Short Interest and Investment*

Alexei Boulatov† Gustavo Grullon‡ Yelena Larkin§
Alexei Zhdanov¶

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Abstract

We examine the informational content of financial markets and its effect on investment decisions by focusing on the role of short interest. For this purpose we develop a model with informed and noise traders and divergence of opinions. Empirically, we find that an increase in short interest induces managers to cut investment. As our theoretical model predicts, the negative relationship between short interest and investment is stronger when short interest is more informative (in particular for more heavily shorted stocks), and also when firms are less transparent. Our findings hold after we address endogeneity concerns, and are not driven by reduction in external financing due to increase in short interest. We conclude that managers view short selling activity as a sign of short sellers' negative view on the company's growth options, and scale down their investment programs in response.

Keywords: Short Interest, Investment, Managerial Learning.

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*Larkin acknowledges the 2017 SSHRC Insight Development Grant.
†Higher School of Economics, ICEF. E-mail: aboulatov@hse.ru
‡Rice University. E-mail: grullon@rice.edu.
§York University. E-mail: ylarkin@schulich.yorku.ca.
¶Penn State University, Smeal College of Business. E-mail: auz15@psu.edu.

1. Introduction

A large body of finance literature examines the determinants of corporate investment. There is ample evidence that Tobin's Q alone is incapable of explaining the whole variation in investment, and recent literature demonstrates that stock prices also have an effect on corporate investment. For example, Baker, Stein, and Wurgler (2003) show that investment of equity-dependent firms is sensitive to non-fundamental movements in stock prices. Chen, Goldstein, and Jiang (2006) argue that managers learn from the private information in stock price when they make investment decisions, and show that the investment-to-price sensitivity correlates positively with measures of the amount of private information. Foucalt and Fresard (2012) document stronger investment-to-price sensitivity for cross-listed firms. Foucalt and Fresard (2014) document a positive association between a firm's investment and the prices of its peers, suggesting that peer stock prices also provide valuable information to managers in making their investment decisions.

In this paper we look deeper into the informational content of financial markets and its effect on investment by focusing on the role of short interest. We argue that short interest potentially reflects the views of informed traders and therefore provides additional valuable information to managers, beyond that already captured in stock prices. As this information is revealed to corporate managers it affects their investment decisions. In particular, an increase in short interest indicates a negative view of short sellers on the company's growth prospects and might induce managers to take a corrective action and reduce investment. As a result, we hypothesize that managerial learning from short interest should lead to negative relation between short interest and subsequent corporate investment.

To better understand the informational role of short interest we build a theoretical model that incorporates both learning from prices and from short interest. In the model, there is a finite number of price taking, risk averse traders who observe private signals about the firm value and submit price contingent (limit) orders. In addition, there are liquidity (noise) traders who submit a random aggregate market order that is normally distributed. The opinions of informed traders about the value of the firm differ as they observe noisy signals with i.i.d. error terms that are also normally distributed. We solve for the equilibrium price and short interest and show that the best estimate of the true fundamental value of the firm is positively related to price and negatively related to short interest. In addition, the sensitivity of the best estimate to short interest is stronger when there is a higher degree of divergence of opinions among the informed traders and when the level of short interest is high. Therefore, if managers learn about the true values of their firms by observing both the price of their stock and the short interest and use this information to adjust their investment programs, we expect similar relations between short interest and firm investments. We therefore use this theoretical predictions to guide the design of our empirical tests.

We start our empirical analysis by estimating investment as a function of short interest and standard control variables in a panel regression setting. In our empirical tests we utilize several measures of corporate investment. First, we rely on a commonly used, but also specific, definition, and consider investment in tangible assets, as measured by capital expenditures. Second, we extend our definition of investment to include intangible investment, and look at the total investment in fixed assets and R&D. Finally, we use the change in assets as our third, and potentially, the broadest, definition of investment. We also use three measures of short interest: the number of all open short positions scaled by shares; the unexpected component of short interest, as proposed by Karpoff and Lou (2010); and days-to-cover, measured as the number of open short positions scaled by turnover (Hong et al., 2016). Our results demonstrate a significant negative association between various proxies for short interest and future investment. This relation is statistically significant and economically meaningful - a one standard deviation in short selling activity leads to a 3-17% reduction in investment, depending on the particular measures of short interest and investment.

After demonstrating a negative link between short interest and investment, we gauge the mechanism of managerial learning. If learning is driving the relation between short interest and investment, then the relation is likely to be stronger when the short interest information is more valuable. The value of short interest information, in turn, depends on several aspects.

On the one side, it increases with the precision, or quality, of the signal. On the other side, the signal is more valuable when the informational environment of the firm is opaque, so that the marginal benefit of the signal is higher.

To examine the role of information precision component, we ask whether the impact of short interest on investment is more pronounced when short selling activity is less subject to short selling constraints. In support of this argument, we find that the effect of short interest on investment is stronger in the second half of our sample. Since the feasibility of short selling has increased over time, fluctuations in short interest in the past two decades are less influenced by shorting limitations, and therefore better reflect the view of short sellers regarding the firm's future prospects. We also show that the effect of short interest on investment is stronger for firms with high levels of short interest. This result is consistent with the prediction of our model. In the model, short interest represents aggregation across the demand by only pessimistic investors (those with negative pricing errors) and hence is non-normally distributed. This truncation effect leads to stronger sensitivity of the estimate of true value to short interest when short interest itself is high. It is also congruent with the idea that some investors routinely short certain stocks (e.g. option market markets short to hedge their outstanding option positions). As a result, cross-sectional variations in the lower end of short interest distribution may capture some random fluctuation in short selling activity, and have little informational content. At the same time, changes in short interest when the level of outstanding interest is high would imply a stronger informational content. Our evidence is consistent with this conjecture, and offers the first layer of evidence consistent with the informational role of short interest.

Our second battery of tests focuses on the information environment of the firms. Guided by our theoretical predictions on the role of information uncertainty, we hypothesize that when information uncertainty is higher there should be more potential for learning. Therefore, information on short interest is likely to be more valuable to managers of less transparent firms. To test this idea empirically, we include various proxies for information transparency, as well as their interaction with short interest, in our specifications. Our first information asymmetry proxy is dispersion of analyst forecasts. We also use two measures of stock return volatility, total and idiosyncratic, to proxy for the degree of information uncertainty. Finally, we examine whether the relation between short interest and investment is sensitive to the presence of institutional investors, who produce information and facilitate its incorporation into prices.

Once again, we find strong evidence supporting the information channel. Firms with less information transparency exhibit stronger investment-to-short interest sensitivities. The effect of short interest is more pronounced for firms with more dispersed analyst forecasts, lower institutional ownership, and more volatile stock prices. In addition, the link between short interest and investment is stronger among stocks with high idiosyncratic volatility, supporting the notion that short interest is valuable when managers cannot rely on alternative sources, such as market-wide indicators, to infer information about the firm's future prospects. Taken together, this set of findings further supports the managerial learning mechanism.

One potential concern is that both short interest and investment can simultaneously react to some omitted underlying factors. The inclusion of firm fixed effects in all of our regressions ensures that our results are not driven by time-invariant firm characteristics. However, we also want to make certain the findings cannot be explained away by time-varying economic shocks. For example, negative guidance released by the company about its future growth potential might generate additional short selling activity in the company's stock and at the same time reduce future investment.

To further alleviate potential endogeneity problems driven by time-varying common factors, we take advantage of a regulatory experiment, Regulation SHO (hereafter Reg SHO), which removed restrictions on short sales for a randomly selected group of firms within the Russell 3000 index. Reg SHO has a direct impact on short-selling activity but is exogenous to investment opportunities. As barriers to short selling were alleviated, more opportunities arose for informed short sellers to enter the markets. This mechanism, in turn, enhanced the informational content of short interest and created more potential for managerial learning.

Consistent with our main hypothesis, we find that the negative sensitivity of investment to short interest has strengthened following the enactment of Reg SHO. As a result, this natural experiment not only alleviates endogeneity concerns, but also provides additional support of the channels by which short interest affects investment.

Finally, we consider alternative channels that can potentially yield a similar effect. It is possible that short sellers are merely good at identifying companies that are likely to perform poorly in the future and realize inferior returns (so short sellers can profit from their short positions). In this case, managers will be forced to scale down their investment projects in response to deterioration of economic conditions, rather than short selling activity. Yet, empirically, we may still observe a negative and significant relation between short interest and investment. Our cross-sectional findings that demonstrate that the impact of short interest on investment is stronger among opaque firms shed doubt on this explanation. Even if short sellers are better in forecasting future economic conditions than other market participants, it is not clear why short sellers would be better in predicting future performance of opaque, rather than transparent, firms. To further address the validity of this explanation, we augment our main regressions with a variable for future returns, as in Chen et al. (2006). If open interest is simply an indicator of a negative economic shock, which short sellers are able to predict, the impact of short selling should be subsumed by future stock prices, which reflect the realization of these negative expectations. Inconsistent with this argument, we find that the investment-short interest sensitivity remains negative and significant after controlling for future returns.

We also disentangle the managerial learning channel from the capital market channel whereby short interest affects future investment through its impact on stock prices and availability of external capital. If short interest leads to poor future performance and inferior returns, increase in short interest could limit availability of external funding and negatively impact investment. Note that this issue is addressed to some extent by the inclusion of future returns, as well as by Reg SHO. Grullon, Michenaud, and Weston (2015) show that firms respond to the price fall following the regulation and reduce their investment. However, this effect should be absorbed by the Reg SHO dummy, and therefore does not explain why the sensitivity of investment to open interest would change after the regulation. One remaining possibility is that investors rely on short interest information and limit external funding available to the firm even if the information is not embedded in the prices. To address this issue, we focus our attention on financially constrained and equity dependent firms whose access to capital markets is crucial for maintaining investment. If capital market channel is the driving mechanism behind the effect of short interest on investment, then we expect this effect to be stronger for financially constrained and equity dependent firms. To measure the degree of dependency on capital markets, we use the equity dependence index by Baker, Stein, Wurgler (2003), as well as the index of financial constraints, constructed as in Hadlock and Pierce (2010). We do not find that the relation between short interest and investment is stronger among financially constrained firm, suggesting that access to external capital is unlikely to play a dominant role in shaping the relationship between short interest and investment.

Our paper is one of the first in the literature to examine the effect of short interest on real activity of firms, in particular on corporate investments. The two most closely related papers are Grullon et al. (2015) and Massa et al. (2016). Grullon et al. (2015) use Reg SHO as a shock to short-selling activity and find that an increase in short selling causes prices to fall. Small, or financially constrained, firms react to this shock by reducing equity issues and investment. Our paper differs from Grullon et al. (2015) on a number of dimensions. First, we examine the effect of short interest in a much broader setting. We find that the relation between short interest and investment holds not just around Reg SHO, but is detectable using over four decades of data. Moreover, we show that the impact of short interest extends beyond the universe of small firms, and therefore, has a larger scope of economic significance than previously suggested. Second, our tests pinpoint managerial learning as previously unexplored channel by which short interest affects investment. While we also take advantage of the Reg SHO in our analysis, we examine the change in sensitivity of investment to short interest around the enactment of that regulation as opposed to its effect on investment per se. As a result, we demonstrate that the impact of short interest on investment is not driven solely by the pricing channel, but also works through managerial learning mechanism. The breadth and the channel aspects also differentiate our paper from Massa et al. (2016). In contrast with their paper, we do not limit our analysis to R&D, and consider both tangible and intangible aspects of investment. In addition, while their paper shows that the disciplining mechanism of short selling activity can induce managers to reduce underinvestment, our study demonstrates that managerial learning is a valid channel within the optimal investment framework. Furthermore, our empirical tests are motivated by the predictions of a theoretical model that examines the role of short interest in the optimal estimate of the firm's fundamental value in a setting with privately informed and noise traders.

The remainder of the paper is organized as follows. We present our theoretical model in Section 2. We develop and discuss our main empirical hypotheses in Section 3. Section 4 provides a description of our data and main variables. Our main empirical tests and cross-sectional analyses are discussed in Sections 5 and 6, respectively. Section 7 presents results from Regulation SHO as a natural shock to short selling, whereas in Section 8 we discuss potential alternative explanation for the negative investment - short interest relation. Section 9 concludes. Technical details are gathered in the Appendix.

2. Model

We construct a two-period model of semistrong form informationally efficient markets where the informational contents of the market prices and short interest are complementary.

2.1. The Economy

The economy features a finite number of $N \geq 1$ price taking, risk averse, privately informed traders who submit price contingent claims (limit orders). There is also a number of liquidity (noise) traders who submit a random aggregate market order $u \sim N\left(0, \sigma_u^2\right)$. There are two tradeable assets: a single risky assets (the firm's stock) and a risk free asset with the risk free rate normalized to zero.

The informed traders privately observe noisy signals, $s_k = v + \sigma_s \varepsilon_k$ with $k = 1, ..N$, and the i.i.d. $\varepsilon_k \sim N(0,1)$, on the fundamental value of the risky asset v, which is a draw from the Normal distribution $v \sim N(0, \sigma_v^2)$. Note that the informed agents become uninformed in the limit $\sigma_s \to \infty$, and are perfectly informed in the opposite limit $\sigma_s = 0$.

Given their private signal and the commonly known priors, the informed trader's best estimate of the fundamental and conditional variance are given by $\widehat{v}_k = E[v|s_k] = s_k \frac{\frac{1}{\sigma_s^2}}{\frac{1}{\sigma_s^2} + \frac{1}{\sigma_v^2}}$ and $\sigma_{v|s}^2 = E\left[(v - \widehat{v}_k)^2 |s_k\right] = \frac{\sigma_v^2 \sigma_s^2}{\sigma_v^2 + \sigma_s^2}$. In what follows, we will for simplicity assume that the prior distribution is "flat" with $\sigma_v \to \infty$, in which case we have $\widehat{v}_k = s_k$ and $\sigma_{v|s}^2 = \sigma_s^2$, respectively.

The informed traders submit limit orders and the market price is defined by the market clearing condition taking into account the noise traders' aggregate demand.

2.2. Nash equilibrium

Each informed trader $k = 1, ..N$ solves the problem

$$\begin{aligned} U_k &= \max_{y_k} E_v \left[-\exp\left(-\alpha w_k\right) \right], \\ w_k &= y_k \left(v - P\right), \end{aligned} \tag{1}$$

where the expectation is taken w.r.t. the realizations of the fundamental value $v \sim N(0, \sigma_v^2)$. We assume that the informed traders are price takers (non-strategic) but they can submit price contingent claims (limit orders), and therefore can effectively condition on the execution price P (see, e.g., Grossman and Stieglitz (1980), Hellwig (1980), DeJong and Rindi (2009)). In what follows, we restrict the analysis to the linear strategies $y_k(\cdot)$ of the informed traders. The certainty equivalent for the informed traders is given by the following standard result (see, e.g., Grossman and Stieglitz (1980), p.396, DeJong and Rindi (2009), p. 40):

Proposition 1 *The certainty equivalent for the informed agent with a CARA utility (1) is given by*

$$W_k = y_k \left(\widehat{v}_k - P\right) - \frac{1}{2}\alpha\sigma^2_{v|s}y^2_k, \tag{2}$$

where y_k is the demand for the asset by trader k, $\widehat{v}_k = E\left[v|s_k\right]$ *is the mean and* $\sigma^2_{v|s} = E\left[\left(v - \widehat{v}_k\right)^2 |s_k\right]$ *is the variance conditional on the agent's k private signal* $s_k = v + \sigma_s\varepsilon_k$*.*

The first term on the r.h.s. of (2) is the agent's expected wealth while the second term is the absolute risk aversion coefficient multiplied by the variance of the informed trader's wealth (conditional on her private signal). Naturally, the second term comes with a negative sign. Also, the informed trader's wealth is proportional to her demand y_k while the variance is proportional to y^2_k.

Note that since all private signals s_k are drawn from the same distribution, the precisions of all private signals are the same and hence the conditional variances $\sigma^2_{v|s}$ are the same for all informed agents $k = 1, ..N$.

The FOC for (2) yields the optimal strategies in the form of the limit orders

$$y^*_k\left(P\right) = \frac{\widehat{v}_k - P}{\alpha\sigma^2_{v|s}}. \tag{3}$$

Aggregating (3) and applying the market clearing condition $\sum_{k=1}^{N} y^*_k\left(P\right) = u$, we obtain the market clearing price in the form

$$P = \frac{1}{N}\sum_{k=1}^{N}\widehat{v}_k - \frac{1}{N}\alpha\sigma^2_{v|s}u. \tag{4}$$

As follows from (4), the execution price is a noisy signal of the aggregate private signal $\sum_{k=1}^{N}\widehat{v}_k$ of the informed agents, reflecting the semistrong form of market efficiency. It is a noisy signal because of the presence of the noise traders with the aggregate demand u.

The magnitude of the noise is also proportional to the informed trader's risk aversion α and conditional variance $\sigma^2_{v|s}$. This happens for the following reason. If the informed traders' signals are perfect, i.e. $\sigma^2_{v|s} = 0$ and they know the fundamental value v exactly, they would trade infinitely large amount if there is any nonzero mispricing, and the price would very quickly revert to the fundamental value. The same logic applies to the case when the risk aversion goes to zero, since the risk neutral informed nonstrategic traders would trade infinitely large amounts if there is any mispricing. This follows from the informed trader's demand (3), since as the denominator goes to zero, demand becomes infinitely large unless the numerator also goes to zero.

Note that the aggregate private signal is still a noisy signal of the true fundamental value v, since $\frac{1}{N}\sum_{k=1}^{N}\widehat{v}_k = v + \frac{\sigma_s}{N}\sum_{k=1}^{N}\varepsilon_k$. As follows from (4), the execution price provides an unbiased estimate of the fundamentals. Namely, we can construct an estimator $\widehat{v}_P = P$ distributed as

$$\begin{aligned} \widehat{v}_P &= P \sim N\left(v, \sigma_P^2\right), \\ \sigma_P^2 &= \frac{\sigma_s^2}{N} + \frac{1}{N}\alpha^2\sigma^4_{v|s}\sigma^2_u. \end{aligned} \tag{5}$$

We now define the informational content of the short interest in this setting.

2.3. Short interest and its informational content

For simplicity, we assume that the informed agents have no initial endowments. In this case, the negative demand in (3) implies that agent k wishes to short the risky asset and hence contributes to the short interest. Therefore, by aggeregating (3), we obtain for the following expression for the short interest S:

$$S = -\sum_{k=1}^{N} y_k^*\left(P\right)\theta\left(-y_k^*\left(P\right)\right) - u\theta\left(-u\right) = \frac{1}{\alpha\sigma^2_{v|s}}Z, \tag{6}$$

where

$$Z = \sum_{k=1}^{N} \left(P - \widehat{v}_k\right) \theta \left(P - \widehat{v}_k\right) + \xi \theta \left(\xi\right), \tag{7}$$

$\xi = -\alpha \sigma^2_{v|s} u$, and $\theta(x)$ is the Theta function defined by

$$\theta(x) = \begin{cases} 1, & x \geq 0, \\ 0, & x < 0. \end{cases} \tag{8}$$

Defining the true mispricing as $\Delta = P - v$, observe that $z_k = P - \widehat{v}_k = \Delta - \sigma_s \varepsilon_k$, and the limit orders contributing to the short interest are sell orders, i.e. $z_k = \Delta - \sigma_s \varepsilon_k \geq 0$.

As follows from (7), $Z = \sum_{k=1}^{N} z_k \theta(z_k) + \xi \theta(\xi) = \sum_{k'=1}^{N} z_{k'} + \xi$, provided that $z_{k'} \geq 0$ and $\xi \geq 0$.

Define a new constant as $\sigma_\xi = \alpha \sigma^2_{v|s} \sigma_u$. Proposition 2 follows.

Proposition 2 *After observing the short interest and execution price, the manager's best estimate of the fundamental value is given by*

$$\widehat{v}_B = P - \gamma \frac{2\alpha \sigma^2_{v|s}}{N} S \left(1 + \frac{\alpha \sigma^2_{v|s}}{N \sigma_s} S\right) + c, \tag{9}$$

where $c = \frac{\gamma}{\sqrt{2\pi}} \left(\sigma_s + \sigma_\xi\right)$ *is an intercept that makes (9) unbiased and the weight* γ *is given by*

$$\gamma = \frac{3 \left(\alpha \sigma^2_{v|s} \sigma_u\right)^2}{N \sigma_s^2 + 9 \left(\alpha \sigma^2_{v|s} \sigma_u\right)^2}. \tag{10}$$

The variance of the best estimate $\widehat{v}_B$ *is given by*

$$\sigma_B^2 = \frac{\sigma_s^2}{N} \frac{N \sigma_s^2 + 10 \left(\alpha \sigma^2_{v|s} \sigma_u\right)^2}{N \sigma_s^2 + 9 \left(\alpha \sigma^2_{v|s} \sigma_u\right)^2}. \tag{11}$$

Proof: See Appendix.

Taking into account that the constant c on the r.h.s. of (9) does not depend on either price or short interest, we obtain the sensitivities of the best estimate to the price and short interest in the following way:

$$\begin{aligned} \frac{\partial \widehat{v}_B}{\partial P} &= 1, \\ \frac{\partial \widehat{v}_B}{\partial S} &= -\gamma \frac{2\alpha\sigma^2_{v|s}}{N}\left(1+\frac{2\alpha\sigma^2_{v|s}}{N\sigma_s}S\right). \end{aligned} \tag{12}$$

These sensitivities are important for our empirical tests and deserve additional discussion. First, note that the estimate $\widehat{v}_B$ monotonically increases in the execution price and decreases in the short interest, consistent with the basic economic intuition. Also, as follows from (12), short interest is important when there is a sufficiently high level of "noise" in the market coming from both the coefficient $\frac{\alpha\sigma^2_{v|s}}{N}$ reflecting the agents' uncertainty about their best estimates of the fundamental value, as well as from the weight γ given by (10). In addition, the sensitivity of the best estimate to the short interest increases in both the information uncertainty of the informed traders and in the intensity of noise trading. Below we discuss the intuition for these results:

1. The term $\frac{\alpha\sigma^2_{v|s}}{N}$ comes from the functional form of the optimal demand (3) because the optimal demand (including the selling demand which in our model is interpreted as the short interest) is proportional to the perceived mispricing in the agent's information set $\widehat{v}_k - P$ and is inversely proportional to $\alpha\sigma^2_{v|s}$, which is the product of the measure of uncertainty of the risky asset $\sigma^2_{v|s}$ and the risk aversion coefficient α. Therefore, the perceived mispricing that reflects the private information of the "pessimistic" traders about the fundamental value v is proportional to the short interest with a factor $\alpha\sigma^2_{v|s}$. Note that the aggregation of beliefs of the "pessimistic" traders is consequently reflected in their aggregate demand, which we interpret as short interest. Essentially, $\alpha\sigma^2_{v|s}$ is a "scaling" factor that applies to match the demand with the agents' perceived mispricing, and therefore it naturally arises in our model.

2. The weight γ given by (10) is increasing in the information uncertainty $\sigma^2_{v|s}$ as well as in the level of noise trading σ^2_u. Equation (10) can be approximated as $\gamma = \frac{3\alpha^2\sigma_s^2\sigma_u^2}{N+9\alpha^2\sigma_s^2\sigma_u^2}$. As follows from (A29), γ reflects the informativeness of the short interest relative to the execution price. Clearly, the execution price becomes less informative when the level of noise trading increases, and hence the short interest becomes relatively more informative.

In particular, the ratio $\frac{\gamma}{1-\gamma} = \frac{Var[\widehat{v}_P]-Cov[\widehat{v}_P,\widehat{v}_M]}{Var[\widehat{v}_M]-Cov[\widehat{v}_P,\widehat{v}_M]} = \frac{3\alpha^2\sigma_s^2\sigma_u^2}{N+6\alpha^2\sigma_s^2\sigma_u^2}$ is increasing in the variance of the execution price $Var\left[\widehat{v}_P\right]$ and decreasing in the variance of the short interest $Var\left[\widehat{v}_M\right]$. Of course, both variances are increasing in both the magnitude of the information noise and the level of the noise trading. However, the short interest only reflects the information of the "pessimistic" traders, and hence is only affected by the "negative" noise as opposed to the execution price reflecting the full information and affected by the full aggregate noise.

3. Third, as follows from (9), the sensitivity of the firm value's best estimate to the short interest increases in the magnitude of the short interest itself due to the quadratic expression in the second term in the r.h.s. of (9). This happens for the following reason. The distribution of the short interest (A6) is not normal but can be approximated asymptotically by a normal distribution of the following nonlinear function of the short interest: $F\left(Z\right) = Z\left(1+\frac{1}{N}\frac{Z}{\sigma_s}\right)$, given by (A19). For this reason, the optimal estimator based on the short interest becomes proportional to $F\left(Z\right)$ which is a linear-quadratic function of Z with a positive second derivative. Therefore the sensitivity of the constructed signal is a linear function with a positive slope, i.e. increasing in Z.

These observations are summarized by

Corollary 1 *1. The best estimate of the risky asset's fundamental value $\widehat{v}_B$ linearly increases in the execution price and decreases in a nonlinear way in the short interest.*

2. The sensitivity of $\widehat{v}_B$ with respect to the short interest increases in the level of uncertainty and noise trade.

3. The sensitivity of $\widehat{v}_B$ with respect to the short interest increases in the magnitude of the short interest itself.

Therefore, our model predicts that short interest becomes more informative when the level of noise and the magnitude of short interest increase.

As follows from (A31), the weight that the manager attributes to the signal based on short interest is increasing in both the level of the traders' informational uncertainty and the level of uncertainty due to noise trading activity captured by the term $\frac{\left(\alpha\sigma_{v|s}^2\sigma_u\right)^2}{N^2}$ in (10).

This is consistent with the intuition that the short interest plays an important role only if the amount of noise trading as well as divergence of opinions of the informed traders measured by the conditional variance $\sigma_{v|s}^2$ are sufficiently high.

It follows from (11) that the variance of the optimal estimate is close to $\frac{\sigma_s^2}{N}$. Comparing (11) and (5), we observe that taking into account the short interest in addition to the price allows one to reduce the variance and hence improve the accuracy of the estimate of the fundamental value (relative to the estimate based on the price alone). In particular, the price is affected by the presence of noise trading and the optimal estimate that accounts for short interest allows one to reduce the level of noise.

The logic of our model is generally consistent with Miller (1977). The key point is that different informed traders may have different opinions about the expected returns of the risky asset leading to different estimates of the true (fundamental) value of the asset. In particular, the "pessimistic" investors who think that the asset's expected returns are negative and hence the asset is currently overpriced will consider short selling strategies. Hence, as Miller (1977) argues, the short selling constraints would effectively exclude the most pessimistic investors (who are potential short sellers) from the price formation process and hence they would lead to the asset overpricing. Consistent with this logic, in our model short interest has a negative impact on the manager's best estimate of the firm's true value.

3. Hypothesis Development and Discussion

Our main hypothesis is about the effect of short interest on subsequent investment by firms. As our model predicts, short interest increases the precision of the manager's best estimate of the firm's true value and has a negative effect on that value. While we do not model the manager's optimal investment decisions explicitly, it is highly likely that a negative update on the firm's fundamental value and its future prospects optimally leads the managers to cut some of their investment projects. Therefore, managerial learning leads to a negative effect of short interest on investment as managers incorporate the informational content of short interest into their corporate decisions and their investment programs in particular. This gives rise to our main hypothesis:

Hypothesis 1: There is a negative relation between short interest and subsequent investment.

Our model shows that short interest provides a more valuable signal for the manager when there is more information uncertainty about the fundamental value of the firm, as measured by the precision of the informed traders' signal, $\sigma^2_{v|s}$, as well as by the level of noise trading σ^2_u. When information uncertainty is high, so is the benefit of learning the perceived mispricing of the pessimistic traders (in addition to observing the price). This leads to Hypothesis 2:

Hypothesis 2: The negative relation between short interest and subsequent investment is stronger when there is more information uncertainty.

Our model also predicts that the sensitivity of the best estimate of the fundamental value to short interest is higher when short interest itself is high. In the model, it happens because of the non-normality of the distribution of short interest. Short interest represents aggregation across the demand by only pessimistic investors (i.e. those with negative pricing errors). This truncation effect results in a stronger sensitivity of true firm values to short interest at higher levels of short interest. It is also likely that short interest usually incorporates some routine activities by market makers while hedging their positions. Those activities are not driven by informed trading. Therefore, there is likely to be some background shorting that makes short interest less informative when short interest is relatively low. We therefore have the following hypothesis:

Hypothesis 3: The negative relation between short interest and subsequent investment is stronger when short interest is high.

Our main conjecture about the negative effect of short interest on investment (Hypothesis 1) implies that short interest reveals negative information about the firm that managers incorporate in their investment decisions. On the contrary, it is conceivable that the negative link between short interest and subsequent investment is driven primarily by declining future prices (returns). If short sellers are good at identifying companies whose equity prices are likely to decline in the future, it becomes harder for such companies to raise new funds in capital markets and finance new investments so they naturally cut down on their investment programs (even in the absence of managerial learning). If this is the primary channel that drives the negative effect of short interest on investment, then this effect should be particularly pronounced for companies that depend more strongly on capital markets, such as equity dependent and financially constrained firms. In our empirical tests, we differentiate this channel from the managerial learning channel by examining the sensitivities of investment to short interest of financially constrained and equity dependent firms. We also examine whether the effect that we document is driven primarily by the ability of short sellers to predict the firm's inferior performance by controlling for future returns. Baker, Stein, and Wurgler (2003) show that corporate investment of equity dependent firms is more sensitive to non-fundamental movements in stock prices. To the extent that short interest is a proxy for future price changes, it is conceivable that a similar effect is present in the sensitivity of investment to short interest.

Finally, we follow Grullon, Michenaud, and Weston (2015) and take advantage of a regulatory experiment (Regulation SHO) that relaxed short selling constraints on a random sample of US stocks. Since the 1930s, short sales could not be placed when stock prices were declining, a regulation commonly referred to as the uptick rule. However, the SEC lifted this restriction in 2005 for a randomly selected sample of one third of the Russell 3000 stocks (the pilot group). Multiple studies have found a positive effect of Regulation SHO on short-selling activity and stock market quality (Diether, Lee, and Werner, 2009; Alexander and Peterson, 2008; Boehmer, Jones, and Zhang, 2008). As the uptick restriction is removed, it became easier to establish a short position in the stock for investors with a negative view on the company's prospects. It is therefore likely that the enactment of Reg SHO had made short interest more informative. Pre Reg SHO the uptick rule had likely prevented many speculators with a negative forecast for the company to actively participate in the trading, making information contained in the short interest less reliable. In other words, Reg SHO had rendered more potential for managers to learn from short interest. If managerial learning is responsible for the negative relation between short interest and subsequent investment, we expect a higher investment to short interest sensitivity for firms that undergo Reg SHO (the pilot group) versus remaining firms. Hypothesis 4 follows:

Hypothesis 4: The sensitivity of investment to short interest is expected to be higher post Reg SHO for the pilot group (versus the control group).

Note that this hypothesis is different from the negative effect of Reg SHO on investment documented by Grullon et al. (2015) who show that firm investment (and particularly investment by small firms) declines post Reg SHO due to intensified short selling activity. On the contrary, we argue that because of increased informativeness of short interest, the sensitivity of investment to short interest should become stronger post Reg SHO.

4. Data and Variables

Our primary variable of interest - *Short Interest* is constructed from the monthly series reported by NASDAQ and NYSE, and reported in the Supplemental Short Interest File, available through Compustat. We use three alternative measures of short selling activity based on these series. We start by calculating each measure at the monthly frequency. Our first measure, *Short interest scaled by shares*, is the number of all open short positions on the last business day on or before the 15th of each calendar month scaled by the number of shares outstanding at the end of the month. To construct our second measure, *Abnormal short interest*, we follow Karpoff and Lou (2010), and extract the unexpected component of short interest. To construct this component, we look at the residual of a firm fixed effect regressions where the monthly short interest is regressed on month dummies, lagged market-to-book, logarithm of lagged total assets, lagged trading volume, lagged return on assets, and a dummy variable for listing on NYSE. Our third and final measure of short interest, *Days-to-cover*, is based on Hong et al. (2015). It is obtained by adjusting (or scaling) *Short interest scaled by shares* by the same month's average daily share turnover.[1] Intuitively, this measure indicates the number of days it would take short sellers to cover their short positions, assuming the average trading volume environment. To convert the short interest data into annual frequency, for every firm we average the monthly short interest throughout its fiscal year t.

We obtain accounting information and stock trading data from Compustat and CRSP, respectively. Our sample period is 1973-2014. We start our sample in 1973, when the short interest data becomes first available. For robustness, we employ several measures of investment. Our first measure is the ratio of capital expenditures (Compustat item CAPX) at the end of year t scaled by fixed assets (Compustat item PPENT) as of the end of year $(t-1)$. This measure is motivated by classical models of investment and their empirical tests, and considers only fixed, or tangible, investment (see, for example, Fazzari, Hubbard, and Petersen, 1988). Since the role of intangible capital, and technological capital in particular, has more than doubled in the past few decades (e.g., Corrado and Hulten, 2010), R&D expenses have become important component of investment (Peters and Taylor, 2018). To account for investment in technology, we construct an alternative measure of investment, and scale the sum of capital expenditures and R&D (Compustat item XRD) by the beginning-of-the-year

[1] Following Hong et al. (2015), we adjust trading volume of NASDAQ stocks during the 2001 - 2003 period in our calculations of turnover. See footnote 8 of their paper for more details.

total assets (Compustat item AT).[2] Finally, we consider *Change in Total Assets* , defined as the percentage change in total assets between years $t-1$ and t, as our last measure of investment.

In addition to our main variables we also use control variables that have been shown to affect corporate investment. Numerous studies have found that investment is sensitive to the Market-to-book ratio, cash flow, and size (see, for example, Fazzari, Hubbard, and Petersen, 1988). We therefore use these variables as additional controls in our investment regressions. We define Market-to-book ratio as the total book value of assets plus market cap (the product of the number of common shares outstanding (CSHO) and share price (PRCC_F) at the end of the fiscal year-end), minus book value of equity (CEQ), all divided by the total book value of assets. Cash Flow is the sum of income before extraordinary items (variable IB) and depreciation and amortization (variable DP), all divided by the total book value of assets.

Our model predicts that the informational content of short interest is more valuable to managers when there is more information uncertainty about the firm in general. In our tests, we use several proxies for information uncertainty. Analyst forecast dispersion is the annual average of monthly standard deviation of analyst forecasts and is obtained from I/B/E/S. We also use measures of stock return volatility - both total and idiosyncratic. Total volatility is measured as the standard deviation of monthly stock returns over the fiscal year. Idiosyncratic volatility is the standard deviation of the residuals from daily regression of stock returns net of risk-free rate on the Fama-French three factors. The regressions are estimated separately for each stock using a three-year rolling time window.

Finally, it is conceivable that firms that are more dependent on capital markets exhibit stronger sensitivities of investment to short interest. We use two measures to identify such a dependency - the BSW index and the HP index. BSW index is the index of equity dependence, based on Baker, Stein, and Wurgler (2003). This index is constructed as a linear combination of cash flow, dividends, and cash balances, all scaled by lagged total assets, and the book

[2]Value of zero are assigned to observations with missing R&D values.

leverage ratio and follows Kaplan and Zingales (1997). HP index is the index of financial constraints, constructed as in Hadlock and Pierce (2010). The two main components of the index are firm size (measured as total assets in constant 2004 dollars) and age.[3]

Table 1 presents the summary statistics for our main variables. The average firm in our sample has 2.52% of its shares shorted. It would take 4.6 days, on average, to cover the outstanding short positions based on the average daily volume. As expected, the mean abnormal short interest is close to zero. These numbers are similar to those reported in Hong et al. (2015). The mean firm also has analyst forecast dispersion of about 16%. The volatility of the idiosyncratic component of daily returns is about 2% (corresponding to annualized idiosyncratic volatility of about 30%). The average annualized monthly return is about 12% and the standard deviation of monthly returns is also about 12%, corresponding to annualized volatility of 41%.

5. Empirical tests

5.1. Baseline results

Our main conjecture (Hypothesis 1) is that managers learn by observing the short selling activity. Managerial learning, in turn, leads to a negative effect of short interest on investment as managers incorporate the informational content of short interest into their investment decisions. To test this prediction empirically we start our analysis by regressing our measures of investment on various proxies for short interest and control variables, used in prior studies. Our empirical specification has the following form:

$$I_{i,t} = \alpha + \beta SI_{i,t-1} + \delta X_{i,t-1} + \eta_i + \nu_t + \varepsilon_{i,t}, \tag{13}$$

where $I_{i,t}$ is a measure of investment of firm i in year t, $SI_{i,t-1}$ is a measure of lagged short interest, and $X_{i,t-1}$ is a vector of control variables that include the market-to-book ratio,

[3] Hadlock and Pierce (2010) measure age since the IPO. To capture firm age in a more precise way, we consider the age since the launch of the company.

cash flow, and the logarithm of firm's assets. We include year fixed effects ν_t to absorb potential impact of global time-varying conditions on firms' investments. We also include firm fixed effects η_i to address several alternative explanations, in addition to several potential endogeneity concerns. For example, if high quality firms invest more and are also targeted by short sellers less often, this matching can lead to a mechanical negative relation between short interest level and investment. The inclusion of firm fixed effects addresses this concern by focusing the analysis on the within-firm variation in short selling and investment over time. To account for potential serial correlation of residuals cluster the standard errors at the firm level.

Table 2 reports the results. Regression coefficients on the three measures of short interest are negative and highly significant in all specifications (with the exception of model 1 in panel C of Table 2, where the coefficient on abnormal short interest is negative but insignificant). The effect of short interest on investment is also economically large. For example, increasing short interest scaled by shares outstanding by one standard deviation results in a decrease in our measures of investment by 4-10% relative to their means. The corresponding economic effect for days-to-cover ranges between 4 and 19%, and between 1.5% and 17% for abnormal short interest. Consistent with prior studies, we also find that investment is strongly and positively associated with market-to-book and cash flow, and negatively associated with size. Coefficients on all three control variables are highly statistically significant.

6. Cross-sectional Analysis

After documenting a negative and significant relation between short interest and investment, we next turn to gauging the channel of managerial learning. We hypothesize that the signal embedded in short interest positions is more valuable when it is more informative, or precise. We also predict that the signal is more valuable for a firm that operates in a high information asymmetry environment (Hypothesis 2). This prediction arises in our theoretical framework in Section 2 where we show that the sensitivity of the best estimate of the true value of the firm to short interest is stronger when the information set of traders is more opaque.

6.1. Signal precision

In this subsection we analyze whether short interest has higher impact on investment when the short interest signal is more precise. To this end, we perform two analyses. First, we ask whether the link is stronger in the more recent years. Hong et al. (2015) document a positive trend in short interest over time, consistent with the idea that barriers to short selling have weakened substantially. This trend is reflected in our sample, too. For example, the average short interest also exhibits a strong positive trend, as short interest scaled by shares grows from 0.5% in the first half of the sample to 3.6% in the second half. Short selling constraints were reduced in part due to regulatory changes, such as several reductions in tick size during the 1990s, which have improved liquidity and market depth, as well as Reg SHO. Financial market development and increasing role of institutional investors in particular, have also contributed to higher market liquidity and higher availability of shares to borrow. As financial markets are becoming more conducive to short selling, more traders with negative views are able to participate in shorting a stock and hence enrich the informativeness of short interest. Thus, we expect a stronger effect of short interest on corporate investment in the later part of our sample versus the earlier part, as more informed investors participate in short selling. To test this conjecture, we split our sample in half - from 1973 to 1993 and from 1994 to 2014 and repeat our tests separately on these two subsamples.

The results from this exercise are presented in Table 3. As expected, the effect of short interest on investment is much stronger in the second half of our sample - the coefficients on short interest are generally higher in magnitude and highly statistically significant. By contrast, those coefficients in the first half of the sample are generally statistically insignificant.

To further explore the signaling role of short interest, we ask whether the documented relation could be non-linear, so that the informativeness of short interest is greater for highly shorted stocks. This prediction is summarized in Hypothesis 3. In the model, this effect arises because of the aggregation across the demand by only pessimistic investors (those with negative pricing errors). A similar effect might be present due to the presence of uninformative shorting (e.g. by market makers when hedging their options positions). To test this hypothesis we use the following empirical specification:

$$I_{i,t} = \alpha + \beta_L LOWSI_{i,t-1} + \beta_H HISI_{i,t-1} + \delta X_{i,t-1} + \eta_i + \nu_t + \varepsilon_{i,t}, \tag{14}$$

where $LOWSI_{i,t-1}$ equals our measures of short interest if the corresponding measure is above the sample median in a given year and equals zero otherwise. Likewise, $HISI_{i,t-1}$ takes on the value of short interest if the latter is above its sample median in that year. This specification allows us to examine the existence of a non-linear effect of short interest on investment. The results from this test are presented in Table 4. Consistent with our intuition that short interest in more heavily shorted stocks is likely more informative, the coefficients on $HISI$ are negative and highly significant across the board. On the other hand, coefficients on $LOWSI$ are lower in magnitude and insignificant statistically.

Taken together, the results of the two tests support the idea that short interest has higher influence on investment when it conveys information about future prospects more precisely.

6.2. Informational uncertainty

In this subsection we ask whether information environment of a firm also impacts the sensitivity of investment to open short interest positions. As stated by Hypothesis 2, if managerial learning is the driving force behind the link between short interest and corporate investment, then this relationship should be stronger for stocks subject to higher information uncertainty, as there is more potential to learn future prospects of the firm.

To test this prediction, we use several measures of information transparency. Our first measure is based on analyst forecast dispersion. Every month we obtain the standard deviation of analysts' earnings projection for the fiscal year-end earnings from I/B/E/S, and then average the monthly data over one-year period to obtain average annual dispersion. We postulate that as analyst forecasts become more dispersed when there is more disagreement among analysts about earnings growth of the company, short selling activity can reduce a higher fraction of this uncertainty by providing an additional signal, and therefore, becomes more valuable to the management. It is also possible that when analyst forecasts are noisy, managers are more likely to seek additional sources of information about the fair value of the company and its growth potential and pay more attention to short interest.

Our second proxy for information uncertainty is stock return volatility. It is likely that company valuations are less precise when stock return volatility is high. When return (and price) volatility is high, the potential to learn from prices is limited and managers might decide to turn to alternative sources of information, including short interest. We use two measures of stock return volatility - total and idiosyncratic. Total volatility is defined as the standard deviation of monthly returns within a fiscal year, while idiosyncratic volatility is constructed as the standard deviation of daily residuals from regressions of stock return on the Fama-French three return factors. If there is more learning potential from short interest for stocks with higher information uncertainty, there should also be a stronger relation between short interest and investment for such stocks.

Finally, we turn our attention to institutional ownership. Boehmer and Kelley (2009) demonstrate that stocks with greater institutional ownership are priced more efficiently. Thus, when institutional holdings are high, the quality of existing information about the company is also higher. In this case, managers are likely to be better informed about their fair valuations and growth prospects and hence learning from short interest becomes less important. To this end, we obtain total institutional ownership from 13F database, and use the fraction of shares owned by all institutional investors, as an inverse measure of information asymmetry.

To test the effect of information asymmetry on managerial learning from short interest, for each of our informational proxies we employ the following regression model:

$$I_{i,t} = \alpha + \beta SI_{i,t-1} + \beta_1 HI\_ASSYM_{i,t-1} + \beta_2 HI\_ASSYM_{i,t-1} \times SI_{i,t-1} + \delta X_{i,t-1} + \eta_i + \nu_t + \varepsilon_{i,t}, \quad (15)$$

where $HI\_ASSYM_{i,t-1}$ is a dummy variable set to one if the measure of information asymmetry is above the sample median in a given year, and zero otherwise.

Table 5 report results for the effect of analyst forecast dispersion. While there is no effect of the high dispersion dummy $HI\_DISP_{i,t-1}$ on investment, the coefficients on the interaction term of $HI\_DISP_{i,t-1}$ and the three measures of short interest are negative and highly statistically significant for all three investment measures. This suggests that the effect of short interest on investment is indeed stronger for stocks with high analyst forecast dispersion.

Table 6 reports similar results for total stock return volatility, while Table 7 reports results for idiosyncratic return volatility. Similar to Table 5, coefficients on the interaction terms of volatility dummies and our measures of short interest are generally negative and highly statistically significant (with a couple of exceptions). Firms with volatile stock returns exhibit a stronger negative relation between short interest and investment. This is consistent with the effect of information uncertainty on managerial learning - when stock return volatility is high and it is likely that information impounded in prices is less precise the managers are motivated to look for other source of information, including the short selling activity.

Finally, we interact the dummy for low versus high level of institutional holdings dummy with our measures of short interest. The results from this exercise are presented in Table 8. We find that the coefficients on the interaction terms are mostly positive and, with the exception of two cases, statistically significant. Thus, as expected, institutional ownership attenuates the effect of short interest on investment.

7. A regulatory experiment - Reg SHO

In this section we test Hypothesis 4 and exploit a natural regulatory experiment - Regulation SHO, to examine whether capital market frictions have an effect on stock prices and corporate decisions. Since the 1930s, short sales could not be placed when stock prices were declining, a regulation commonly referred to as the uptick rule. The regulation, introduced in

July 2004, has relaxed short selling constraints in a random sample of Russell 3000 stocks. In particular, Reg SHO removed the uptick rule, whose purpose was to limit short selling activity for a random sample of 968 firms. The uptick rule stated that short sales cannot be executed (i) at a lower price than the previous price, (ii) at the same price as the previous price if the preceding trade was executed at a higher price than the previous and current one. The SEC selected firms from the Russell 3000 index listed on NYSE, NASDAQ, and AMEX and ranked them independently for each stock exchange by average daily trading volume. Every third firm on these lists was then selected in the pilot group. Two years later the SEC removed restrictions for all stocks after analyzing the results from the experiment.

Multiple studies have examined the effect of Reg SHO on prices, liquidity and volatility but the results are mixed. Boehmer, Jones, and Zhang (2008) find the effect on short selling activity and potentially return volatility but not prices. Alexander and Peterson (2009) document that the pilot stocks have lower price locations relative to quotes, more short trades and more short volume. Grullon et al (2015) find that Reg SHO and the subsequent increase in short selling activity causes prices to fall, inducing firms, especially small ones, to reduce equity issuance and investment. In this paper we examine a different aspect of Reg SHO. We argue that the uptick rule that has been in place prior to Reg SHO has inhibited short selling activity by potentially informed speculators. When the uptick restriction was removed, it became easier to establish a short position in the stock for investors with a negative view on the company's prospects. It is therefore likely that the enactment of Reg SHO had made short interest more informative. Pre Reg SHO the uptick rule had likely prevented many speculators with a negative forecast for the company to actively participate in the trading, making information contained in the short interest less reliable. In other words, Reg SHO had rendered more potential for managers to learn from short interest. If managerial learning is responsible for the negative relation between short interest and subsequent investment, we expect a higher investment to short interest sensitivity for firms that undergo Reg SHO (the pilot group) versus remaining firms, due to a richer informational content of short interest.

Note that this hypothesis is different from the negative effect of Reg SHO on investment documented by Grullon et al. (2015). Their paper shows that firm investment (and particularly investment by small firms) declines post Reg SHO due to intensified short selling activity. We argue that Reg SHO has also affected investment through the learning channel. Because of increased informativeness of short interest, not just the level of investment, but also the sensitivity of investment to short interest should be affected by the Reg SHO.

To test this hypothesis, we use a difference-in-differences specification and introduce a dummy variable, SHO. For pilot stocks, the dummy variable equals one if the stock was in the sample of pilot stocks and was subject to the Reg SHO for at least seven months of its fiscal year, starting from August 2004 and onward. For non-pilot stocks, the dummy variable SHO equals one if the stock was in the Russell 3000 index (as of May 2004) and was subject to the repeal of Reg SHO, announced in July 2007, for at least seven months of its fiscal year Otherwise SHO is set to zero. We restrict our sample to stocks included in the Russell 3000 index as of 2004 and to the period before and after the announcement of Reg SHO (2001-2008). We then regress our proxies for corporate investment on the three measures of short interest, the set of control variables, the SHO dummy, and the interaction term of the SHO dummy and short interest:

$$I_{i,t} = \alpha + \beta SI_{i,t-1} + \beta_1 SHO_{i,t-1} + \beta_2 SHO_{i,t-1} \times SI_{i,t-1} + \delta X_{i,t-1} + \eta_i + \nu_t + \varepsilon_{i,t}, \quad (16)$$

We are interested in the coefficient β_2 on the interaction term of $SHO_{i,t-1}$ and short interest, as its shows the incremental effect of Reg SHO on the sensitivity of investment to short interest.

The results from this analysis are presented in Table 9. As follows from this table, the coefficients on the interaction terms are negative and statistically significant in most specifications. The conceptual interpretation is that the negative sensitivity of investment to short interest has strengthened following the enactment of Regulation SHO, consistent with our main hypothesis.

The implications of Reg SHO results are two-fold. First, since Reg SHO has had a direct impact on short-selling activity but was exogenous to investment opportunities, the results help address a number of endogeneity concerns. Second, these results provide additional evidence in support of the managerial learning hypothesis. As barriers to short selling were alleviated, more opportunities arose for informed short sellers to enter the markets. Since Reg SHO has enhanced the information content of short interest, the signal has induced more learning on the managers' side, leading to a stronger investment - to - short interest sensitivity.

8. Alternative explanations

The main assumption behind our learning channel is that short selling activity, and short interest in particular, potentially convey information that may not be fully incorporated into prices. There is strong evidence that corporate investment responds to prices in ways consistent with managerial learning - corporate managers learn from prices (Chen, Goldstein, and Jiang, 2006; Foucalt and Fresard, 2012) and also learn from peer prices (Foucalt and Fresard, 2014). As long as the negative views of short sellers are not fully priced in, it is likely that short interest can provide additional information to corporate managers about the quality of the firm's growth prospects and investment opportunities, so the managers react to short interest by adjusting their investment programs.

It is also possible, however, that short selling affects corporate investment via a different channel, unrelated to managerial learning. We explore the role of these alternative explanations in this section.

8.1. Predictive power of short interest

It is possible that short sellers are skillful in identifying companies that are likely to realize inferior returns in the future and therefore exhibit poor performance and possibly cut their investment. For example, Grullon et al (2015) find that increase in short selling activity leads to lower prices. Desai et al. (2002) document significant negative abnormal returns for heavily shorted stocks on NASDAQ. Diether, Lee, and Werner (2009) also report that short sellers can correctly predict future negative abnormal returns. In this case, it is possible that outstanding short interest is an indicator of future underperformance, which leads managers to reduce investment not because they learn from the short interest, but rather because they respond to the same fundamentals as short sellers.

We address this explanation in a number of ways. First, we refer back to our cross-sectional findings, which point to higher sensitivity of investment to short interest among less transparent firms. These results not only confirm the validity of the learning channel, but also shed doubt on the validity of future performance predictability explanation. If short sellers are better in forecasting future economic conditions than other market participants, then their signal should predict future performance more precisely among transparent, rather than opaque, firms. This, in turn, should strengthen the association between short interest and investment. Our results find the opposite: the impact of short selling on investment is actually stronger among opaque firms.

To further alleviate the concern of return predictability, we augment our base regression specification by adding future returns as of year $t+1$ to the set of our control variables. If predictability of short interest for investment comes solely from its potential effect on future prices and returns, then we expect our measures of short interest to become insignificant once we include future returns as additional controls. We define future returns as cumulative stock returns over the next fiscal year. The results from these regressions are reported in table 10. Not surprisingly, coefficients on future returns are negative and highly significant statistically across all regression models - firms that experience low returns also tend to downsize their investment programs. However, coefficients on our measures of short interest remain negative (and highly significant in all but one specification). These coefficients also remain similar in magnitude. For robustness, we repeat the estimation after controlling for returns as of t, rather than $t+1$ period, and find similar results. Taken together, this evidence suggests that the informational content of short interest beyond its potential power to predict future prices or returns plays a role in affecting corporate investment. These results are consistent with managers learning from short interest as opposed to merely reacting to future price declines.

8.2. The effect of equity dependence and financial constraints

It is possible that the negative relation between investment and short interest is driven by the ability of our measures of short interest to predict future declines in economic conditions, which inhibit the company's ability to raise funds in capital markets and finance its investment projects. As their equity prices decline, it becomes costlier for the managers to raise funds in capital markets to finance their investment projects and investment resulting in a negative effect on investment. Consistent with this intuition, Grullon et al. (2015) find that firms with removed barriers to short selling (those in the Reg SHO pilot group) experience both inferior returns and declines in investment.

Thus, even though according to this channel short interest does have a direct effect on investment, the mechanism is different: managers reduce investment not because they learn about their future investment opportunities, but because access to external capital becomes more expensive.

Note that this explanation is addressed to a large extent by our analysis in the previous subsection, where we control for the effect of short interest on future price changes by including future returns in our regressions. Nevertheless, we look deeper into this issue here. We argue that if capital market channel is the mechanism at work, it should be more relevant for firms that are financially constrained and dependent on external capital markets. Therefore, if investors anticipate a decline in future stock prices after observing high levels of short interest, and therefore, impede firms' access to capital markets, thus limiting future investment, this effect is likely to be stronger for more equity dependent and more financially constrained firms. To test this hypothesis we use two measures of dependence of capital markets /financial constraints. The first one is the equity dependence index based on Baker, Stein, and Wurgler (2003) (henceforth the BSW index). This index follows Kaplan and Zingales (1997) and is constructed as a linear combination of cash flow, dividends, and cash balances, all scaled by lagged total assets, and the book leverage ratio. Unprofitable and highly leveraged firms with low cash reserves and payouts are more reliant on external capital, and thus, will receive a higher index score. The second measure is an index of financial constraints, constructed as in Hadlock and Pierce (2010), henceforth the HP index. According to this classification, larger and more mature firms are less subject to financial constraints.

To test whether dependence on capital markets and financial constraints indeed amplifies the effect of short interest on investment, we follow our approach in the previous section and define a dummy variable (high BSW index dummy) that we set equal to one if the BSW index is above its sample median in a given year, and set it to zero otherwise. We use a similar approach do introduce the high HP dummy based on the HP index. We then augment our base regression specifications by adding each of these two dummies, as well as their interactions with the measures of short interest. The results for BSW and HP index are reported in Tables 11 and 12, respectively. As follows from the tables, both high BSW and high HP index dummies have a negative and statistically highly significant effect on investment. This result is expected - financially constrained firms have more limited access to capital markets and hence have to restrict their investments. More importantly, the coefficients on the interaction terms of the high BSW index /high HP index dummies with the measures of short interest are statistically insignificant and change sign depending on the specification. Thus, there is no evidence that financial constraints and equity dependence amplify the effect of short interest on investment. This evidence speaks against the conjecture that this effect is driven primarily by declining prices and impeded access to capital markets, and suggests that managerial learning is likely at play.

9. Conclusions

In this paper we argue that short selling by potentially informed traders represents a new channel for corporate managers to learn about their companies' quality and future growth prospects. While there is ample evidence that managers do learn from stock prices, we posit that short interest represent an additional source of information (that is not necessarily fully impounded in prices).

To better understand the informational role of short interest in a theoretical framework, we build a model that incorporates learning from both prices and short interest and allows for informed as well as liquidity (noise) trading. We show that in equilibrium the best estimate of the fundamental firm value is negatively related to short interest, and its sensitivity to short interest is stronger when there is more informational uncertainty about the true value and when the level of short interest is high. Equipped with these theoretical predictions, we proceed to empirically test the effect of short interest on managerial learning.

We present evidence consistent with managerial learning from short interest. First, we demonstrate a negative and significant relation between short interest and subsequent corporate investment. This relation survives controlling for future returns and is stronger for firms subject to higher information uncertainty, consistent with the managerial learning hypothesis. We find no evidence that this relation intensifies for financially constrained or equity dependent firms. This finding again points toward managerial learning - if the negative sensitivity of investment to short interest is driven primarily by the effect of short interest on future price declines and resulting impeded ability of firms to raise funds in capital markets, then this effect is likely to be stronger for financially constrained and equity dependent firms.

Finally, we take advantage of a regulatory experiment - Regulation SHO that removed barriers to short selling (and likely enhanced the informational content of short interest) for a group of pilot stocks in 2005 and examine the effect of this regulation on the sensitivity of investment to short interest. Consistent with the managerial learning hypothesis, we find that the relation between investment and short interest becomes stronger post Reg SHO.

Overall, our paper contributes to the growing literature that examines the interplay of corporate decisions and capital markets through the lens of managerial learning. We show that managerial learning goes beyond learning from prices and that short interest presents potentially valuable information for managerial decision making and therefore affects corporate investment.

Appendix

Proof of Proposition 2

First we derive the p.d.f. of the distribution of the short interest for the simple model considered above. With the Dirac's delta function $\delta(x) = \theta'(x)$, making use of the standard representation

$$\delta(x) = \int_{-\infty}^{+\infty} \frac{dq}{2\pi} \exp(iqx), \quad x \in R, \tag{A1}$$

and introducing the notation $\Sigma = \sum_{k=1}^{N} z_k + \xi - Z$, we have for the conditional p.d.f.

$$\begin{aligned} \rho(\Delta|Z) &= C\frac{1}{2^N}\sum_{m=0}^{N}\begin{pmatrix} n \\ m \end{pmatrix} A_m(\Delta|Z), && \text{(A2)} \\ A_m(\Delta|Z) &= \prod_{k=1}^{m}\int_0^{+\infty} dz_k \left(-\frac{(\Delta - z_k)^2}{2\sigma_s^2}\right)\int_0^{+\infty} d\xi \exp\left(-\frac{\xi^2}{2\sigma_\xi^2}\right)\delta(\Sigma) \\ &= \int_{-\infty}^{+\infty}\frac{dq}{2\pi}\exp(-iqZ)\int_0^{+\infty} d\xi \exp\left(-\frac{\xi^2}{2\sigma_\xi^2} + iq\xi\right)\varphi^m(q,\Delta), \end{aligned}$$

with

$$\varphi(q,\Delta) = \int_0^{+\infty} d\eta \left(-\frac{(\Delta - \eta)^2}{2\sigma_s^2}\right)\exp(iq\eta) \tag{A3}$$

and

$$\sigma_\xi^2 = \alpha^2 \sigma_{v|s}^4 \sigma_u^2. \tag{A4}$$

The normalization constant is given by

$$C = \int_{-\infty}^{+\infty} d\Delta \frac{1}{2^N}\sum_{m=0}^{N}\begin{pmatrix} n \\ m \end{pmatrix} A_m(\Delta|Z). \tag{A5}$$

Simplifying and making use of the Newton's binomial expansion $\frac{1}{2^N}\sum_{m=0}^{N}\begin{pmatrix} n \\ m \end{pmatrix} x^m =$

$\left(\frac{1+x}{2}\right)^N$, we obtain from (A2), in the large N limit

$$\rho\left(\Delta|Z\right) = B\int_{-\infty}^{+\infty}\frac{dq}{2\pi}e^{-iqZ}\int_{0}^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}+iq\xi}\left(\frac{1+\varphi\left(q,\Delta\right)}{2}\right)^N, \tag{A6}$$

and the normalization constant B given by

$$B^{-1} = \int_{-\infty}^{+\infty}d\Delta\int_{-\infty}^{+\infty}\frac{dq}{2\pi}e^{-iqZ}\int_{0}^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}+iq\xi}\left(\frac{1+\varphi\left(q,\Delta\right)}{2}\right)^N. \tag{A7}$$

Recalling the notation for the error function $\Phi\left(\cdot\right)$ and making use of (A3), we obtain

$$\varphi\left(q,\Delta\right) = \exp\left(iq\Delta - \frac{\sigma_s^2 q^2}{2}\right)\left(\frac{1+\Phi\left(\frac{\Delta}{\sigma_s}\right)}{2}\right). \tag{A8}$$

Substitution back into (A6) yields

$$\begin{aligned}\rho\left(\Delta|Z\right) &= B\int_{-\infty}^{+\infty}\frac{dq}{2\pi}e^{-iqZ}\int_{0}^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}+iq\xi}\left(1-\frac{1-\varphi\left(q,\Delta\right)}{2}\right)^N \\ &= B\int_{-\infty}^{+\infty}\frac{dq}{2\pi}e^{-iqZ}\int_{0}^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}+iq\xi}e^{N\log\left(1-\frac{1-\varphi(q,\Delta)}{2}\right)} \\ &\approx B\int_{-\infty}^{+\infty}\frac{dq}{2\pi}e^{-iqZ}\int_{0}^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}+iq\xi}e^{-\frac{N}{2}(1-\varphi(q,\Delta))-\frac{N}{8}(1-\varphi(q,\Delta))^2}.\end{aligned} \tag{A9}$$

Based on economic intuition, we expect that the conditional p.d.f. of the mispricing $\rho\left(\Delta|Z\right)$ in the limit of large number of informed traders $N >> 1$ should be located in the range of low mispricings Δ and sharp peaked. As we see below, this is indeed the case with $\frac{\Delta}{\sigma_s} \sim \frac{1}{\sqrt{N}} << 1$ in the large N limit.

This enables one to use the stationary phase method in order to evaluate the inverse Fourier transform in (A9). To summarize, we use a variant of the stationary phase method which says the following (see, e.g., DeBruijn, 1981). If the function $\Omega\left(q\right) = \lambda\Psi\left(q\right) - iqZ$ has a sharp maximum at $q = q_*$, so that $\Omega'\left(q\right)|_{q=q_*} = 0$, and $\Omega\left(q\right) = \Omega\left(q_*\right) - \frac{1}{2}\Omega''\left(q_*\right)\left(q-q_*\right)^2$ with $\Omega''\left(q_*\right) > 0$ and $\lambda >> 1$, then

$$\int_{-\infty}^{+\infty}\frac{dq}{2\pi}e^{\Omega(q)} \approx e^{\Omega(q_*)}\frac{1}{\sqrt{2\pi\Omega''\left(q_*\right)}} + o\left(\frac{1}{\sqrt{\lambda}}\right). \tag{A10}$$

Making use of the expansion

$$1-\varphi\left(q,\Delta\right)\approx -iq\Delta+\frac{\sigma_s^2 q^2}{2}-\Phi\left(\frac{\Delta}{\sigma_s}\right), \tag{A11}$$

changing the order of integration in (A9), we first observe that the stationary phase is achieved at

$$\begin{aligned} q_* &= \frac{i}{\sigma_s^2}\left(\Delta-\frac{2}{N}\frac{Z-\xi}{1-\frac{1}{2}\Phi\left(\frac{\Delta}{\sigma_s}\right)-\frac{1}{4}\frac{\Delta^2-\left(\frac{2}{N}(Z-\xi)\right)^2}{\sigma_s^2}}\right) \\ &= \frac{i}{\sigma_s^2}\left(\Delta-\frac{2}{N}\left(Z-\xi\right)\left(1+\frac{1}{\sqrt{2\pi}}\frac{1}{\sigma_s}\frac{2}{N}\left(Z-\xi\right)\right)\right)+o\left(N^{-3}\right). \end{aligned} \tag{A12}$$

Substitution back into (A9) and applying the stationary phase method yields

$$\rho\left(\Delta|Z\right)=B_1 e^{-\frac{N}{2}\left(\frac{1-\Phi\left(\frac{\Delta}{\sigma_s}\right)}{2}\right)}\int_0^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}}e^{-\frac{\left(\frac{N}{2}\Delta+\xi-F(Z)+\frac{N}{2}\frac{\sigma_s}{\sqrt{2\pi}}\right)^2}{2\sigma_s^2\frac{N}{2}}}, \tag{A13}$$

with

$$F\left(Z\right)=Z\left(1+\frac{1}{N}\frac{Z}{\sigma_s}\right). \tag{A14}$$

Integrating and renormalizing, we obtain

$$\begin{aligned} \rho\left(\Delta|Z\right) &= B_2 e^{-\frac{N}{2}\left(\frac{1-\Phi\left(\frac{\Delta}{\sigma_s}\right)}{2}\right)}\int_0^{+\infty}d\xi e^{-\frac{\xi^2}{2\sigma_\xi^2}}e^{-\frac{\left(\frac{N}{2}\Delta+\xi-F(Z)+\frac{N}{2}\frac{\sigma_s}{\sqrt{2\pi}}\right)^2}{2\sigma_s^2\frac{N}{2}}} \\ &= B_2 e^{-\frac{\left(\Delta-\frac{2}{N}F(Z)+\frac{\sigma_s}{\sqrt{2\pi}}\right)^2}{2\sigma_\Delta^2}}\left(1+\Phi\left(\frac{\left(\Delta-\frac{2}{N}F\left(Z\right)+\frac{\sigma_s}{\sqrt{2\pi}}\right)}{\frac{N}{2}\frac{\sigma_s^2}{\sigma_2}}\right)\right), \end{aligned} \tag{A15}$$

with

$$\frac{1}{\sigma_2^2}=\frac{1}{\frac{N}{2}\sigma_s^2}+\frac{1}{\sigma_\xi^2}, \tag{A16}$$

and

$$\frac{1}{\sigma_\Delta^2}=\frac{1}{\sigma_s^2}\frac{N}{2}-\frac{\sigma_\xi^2}{\sigma_s^4}, \tag{A17}$$

where the normalization constant is given by

$$B_2^{-1} = \int_{-\infty}^{+\infty} d\Delta e^{-\frac{\left(\Delta - \frac{2}{N}F(Z) + \frac{\sigma_s}{\sqrt{2\pi}}\right)^2}{2\sigma_\Delta^2}} \left(1 + \Phi\left(\frac{\left(\Delta - \frac{2}{N}F\left(Z\right) + \frac{\sigma_s}{\sqrt{2\pi}}\right)}{\frac{N}{2}\frac{\sigma_s^2}{\sigma_2}}\right)\right).$$

Finally, we note that the resulting distribution has a sharp peak at $\Delta = \frac{2}{N}F\left(Z\right) - \frac{\sigma_s}{\sqrt{2\pi}}$. Expanding the second factor in (A15) in the limit $\frac{\Delta}{\sigma_s} \ll 1$, we obtain

$$1 + \Phi\left(\frac{\left(\Delta - \frac{2}{N}F\left(Z\right) + \frac{\sigma_s}{\sqrt{2\pi}}\right)}{\frac{2}{N}\frac{\sigma_s^2}{\sigma_2}}\right) \approx e^{\frac{N}{2}\frac{\sigma_2}{\sigma_s^2}\sqrt{\frac{2}{\pi}}\left(\Delta - \frac{2}{N}F(Z) + \frac{\sigma_s}{\sqrt{2\pi}}\right)}. \tag{A18}$$

Substitution of this into (A15) and renormalizing again finally yields

$$\rho\left(\Delta|Z\right) = \frac{1}{\sqrt{2\pi\sigma_\Delta^2}} \exp\left(-\frac{\left(\Delta - \overline{\Delta}\right)^2}{2\sigma_\Delta^2}\right), \tag{A19}$$

with

$$\begin{aligned} \overline{\Delta} &= \frac{2}{N}F(Z) - \frac{\sigma_s}{\sqrt{2\pi}} - \sqrt{\frac{2}{\pi}}\frac{N}{2}\frac{\sigma_\Delta^2\sigma_\xi}{\sigma_s^2} \\ &\approx \frac{2}{N}Z\left(1 + \frac{1}{N}\frac{Z}{\sigma_s}\right) - \frac{1}{\sqrt{2\pi}}\left(\sigma_s + \sigma_\xi\right), \end{aligned} \tag{A20}$$

and

$$\sigma_\Delta^2 = \frac{2}{N}\sigma_s^2 + \frac{4}{N^2}\sigma_\xi^2, \tag{A21}$$

which means that the conditional p.d.f. is Normal with the mean $E\left[\Delta|Z\right]$ given by (A20) and $Var\left[\Delta|Z\right]$ given by (A21). Recall that $\sigma_\xi = \alpha\sigma_{v|s}^2\sigma_u$.

Informational content of short interest

The manager who can observe the short interest S in addition to observing the execution price P, may improve the precision of her estimate of the fundamental value v. Namely, in the cases when she observes only the exacution price and both the execution price and the short interest, the manager's best estimates of the fundamental are given by

$$\widehat{v}_P = P, \tag{A22}$$

and

$$\widehat{v}_M = P - \frac{2\alpha\sigma_{v|s}^2}{N} S \left(1 + \frac{\alpha\sigma_{v|s}^2}{N\sigma_s} S\right) + \frac{1}{\sqrt{2\pi}} \left(\sigma_s + \sigma_\xi\right), \tag{A23}$$

respectively. Note that the constant term in (A23) is a correction for the unconditional mean of the short interest.

First, the result (A23) says that the short interest provides a useful signal in the case when there is a sufficiently high level of "noise" in the market measured by the coefficient $\frac{\alpha\sigma_{v|s}^2}{N\sigma_s}$ reflecting the agents' uncertainty on their best estimates of the fundamental value. Clearly, the signal sensitivity with respect to the short interest increases in the level of noise. Second, as it follows from (A23), the signal sensitivity with respect to the short interest increases in the magnitude of the short interest itself due to the quadratic term in the second term in the r.h.s. of (A23). Therefore, our simple model predicts that, other things equal, short interest becomes more informative when the level of noise and magnitude of short interest increase. This is consistent with the empirical results.

The error term of the price signal takes the form

$$\begin{aligned}\widehat{v}_P - v &= \frac{\sigma_s}{N}\sum_{k=1}^{N} \varepsilon_k - \frac{1}{N}\alpha\sigma_{v|s}^2 u \qquad \text{(A24)}\\ &= \frac{\sigma_s}{N}\sum_{k=1}^{N} \left(\varepsilon_{k,+} + \varepsilon_{k,-}\right) - \frac{1}{N}\alpha\sigma_{v|s}^2 \left(u_+ + u_-\right).\end{aligned}$$

Similarly, we have for the error of the short interest signal (A23)

$$\widehat{v}_M - v = \frac{2\sigma_s}{N}\sum_{k=1}^{N/2} \left(\varepsilon_{k,-} - \overline{\varepsilon_{k,-}}\right) + \frac{2}{N}\alpha\sigma_{v|s}^2 \left(u_- - \overline{u_-}\right), \tag{A25}$$

where $\varepsilon_{k,-}$ correspond to the signals of the informed agents who short, and u_- stand for the aggregate demand of the noise traders who short the risky asset. Note that, strictly speaking, the unconditional distribution of the error (A25) is not Normal. However, it is close to Normal in the large N limit when the number of the agents becomes very large.

The corresponding variances are characterized by

$$\sigma_P^2 = \frac{\sigma_s^2}{N} + \frac{\left(\alpha\sigma_{v|s}^2\sigma_u\right)^2}{N^2}, \tag{A26}$$

and

$$\sigma_{\Delta}^{2}=\frac{2\sigma_{s}^{2}}{N}+\frac{4\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}}, \tag{A27}$$

respectively. Clearly, $\sigma_{\Delta}^{2}\geq\sigma_{P}^{2}$, and $\frac{\sigma_{\Delta}^{2}}{\sigma_{P}^{2}}\in[2;4]$.

Note that the signals $\widehat{v}_P$ and $\widehat{v}_M$ are less than perfectly correlated and therefore the manager will use both of them in order to improve the precision of her information set. Namely, we can calculate the covariance of $\widehat{v}_P$ and $\widehat{v}_M$ as

$$\begin{aligned} Cov\left[\widehat{v}_P,\widehat{v}_M\right] &= \frac{N}{2}\frac{2\sigma_{s}^{2}}{N^{2}}-\frac{2\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}} \\ &= \frac{\sigma_{s}^{2}}{N}-\frac{2\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}}. \end{aligned} \tag{A28}$$

Manager's learning

Now consider a simple manager's Bayesian learning mechanism. Suppose that the manager observes a prior distribution of the project value with finite mean and sufficiently small precision μ_0. Then, the prior distribution becomes uninformative and, after observing the short interest and execution price, the manager's best estimate of the fundamental is given by

$$v_B=(1-\gamma)\,\widehat{v}_P+\gamma\widehat{v}_M, \tag{A29}$$

with

$$\begin{aligned} 1-\gamma &= \frac{Var\left[\widehat{v}_M\right]-Cov\left[\widehat{v}_P,\widehat{v}_M\right]}{Var\left[\widehat{v}_P+\widehat{v}_M\right]} \\ &= \frac{\sigma_{\Delta}^{2}-Cov\left[\widehat{v}_P,\widehat{v}_M\right]}{\sigma_{\Delta}^{2}+\sigma_{P}^{2}-2Cov\left[\widehat{v}_P,\widehat{v}_M\right]}=\frac{\frac{\sigma_{s}^{2}}{N}+\frac{6\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}}}{\frac{\sigma_{s}^{2}}{N}+\frac{9\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}}}. \end{aligned} \tag{A30}$$

Similarly,

$$\gamma=\frac{Var\left[\widehat{v}_P\right]-Cov\left[\widehat{v}_P,\widehat{v}_M\right]}{Var\left[\widehat{v}_P+\widehat{v}_M\right]}=\frac{\frac{3\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}}}{\frac{\sigma_{s}^{2}}{N}+\frac{9\left(\alpha\sigma_{v|s}^{2}\sigma_{u}\right)^{2}}{N^{2}}}. \tag{A31}$$

Then the variance of the best estimate (A29) is given by

$$\sigma_B^2 = \frac{\sigma_\Delta^2 \sigma_P^2 - \left(Cov\left[\widehat{v}_P, \widehat{v}_M\right]\right)^2}{\sigma_\Delta^2 + \sigma_P^2 - 2Cov\left[\widehat{v}_P, \widehat{v}_M\right]} \tag{A32}$$

$$= \frac{\sigma_s^2}{N} \frac{\frac{\sigma_s^2}{N} + \frac{10\left(\alpha\sigma_{v|s}^2\sigma_u\right)^2}{N^2}}{\frac{\sigma_s^2}{N} + \frac{9\left(\alpha\sigma_{v|s}^2\sigma_u\right)^2}{N^2}}.$$

As it follows from (A31) the weight which the manager attributes to the signal based on short interest is increasing in both the level of the traders' informational uncertainty and the level of uncertainty due to the noise trading activity captured by the factor $\frac{\left(\alpha\sigma_{v|s}^2\sigma_u\right)^2}{N^2}$ in (A31).

This is consistent with the intuition that the short interest plays important role only if the amount of noise trading as well as "difference of opinions" of the informed traders measured by the conditional variance $\sigma_{v|s}^2$ are sufficiently high.

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Table 1: Descriptive statistics

This table reports the distribution of short interest and investment measures, as well as control variables, over the period 1973 2014. See Section 3 for sample description. *SI/Shares* is the monthly ratio of short interest (shares held short on the 15th business day of each month) scaled by total shares. *Days-to-cover* is short interest scaled by volume, constructed as described in Hong et al. (2015). *Abnormal SI* is scaled short interest (*SI/Shares*) net of expected short interest based upon the Karpoff and Lous (2010) benchmark that reflects the firms characteristics (see Section X for details). All short interest measures are calculated monthly and averaged over the fiscal year period. *Capex/PPE* is capital expenditures in year t (variable CAPX) scaled by total net plant, propery, and equipment (variable PPENT) as of the end of $t1$. *(Capex+R&D)/AT* is capital and R&D (variable XRD) expenditures in year t scaled by the total book value of assets (variable AT) as of the end of $t1$; values of zero are assigned to missing R&D values. Δ*(AT)* is the percentage change in the total book value of assets between years $t1$ and t. *M/B* is market-to-book ratio, defined as the total book value of assets plus market cap (the product of the number of common shares outstanding (CSHO) and share price (PRCC_F) at the end of the fiscal year-end), minus book value of equity (CEQ), all divided by the total book value of assets. *CF* is the sum of income before extraordinary items (variable IB) and depreciation and amortization (variable DP), all divided by the total book value of assets. *Ret* is stock monthly returns, averaged over the fiscal year. *Analyst dispersion* is monthly analyst forecast dispersion (unscaled), averaged over a one-year period. *St. dev (Ret)* is the standard deviation of monthly return over the fiscal year. *Idiosync. vol* is the residual volatility of the market model regression of monthly return over a 36-month period. *BSW index* is the index of equity dependence, based on Baker, Stein, Wurgler (2003). *HP index* is the index of financial constraints, constructed as in Hadlock and Pierce (2010).

	N	Mean	Median	25th Pctl	75th Pctl	St. Dev
			Main dependent and independent variables			
SI/shares (%)	70,028	2.52	0.75	0.12	3.2	3.97
Days-to-cover	70,016	4.6	2.69	0.92	6.2	5.46
Abnormal SI (%)	64,681	-0.003	-0.36	-1.32	0.2	3.07
Capex/PPE (%)	69,818	30.63	21.09	12.53	35.3	36.01
(Capex+R&D)/AT (%)	69,968	11.24	7.57	3.75	13.79	12.53
Δ(AT) (%)	69,968	11.13	5.91	-3.06	16.87	34.17
			Control variables			
M/B	69,954	1.81	1.36	1.04	1.99	1.44
CF (%)	69,929	4.26	8.28	3.56	12.48	18.86
log(AT)	69,968	5.83	5.77	4.38	7.2	1.99
Ret	63,581	0.12	0.06	-0.18	0.32	0.51
Analyst dispersion	40,189	0.16	0.06	0.03	0.13	0.45
St. dev (Ret)	68,264	0.12	0.11	0.08	0.15	0.06
Idiosync. Vol	58,292	0.02	0.02	0.01	0.03	0.02
BSW index	67,321	0.22	0.24	-0.52	1.08	1.47
HP index	52,901	-3.91	-4.04	-4.53	-3.43	0.67

Table 2: Short interest and investment - baseline results

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover* in Panel B, and *Abnormal SI* in Panel C. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	6.253***	2.001***	9.017***
	(0.369)	(0.101)	(0.445)
CF	0.338***	-0.017	0.146***
	(0.028)	(0.012)	(0.03)
log(Assets)	-5.783***	-2.403***	-14.986***
	(0.437)	(0.202)	(1.022)
SI/shares	-0.264***	-0.088***	-0.414***
	(0.086)	(0.021)	(0.07)
N	68974	69100	69100
adj. R^2	0.33	0.69	0.23
Panel B: Days-to-cover			
M/B	6.215***	1.991***	8.966***
	(0.365)	(0.101)	(0.44)
CF	0.334***	-0.017	0.145***
	(0.028)	(0.012)	(0.03)
log(Assets)	-5.889***	-2.456***	-15.215***
	(0.439)	(0.209)	(1.041)
days-to-cover	-0.236***	-0.025**	-0.207***
	(0.052)	(0.011)	(0.041)
N	68962	69088	69088
adj. R^2	0.33	0.69	0.23
Panel C: Abnormal short interest			
M/B	5.696***	2.019***	9.085***
	(0.4)	(0.109)	(0.443)
CF	0.317***	-0.008	0.153***
	(0.027)	(0.013)	(0.034)
log(Assets)	-5.048***	-2.213***	-13.787***
	(0.435)	(0.196)	(0.926)
Abnormal SI	-0.104	-0.053**	-0.341***
	(0.071)	(0.021)	(0.073)
N	63866	63960	63960
adj. R^2	0.31	0.69	0.21

Table 3: Short interest and investment early versus late (1994-2014) sub-period

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over early (1973 1993) versus late (1994 2014) sample sub-period. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover* in Panel B, and *Abnormal SI (ASI)* in Panel C. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	1973-1993			1994-2014		
	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)	(4) Capex/PPE	(5) (Capex+R&D)/AT	(6) Δ(AT)
	Panel A: Short interest scaled by shares					
M/B	7.259***	2.563***	8.349***	5.516***	1.817***	8.770***
	(0.997)	(0.330)	(1.113)	(0.456)	(0.102)	(0.488)
CF	0.525***	0.171***	0.564***	0.286***	-0.036***	0.125***
	(0.062)	(0.019)	(0.064)	(0.029)	(0.008)	(0.032)
log(Assets)	-7.733***	-1.641***	-12.944***	-4.671***	-3.322***	-21.126***
	(0.836)	(0.238)	(1.323)	(0.675)	(0.269)	(1.602)
SI/shares	-0.05	-0.101	-0.446*	-0.173**	-0.080***	-0.308***
	(0.254)	(0.070)	(0.250)	(0.081)	(0.021)	(0.070)
N	22372	22396	22396	41326	41396	41396
adj. R^2	0.277	0.579	0.208	0.321	0.738	0.239

Table 3: Short interest and investment early versus late (1994-2014) sub-period – Continued

	1973-1993			1994-2014		
	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)	(4) Capex/PPE	(5) (Capex+R&D)/AT	(6) Δ(AT)
Panel B: Days-to-cover						
M/B	8.087***	2.724***	9.133***	5.882***	1.745***	8.377***
	(1.020)	(0.326)	(1.134)	(0.395)	(0.094)	(0.503)
CF	0.553***	0.171***	0.571***	0.306***	-0.043***	0.123***
	(0.061)	(0.020)	(0.065)	(0.029)	(0.008)	(0.028)
log(Assets)	-8.384***	-1.827***	-13.976***	-5.972***	-3.657***	-22.997***
	(0.834)	(0.258)	(1.425)	(0.695)	(0.288)	(1.767)
days-to-cover	-0.08	-0.022	-0.141*	-0.306***	-0.018	-0.165***
	(0.054)	(0.020)	(0.076)	(0.070)	(0.013)	(0.051)
N	23367	23391	23391	45403	45505	45505
adj. R^2	0.298	0.572	0.225	0.339	0.742	0.256
Panel C: Abnormal short interest						
M/B	7.256***	2.559***	8.331***	5.487***	1.803***	8.718***
	(0.996)	(0.329)	(1.110)	(0.450)	(0.102)	(0.488)
CF	0.526***	0.171***	0.565***	0.286***	-0.036***	0.125***
	(0.062)	(0.019)	(0.063)	(0.029)	(0.008)	(0.032)
log(Assets)	-7.735***	-1.649***	-12.964***	-4.777***	-3.378***	-21.319***
	(0.830)	(0.239)	(1.327)	(0.660)	(0.272)	(1.602)
ASI	-0.053	-0.073	-0.450*	-0.152*	-0.065***	-0.299***
	(0.233)	(0.066)	(0.239)	(0.078)	(0.020)	(0.076)
N	22379	22403	22403	41331	41401	41401
adj. R^2	0.277	0.579	0.208	0.321	0.738	0.239

Table 4: Short interest and investment high versus low short interest

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. See Section 4 and Table 1 for sample description and variables construction. Each measure of short interest is split into two measures of high versus low short interest. High SI [DTC; ASI] takes on the value of SI [DTC; ASI] if it is above the sample median in a given year, and zero otherwise. Low SI takes on the value of SI [DTC; ASI] if it is below the sample median in a given year, and zero otherwise. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	6.251***	2.000***	9.013***
	(0.369)	(0.101)	(0.444)
CF	0.338***	-0.017	0.147***
	(0.028)	(0.012)	(0.030)
log(Assets)	-5.791***	-2.404***	-15.000***
	(0.437)	(0.203)	(1.024)
High SI(¿median)	-0.255***	-0.087***	-0.398***
	(0.089)	(0.021)	(0.067)
Low SI(¡=median)	-0.113	-0.071	-0.150
	(0.253)	(0.064)	(0.244)
N	68974	69100	69100
adj. R^2	0.328	0.691	0.229

Table 4: Short interest and investment high versus low short interest – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
	Panel B: Days-to-cover		
M/B	6.212***	1.990***	8.959***
	(0.365)	(0.101)	(0.438)
CF	0.334***	-0.017	0.145***
	(0.028)	(0.012)	(0.030)
log(Assets)	-5.892***	-2.457***	-15.228***
	(0.438)	(0.208)	(1.042)
High DTC(¿median)	-0.231***	-0.024**	-0.193***
	(0.056)	(0.011)	(0.042)
Low DTC(¡=median)	-0.179	-0.016	-0.013
	(0.138)	(0.043)	(0.128)
N	68962	69088	69088
adj. R^2	0.328	0.691	0.229
	Panel C: Abnormal short interest		
M/B	5.688***	2.027***	9.109***
	(0.399)	(0.110)	(0.446)
CF	0.317***	-0.008	0.153***
	(0.027)	(0.013)	(0.034)
log(Assets)	-5.066***	-2.194***	-13.733***
	(0.435)	(0.196)	(0.930)
High ASI(¿median)	-0.062	-0.096***	-0.467***
	(0.092)	(0.027)	(0.083)
Low ASI(¡=median)	-0.230	0.076	0.045
	(0.158)	(0.048)	(0.234)
N	63866	63960	63960
adj. R^2	0.307	0.685	0.211

Table 5: Short interest and investment interaction with analyst dispersion

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. *High disper* is a dummy variable that takes on a value of one if *Analyst dispersion* is above sample median in a given year, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
	Panel A: Short interest scaled by shares		
M/B	6.175***	1.885***	8.275***
	(0.397)	(0.100)	(0.514)
CF	0.340***	-0.025*	0.129**
	(0.037)	(0.013)	(0.048)
log(Assets)	-4.262***	-3.050***	-16.725***
	(0.496)	(0.222)	(1.218)
SI/shares	-0.129	-0.033	-0.149
	(0.103)	(0.020)	(0.098)
high disper (dummy=1)	-0.793*	0.133	-0.317
	(0.423)	(0.156)	(0.659)
SI/shares*high disper	-0.280**	-0.101***	-0.421***
	(0.112)	(0.022)	(0.087)
N	39401	39420	39420
adj. R^2	0.405	0.746	0.242

Table 5: Short interest and investment interaction with analyst dispersion – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel B: Days-to-cover			
M/B	6.092***	1.878***	8.209***
	(0.388)	(0.100)	(0.517)
CF	0.336***	-0.024*	0.128**
	(0.037)	(0.013)	(0.049)
log(Assets)	-4.448***	-3.091***	-16.929***
	(0.486)	(0.225)	(1.231)
days-to-cover (DTC)	-0.180**	0.002	-0.108
	(0.068)	(0.015)	(0.074)
high disper (dummy=1)	-0.695	0.031	-0.613
	(0.584)	(0.160)	(0.651)
DTC*high disper	-0.211***	-0.055***	-0.245***
	(0.072)	(0.020)	(0.082)
N	39401	39420	39420
adj. R^2	0.406	0.745	0.241
Panel C: Abnormal short interest			
M/B	5.749***	1.882***	8.284***
	(0.452)	(0.102)	(0.509)
CF	0.310***	-0.017	0.141**
	(0.033)	(0.014)	(0.053)
log(Assets)	-3.661***	-2.875***	-15.855***
	(0.494)	(0.231)	(1.183)
Abnormal SI (ASI)	0	-0.022	-0.081
	(0.117)	(0.022)	(0.130)
high disper (dummy=1)	-2.160***	-0.255**	-1.945***
	(0.343)	(0.113)	(0.506)
ASI*high disper	-0.265**	-0.067***	-0.383***
	(0.116)	(0.023)	(0.129)
N	36403	36419	36419
adj. R^2	0.389	0.739	0.221

Table 6: Short interest and investment interaction with total return volatility

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. *High vol* is a dummy variable that takes on a value of one if SD(Ret) is above sample median in a given year, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	6.237***	2.014***	8.988***
	(0.361)	(0.101)	(0.450)
CF	0.331***	-0.019	0.143***
	(0.028)	(0.012)	(0.030)
log(Assets)	-5.668***	-2.441***	-15.067***
	(0.429)	(0.205)	(1.043)
SI/shares	-0.123	-0.048**	-0.155*
	(0.101)	(0.020)	(0.091)
high vol (dummy=1)	0.358	-0.078	-0.485
	(0.365)	(0.090)	(0.338)
SI/shares*high vol	-0.192***	-0.060***	-0.367***
	(0.060)	(0.018)	(0.073)
N	67214	67333	67333
adj. R^2	0.329	0.694	0.229

Table 6: Short interest and investment interaction with total return volatility – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel B: Days-to-cover			
M/B	6.199***	2.004***	8.936***
	(0.357)	(0.101)	(0.445)
CF	0.326***	-0.019	0.140***
	(0.028)	(0.012)	(0.030)
log(Assets)	-5.773***	-2.497***	-15.283***
	(0.432)	(0.212)	(1.060)
Days-to-cover	-0.151***	-0.017	-0.070
	(0.050)	(0.010)	(0.048)
high vol (dummy=1)	0.417	-0.183*	-0.386
	(0.426)	(0.106)	(0.422)
DTC*high vol	-0.154***	-0.021	-0.273***
	(0.052)	(0.013)	(0.051)
N	67208	67327	67327
adj. R^2	0.329	0.694	0.229
Panel C: Abnormal short interest			
M/B	5.681***	2.008***	9.067***
	(0.397)	(0.108)	(0.447)
CF	0.313***	-0.011	0.151***
	(0.027)	(0.013)	(0.034)
log(Assets)	-4.977***	-2.257***	-13.889***
	(0.429)	(0.198)	(0.950)
Abnormal SI (ASI)	0.017	0.006	-0.074
	(0.075)	(0.025)	(0.104)
high vol (dummy=1)	-0.140	-0.234***	-1.398***
	(0.330)	(0.077)	(0.351)
ASI*high vol	-0.204**	-0.095***	-0.415***
	(0.080)	(0.024)	(0.095)
N	62481	62571	62571
adj. R^2	0.309	0.688	0.212

Table 7: Short interest and investment interaction with idiosyncratic return volatility

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. *High Ivol* is a dummy variable that takes on a value of one if *Idiosync.vol* is above sample median in a given year, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	5.932***	1.925***	8.853***
	(0.363)	(0.095)	(0.444)
CF	0.303***	-0.026**	0.144***
	(0.026)	(0.011)	(0.031)
log(Assets)	-5.077***	-2.624***	-16.634***
	(0.483)	(0.229)	(1.057)
SI/shares	-0.082	-0.056***	-0.189**
	(0.078)	(0.019)	(0.072)
high Ivol (dummy=1)	-0.930**	-0.531***	-1.423***
	(0.375)	(0.104)	(0.394)
SI/shares*High Ivol	-0.162**	-0.041*	-0.309***
	(0.070)	(0.021)	(0.074)
N	57377	57476	57476
adj. R^2	0.323	0.710	0.224

Table 7: Short interest and investment interaction with idiosyncratic return volatility – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel B: Days-to-cover			
M/B	5.894***	1.911***	8.783***
	(0.357)	(0.095)	(0.441)
CF	0.299***	-0.026**	0.142***
	(0.026)	(0.011)	(0.031)
log(Assets)	-5.148***	-2.684***	-16.873***
	(0.478)	(0.236)	(1.082)
days-to-cover (DTC)	-0.109**	-0.017	-0.107**
	(0.043)	(0.011)	(0.044)
high Ivol (dummy=1)	-0.621	-0.624***	-1.543***
	(0.417)	(0.115)	(0.433)
DTC*High Ivol	-0.170***	-0.011	-0.184***
	(0.056)	(0.016)	(0.052)
N	57376	57475	57475
adj. R^2	0.323	0.710	0.224
Panel C: Abnormal short interest			
M/B	5.518***	1.888***	8.847***
	(0.406)	(0.098)	(0.465)
CF	0.291***	-0.022*	0.132***
	(0.026)	(0.011)	(0.031)
log(Assets)	-4.892***	-2.573***	-16.279***
	(0.481)	(0.223)	(1.006)
Abnormal SI (ASI)	-0.033	-0.009	-0.139*
	(0.064)	(0.022)	(0.081)
high Ivol (dummy=1)	-1.700***	-0.839***	-3.436***
	(0.384)	(0.089)	(0.431)
ASI*High Ivol	-0.189**	-0.086***	-0.387***
	(0.091)	(0.028)	(0.086)
N	54979	55064	55064
adj. R^2	0.314	0.708	0.218

Table 8: Short interest and investment interaction with institutional holding

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1980 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. *High inst hold* is a dummy variable that takes on a value of one if institutional holding is above sample median in a given year, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	6.142***	1.896***	8.777***
	(0.374)	(0.100)	(0.462)
CF	0.323***	-0.025**	0.135***
	(0.027)	(0.011)	(0.028)
log(Assets)	-5.828***	-2.811***	-17.458***
	(0.504)	(0.215)	(1.118)
SI/shares	-0.675***	-0.142***	-0.826***
	(0.164)	(0.039)	(0.145)
high inst hold (dummy=1)	0.748	1.286***	3.883***
	(0.617)	(0.205)	(0.630)
SI/shares*high inst hold	0.515***	0.052	0.522***
	(0.141)	(0.037)	(0.152)
N	61052	61172	61172
adj. R^2	0.332	0.706	0.236

Table 8: Short interest and investment interaction with institutional holding – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel B: Days-to-cover			
M/B	6.081***	1.881***	8.705***
	(0.369)	(0.100)	(0.454)
CF	0.320***	-0.025**	0.136***
	(0.027)	(0.011)	(0.028)
log(Assets)	-6.041***	-2.889***	-17.793***
	(0.504)	(0.223)	(1.145)
days-to-cover (DTC)	-0.341***	-0.015	-0.272***
	(0.074)	(0.014)	(0.057)
high inst hold (dummy=1)	0.916	1.512***	4.228***
	(0.652)	(0.202)	(0.663)
DTC*high inst hold	0.194***	-0.037**	0.124*
	(0.066)	(0.018)	(0.070)
N	61050	61170	61170
adj. R^2	0.332	0.706	0.235
Panel C: Abnormal short interest			
M/B	5.524***	1.907***	8.860***
	(0.404)	(0.108)	(0.451)
CF	0.298***	-0.018	0.139***
	(0.027)	(0.011)	(0.032)
log(Assets)	-5.135***	-2.625***	-16.244***
	(0.492)	(0.211)	(1.005)
Abnorm SI (ASI)	-0.456***	-0.132***	-0.776***
	(0.136)	(0.040)	(0.119)
high inst hold (dummy=1)	2.901***	1.465***	5.160***
	(0.483)	(0.171)	(0.587)
ASI*high inst hold	0.465***	0.099**	0.592***
	(0.145)	(0.042)	(0.134)
N	56193	56281	56281
adj. R^2	0.312	0.702	0.218

Table 9: Short interest and investment the impact of Reg SHO

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period of before and after Regulation SHO (2001 2008) for the sample of stocks included in Russell 3000 index (as of 2004). The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. *SHO* is a dummy variable that takes on a value of one if the stock was in the sample of pilot stocks and was subject to the Reg SHO (which started in June 2004) for at least 7 months of its fiscal year starting from year 2004 and onward, and zero otherwise. *SHO* also takes on a value of one if the stock was in the sample of non-pilot stocks (but part of Russell 3000 index) for at least 7 months of its fiscal year starting from year 2007 and onward, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(Assets)
		Panel A: Short interest scaled by shares	
M/B	5.432***	2.011***	9.785***
	(0.786)	(0.172)	(0.682)
CF	0.363***	-0.023	0.200***
	(0.054)	(0.014)	(0.057)
log(Assets)	-2.839*	-4.095***	-39.561***
	(1.486)	(0.454)	(1.767)
SHO	4.458***	0.693**	0.067
	(1.283)	(0.276)	(1.395)
SI/shares*SHO	-0.688***	-0.122***	-0.230
	(0.190)	(0.040)	(0.156)
SI/Shares	-0.097	-0.038	-0.303**
	(0.155)	(0.033)	(0.148)
N	11147	11158	11158
adj. R^2	0.428	0.785	0.328

Table 9: Short interest and investment the impact of Reg SHO – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(Assets)
	Panel B: Days-to-cover		
M/B	5.427***	2.002***	9.747***
	(0.789)	(0.173)	(0.682)
CF	0.362***	-0.023	0.205***
	(0.054)	(0.014)	(0.057)
log(Assets)	-3.393**	-4.235***	-40.224***
	(1.508)	(0.462)	(1.780)
SHO	3.034**	0.738**	1.998
	(1.420)	(0.300)	(1.593)
days-to-cover* SHO	-0.362**	-0.108***	-0.468***
	(0.147)	(0.029)	(0.141)
days-to-cover	-0.211**	-0.040*	-0.005
	(0.096)	(0.022)	(0.095)
N	11147	11158	11158
adj. R^2	0.427	0.785	0.328
	Panel C: Abnormal short interest		
M/B	5.206***	2.047***	9.660***
	(0.807)	(0.176)	(0.694)
CF	0.321***	-0.026*	0.224***
	(0.051)	(0.015)	(0.060)
log(Assets)	-1.598	-3.890***	-40.060***
	(1.466)	(0.463)	(1.870)
SHO	0.823	0.090	-0.911
	(1.081)	(0.225)	(1.140)
SHO*Abnormal SI	-0.764***	-0.134***	-0.213
	(0.201)	(0.042)	(0.157)
Abnormal SI	-0.005	-0.028	-0.219
	(0.154)	(0.035)	(0.149)
N	10722	10728	10728
adj. R^2	0.429	0.790	0.326

Table 10: Short interest and investment baseline results with control for future return

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover* in Panel B, and *Abnormal SI* in Panel C. See Section 4 and Table 1 for sample description and variables construction. *Ret (F1)* is return during the fiscal year $t+1$. All other control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
	Panel A: Short interest scaled by shares		
M/B	5.981***	1.934***	8.473***
	(0.382)	(0.105)	(0.485)
CF	0.346***	-0.021*	0.114***
	(0.030)	(0.012)	(0.031)
log(Assets)	-5.853***	-2.510***	-15.592***
	(0.436)	(0.207)	(1.086)
SI/shares	-0.284***	-0.084***	-0.410***
	(0.085)	(0.022)	(0.079)
Ret (F1)	-2.897***	-0.734***	-4.614***
	(0.389)	(0.122)	(0.543)
N	62621	62729	62729
adj. R^2	0.34	0.70	0.23

Table 10: Short interest and investment baseline results with control for future return – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel B: Days-to-cover			
M/B	5.939***	1.924***	8.421***
	(0.378)	(0.105)	(0.479)
CF	0.343***	-0.021*	0.113***
	(0.030)	(0.012)	(0.030)
log(Assets)	-5.978***	-2.559***	-15.815***
	(0.442)	(0.213)	(1.107)
days-to-cover	-0.227***	-0.026**	-0.205***
	(0.052)	(0.011)	(0.047)
Ret (F1)	-2.877***	-0.727***	-4.580***
	(0.381)	(0.121)	(0.541)
N	62612	62720	62720
adj. R^2	0.34	0.70	0.23
Panel C: Abnormal short interest			
M/B	5.452***	1.955***	8.521***
	(0.424)	(0.109)	(0.483)
CF	0.325***	-0.013	0.120***
	(0.029)	(0.013)	(0.033)
log(Assets)	-5.089***	-2.310***	-14.463***
	(0.427)	(0.207)	(0.994)
abnormal SI	-0.122	-0.049**	-0.325***
	(0.074)	(0.022)	(0.082)
Ret (F1)	-2.720***	-0.699***	-4.159***
	(0.357)	(0.120)	(0.514)
N	58092	58172	58172
adj. R^2	0.32	0.69	0.21

Table 11: Short interest and investment interaction with equity dependence index

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. *High BSW* is a dummy variable that takes on a value of one if *BSW* index is above sample median in a given year, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period $t1$. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	5.929***	2.001***	8.561***
	(0.368)	(0.109)	(0.447)
CF	0.284***	-0.022*	0.146***
	(0.029)	(0.012)	(0.031)
log(Assets)	-5.150***	-2.269***	-13.943***
	(0.403)	(0.194)	(0.958)
SI/shares	-0.102	-0.093***	-0.397***
	(0.115)	(0.022)	(0.115)
High BWS index(dummy=1)	-5.751***	-1.330***	-4.338***
	(0.485)	(0.145)	(0.554)
SI/shares*High BWS	-0.035	0.037	0.049
	(0.124)	(0.029)	(0.128)
N	66435	66535	66535
adj. R^2	0.323	0.690	0.219

Table 11: Short interest and investment interaction with equity dependence index – Continued

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel B: Days-to-cover			
M/B	5.921***	1.988***	8.506***
	(0.363)	(0.108)	(0.445)
CF	0.282***	-0.023*	0.145***
	(0.029)	(0.012)	(0.031)
log(Assets)	-5.167***	-2.312***	-14.138***
	(0.409)	(0.198)	(0.973)
days-to-cover (DTC)	-0.253***	-0.021	-0.211***
	(0.059)	(0.014)	(0.065)
High BWS index(dummy=1)	-6.543***	-1.286***	-4.446***
	(0.505)	(0.139)	(0.557)
DTC*High BWS	0.166***	0.007	0.045
	(0.060)	(0.018)	(0.075)
N	66424	66524	66524
adj. R^2	0.324	0.690	0.219
Panel C: Abnormal short interest			
M/B	5.559***	2.008***	8.560***
	(0.394)	(0.111)	(0.449)
CF	0.275***	-0.016	0.150***
	(0.027)	(0.012)	(0.033)
log(Assets)	-4.814***	-2.169***	-13.306***
	(0.403)	(0.189)	(0.899)
Abnormal SI (ASI)	-0.005	-0.039	-0.393***
	(0.115)	(0.024)	(0.127)
High BWS index (dummy=1)	-5.529***	-1.258***	-4.037***
	(0.414)	(0.125)	(0.473)
ASI*High BWS	-0.103	0.004	0.156
	(0.140)	(0.030)	(0.150)
N	63130	63216	63216
adj. R^2	0.313	0.684	0.207

Table 12: Short interest and investment interaction with financial constraints index

This table reports estimates of regressions relating measures of investment as a function of short interest proxies and control variables over the period 1973 2014. The short interest proxies are *SI/shares* in Panel A; *Days-to-cover (DTC)* in Panel B, and *Abnormal SI (ASI)* in Panel C. High HP is a dummy variable that takes on a value of one if HP index is above sample median in a given year, and zero otherwise. See Section 4 and Table 1 for sample description and variables construction. All control variables are as of period t1. The regressions are estimated using the OLS model, and include firm and year fixed effects. Standard errors adjusted for within-firm correlation are reported in parentheses below coefficient estimates. Significance at the 1%, 5%, and 10% level are indicated by ***, **, and *, respectively.

	(1) Capex/PPE	(2) (Capex+R&D)/AT	(3) Δ(AT)
Panel A: Short interest scaled by shares			
M/B	5.738***	1.995***	8.882***
	(0.390)	(0.121)	(0.469)
CF	0.328***	-0.005	0.192***
	(0.031)	(0.014)	(0.036)
log(Assets)	-5.403***	-2.196***	-13.299***
	(0.427)	(0.198)	(0.891)
SI/shares	-0.175**	-0.077***	-0.298***
	(0.068)	(0.023)	(0.079)
High HP index(dummy=1)	-1.011	-1.065***	-3.028***
	(0.641)	(0.249)	(0.832)
SI/shares*High HP	0.132	0.006	-0.114
	(0.119)	(0.032)	(0.118)
N	52439	52507	52507
adj. R^2	0.315	0.669	0.211

Table 12: Short interest and investment interaction with financial constraints index – Continued

Panel B: Days-to-cover

M/B	5.734***	1.981***	8.824***
	(0.385)	(0.120)	(0.463)
CF	0.324***	-0.005	0.190***
	(0.031)	(0.014)	(0.036)
log(Assets)	-5.395***	-2.242***	-13.468***
	(0.429)	(0.201)	(0.903)
days to cover (DTC)	-0.141***	-0.049***	-0.179***
	(0.040)	(0.014)	(0.058)
High HP index(dummy=1)	-0.622	-1.298***	-3.099***
	(0.670)	(0.266)	(0.831)
DTC*High HP	-0.023	0.059***	-0.023
	(0.048)	(0.021)	(0.082)
N	52427	52495	52495
adj. R^2	0.315	0.668	0.210

Panel C: Abnormal short interest

M/B	5.329***	1.965***	8.806***
	(0.374)	(0.122)	(0.503)
CF	0.318***	-0.003	0.184***
	(0.031)	(0.014)	(0.037)
log(Assets)	-4.728***	-2.109***	-12.677***
	(0.395)	(0.202)	(0.864)
Abnormal SI (ASI)	-0.177***	-0.050*	-0.315***
	(0.065)	(0.027)	(0.088)
High HP index(dummy=1)	0.097	-0.774***	-2.359***
	(0.549)	(0.222)	(0.700)
ASI*High HP	0.359**	0.011	0.104
	(0.134)	(0.036)	(0.128)
N	50439	50502	50502
adj. R^2	0.306	0.674	0.201