Does the Board of Directors Learn from Short Sellers?

Evidence from CEO Turnovers[1]

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Abstract

We provide evidence that the board of directors learns about CEO quality from information contained in short sales: Forced CEO turnover is positively related to short interest even when controlling for a range of other firm performance indicators. The sensitivity is higher in firms with more independent boards. Using an instrumental variable approach, we show that there is a negative feedback effect from CEO turnover probability to short selling. A negative feedback loop is consistent with short sellers incorporating that boards learn from their information. The results suggest that short selling can benefit the real economy by providing information to decision makers.

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1 Introduction

The discussion on the merits and dangers of short selling has not been resolved so far. Most researchers emphasize the necessity of short sales for price efficiency, while the public is much more concerned about a possible destabilizing influence on markets and the real economy. Similarly, a growing literature in finance on the real effects of financial markets argues that price efficiency and real efficiency are not necessarily the same if markets do not provide information to guide real decision makers (Bond, Edmans, and Goldstein, 2012). Research has shown that short sales improve price efficiency, since they accurately predict future values of securities (Boehmer and Wu, 2013; Cohen, Diether, and Malloy, 2007; Diether, Lee, and Werner, 2009; Desai et al., 2002). Yet so far, research on the informational content of short selling to real decision makers is scarce. In line with Bond, Edmans, and Goldstein, 2012, we analyze whether short selling provides information to decision makers and thereby positively affects the efficiency of the real economy.

In this paper, we investigate whether short sales contain information that is used by the board of directors when deciding whether to retain or fire the CEO. We use short interest as a publicly observable signal of short selling activity in a particular stock. Using a sample of 2,059 voluntary and 711 forced CEO turnovers in 2,801 firms from 1993 to 2015, we analyze whether short interest provides additional information to boards on top of common measures of firm performance, most prominently idiosyncratic stock returns.[4] We measure the sensitivity of CEO turnover to short interest using semi-parametric and parametric hazard models, a probit model, and a linear probability model.

By looking at short sales as a market signal for firm performance, we can empirically test the predictions of the model by Bond, Goldstein, and Prescott, 2010. According to their equilibrium model on corrective actions, if economic agents learn from the market and the market is forward looking, then the market should incorporate the agents' use of its information in current prices. That is, if the future value of an asset increases due to a value enhancing corrective action, then the market should incorporate this change in future value. We use an instrumental variable estimation to address this possible feedback effect on short interest. Thus, we are able to disentangle the effect of short selling on CEO turnover from the feedback effect of the corrective action on the level of short selling. To the best of our

[4] The classification on forced and voluntary turnovers stems from Jenter and Kanaan (2015) and Peters and Wagner (2014). We thank Dirk Jenter for providing us with this data.

knowledge, we are the first to empirically document this effect with respect to CEO turnover decisions.

Our results show that there is a significantly positive sensitivity of forced CEO turnover to short selling, dominating the feedback effect. Higher levels of short interest signal lower future firm performance and, therefore, are associated with an increase in the probability of forced CEO turnovers. In this first step, we do not control for a possible feedback effect. Using a Cox hazard model, a CEO in a firm with short interest in the 90th percentile faces a 42% higher probability of being fired in the next month than a CEO in a firm in the 10^{th} percentile. The linear probability models and the probit models provide the same qualitative results although they are not equally fit to estimate the probability of failure over time.

As with stock returns and other firm performance measures, these results do not allow a causal inference. The association between short interest and CEO turnover does not necessarily arise because boards learn about the CEO's ability from short selling. For example, an alternative explanation could be that the board does not react to short selling but rather that both the board and the short sellers react to the same information on future firm performance. To gather more evidence for the conjecture that boards actually learn from short selling, we first analyze whether short sellers incorporate an increased probability on forced turnover. Second, we test whether the effect of short selling on CEO turnover is more pronounced in firms in which boards rely more on public information.

If boards learn from short sellers, then the probability of forced CEO turnover should increase with short-selling. However, following Bond, Goldstein, and Prescott, 2010, if firing the CEO is in shareholders' interests, then an increase in the probability of a forced turnover should, at the same time, increase the future value of the firm. This, in turn, should lead to a decrease of short interest. In a simple OLS regression, we would thus underestimate the effect of short interest on forced CEO turnover. Conversely, accounting for the reverse causality should result in a higher coefficient estimate. When using instrumental variable regressions, we can see that there is indeed a negative feedback loop of the probability of forced CEO turnover on short selling. In line with our predictions, the coefficient on short selling increases by more than threefold. The results support the conjecture that the board learns about CEO ability from negative information from short interest, causing the probability of a turnover to increase, which in turn decreases short interest.

We furthermore reason that if boards use short interest as a public signal of (low) CEO quality, then the effect should be stronger for firms where boards have less access to

private information. Following Ravina and Sapienza, 2010 and Weisbach, 1988, we assume independent directors on average have less private information about the firm than non-independent directors. Therefore, all else equal, the sensitivity to short interest should be higher in firms with more independent boards. In line with this argument, we find that the effect is concentrated in firms with more independent boards.

Our study contributes to the literature on how short selling influences firm behavior. Most closely related to our paper are He and Tian, 2014 and Massa, Zhang, and Zhang, 2013. He and Tian, 2014 use a policy change as an exogenous change in short selling constraints. Regulation SHO temporarily removed the uptick rule for a random sample of Russell 3000 firms. The uptick rule restricts shorting to be at an "uptick", that is, at a price above the last trading price. They find that the removal of these constraints leads to an increase in innovation. The authors propose that the *threat* of short selling has a disciplining effect on managers. Similarly, Massa, Zhang, and Zhang, 2015 argue that short selling disciplines managers, causing them to reduce earnings management. The argument in Massa, Zhang, and Zhang, 2013 differs from the argument in He and Tian, 2014 by claiming that the threat of short selling changes the existing shareholders' incentives for monitoring, leading shareholders to increase internal corporate governance.

Our paper differs from these papers in that in our setting we do not examine *potential* short selling and how this threat influences decision making but rather we look at the informational content in *actual* short selling and how this information is used in the decision to retain or fire a CEO. In our study, we argue that the board learns from short sales whereas the previous studies focus on short selling as a disciplining mechanism for managers. A similar argument is used by He and Tian, 2014 as an alternative explanation to their findings. In this alternative explanation they argue that managers may be better able to learn from a firm's stock price because it is more efficient if there are fewer constraints on short selling.

2 Background and Hypothesis development

In this chapter, we review past literature on short selling to derive our main hypothesis that short selling provides information on CEO quality. We then argue that there is a negative feedback loop between short selling and CEO turnover. Last, we derive a setting in which, if our main hypothesis holds, we think short selling will be most important.

Short selling is a likely medium to obtain information on the quality of the CEO and the firm-CEO match because of three reasons: It is available, it is informative, and it provides the information in a timely manner.

First, information from short sales is available because these transactions happen very frequently and are by no means rare events. Boehmer, Jones, and Zhang, 2008 find that from 2000 to 2014, short sales amounted to more than 12.9% of NYSE trading volume. Further, the amount of short sales is publicly available information. The total number of a stock's shorted shares on one specific day during the month is publicly reported by the exchanges. Taking these to facts together, short sales can make information publicly observable.

Second, Diamond and Verrecchia, 1987 give theoretical reasoning that all else equal, short sellers should be more informed than other sellers. This is because short sellers are unlikely to trade out of liquidity reasons. Due to requirements by brokerage firms and regulators, short sellers cannot consume the proceeds of a short sale immediately. Instead, the proceeds must be kept on deposit to secure the broker in the case of default of the short seller (Boehmer, Jones, and Zhang, 2008). Institutional traders account for the majority of short sales. These traders acquire information through costly research (Boehmer, Jones, and Zhang, 2008). Those few individual traders that sell short (1% to 2% of NYSE trading volume) are likely endowed with negative private information, e.g., due to being connected to the firm (Boehmer, Jones, and Zhang, 2008). Corporate insiders, although forbidden to short the stock of their own firm, may still short other firms in the industry. This is another indication that short sellers are likely to be more informed than the average trader.

Several studies find empirical support that short sellers act on value relevant information that has not yet been incorporated into prices. Short-selling activity predicts negative future returns controlling for standard firm characteristics such as size, book-to-market, and turnover as well as when controlling for order imbalances (Boehmer, Jones, and Zhang, 2008; Desai et al., 2002; Cohen, Diether, and Malloy, 2007). Importantly, the negative returns are unlikely to be due to price manipulations or overreactions of other market participants to short selling since there is no evidence of reversals (Boehmer, Jones, and Zhang, 2008).

Moreover, short selling carries information on future *negative* events. A number of studies find that short sales can predict negative events such as negative earnings surprises (Christophe, Ferri, and Angel, 2004), earnings restatements (Desai, Krishnamurthy, and Kumar, 2006), downward revisions in analyst earnings forecasts, and negative public news in the media (Akbas et al., 2016).

Third, short selling is even more relevant to the decision of CEO turnovers since the information it carries covers a long time horizon. Boehmer, Jones, and Zhang, 2008 report that the short sale flow remains informative up to 3 months and Akbas et al., 2016 claim that

abnormal short interest predicts negative events as far as 12 months into the future. In sum, observing short interest can be a useful signal in the CEO turnover decision as it provides information about future declines in firm performance before this information is incorporated into prices.

This leads to our first hypothesis that short selling conveys information relevant for the board's directors to update its beliefs on the quality of the CEO-firm match or CEO ability beyond the information in stock prices.

Furthermore, following Bond, Goldstein, and Prescott, 2010, we argue there is a fundamental challenge to finding the true relation between short sales as a forward looking measure of firm value and CEO turnover in the data. Short-interest may exhibit a *trigger effect*, whereby high levels of short interest signal low CEO quality, leading the board to fire the CEO. Yet at the same time, firing a bad CEO increases firm value (Demerjian, Lev, and MacVay, 2012; Huson, Malatesta, and Parrino, 2004). Since short interest is forward looking, short interest should incorporate a change in the probability of a CEO turnover in the future. If the CEO turnover is value-enhancing, an increase in its probability should *decrease* short interest, causing an *anticipation effect* (compare to Edmans, Goldstein, and Jiang, 2012; Bradley et al., 2010.) Thus, failing to account for the dual causality will produce an endogeneity problem, such that the empirical results appear as just a weak relation between short interest and CEO turnover. Therefore, we predict a negative feedback loop from forced CEO turnover to short interest. This causes us to underestimate the coefficient on short interest, if we do not account for the negative feedback effect. Consequently, we predict that when controlling for this feedback loop sensitivity of forced CEO turnover to short interest increases.

Next, we explore our proposed mechanism more closely by analyzing situations in which we expect the effect to be stronger if our arguments holds true. Since the board cannot observe the CEO's ability directly, it has to learn about it from different sources over time (Weisbach, 1988). Independent directors have less private information about the firm then executive or grey directors, CEO ability, and the firm-CEO match. Hence, they have to rely more heavily on public information to learn about CEO ability and decide whether to retain or to replace a CEO. We therefore propose that the association between short interest and forced CEO turnover should be stronger in firms with more independent boards. If the board of directors and short sellers were merely reacting to the same private information to the firm, we would not expect this relationship. If the less informed boards react more strongly to short interest, then this finding would contradict the argument that the board of directors and short

sellers are reacting to the same private information. Instead, one would expect those boards with more private information to have a stronger correlation with short selling. Once could argue that a stronger effect in boards with more independent investors could also be a sign of less entrenchment of the CEO. Therefore, a more detailed analysis is needed.

Lastly, the argument that board of directors and short sellers are reacting to the same information suggests an omitted variable problem. We control for a number of publicly available firm performance measures that are also associated with common short selling strategies. Dechow et al., 2001 find that short selling is higher in firms with high earnings-to-price and book-to-market ratios. These variables also contain information on the performance of the firm, the management quality, and its future growth options. Therefore, they may also be informative about CEO ability and constitute omitted variables. We therefore control for them in all of our regressions. Moreover, short sellers can profit more during high market uncertainty and in firms where there is a larger dispersion in opinion (Cohen, Diether, and Malloy, 2007; Boehmer, Jones, and Zhang, 2008). Both of these characteristics could potentially be related with a higher probability of CEO turnover. We therefore also control for these variables.

3 Data Sources, Sample Construction, and Variable Definitions

In this paper, we use a 1993 to 2015 Execucomp sample to study the sensitivity of forced CEO turnover to short interest. We merge this with data accounting and security information from COMPUSTAT and CRSP, as well as information on analyst forecasts from I/B/E/S. We now briefly describe the individual data sources and our final sample.

Our turnover data comes from two sources. For the Execucomp sample from 1993 to 2009, we received information on turnovers and the exact announcement dates from Jenter and Kanaan, 2015 and Peters and Wagner, 2014. In addition, received information on whether the turnover was forced or voluntary according to the classification scheme in Parrino, 1997. We augmented their data by collecting the same information for 80% of the remaining turnovers from 2010 until 2015. We observe a turnover for each year in which the person classified as CEO in Execucomp changes. We subsequently search LexisNexis for the exact date on which the turnover was announced and classify each turnover as voluntary or forced according to Parrino, 1997. We classify turnovers for which we do not have the necessary information on the reason for departure as voluntary.

We classify a turnover as forced if the press reports that the CEO is fired, forced out, retires or resigns due to policy differences or pressure. If the press does not report any of

these reasons and the CEO is above 59 years old, we classify the turnover as voluntary. We review turnovers of CEOs under 60 years old further. We first check whether the press reports death, poor health, or the acceptance of another position as the reason for departure. If so, we classify the turnover as voluntary. If the CEO is younger than 60 years old and the press reports none of the above reasons, then we classify the turnover as forced. The departure is also classified as forced if CEO age is below 60 and retirement was not announced at least six months before the turnover. We use this detailed classification scheme to account for the fact that CEOs are rarely openly fired. The data excludes turnovers related to mergers and spin-offs.

We collect data on monthly short interest from the "Supplemental Short Interest File" in COMPUSTAT. Short-interest depicts the open short positions in a particular stock on the last business day on or before the 15th of each calendar month. We assign this value to the calendar month in which we observe it.

We gather all accounting data as well as data on options outstanding from COMPUSTAT and all stock return information from CRSP monthly stock files. We use the VIX index provided by the Chicago Board Options Exchange as a volatility index. Further, we obtain the number of analysts following the firm as well as data on analyst dispersion from I/B/E/S. Execucomp provides data on CEO age and share ownership. Moreover, we use the information given by ISS on director independence. We classify firms into industries using the Fama and French 48 industry classification. Next, we exclude all firms in the category "Other" and CEOs who were in office for less than 12 months.

We further drop any observations for which any of this information is missing from our sample. The final sample consists of 28,520 firm-years. The Appendix contains all variable definitions.

4 Empirical results

The following section describes our empirical results. Identifying the sensitivity of forced turnover to short interest poses an empirical challenge. As outlined in Section 2, there is likely a feedback effect from CEO turnover to short interest. This section outlines our empirical approach to solving this problem. We begin in Section 4.1 by providing an overview of the variables in our dataset. To better understand the behavior of short interest around forced and voluntary turnovers, Section 4.2 describes short interest levels over time. In Section 4.3 we analyze the sensitivity of CEO turnover to short interest using simple OLS and probit regressions. We find a significant positive association even when controlling for

various other performance benchmarks. These analyses treat each observation as independent in the sense that the time dependence of a turnover as well as the censoring of our data is not taken into account. In Section 4.4, we therefore estimate the turnover sensitivity to short interest using hazard models. In Section 4.5, we finally address the feedback loop by using an instrument for short interest. As expected, we find a negative feedback loop and larger coefficients than in the one-stage models from Section 4.3. Finally in Section 4.6, we analyze whether the effect is concentrated in certain types of firms.

4.1 Descriptive Statistics

Table 1 Panel A shows the frequencies of forced and voluntary turnovers in our sample. Our sample contains 711 forced and 2,059 voluntary turnovers. Overall, 9.89% of all firm-years are turnover years. These make up 2.06% and 7.22% of all firm years, respectively. Panel B shows the cumulative stock return and average short interest over the 12 months preceding a forced turnover. As in Jenter and Kanaan, 2015, average cumulative stock return is lowest 12 months before the CEO is dismissed (-14.52%) and highest if there is no turnover (17.77%). The stock return is somewhat lower before voluntary turnovers (11.40%). What we observe is therefore inconsistent with the notion that voluntary turnovers are completely independent from performance. If voluntary turnovers are not related to bad performance, we would, by definition, not expect a difference between the years in which a CEO is retained and the years in which there is a voluntary turnover. The difference in our sample likely arises because of misclassification of forced turnovers as voluntary turnovers. The number of forced turnovers is probably downward biased since CEOs are rarely overtly fired. Similar to the pattern we found for stock returns, we obtain the highest mean and median short interest values in the 12 months before a CEO is dismissed (4.72% and 3.06%).

Table 2 contains descriptive statistics for all of our variables. Following Jenter and Kanaan, 2015, we decompose a firm's stock performance into a systematic component caused by the industry performance and an idiosyncratic component. To do so, we regress a firm's cumulative stock return in the 12 months preceding a turnover on the average value-weighted industry return over the same period. We exclude each sample firm from its own industry benchmark. In unreported results, significance levels and coefficients in these regressions are very similar to the results found by Jenter and Kanaan, 2015.

4.2 Short-selling around CEO turnovers

We begin our analysis of forced CEO turnovers and the relation to short interest by looking at the behavior of short interest around forced turnovers. Figure 1 reports the average short interest, starting 36 months before and ending 36 months after forced and voluntary turnovers in our sample. Since the average short interest increases over time and differs across firms in our sample, we use the residuals from a regression of raw short interest on firm and month fixed effects.

The average short interest is higher in firms with forced turnovers than in firms with voluntary turnovers, over almost the whole period of 72 months around the turnover. There is a steady incline in short interest leading up to the forced turnover in month 0. The increase is steepest from around 17 to 3 months before the dismissal. There is another small increase just after the announcement. This could be due to remaining uncertainty regarding the replacement of the CEO. Then average short interest declines again to around its original level around 3 years before the announcement. This matches the level in firms with voluntary turnover.

For firms with voluntary turnovers we do not find a peak at the turnover month. Instead, short interest remains mostly stable over the 36 pre-turnover and post-turnover months. The values for voluntary turnovers may be biased towards the values for forced turnovers, since some forced turnovers may be falsely classified as voluntary turnovers. This is due to firms rarely openly firing their CEOs. This figure provides suggestive evidence that an increase in short interest precedes forced turnovers.

4.3 Short-interest as a predictor of CEO turnover

We now turn to a more economically rigorous analysis of the relations between short interest and forced CEO turnover. The underlying model is a latent variable model:

$$Turnover^*_{i,t} = \beta ShortInterest_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$Turnover_{i,t} = 1[Turnover^*_{i,t} > 0] \quad (2)$$

The subscripts *i* and *t* index for firm and year, respectively. $Turnover^*_{i,t}$ denotes a latent variable for the propensity of firm *i* to replace its CEO in year *t*. $1[\cdot]$ denotes an indicator function which takes on the value 1 if the latent turnover propensity variable passes the threshold of 0. Therefore, $Turnover_{i,t}$ is the observed binary outcome summarizing whether the CEO was fired or not. Because $Turnover^*$ is an unobserved latent variable, we use a probit model in order to restrict the turnover probability to the open unit interval. We

also estimate the model using a linear probability model. Because it estimates constant effects, it can sometimes be a convenient approximation of the effect around the center of the sample distribution. In our case, the linear probability model predicts negative values for 21% of the observations. These values lie out of the unit interval. We will, therefore, focus on the probit model and only return to the linear probability model for robustness.

$X_{i,t}$ contains a vector of control variables. We want to measure the predictive probability of short interest for CEO turnover on top of what is already predicted by other public performance indicators such as the firm's idiosyncratic return as well as its book-to-market and earnings-to-price ratios. These variables are also known to be related to higher levels of short interest (Dechow et al., 2001). Hence, we try to control for any possibly firm performance measures. Further, we control for industry performance, because past literature has documented a positive correlation between industry performance and forced CEO turnover (Jenter and Kanaan, 2015). To control for the market quality or the public information present in the market, we include controls for the dispersion in analyst forecasts and the number of analysts following a firm. Furthermore, we use a dummy for whether the CEO is older than 63 years old to account for likely retirements and another dummy for CEOs with a high amount of equity ownership (more than 5%) to account for the alignment of manager and shareholder interests. In addition, we try to control for the varying probability of turnover over the time that a CEO holds his position by including tenure as a control variable.

Table 3 presents the coefficient estimates for the linear probability model in Panel A. Panel B reports the estimates of the probit model. In line with our expectations, the coefficient on short interest is significantly positive across all specifications. Higher short interest should signal a worse firm-CEO match quality and, therefore, be associated with a higher probability of forced turnover. As indicated by the coefficient estimates in Column 1 of Panel B, the predicted probability of a forced CEO turnover when all values are set at their means is only 1.63%. An increase in short interest from the 10^{th} to the 90^{th} percentile raises the probability of a forced turnover by approximately 50% from 1.39% to 2.09%. As such, the predictive power of short interest is of larger magnitude than the effect of industry performance (32%). Column 2 of Panel B adds year fixed effects to control for time trends in short interest and CEO turnovers, and Colum 3 additionally includes industry fixed effects to consider firm heterogeneity across industries. The coefficient of short interest decreases slightly compared to the specification in Column 1 but is still significantly positive at the 1%

level. Its magnitude of 1.41 implies that an increase in short interest from the 10th to the 90th percentile raises the probability of a forced turnover by 40% from 1.26% to 1.77%. [5]

When comparing the effects estimated by the linear model in Column 3 of Panel A to the effect estimated by the probit model in Column 3 of Panel B, we notice that the effect of a one standard deviation increase in short interest is considerably larger in the linear than in the probit model when estimated at the mean (0.47 vs. 0.23 percentage points). The effect from the linear model becomes more comparable to the probit model when we consider values of short interest outside of the actual range of our sample. Since the probit model is better equipped to model a relationship with a binary dependent variable, we conclude that the linear probability model does not estimate the true relationship well, not even at the center of our value range.

Both the linear and the probit model cannot adequately describe a standard learning model where boards learn about CEO quality *over time*. We try to mitigate this problem by controlling for tenure in both models. This assumes a linear influence of time, which the models do not imply. Moreover, our sample is right-truncated because we do not observe dismissal for all (and actually most) CEOs. We therefore turn to duration analysis in the next chapter, which is more suitable to modeling the time until an event occurs.

4.4 Hazard models

In line with Jenter and Kanaan, 2015, we argue that survival models are best suited to model forced CEO turnover. In contrast to linear models, this type of analysis can manage a binary outcome variable. In contrast to index models, such as the probit model used here, survival analysis takes into account how time affects the probability of a forced CEO turnover and how the covariates affect this time. Moreover, they are better equipped to deal with the right censoring in the data.

Survival analysis is typically used to model time to event data. Survival models estimate hazard rates, that is, the probability that a forced turnover will occur in the next month, conditional on the CEO having remained in office until this point in time. As such, these models take into account the time that has already passed. We use two proportional hazard models to estimate how short selling affects the time it takes for a CEO to be fired. In these models, the baseline probability of failure that is common to all individuals is

[5] In unreported results, we also replicate the specification of Jenter and Kanaan (2015). The coefficients of our control variables are all comparable with their results. We use a probit model instead of a logit model because we will later perform a two-stage procedure not possible with logit models.

multiplied by a function of the covariates, meaning that the individual hazard functions differ proportionally. Specifically, we model the hazard as:

$$h_i(t) = h_0(t)\exp(x_j\beta_x) \tag{3}$$

Where $h_0(t)$ denotes the baseline hazard. We use a parametric (Weibull model), where we assume a baseline hazard of the form

$$h_0(t) = pt^{p-1}\exp(\beta_0)\,. \tag{4}$$

In addition, we use a semi-parametric specification (Cox model), where we leave the baseline hazard unspecified. The former has the advantage that we can make predictions about the actual time until the event occurs. The latter has the advantage that we do not impose a specific distributional form on the distribution of time since the literature provides little evidence to this question.[6] We obtain the same qualitative results for both models. In either case, we treat voluntary turnovers as right-censored observations.

Table 4 shows the results of the Cox and the Weibull model. Columns 1 and 2 show the results using the same specifications as Jenter and Kanaan, 2015. Short interest has a highly significant positive effect on the hazard rate, that is, approximately the probability that a forced turnover will occur in the next month, conditional on the CEO having remained in office until this point in time. In Column 1, an increase from the 10th to the 90th percentile in short interest increases the hazard rate by 67%.[7] Columns 3 and 4 display the results of a more restrictive specification, controlling for additional potential cofounding effects. For the more restrictive specification, the hazard rate is 58% (53%) higher for firms in the 90th percentile than for firms in the 10th percentile of the average short interest distribution according to the Cox (Weibull) model.

In summary, we find a significant and sizable effect of short interest on the probability of forced CEO turnover even when controlling for a wide range of determinants of short interest and other determinants of forced CEO turnover. Most importantly, short interest predictives CEO dismissal even when controlling for idiosyncratic stock returns, which is the most important and strongest predictor of forced CEO turnover in the literature so far. Yet, as with stock returns, the relationship is merely a correlation. Moreover, coefficient estimates so far do not take into account a possible feedback effect from the probability of forced turnover

[6] Lee, Matsunaga, and Park (2012) assume that CEOs with shorter tenure are more vulnerable to being fired based on signals of poor performance because they have had less time to influence board composition. Taylor (2010) estimates different hazard rates over survival time depending on the total costs of CEO dismissal and the variance of CEO ability of replacement CEOs.

[7] This effect is larger than the effect for the industry performance reported by Jenter and Kanaan (2015).

to short interest. Such a feedback effect would lend evidence that the board uses information from short interest and that this is again taken into account by short sellers. We will analyze this mechanism in the following section.

4.5 The dual relation between short-selling and CEO turnovers

The results in Section 4.3 show that short interest is a predictor of CEO turnover. However, the above specification likely underestimates the effect. If investors know that higher levels of short interest lead to an increase in the probability of a forced turnover, they should decrease their short positions in anticipation of higher future performance in response to this corrective action (Bond, Goldstein, and Prescott, 2010).

We follow Bradley et al., 2010, for our empirical specification. Hence, we add equation (5) to equations (1) and (2):

$$ShortInterest_{i,t} = \mu_1 X_{i,t} + \mu_2 Z_{i,t} + \eta_t + \omega_{i,t} \quad (5)$$

$X_{i,t}$ is a vector of variables that affect both the probability of a CEO turnover and short interest. $Z_{i,t}$ is a vector of instrumental variables that only affect short interest directly.

A key feature of the model is that an unobserved shock in $Turnover$ may negatively affect the residual short interest (i.e., $\rho = corr(\varepsilon_{i,t}, \omega_{i,t-1}) \leq 0$). This reflects the fact that shocks to the likelihood of a forced CEO turnover may be observed by market participants, in turn, affecting the amount of short interest.

The model outlined above implies a feedback loop between the probability of a CEO turnover and short-selling. Therefore, it falls within the class of probit models with an endogenous continuous variable. However, in this case two endogenous variables cannot be solved as linear functions of exogenous variables, so that the conventional instrumental variable method does not apply. To analyze each effect separately, we follow the approach used by Bradley et al., 2010. We deploy a two-stage conditional maximum likelihood (2SCML) method.[8] Again to ease interpretation and check for the robustness of our results, we also estimate a linear model using 2SLS.

We use two instruments for short interest. The first instrument is share turnover, which we measure as the average monthly trading volume divided by shares outstanding in year *t* (D'Avolio, 2002). In order to close her short position, a short-seller has to deliver the specific security that she initially borrowed and sold short. The easier a security can be

[8] Untabulated results using the method proposed by Rivers and Vuong (1988) yield similar results. Where the approach by Rivers and Vuong (1988) has computational advantages it is less efficient than the maximum likelihood procedure we use.

bought and sold, the easier it can be bought back at the desired point in time (Boehmer, Jones, and Zhang, 2008). Therefore, the higher the ex-ante known liquidity of the security, the more willing the speculator is to sell the security short. Hence, if a short-seller has price relevant negative information, she will be more likely to trade on this information if the security has a higher share turnover.

However, share turnover may also be higher in case where there is a larger uncertainty or differences in opinion in the market. This, in turn, may be connected to forced CEO turnover. We control for this effect using lagged analyst dispersion and the VIX-index. Conditional on these two variables, share turnover should therefore only influence forced CEO turnover through its influence on short interest. We lag share turnover one year relative to short interest to avoid potential simultaneity.

Following Karpoff and Lou, 2010, our second instrument is a dummy variable that indicates whether a company has listed options outstanding in a given year *t*. Again, options decrease the costs of shorting by providing an easy hedging possibility. Accordingly, Diether, Malloy, and Scherbina, 2002 find a positive relationship between short selling and the availability of options.

Table 5 shows the results of the first stage regressions of short interest on the two instruments and a vector of control variables. The instruments are statistically significantly different from zero and have the predicted signs: higher *Average share turnover* and *Option* are both associated with higher *short interest*. Since the instruments can still be weak (Staiger and Stock, 1997), we additionally test for weak instruments using the weak-identification test by the Stock and Yogo, 2005. The hypothesis tested is that the maximum bias due to weak instruments relative to the OLS estimator is larger than a certain threshold. In all of our specifications, the test statistic is well above the critical values, rejecting the hypothesis that the maximal bias is above 10% of the OLS estimator (untabulated). We conclude that our instruments meet the relevance condition.

We tabulate the results of the 2SLS and 2SCML estimations in Panel A and B of Table 6, respectively. The Hansen J statistic for the test of overidentifying restrictions cannot reject the null that the instruments are valid in any of the specifications in Table 6. We treat this as evidence in favor of our instruments satisfying the exclusion restriction. The estimations presented in this table now control for the simultaneity of short interest. Similar to the linear probability model in Section 4.3, 2SLS is not well suited to estimate the exact size of the effect for two reasons: first, it does not restrict the dependent variable to be within the unit interval. Second, it cannot effectively handle the censoring of observations. Still, we include

it because it is easy to interpret, well researched, and may offer a rough estimate of the effect. The first specification in Panel A, Column 1 includes all control variables but no fixed effects. In Column 2, we add year fixed effects and in Column 3 year and industry fixed effects. As predicted, the coefficient on short interest is positively significant at the 1%-level in all specifications. The coefficient on our most restrictive specification implies an increase in the probability of CEO dismissal of 1.4% for a one standard deviation increase in short interest. This implies more than a 50% increase in the probability of forced CEO turnover. More importantly when comparing the coefficients in Table 6 to the coefficients from the OLS estimates in Table 3, all coefficients approximately triple. In line with our theoretical predictions, we seem to have underestimated the true relation between short interest in the OLS regression.

Panel B of Table 6 displays the estimation results for different specifications of the 2SCML model. Similar to the probit model in Section 4.3, the 2SCML has the advantage that it can estimate relationships with a binary dependent variable. As for the 2SLS model, Column 1 displays a specification without any fixed effects, Column 2 includes year fixed effects, and Column 3 year and industry fixed effects. Again, the coefficient on short interest is positive and significant. The coefficient in the strictest specification implies an increase in the probability of turnover from 1.00 % to 2.60 % when moving from the 10th to the 90th percentile of short interest. Moreover, when comparing the coefficients in Panel B of Table 6 to the coefficients of the corresponding specifications of the probit estimation in Table 3, the coefficient more than doubles in Columns 1 and 3 and more than triples in Column 2. We estimate the implied correlation between the two error disturbances of equation (1) and (5), $\rho = corr(\varepsilon_{i,t}, \omega_{i,t-1})$ to be -0.0949. As expected, the correlation is negative, implying a negative feedback effect between the probability of CEO dismissal and short interest. Accordingly, using the Wald test of exogeneity, we can reject the null hypothesis that short interest is exogenous to CEO turnover at the 10% level.

So far, we have presented evidence that there is a predictive relationship between the level of short interest in a firm and the probability of forced CEO turnover. Furthermore, there seems to be a negative feedback loop between the probability of forced CEO turnover and short interest. When controlling for this feedback loop by using instrumental variables, the relationship between short interest and forced turnover increases. We propose this is because the board learns from high short interest levels by increasing the probability of a forced turnover. Short sellers in turn anticipate this increased probability by decreasing their

short positions. This can be interpreted as evidence in favor of a dual relationship between market information and the real behavior of firms. Not only do firms learn from the information in the markets, but the market in turn also anticipates this learning effect and incorporates it into its own behavior.

4.6 How informed is the board and its effect of short-selling sensitivity

In this section, we want to provide further evidence in favor of the idea that boards in fact react to the information contained in short interest levels instead of merely reacting to the same information as short sellers. If this hypothesis is true, we reason that boards with less private information should be more inclined to react to the public information about CEO quality. In other words, if a board has less private information, then short sellers should have more incremental information and thus we should see a greater sensitivity of the probability of forced CEO turnover to short interest in these boards. If boards merely react to the same information as short sellers, i.e., this information functions as an omitted variable, we would be more likely to anticipate the opposite effect. That is, the decisions of firms with more informed boards should be more closely aligned with short interest, and thus, the correlation should be stronger within these firms.

Following Ravina and Sapienza, 2010 and Cornelli and Karakas 2015, we propose that independent directors have less private information about the ability of the CEO. Therefore, boards with a high percentage of independent directors should be less informed and therefore react more strongly to short interest. We test this hypothesis in Table 7. The coefficient on the interaction of board independence and short interest is positive and marginally significant in all models except for in the probit model with firm and industry fixed effects in Column 4. This finding is in line with the conjecture that boards with less private information learn more from short interest.

5 Conclusion

In this paper we show that short interest predicts forced CEO turnover even when controlling for a number of other known predictors of forced turnover, such as firm stock price performance. This is an example of how real decision makers learn from the information contained in the market. Moreover, by using an instrumental variable approach, we are able to show that there is a negative feedback effect between short interest and forced CEO turnover. This provides an example for the results from the model by Bond, Goldstein,

and Prescott, 2010 that the market anticipates reactions from firm decision makers and in turn incorporates these actions into its own behavior.

Appendix

Variable name	Definition
Forced	A dummy indicating a forced turnover according to the classification by Parrino, 1997.
Short-interest	Monthly short interest (in% of shares outstanding) averaged over one year, i.e. from month t-1 to month t-12.
Option	A dummy indicating that the firm has outstanding options at the end of the prior fiscal year.
Book-to-market	Book-to-market ratio = (book value of common equity/ market value of common equity) at the end of the prior fiscal year. For further details see Dechow et al, 2001.
Analyst dispersion	Monthly standard deviation of 1-year earnings forecasts from the IBES summary file, averaged over one year, i.e. from month t-1 to month t-12.
Analyst following	Monthly number of analysts following from IBES summary file for 1-year earnings forecasts, averaged over one year, i.e. from month t-1 to month t-12.
Average VIX	Monthly VIX from the CBOE, averaged over one year, i.e. from month t-1 to month t-12.
Earnings-to-price	Earnings-to-price ratio = (operating income before depreciation / market value of common equity) at the end of the prior fiscal year. For further details see Dechow et al., 2001.
Log(Assets)	Log of total assets at the end of the prior fiscal year.
Idiosyncratic stock return	Cumulative idiosyncratic return (residuals from a regression of firm stock returns on a value-weighted industry return over one year, i.e. from month t-1 to month t-12). For further details see Jenter and Kanaan, 2015.
Industry stock return	Industry return (predicted values from a regression of firm stock returns on a value-weighted industry return over one year, i.e. from month t-1 to month t-12). For further details see Jenter and Kanaan (2015).
CEO of retirement age	A dummy indicating whether the CEO is over 63 years old in year t.
CEO with high equity ownership	A dummy indicating whether CEO equity ownership is high, i.e. the CEO owns more than 5% of all outstanding shares in year t.
Tenure	Tenure of the CEO, measured in months.
Board Independence	A dummy indicating whether the board is independent, i.e. more than 75% of all directors are classified as independent by ISS.

7 References

Akbas, F., Boehmer, E., Erturk, B., Sorescu, S., 2016. Short Interest, Returns, and Information. Financial Management, n/a.

Boehmer, E., Jones, C.M., Zhang, X., 2008. Which Shorts Are Informed? Journal of Finance 63 (2), 491–527.

Boehmer, E., Wu, J., 2013. Short Selling and the Price Discovery Process. Review of Financial Studies 26 (2), 287–322.

Bond, P., Edmans, A., Goldstein, I., 2012. The Real Effects of Financial Markets. Annual Review of Financial Economics 4 (1), 339–360.

Bond, P., Goldstein, I., Prescott, E.S., 2010. Market-Based Corrective Actions. The Review of Financial Studies 23 (2), 781–820.

Bradley, M., Brav, A., Goldstein, I., Jiang, W., 2010. Activist arbitrage: A study of open-ending attempts of closed-end funds. Journal of Financial Economics 95 (1), 1–19.

Christophe, S.E., Ferri, M.G., Angel, J.J., 2004. Short-Selling Prior to Earnings Announcements. The Journal of Finance 59 (4), 1845–1876.

Cohen, L., Diether, K.B., Malloy, C.J., 2007. Supply and Demand Shifts in the Shorting Market. The Journal of Finance 62 (5), 2061–2096.

D'Avolio, G., 2002. The market for borrowing stock. Limits on Arbitrage 66 (2–3), 271–306.

Dechow, P.M., Hutton, A.P., Meulbroek, L., Sloan, R.G., 2001. Short-sellers, fundamental analysis, and stock returns. Journal of Financial Economics 61 (1), 77–106.

Demerjian, P., Lev, B., MacVay, S., 2012. Quantifying Managerial Ability: A New Measure and Validity Tests. Management Science 58 (7), 1229–1248.

Desai, H., Krishnamurthy, S., Kumar, V., 2006. Do Short Sellers Target Firms with Poor Earnings Quality? Evidence from Earnings Restatements. Review of Accounting Studies 11 (1), 71–90.

Desai, H., Ramesh, K., Thiagarajan, S.R., Balachandran, B.V., 2002. An Investigation of the Informational Role of Short Interest in the Nasdaq Market. Journal of Finance 57 (5), 2263–2287.

Diamond, D.W., Verrecchia, R.E., 1987. Constraints on short-selling and asset price adjustment to private information. Journal of Financial Economics 18 (2), 277–311.

Diether, K.B., Lee, K.-H., Werner, I.M., 2009. Short-Sale Strategies and Return Predictability. Review of Financial Studies 22 (2), 575–607.

Diether, K.B., Malloy, C.J., Scherbina, A., 2002. Differences of Opinion and the Cross Section of Stock Returns. Journal of Finance 57 (5), 2113–2141.

Edmans, A., Goldstein, I., Jiang, W., 2012. The Real Effects of Financial Markets: The Impact of Prices on Takeovers. Journal of Finance 67 (3), 933–971.

He, J., Tian, X., 2014. Short Sellers and Innovation: Evidence from a Quasi-Natural Experiment. SSRN Electronic Journal.

Huson, M.R., Malatesta, P.H., Parrino, R., 2004. Managerial succession and firm performance. Journal of Financial Economics 74 (2), 237–275.

Jenter, D., Kanaan, F., 2015. CEO Turnover and relative performance evaluation. Journal of Finance LXV (5), 1879–1913.

Karpoff, J.M., Lou, X., 2010. Short Sellers and Financial Misconduct. Journal of Finance 65 (5), 1879–1913.

Lee, S.S., Matsunaga, S.R., Park, C.W., 2012. Management Forecast Accuracy and CEO Turnover. Accounting Review 87 (6), 2095–2122.

Massa, M., Zhang, B., Zhang, H., 2013. Governance through threat: Does short selling improve internal governance?

Massa, M., Zhang, B., Zhang, H., 2015. The Invisible Hand of Short Selling: Does Short Selling Discipline Earnings Management? Review of Financial Studies 28 (6), 1701–1736.

Parrino, R., 1997. CEO turnover and outside succession A cross-sectional analysis. Journal of Financial Economics 46 (2), 165–197.

Peters, F.S., Wagner, A.F., 2014. The Executive Turnover Risk Premium. Journal of Finance 69 (4), 1529–1563.

Ravina, E., Sapienza, P., 2010. What Do Independent Directors Know? Evidence from Their Trading. Review of Financial Studies 23 (3), 962–1003.

Rivers, D., Vuong, Q.H., 1988. Limited information estimators and exogeneity tests for simultaneous probit models. Journal of Econometrics 39 (3), 347–366.

Staiger, D., Stock, J.H., 1997. Instrumental Variables Regression with Weak Instruments. Econometrica 65 (3), 557–586.

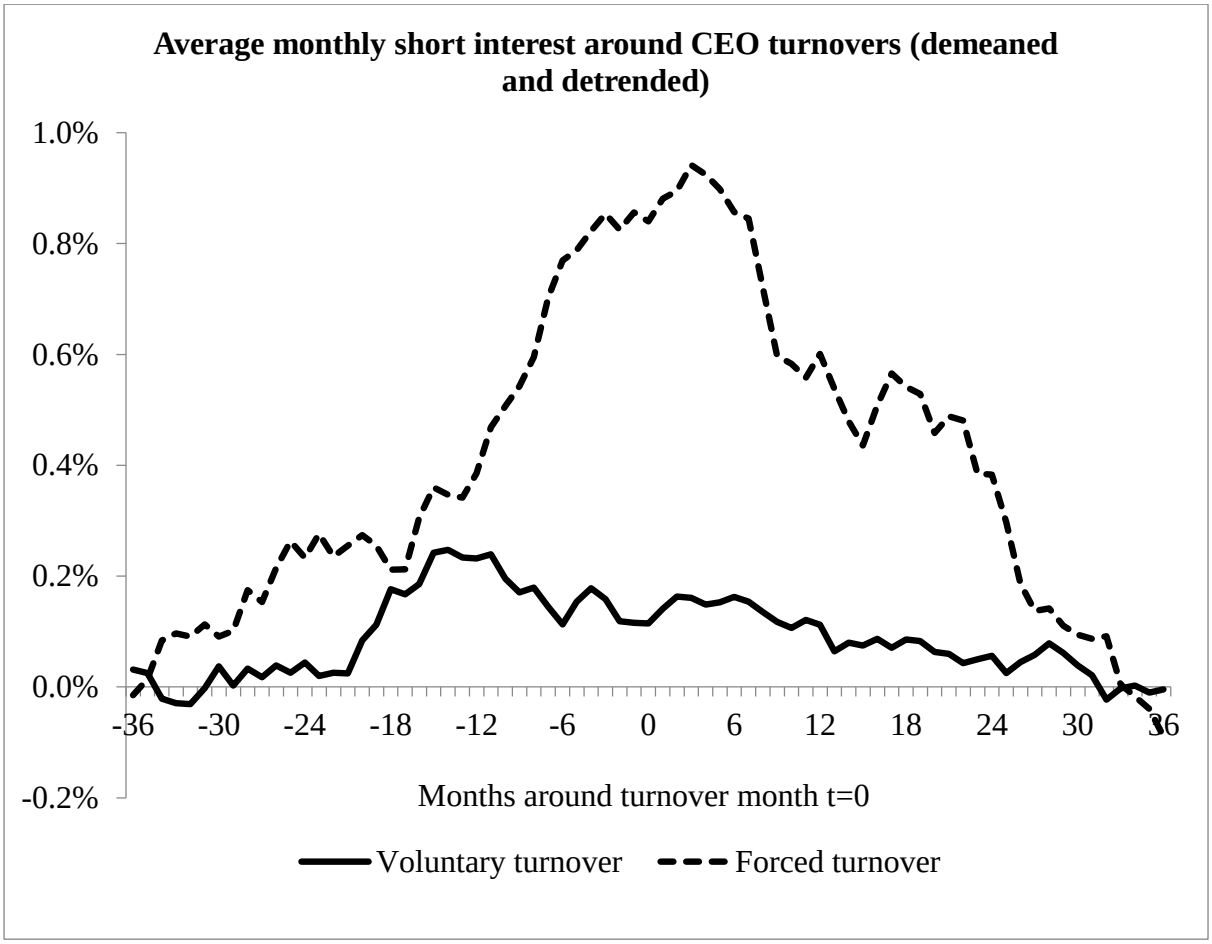
Stock, J.H., Yogo, M., 2005. Testing for Weak Instruments in Linear IV Regression. In: Andrews, D.W.K., Stock, J.H. (Eds.), Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg. Cambridge University Press, Cambridge, pp. 80–108.

Taylor, L.A., 2010. Why Are CEOs Rarely Fired? Evidence from Structural Estimation. Journal of Finance 65 (6), 2051–2087.

Weisbach, M.S., 1988. Outside directors and CEO turnover. Journal of Financial Economics 20, 431–460.

Figures

Figure 1: Short interest around CEO turnovers. Figure 1 reports the average short interest demeaned with respect to the firm average and detrended monthly, starting 36 months before and ending 36 months after forced and voluntary turnovers in our sample. The sample includes US firms in the S&P1500 index from 1993 to 2015 for which we found information on all variables.



Tables

Table 1: Turnover distributions. Panel A reports the frequencies of forced and voluntary turnovers in our sample. The sample includes US firms in the S&P1500 index from 1993 to 2015 for which we found information on all variables. Panel B reports stock returns and short interest by CEO turnover outcome. The Appendix contains all variable definitions.

Panel Á:

Number of Firm-Years	Number of Forced CEO Turnovers	Number of Voluntary CEO Turnovers	% of Firm-Years with at Least One CEO Turnover	% of Firm-Years with at Least One Forced CEO Turnover	% of Firm-Years with at Least One Vountary CEO Turnover
28,520	711	2,059	9.71%	2.49%	7.22%

Panel B:

Variable	CEO Is Retained	Voluntary CEO Turnover	CEO Is Dismissed
Cumulative stock return in the 12 months before the CEO turnover	17.77%	11.40%	-14.52%
	[11.14%]	[6.75%]	[-16.38%]
Average short interest in the 12 months before the CEO turnover	3.60%	3.29%	4.72%
	[2.10%]	[1.84%]	[3.06%]

Table 2: Descriptive Statistics. Table 2 provides descriptive statistics for the variables used in the regressions in this paper. The Appendix contains all variable definitions. The sample includes US firms in the S&P1500 index from 1993 to 2015 for which we found information on all variables. The table reports the number of observations, the mean, the median, the standard deviation (SD), as well as the 25th and 75th percentile of each distribution.

Variable	N	Mean	Median	SD	p25	p75
Average short-interest	28520	0.04	0.02	0.04	0.01	0.05
Average share turnover	28520	0.18	0.13	0.15	0.07	0.23
Option	28520	0.67	1.00	0.47	0.00	1.00
Average analyst dispersion	28520	0.13	0.03	0.33	0.02	0.08
Analyst following	28520	10.94	9.17	7.19	5.25	15.17
Average VIX	28520	20.32	21.59	6.38	14.07	24.73
Earnings-to-price	28520	0.15	0.13	0.29	0.08	0.19
Book-to-market	28520	0.50	0.43	0.53	0.27	0.65
Assets	28520	12513	1585	72833	514	5634
Idiosyncratic stock return	28520	-0.01	-0.06	0.55	-0.26	0.15
Average industry stock return	28520	0.17	0.16	0.23	0.05	0.28
Tenure (months)	28520	95.54	72.00	92.73	36.00	131.00
CEO age	28520	55.92	56.00	7.36	51.00	61.00
CEO with high equity ownership	28520	0.11	0.00	0.32	0.00	0.00
Board independence	20190	0.25	0.00	0.43	0.00	1.00

Table 3: CEO turnover sensitivity to short interest. This table reports coefficient estimates for different estimation procedures of Eq. (1). Panel A reports the coefficients of linear probability model estimates. Panel B reports the coefficients of probit model estimates. Short interest, idiosyncratic and industry stock returns are measured from twelve months to one month before a turnover or the fiscal year end if there wasn't a turnover. We measure all other variables at the last known date before the turnover or the fiscal year end. The Appendix contains all variable definitions. The table reports *t*- and *z*-statistics in parentheses. Standard errors are robust and clustered by industry. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A:

	(1)	(2)	(3)
Model:	LPM	LPM	LPM
Average short interest (t-12,t-1)	0.1216***	0.1085**	0.1122***
	(3.31)	(2.46)	(2.85)
Idiosyncratic stock return (t-12,t-1)	-0.0239***	-0.0246***	-0.0242***
	(-7.34)	(-7.35)	(-7.30)
Average industry stock return (t-12,t-1)	-0.0012	-0.0037	-0.0103
	(-0.24)	(-0.61)	(-1.63)
CEO of retirement age	-0.0170***	-0.0169***	-0.0158***
	(-8.69)	(-9.06)	(-8.80)
CEO with high equity ownership	-0.0134***	-0.0131***	-0.0150***
	(-5.43)	(-5.24)	(-5.80)
Tenure (months)	-0.0000***	-0.0000***	-0.0000***
	(-3.21)	(-3.26)	(-3.11)
Average analyst dispersion (t-12,t-1)	0.0172***	0.0180***	0.0187***
	(3.02)	(3.13)	(3.34)
Average VIX (t-12, t-1)	0.0004*	0.0001	-0.0000
	(2.01)	(0.13)	(-0.07)
Analyst following	0.0000	0.0001	-0.0003
	(0.01)	(0.39)	(-1.24)
Earnings-to-price	-0.0076	-0.0072	-0.0062
	(-1.05)	(-0.99)	(-0.89)
Book-to-market	0.0054	0.0054	0.0062
	(0.65)	(0.64)	(0.71)
Assets (log)	0.0003	-0.0002	0.0021*
	(0.23)	(-0.18)	(1.69)
Constant	0.0148		
	(1.44)		
Year fixed effects	No	Yes	Yes
Industry fixed effects	No	No	Yes
Adjusted R-squared	0.02	0.02	0.02
N	28520	28520	28520

Panel B:

	(1)	(2)	(3)	(4)
Model:	Probit	Probit	Probit	Probit
Average short interest (t-12,t-1)	1.4221***	1.7350***	1.2003**	1.4146***
	(2.84)	(4.02)	(2.30)	(3.19)
Idiosyncratic stock return (t-12,t-1)	-0.8190***	-0.7429***	-0.8118***	-0.7515***
	(-6.72)	(-6.64)	(-6.41)	(-6.38)
Average industry stock return (t-12,t-1)	-0.3175***	-0.2198***	-0.3208***	-0.3971***
	(-2.81)	(-2.65)	(-2.91)	(-3.59)
CEO of retirement age	-0.4321***	-0.4437***	-0.4454***	-0.4289***
	(-7.30)	(-7.49)	(-7.64)	(-7.49)
CEO with high equity ownership	-0.4725***	-0.4802***	-0.4536***	-0.4994***
	(-6.49)	(-6.70)	(-6.17)	(-6.32)
Tenure (months)	-0.0009***	-0.0008***	-0.0009***	-0.0009***
	(-3.88)	(-3.32)	(-3.77)	(-3.68)
Average analyst dispersion (t-12,t-1)		0.1585***	0.1545***	0.1783***
		(3.32)	(2.98)	(3.64)
Average VIX (t-12, t-1)		0.0022	-0.0020	-0.0037
		(0.84)	(-0.22)	(-0.41)
Analyst following		-0.0015	0.0006	-0.0061**
		(-0.52)	(0.21)	(-2.28)
Earnings-to-price		-0.0898*	-0.0852*	-0.0761
		(-1.86)	(-1.74)	(-1.64)
Book-to-market		0.0210	0.0168	0.0263
		(0.50)	(0.41)	(0.59)
Assets (log)		0.0237	0.0117	0.0495***
		(1.63)	(0.76)	(2.98)
Constant	-2.2644***	-2.1858***	-2.3518***	-2.6436***
	(-11.74)	(-13.46)	(-7.56)	(-8.95)
Year fixed effects	Yes	No	Yes	Yes
Industry fixed effects	No	No	No	Yes
Pseudo R-squared	0.09	0.08	0.10	0.11
N	28349	28520	28349	28215

Table 4: CEO turnover sensitivity to short interest using hazard models. This table reports coefficient estimates and z-statistics for the following proportional survival model:

$$h_i(t) = h_0(t)\exp(x_j\beta_x).$$

Columns (2) and (4) specify the baseline hazard as:

$$h_0(t) = pt^{p-1}\exp(\beta_0).$$

Columns (1) and (3) make no assumptions regarding the baseline hazard. Short interest, idiosyncratic and industry stock returns are measured from twelve months to one month before a turnover or the fiscal year end if there wasn't a turnover. We measure all other variables at the last known date before the turnover or the fiscal year end. The Appendix contains all variable definitions. The table reports *z*-statistics in parentheses. Standard errors are robust and clustered by industry. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Model:	Cox	Weibull	Cox	Weibull
Average short interest (t-12,t-1)	5.4168***	5.1236***	4.8459***	4.4949***
	(5.65)	(5.45)	(4.75)	(4.48)
Idiosyncratic stock return (t-12, t-1)	-2.1704***	-2.1728***	-2.1122***	-2.1190***
	(-8.49)	(-8.75)	(-8.53)	(-8.73)
Average industry stock return (t-12,t-1)	-1.0068***	-1.0247***	-0.7535***	-0.7678***
	(-4.79)	(-4.89)	(-4.35)	(-4.40)
CEO of retirement age	-1.4429***	-1.5622***	-1.4359***	-1.5535***
	(-7.73)	(-7.71)	(-7.71)	(-7.63)
CEO with high equity ownership	-1.9898***	-2.0941***	-1.8403***	-1.9403***
	(-10.62)	(-10.68)	(-9.47)	(-9.63)
Average analyst dispersion (t-12,t-1)			0.2302**	0.2267**
			(2.49)	(2.44)
Average VIX (t-12, t-1)			0.0158***	0.0163***
			(2.59)	(2.79)
Analyst following			-0.0025	-0.0041
			(-0.29)	(-0.48)
Earnings-to-price			-0.1764***	-0.1492***
			(-3.00)	(-3.16)
Book-to-market			0.1328	0.1177
			(0.58)	(0.52)
Assets (log)			0.1180***	0.1258***
			(3.22)	(3.39)
Constant		-4.5534***		-5.8852***
		(-31.37)		(-17.73)
aux_p		1.16		1.16
chi2	748.89	740.46	779.82	914.31
N	27382	27382	27382	27382

Table 5: Determinants of short interest. This table reports the first stage coefficient estimates of the 2SLS and IV Probit regressions in Table 6. The dependent variable is average short interest. Short interest, idiosyncratic and industry stock returns are measured from twelve months to one month before a turnover or the fiscal year end if there wasn't a turnover. Average share turnover, average analyst dispersion, and the average VIX returns are measured from 24 months to 12 months before a turnover or the fiscal year end if there wasn't a turnover. We measure all other variables at the last known date before the turnover or the fiscal year end. The Appendix contains all variable definitions. The table reports *t*- and *z*-statistics in parentheses. Standard errors are robust and clustered by industry. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)
Model:	LPM	LPM	LPM
Average share turnover (t-24,t-13)	0.1259***	0.0908***	0.0942***
	(8.20)	(7.65)	(8.66)
Option	0.0188***	0.0024	0.0036
	(9.72)	(1.04)	(1.61)
Idiosyncratic stock return (t-12, t-1)	-0.0027***	-0.0028***	-0.0029***
	(-4.76)	(-4.69)	(-5.40)
Average industry stock return (t-12,t-1)	-0.0185***	-0.0100***	-0.0049***
	(-6.21)	(-7.82)	(-2.95)
CEO of retirement age	0.0008	0.0008	0.0007
	(0.83)	(0.94)	(0.80)
CEO with high equity ownership	-0.0026*	0.0001	-0.0015
	(-1.70)	(0.08)	(-1.08)
Tenure (months)	0.0000**	0.0000	0.0000
	(2.42)	(0.67)	(0.60)
Average analyst dispersion (t-24,t-13)	0.0039**	0.0048***	0.0051***
	(2.48)	(3.11)	(3.27)
Average VIX (t-24, t-13)	-0.0006***	-0.0006***	-0.0006***
	(-9.06)	(-3.12)	(-3.64)
Analyst following	-0.0011***	-0.0004***	-0.0003**
	(-10.43)	(-3.42)	(-2.22)
Earnings-to-price	0.0038	0.0062**	0.0051**
	(1.62)	(2.04)	(2.12)
Book-to-market	0.0024*	0.0019	0.0013
	(1.71)	(1.47)	(1.31)
Assets (log)	0.0015***	-0.0011*	-0.0023***
	(3.29)	(-1.95)	(-4.77)
Constant	0.0129***		
	(4.20)		
Year fixed effects	No	Yes	Yes
Industry fixed effects	No	No	Yes
R-squared	0.29	0.39	0.41
N	28520	28520	28520

Table 6: Feedback Loop. This table reports coefficient estimates for different estimation procedures of Eq. 5. Panel A reports the coefficients of 2SLS estimates. Panel B reports the coefficients of IV Probit estimates. Short interest, idiosyncratic and industry stock returns are measured from twelve months to one month before a turnover or the fiscal year end if there wasn't a turnover. Average analyst dispersion, and the average VIX returns are measured from 24 months to 12 months before a turnover or the fiscal year end if there wasn't a turnover. We measure all other variables at the last known date before the turnover or the fiscal year end. The Appendix contains all variable definitions. The table reports *t*- and *z*-statistics in parentheses. Standard errors are robust and clustered by industry. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A:

	(1)	(2)	(3)
Model:	2SLS	2SLS	2SLS
Average short interest (t-12,t-1)	0.2977***	0.4257***	0.3370***
	(4.09)	(3.67)	(2.91)
Idiosyncratic stock return (t-12, t-1)	-0.0245***	-0.0243***	-0.0243***
	(-7.34)	(-7.51)	(-7.47)
Average industry stock return (t-12,t-1)	0.0001	-0.0001	-0.0077
	(0.01)	(-0.01)	(-1.20)
CEO of retirement age	-0.0168***	-0.0166***	-0.0156***
	(-8.68)	(-8.74)	(-8.68)
CEO with high equity ownership	-0.0120***	-0.0129***	-0.0144***
	(-4.56)	(-5.09)	(-5.41)
Tenure (months)	-0.0000***	-0.0000***	-0.0000***
	(-3.79)	(-3.39)	(-3.10)
Average analyst dispersion (t-24,t-13)	0.0179***	0.0175***	0.0197***
	(4.96)	(4.55)	(5.14)
Average VIX (t-24, t-13)	0.0003	-0.0012	-0.0011
	(1.46)	(-1.17)	(-1.10)
Analyst following	0.0001	0.0000	-0.0003
	(0.26)	(0.02)	(-1.51)
Earnings-to-price	-0.0061	-0.0077	-0.0060
	(-0.91)	(-1.02)	(-0.83)
Book-to-market	0.0053	0.0051	0.0063
	(0.69)	(0.66)	(0.77)
Assets (log)	0.0003	0.0010	0.0030**
	(0.24)	(0.78)	(2.16)
Constant	0.0093		
	(1.03)		
Year fixed effects	No	Yes	Yes
Industry fixed effects	No	No	Yes
Adjusted R-squared	0.01	0.01	0.02
Hansen J statistic	0.686	0.051	0.803
Hansen J statistic (p-value)	40.75%	82.06%	37.02%
N	28520	28520	28520

Panel B:

	(4)	(5)	(6)
Model:	IV Probit	IV Probit	IV Probit
Average short interest (t-12,t-1)	4.3059***	4.7856***	4.0419**
	(4.08)	(3.37)	(2.54)
Idiosyncratic stock return (t-1)	-0.7438***	-0.7639***	-0.7449***
	(-6.64)	(-6.34)	(-6.35)
Average industry stock return (t-12,t-1)	-0.1820*	-0.2421**	-0.3455***
	(-1.90)	(-2.25)	(-3.15)
CEO of retirement age	-0.4291***	-0.4283***	-0.4198***
	(-7.14)	(-7.37)	(-7.19)
CEO with high equity ownership	-0.4569***	-0.4583***	-0.4906***
	(-6.05)	(-6.00)	(-6.08)
Tenure (months)	-0.0009***	-0.0009***	-0.0009***
	(-3.93)	(-4.05)	(-3.77)
Average analyst dispersion (t-24,t-13)	0.1870***	0.1912***	0.2226***
	(5.98)	(5.76)	(6.19)
Average VIX (t-24, t-13)	0.0061*	-0.0141	-0.0124
	(1.93)	(-1.32)	(-1.20)
Analyst following	-0.0005	-0.0007	-0.0068**
	(-0.19)	(-0.22)	(-2.34)
Earnings-to-price	-0.0645	-0.0799*	-0.0673
	(-1.37)	(-1.68)	(-1.47)
Book-to-market	0.0156	0.0162	0.0283
	(0.46)	(0.50)	(0.75)
Assets (log)	0.0234	0.0260*	0.0609***
	(1.49)	(1.65)	(3.25)
Constant	-2.3642***	-2.4233***	-2.7344***
	(-14.74)	(-11.56)	(-14.27)
Year fixed effects	No	Yes	Yes
Industry fixed effects	No	No	Yes
N	28520	28349	28215

Table 7: Short-interest sensitivity in informed and uninformed boards. Table 7 reports the coefficient estimates of 4 different models analyzing the moderating effect of board independence on the sensitivity of forced CEO turnover to short interest. Columns 1 and 2 show the results of a LPM. Columns 3 and 4 show the results of a probit model. Columns 5 and 6 show the results of a Cox proportional hazard model and a Weibull proportional hazard model, respectively. Columns 1, 3, 5 (2, 4, 6) include year fixed effects (year and industry fixed effects). Short interest, idiosyncratic and industry stock returns are measured from twelve months to one month before a turnover or the fiscal year end if there wasn't a turnover. We measure all other variables at the last known date before the turnover or the fiscal year end. The Appendix contains all variable definitions. The table reports *t*- and *z*-statistics in parentheses. Standard errors are robust and clustered by industry. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	LPM	LPM	Probit	Probit	Cox	Weibull
Short interest X Ind. Board	0.1875**	0.1644*	2.0176*	1.5665	5.4012**	5.6421**
	(2.19)	(1.95)	(1.73)	(1.34)	-2.44	-2.55
Average short interest (t-12,t-1)	0.0891*	0.1013**	1.5229**	1.8502***	2.2244*	1.9667*
	(1.86)	(2.24)	(2.09)	(2.68)	-1.88	-1.65
Independent Board	-0.0070*	-0.0050	-0.0965	-0.0543	-0.2522*	-0.2259
	(-1.74)	(-1.28)	(-1.30)	(-0.74)	(-1.79)	(-1.59)
Constant			-2.7077***	-3.1667***		-4.8449***
			(-7.42)	(-9.36)		(-15.36)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	No	No
Industry fixed effects	No	Yes	No	Yes	No	No
Adjusted R-squared	0.02	0.02				
Pseudo R-Squared			0.09	0.12	0.06	
Auxiliary p						1.1
Observations	20189	20189	20076	19848	19480	19480