indicator 'Cartel end' that takes the value one for a firm that is part of a collusive agreement at the point in time when the last period of a collusive agreement is reached. Controls are applied as described in Section 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 industry 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. Note that no results could be obtained for 'Cartel end' in Panel B Longholder[T]_lag due to a lack of observations.

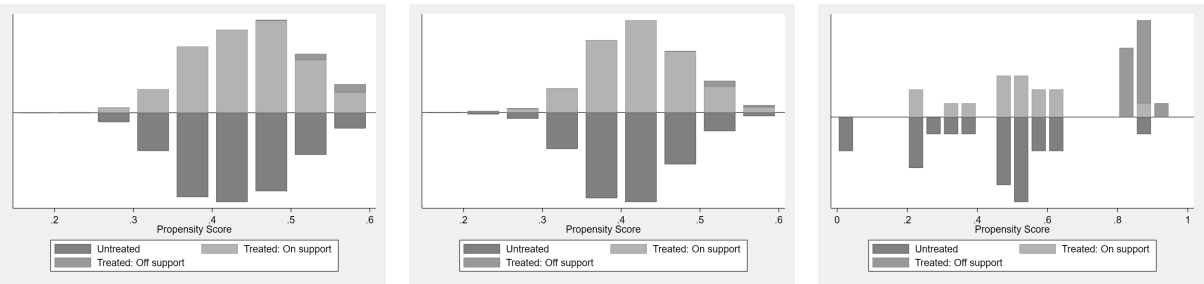
Figure 1: Propensity score matching for netbuyer_lag



Cartel **Cartel start** **Cartel end**

Note. This figure shows the propensity scores for the measure netbuyer_lag. The x-axis represents 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 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.

Figure 2: Propensity score matching for Longholder[T]_lag



Cartel **Cartel start** **Cartel end**

Note. This figure shows the propensity scores for the measure longholder[T]_lag. The x-axis represents 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 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.

Table 12: Propensity score matching without off-support observations

	(1) Cartel	(2) Cartel start	(3) Cartel end
Panel A: Netbuyer_lag			
Overconfidence	0.010***	-0.023	0.000
	(0.003)	(0.060)	(0.159)
Firm controls	Yes	Yes	Yes
CEO controls	Yes	Yes	Yes
FE Industry	Yes	Yes	Yes
FE Year	No	No	No
R-squared	0.002	0.002	0.000
Observations	6728	86	24
Panel B: Longholder[T]_lag			
Overconfidence	0.045***	0.010***	-
	(0.005)	(0.002)	-
Firm controls	Yes	Yes	-
CEO controls	Yes	Yes	-
FE Industry	Yes	Yes	-
FE Year	Yes	Yes	-
R-squared	0.010	0.003	-
Observations	7920	7128	-

Note. This table shows the estimation results of a linear regression model of equation (1). The measure of interest 'netbuyer' and 'Longholder[T]' are described in Section 3.3. The first 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 (columns 1). The outcome in column (2) is an indicator 'Cartel start' that takes the value one for a firm that is part of a collusive agreement at the point in time when the collusive agreement started. For column (3), the outcome is an indicator 'Cartel end' that takes the value one for a firm that is part of a collusive agreement at the point in time when the last period of a collusive agreement is reached. Controls are applied as described in Section 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 industry 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. Note that no results could be obtained for 'Cartel end' in Panel B Longholder[T]_lag due to a lack of observations.

Table 13: Leniency applicants

	within cartel		Leniency reporters	
	overconfident=1	ov.=0	overconfident=1	ov.=0
Longholder(T)	302	170	23	27
	64%	36%	46%	54%
Netbuyer	411	447	67	72
	48%	52%	48%	52%

Appendix B: Alternative *Longholder* measure, using ComputStat data

Table 14: Overconfidence measures

	full sample		within cartel	
	overconfident=1	ov.=0	overconfident=1	ov.=0
Longholder	9455	32386	28	802
	22.6%	77.4%	0.3%	96.6%
Longholder(T)	8257	13059	302	170
	38.7%	61.3%	64.0%	36.0%
Netbuyer	14237	36297	411	447
	28.2%	71.8%	47.9%	52.1%
Holder67	6110	16098	27	28
	27.5%	72.5%	49.1%	50.9%
Holder67(R)	6107	16101	27	28
	27.5%	72.5%	49.1%	50.9%

Table 15: This table presents results on the relation between cartel membership and overconfidence measures, using variants on the regression specification: $\text{CARTEL}_{i,t} = \beta\, overconfidence_{i,t-1} + \mu_i + \tau_{j,t} + \varepsilon_{i,t}$

Panel A	[1]	[2]	[3]	[4]	[5]	[6]
Longholder_lag	0.002	-0.008**	0.004	0.004	0.004	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
logage			0.028***	0.024***	0.021**	0.024***
			(0.009)	(0.009)	(0.009)	(0.009)
logtenure			-0.002	-0.002	-0.003	-0.002
			(0.002)	(0.002)	(0.002)	(0.002)
N	39,200	39,195	20,174	20,170	20,170	20,170
R-squared	0.018	0.020	0.029	0.041	0.082	0.041
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	