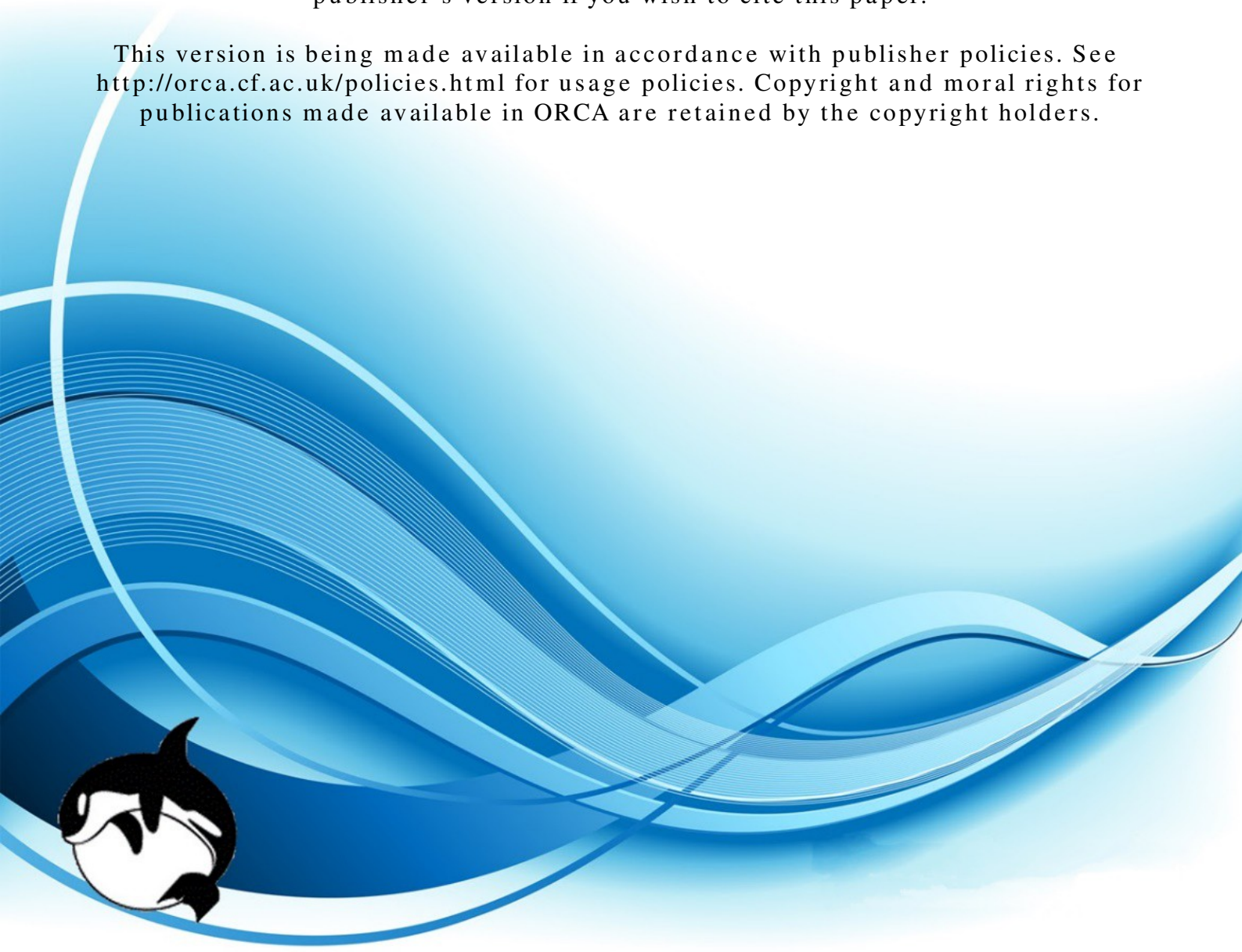


Why do firm fundamentals predict returns? Evidence from short selling activity

Abstract

This study uses short selling activity to test whether the relation between fundamentals and future returns is due to rational pricing or mispricing. We find that short sellers target firms with fundamental performance below market expectations. We also show that short selling activity reduces the return predictability of fundamentals by speeding up the price adjustments to negative fundamental signals. To further investigate whether the returns earned by short sellers reflect rational risk premia or mispricing, we exploit a natural experiment, namely Regulation of SHO, which creates exogenous shocks to short selling by temporarily relaxing short-sale constraints. Evidence from the experiment confirms that the superior returns to short sellers result from exploiting overpricing. Overall, our study suggests that the return predictability of fundamentals reflects mispricing rather than rational risk premia.

Key words: short selling, F-score, mispricing, SHO

JEL classification: G12 G14

1. Introduction

While there is ample evidence that firm fundamentals predict stock returns[1], the literature has not reached a consensus on why such patterns exist. Several researchers argue that these patterns arise because markets are slow to fully incorporate fundamental information (Piotroski, 2000; Hou and Moskowitz, 2005; Piotroski and So, 2012; Choi and Sias, 2012). However, others contend that the relationship between firm fundamentals and future returns is consistent with a risk-based explanation. For example, Fama and French (2006; 2008; 2015) show that in the standard valuation model, higher expected profitability indicates greater risk after controlling for book-to-market ratios and expected investment. As the strength of fundamentals also proxies for expected profitability, firms with improved (deteriorated) fundamentals may have higher (lower) risk and therefore higher (lower) expected returns.

Fama and French (2006) highlight that tests based on the valuation equations are generally powerless to determine whether the observed relations between expected returns and financial strength are driven by rational or irrational pricing. To overcome this limitation, we develop new tests for evaluating the extent to which short sellers exploit the gradual incorporation of investors' revised expectations into prices and whether short selling activity affects the relationship between fundamentals and future returns. Under the risk-based explanation, investors immediately revise expectations about firms' future performance and their revised expectations are instantaneously impounded into prices. This implies that deteriorated fundamentals predict negative returns because lower expected profitability is associated with lower risk (and therefore low future returns). Rational pricing also suggests that short selling activity alters neither market expectations nor the return predictability of

[1] For example, accruals (Sloan, 1996; Fama and French, 2006; Richardson et al., 2005; Hou et al. 2012), return on equity (Haugen and Baker, 1996), return on asset (Jegadeesh and Livnat, 2006; Fama and French, 2006; Novy-Marx, 2013), asset growth (Cooper et al., 2008) and investment (Liu et al., 2009; Hou et al., 2015).

fundamentals. In contrast, under the mispricing explanation, investors slowly revise their expectations due to market frictions[2] or behavioral biases (DeBondt and Thaler, 1985; Barberis et al., 1998; Daniel et al., 1998; Hong and Stein, 1999). The slow revisions of expectations are associated with an underreaction to negative fundamental information and the resulting overpricing would attract short sellers. The exploitation of overpricing impounds short sellers' negative expectations into prices and speeds up price adjustment to negative information. Thus, the mispricing argument predicts that short selling activity affects both market expectations and the return predictability of fundamentals.

Specifically, in the presence of investors' biased expectations, short sellers may have greater profit opportunities. For example, low returns are likely to arise when investors over-extrapolate past growth and underweight negative fundamental information, which contradicts their beliefs about firms' growth prospects (Lakonishok et al., 1994; LaPorta, 1996; LaPorta et al., 1997; Dechow and Sloan, 1997; Mohanram, 2005; Piotroski and So, 2012). Thus, under the mispricing argument, short selling is likely to be more active when the negative fundamental performance is incongruent with market expectations and less active when deteriorated fundamentals are expected by the market. In contrast, the rational argument emphasizes that the market quickly adjusts its expectations to fully reflect negative fundamental signals, leaving short sellers with no chance to exploit overpricing.

To empirically discriminate between the mispricing and risk explanations, we explore whether and how short sellers use fundamental signals to identify overvalued stocks. Prior studies find that short sellers are attracted to stocks with high market expectations (e.g., Dechow et al., 2001; Curtis and Fargher, 2014). The rationale is that stocks with low book-to-

[2] Mispricing can persist if market frictions impede investors from quickly incorporating their revised expectations into prices and/or if short sellers have constraints that limit their abilities to exploit mispricing (Miller, 1977; Harrison and Kreps, 1978; Diamond and Verrecchia, 1987; Scheinkman and Xiong, 2003).

market (BM), low earnings-to-price, and low cash-flow-to-price ratios are customarily perceived to be "expensive" or overpriced (e.g., Lee, 2014). Nevertheless, low price multiples do not always indicate overpricing and may sometimes reflect unbiased market expectations about firms' future performance. For example, a firm's share may be "expensive", but unattractive to short sellers, when the firm's growth prospects are largely factored into its price. In contrast, overpricing is likely to arise when the market overestimates the growth prospects implied by a firm's fundamentals. Based on the above arguments, we predict that short selling activity is more likely to be prevalent when weak fundamentals are incongruent with market expectations.

By using Piotroski's F-score (2000) to measure the strength of fundamentals, we find that F-score can predict not only returns but also short selling activity, implying that short sellers may use fundamental signals to exploit overpricing. To further explore how short selling activity is linked with fundamental signals and market expectations, we construct F-score and BM-based portfolios by ranking the sample firms independently based on BM and F-score. We find that short selling activity is significant in firms whose fundamental performance is below market expectations (e.g., firms with low BM and low F-score) and insignificant in firms whose fundamental performance is congruent with market expectations (e.g., firms with low BM and high F-score). This evidence suggests that short sellers exploit the market's slow revisions of expectations.

The exploitation of overpricing also implies that short selling incorporates negative expectations into prices and, therefore, increases the speed at which negative fundamental signals are incorporated into prices. By sorting low F-score firms into quintile portfolios according to short interest, we find that the future returns to low F-score firms are insignificant when short interest is high and significantly negative when short interest is low. We also stratify low F-score firms with low BM ratios, which are more likely to be

overpriced than other stocks, into terciles based on short interest. We find that the return predictability of F-score declines with short interest, implying that short selling attenuates the return predictability of fundamentals by speeding up information diffusion.

So far, our analysis is based on the premise that short sellers are arbitrageurs and their activity has no relation with risk. Although this assumption is plausible and consistent with prior studies (e.g., Miller, 1977; D'Avolio, 2002; Christophe et al., 2004; Engelberg et al., 2012; Boehmer and Wu, 2013; Curtis and Fargher, 2014), it is also possible that short sellers are more risk-tolerant than individual investors (e.g., Engelberg et al., 2018). This risk interpretation implies that, if risk remains constant, current short selling activity already reflects risk-tolerances and the activity should exert no influence on the relationship between future returns and firm fundamentals.

However, it is empirically challenging to disentangle short selling driven by mispricing from that driven by high risk-tolerances. To address this issue, we evaluate the consequence of relaxing short-sale constraints, namely the pilot program of Regulation SHO (Reg SHO), on the return predictability of F-score. Exploiting Reg SHO as a natural experiment has the advantage of creating exogenous variations in short selling through a temporary regulation change that is unlikely to be correlated with variations in factor risk (e.g., Massa et al., 2015; Grullon et al., 2015; He and Tian, 2015; Fang et al., 2016; Chu et al., 2020)[3]. Thus, the pilot program is an ideal setting to test whether risk or mispricing can explain the return predictability of fundamentals.

The risk-based explanation does not predict any change in the return predictability of fundamentals. In contrast, the mispricing explanation makes the following predictions: (i) a

[3] In particular, Massa et al. (2015) and Fang et al. (2015) investigate the role of short selling in mitigating earnings management. Grullon et al. (2015) and He and Tian (2015) shed light on the role of short sellers in shaping corporate investment. Chu et al. (2020) are interested in the role of limit-to-arbitrage via relaxing short-sale constraints in mitigating asset pricing anomalies.

reduction in the return predictability of fundamentals for pilot firms relative to non-pilot firms during the pilot period; (ii) such a reduction comes mainly from the short-leg portfolios with poor fundamentals; and (iii) the pilot portfolio, which contains pilot stocks with poor fundamentals and low BM, would outperform its non-pilot counterpart during the pilot period. The three predictions are based on the same logic: during the implementation of Reg SHO, pilot stocks with a high likelihood of overpricing (e.g., characteristics such as poor fundamentals and low BM) could be more easily short sold than their non-pilot counterparts, resulting in the subsequent returns of the former being higher than those of the latter. By using a difference-in-differences approach, we confirm the above predictions in support of the mispricing explanation.

However, one may argue that short sellers trade low F-score firms because these firms have experienced poor past performance. That is, short sellers are momentum traders. To test this possible alternative explanation, we compare the difference in short selling between low and high F-score firms conditional upon past performance. We find that short sellers are repelled from low F-score firms with poor past performance and are attracted to low F-score firms with good past performance. This suggests that short sellers are contrarian traders. Another potential concern is that short sellers may move the price of low F-score firms far below fundamental values during economic downturns when poor performance is more likely to occur (e.g., Cox, 2008). We address this concern by comparing the difference in short selling between low and high F-score firms conditional upon investor sentiment. We find that short selling low F-score firms prevails during high sentiment periods, indicating that short selling helps correct the overpricing induced by the speculative demand of noise traders (e.g., Shiller, 1984; Yu and Yuan, 2011). Overall, we provide evidence in favor of the mispricing explanation for the return predictability of fundamentals.

Our contribution to the literature is twofold. First, we contribute to the long standing debate on whether the return predictability of fundamentals is due to rational pricing or mispricing by providing a new test based on short sellers' trading behavior following the release of fundamental signals. Unlike prior studies, which show that short sellers are attracted to stocks with either high market expectations or weak fundamentals (e.g., Dechow et al., 2001; Christophe et al., 2004; Drake et al. 2011; Chi et al. 2014; Curtis and Fargher, 2014), we propose and test the hypothesis that short sellers use signals from both market expectations and the quality of fundamentals to identify and exploit overvalued stocks. We also examine the extent to which the returns earned by short sellers represent compensation for bearing additional risk. Previous studies indirectly test this risk explanation by conducting surveys from the hedge fund industry (Dechow et al., 2001). In contrast, we directly test the risk explanation by exploiting a natural experiment, namely Regulation SHO, which creates plausibly exogenous shocks to short-sale constraints and is unlikely to be correlated with shifts in factor risk. The results from the experiment indicate that the superior returns earned by short sellers are due to exploiting overpricing rather than taking additional risk, consistent with the notion that the relaxation of short-sale constraints increases price efficiency by facilitating the flow of wealth from irrational to sophisticated investors (e.g., Shleifer and Vishny, 1997; Lamont and Thaler, 2003; Chu et al., 2020).

Second, we contribute to a strand of research, which documents that short sellers are sophisticated and informed traders (e.g., Desai et al., 2006; Efendi et al., 2005; Boehmer et al., 2008; Karpoff and Lou, 2010; Christophe et al., 2010; Boehmer and Wu, 2013; Christensen et al., 2014; Fang et al., 2016), by showing that short sellers are also value investors who can sell growth stocks with deteriorated fundamentals. This unique style of value investing represents a departure from, and an important complement to the conventional value investing strategies, which investors use to buy value stocks with improved fundamentals

(Graham and Dodd, 1934; Piotroski, 2000; Piotroski and So, 2012). Our study implies that value investors in general, and short sellers in particular, play an important role in aligning stock prices with fundamental values in a timely manner. Given this role, the trading behavior of short sellers helps stabilize the market. Our results support the Beber and Pagno's (2013) proposition that short selling should not be banned during the 2008 financial crisis, as overpricing is unlikely to occur in economic downturns. Overall, the regulatory concern that short sellers can destabilize the markets is largely unwarranted.

The remainder of the paper is organized as follows. Section 2 presents the research design and discusses the empirical predictions. Section 3 describes the data and defines the variables. Section 4 discusses the empirical results. Section 5 concludes.

2. Research design and our empirical predictions

This study uses short selling activity to test whether the relation between the strength of fundamentals and future returns is due to rational pricing or mispricing. Using U.S. data for the period 1972-2016, we annually sort our stocks into portfolios based on the strength of fundamentals (F-score) and price multiples and then examine variations in short selling activity and future returns within and across these portfolios. The following subsections outline our research design and primary empirical predictions.

2.1. The strength of fundamentals and market expectations

To measure the strength of fundamentals, we use F-scores[4] developed by Piotroski (2000; 2005). Fama and French (2006, p496) point out that F-score is a "composite measure of firm strength". Specifically, F-score has strong predictive power for future profitability (Fama and

[4] See Appendix 1 for further details about the construction of F-scores.

French, 2006). In addition, several studies show that F-score is a leading predictor of future returns even after controlling for size, book-to-market, and asset growth (Piotroski and So, 2012; Choi and Sias, 2012). Following these studies, we label firms with F-scores of less than or equal to three, between four and six, and greater than or equal to seven, as low, middle, and high F-score firms, respectively.

We use BM ratio to measure market expectations about firms' future performance. Low BM firms are expected to grow faster than their high BM counterparts. Consistent with this interpretation, Fama and French (1995) and Penman (1996) find that BM ratio is negatively associated with both expected and realized earnings growth. A firm's BM ratio is defined as the book value of equity scaled by the market value of equity at fiscal year-end. Following Fama and French (1993) and Piotroski and So (2012), we rank firm-year observations with BM ratios below the 30th percentile, between the 30th and 70th percentile, and above the 70th percentile as growth, neutral, and value firms, respectively[5].

2.2. The exploitation of overpricing

Previous studies document abnormal short selling activity prior to major negative corporate events, such as negative earnings announcements (Christophe et al., 2004; Lasser et al., 2010), earnings restatements (Desai et al., 2006), financial misconduct (Karopp and Lou, 2010), analyst downgrades (Christophe et al., 2010), misleading pro forma disclosures (Christensen et al., 2014), and credit rating downgrades (Henry et al., 2014). There is also evidence that short sellers possess the superior ability to process public information. For example, Engelberg et al. (2012) find that short sellers increase their trading on the day of negative news announcements and that abnormal short selling predicts future negative returns.

[5] The BM ratio is the main measure and earnings-to-price and cash-flow-to-price are also included as alternative measures in our empirical analysis.

Boehmer and Wu (2013) show that short sellers can mitigate negative post-earnings-announcement drifts by exploiting negative earnings surprises. Lee and Piqueria (2017) find that short sellers exploit other investors' anchoring biases by selling stocks with prices far from the 52-week high. Collectively, existing evidence suggests that short sellers are informed and sophisticated traders who sell overpriced stocks ahead of other investors.

Unlike previous studies, we are interested in the trading behavior of short sellers following the release of fundamental signals and how short sellers use such signals to identify overpriced stocks. Mispricing arises when markets are slow to fully incorporate public information (e.g., Bernard and Thomas, 1989; Chen et al., 1996; Sloan, 1996; Dichev and Piotroski, 2001; Gleason and Lee, 2003; Bradshaw et al., 2006; Doyle, 2006; Balakrishnan et al., 2010). For example, Choi and Sias (2012) find that F-score predicts subsequent institutional demand and conclude that institutional investors suffer from slow reactions to fundamental signals. Such slow reactions may occur either because behavioral biases induce market participants to underweight new information or because market frictions prevent prices from fully and quickly incorporating investors' revised expectations (e.g., DeBondt and Thaler, 1985; Daniel et al., 1998; Hong and Stein, 1999). In the presence of investors' slow reactions to negative fundamental signals, prices become temporarily higher than the values implied by their fundamentals and short sellers would use the signals to exploit overpricing. Thus, we expect short selling activity to be negatively related to F-score.

However, the extent to which negative fundamental signals attract short sellers depends on market expectations. Short sellers may be repelled from firms whose fundamental performance is congruent with market expectations. Consistent with this notion, Piotrioski and So (2012) show that value firms with poor fundamentals have no significant abnormal returns. In contrast, when a firm's fundamental performance contradicts the expected growth prospects, investors who hold the firm's stocks are more likely to suffer from the slow

revision of their expectations into prices (e.g., Lankonishok, 1994; LaPorta, 1996; LaPorta et al., 1997). Particularly, the negative returns will arise from a subset of growth firms with poor

	Value/growth based on BM		
Strength of fundamentals	Growth-Low BM	Neutral BM	Value-High BM
Low F-score	**E**[Growth|BM]>	Potential expectation	**E**[Growth|BM]≈

fundamentals. In turn, this overpricing can be exploited by short sellers who believe that prices will eventually converge to fundamental values. Thus, we predict low BM firms to have a higher short interest when their F-scores are also relatively low.

To illustrate our predictions more clearly, we define the growth expectations implied by BM and fundamentals as **E**[Growth| BM] and **E**[Growth| F-score], respectively. When **E**[Growth| BM] is above **E**[Growth| F-score], the difference in expectations is referred to as expectation errors about growth, meaning that the market overestimates growth prospects implied by fundamentals. Conversely, when **E**[Growth| BM] is below **E**[Growth| F-score], the difference in expectations is called expectation errors about value. That is, the market underestimates growth prospects implied by fundamentals. The following table presents the relevant expectation errors across value/growth characteristics and the strength of fundamentals.

	E[Growth| F-score Expectation errors about growth (1)	errors about growth (2)	**E**[Growth| F-score No expectation errors (3)
Middle F-score	Potential expectation errors about growth (4)	**E**[Growth|BM]≈ **E**[Growth| F-score No expectation errors (5)	Potential expectation errors about value (6)
High F-score	**E**[Growth|BM]≈ **E**[Growth| F-score No expectation errors (7)	Potential expectation errors about value (8)	**E**[Growth|BM]< **E**[Growth| F-score Expectation errors about value (9)

In this framework, the largest expectation errors about growth reside in portfolio (1), as investors who hold these stocks are likely to underreact to information that contradicts their beliefs about firms' growth prospects (e.g., Mohanram, 2005; Lakonishok et al., 1994). Thus, portfolio (1) should have the highest short interest among the nine portfolios. In addition, there are potential expectation errors about growth in stocks in portfolios (2) and (4), while these stocks may be of interest to short sellers. In contrast, the largest expectation errors about value are concentrated in portfolio (9), as this subset of value stocks is likely to be neglected by the market despite their strong fundamentals (e.g., Lakonishok et al., 1994; Piotroski, 2000; Piotroski and So, 2012). This subset of value stocks is unlikely to attract short sellers, because short selling strategies cannot be used to exploit underpricing. Analogous reasoning applies to portfolios (6) and (8). Finally, since the market expectations about the growth of the firms in portfolios (3), (5), and (7) are congruent with the strength of fundamentals, we do not expect these firms to attract short sellers.

Thus, by establishing links between F-score, BM, and short selling, we are able to answer two important questions: Do growth firms with different F-scores attract the same level of short selling? Are the market expectations reflected in BM biased or unbiased? Our central prediction is that short sellers will target firms with fundamental performance below market

expectations. To the extent that the exploitation of overpricing increases the speed at which negative fundamental signals are impounded into prices, we also expect short selling activity to attenuate the relationship between firm fundamentals and future returns.

3. Data and variables

Our sample consists of all common stocks (share codes of 10 and 11 in CRSP) listed on NYSE, AMEX and NASDAQ over the period 1972-2016. Stock prices and financial statement data are extracted from CRSP and Compustat, respectively. For each firm, we measure the market value of equity, BM ratios, and the components of F-score at the fiscal year-end. We obtain the number of analysts providing firms' earnings forecasts from I/B/E/S. The quarterly institutional ownership is obtained from the Thomson Reuters database. Following Fama and French (2006) and Choi and Sias (2012), we exclude financial firms in our sample and require firms to have total assets of at least $25 million and book equity of at least $12.5 million.

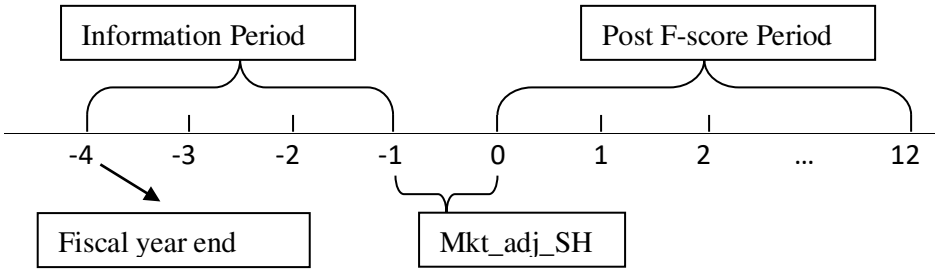
Short interest data are obtained from the Computstat's Supplemental Short Interest File.[6] Following Dechow et al. (2001), we measure the raw short turnover averaged between three and four months after the fiscal year-end (see Figure 1) to allow sufficient time for short sellers to process financial information. The raw short turnover is defined as the number of shares shorted as a percentage of shares outstanding. Since short selling activity has shown a significant increase over the last two decades (Asquith et al., 2005; Boehmer and Wu, 2013), we use market-adjusted short turnover (*mkt_adj_SH*), defined as the raw of the firm's short

[6] NYSE, AMEX and NASDAQ firms are required to report their short interest as of settlement on the 15th each month. Since September 2007, the short interest reports must also be filed as of settlement on the last business day of the month. Accordingly, we use short interest on the 15th month before September 2007 and on the last business day of the month after September 2007. Our results are qualitatively similar if we use short interest on the 15th month throughout the sample years.

turnover in a given month minus the market average short turnover in the same month, to control for the market-wide impact.

Following prior studies (e.g., Piotroski, 2000; Choi and Sias, 2012; Piotroski and So, 2012), we define the information period as three months following the fiscal year-end and the post F-score period as the year beginning four months following the fiscal year-end (see Figure 1). We measure market-adjusted buy-and-hold returns, i.e., a firm's buy-and-hold returns less the CRSP value-weighted buy-and-hold return, over the information and the post F-score periods. Following Bushee and Goodman (2007) and Choi and Sias (2012), we truncate the top and bottom one percent of firms with the highest and lowest market-adjusted returns over the information period and the post F-score period to ensure that return estimates are not driven by outliers. Our final sample consists of 127,836 firm-fiscal year observations with an average of 2,857 unique firms per fiscal year.

Figure 1: Timeline



4. Results

4.1. Preliminary results

Panel A in Table 1 reports the main characteristics for the ten portfolios sorted by F-score. Each of these characteristics is calculated as the time-series mean of cross-sectional averages

over 44 fiscal years (i.e., the fiscal years of 1972 to 2015)[7]. We document a monotonically positive association between F-score and future returns. We also show that low F-score firms (i.e., firms with F-score between one and three) have positive market-adjusted short turnover, while the short turnover of the remaining firms is below the market average. BM varies considerably across the strength of fundamentals. In particular, the two highest BM ratios (0.99 and 1.04) appear in firms with the lowest and highest F-score, while the two lowest BM ratios (0.79 and 0.80) are observed for firms with F-scores between five and seven and those with F-score equals one. Lastly, we document a negative association between F-score and past performance (measured by the returns over the window [-8, -2]), implying that the relation between F-score and future returns can be tainted by the momentum effect.

In Panel B, we compare the market-adjusted returns and the market-adjusted short turnover associated with high and low F-score firms across the information period and the post F-score period over our sample years. We show that low F-score firms not only have significant market-adjusted short turnover (1.98%), but also have a significantly higher short turnover than their high F-score counterparts. On the right-hand side of Panel B, we present the market-adjusted returns and short turnover in the post F-score period. The results reveal that low F-score firms significantly underperform high F-score firms by 9.09% per year. However, the insignificant difference in the market-adjusted short turnover between low and high F-score firms indicates that low F-score firms are less attractive to short sellers in the post F-score period.

4.2. Short selling and F-score

[7] We use fiscal years defined by COMPUSTAT. If a firm has a fiscal year ending in any month between January and May, its fiscal year is assigned to be the last calendar year. If a firm has a fiscal year ending in any month between June and December, its fiscal year is assigned to be the current calendar year.

In this section, we formally test whether F-score can predict short interest after controlling for other determinants of short selling. Following previous studies (Dechow et al., 2001; Boehmer and Wu, 2013; Lee and Piqueria, 2017), we use the Fama-MacBeth (1973) procedure to estimate the following model:

$$Mkt\_adj\_SH_i = \alpha + \beta_1 F\_socre_i + \beta_2 size_i + \beta_3 BM_i + \beta_4 Mom_i + \beta_5 illiquidity_i + \beta_6 \sigma_i + \beta_7 IO_i + \beta_8 DP_i + \beta_9 analyst_i + \varepsilon \quad (1)$$

where $Mkt\_adj\_SH_i$ is the market-adjusted short turnover for firm i for the period from the third to the fourth month following the fiscal year end. $Size_i$ and BM_i are firm i's market value and the book-to-market ratio at the fiscal year-end, respectively. Mom_i is firm i's past 6-month buy-and-hold return ending up to the second month following the fiscal year-end. $Illiquidity_i$ is calculated as the monthly average of the daily ratio of absolute stock return to dollar volume over a three-month period including the month of fiscal year end and the subsequent two months (Amihud, 2002). σ_i is a volatility measure calculated as the difference between the highest and lowest prices during the three month period scaled by the highest price (Boehmer and Wu, 2013; Lee and Piqueria, 2017). IO_i is the percentage of institutional ownership in firm i at the end of fiscal year and can be a proxy for the availability of lendable stocks (Asquith et al., 2005). DP_i is defined as firm i's cash dividend yield (i.e., cash dividend paid per share divided by stock price), which is a proxy for the cost of borrowing shares. It has been reported that short sellers are less willing to short cash dividend-paying stocks because dividends must be paid out of their own capital (D'Avolio, 2002; Dechow et al., 2001). $Analyst_i$ is the number of analysts following firm i at the fiscal year-end (Boehmer and Wu, 2013). Further details on variable definitions are presented in Appendix 2.

Table 2 reports the time-series means of the coefficient estimates from cross-sectional regressions. Column (1) reports the results with F-score as the only independent variable in

the regression. The coefficient on F-score is significantly negative, indicating the inverse relationship between short selling and the strength of fundamentals. Column (2) shows that the coefficient on F-score remains negative and highly significant after controlling for firm-specific characteristics. The coefficient on BM is significantly negative, suggesting that growth stocks are more likely to be short sold than value stocks (Dechow et al., 2001). The coefficient on σ_i is also significantly positive, indicating that volatile stocks are more likely to be short sold. Finally, *IO* and *DP* have significant relationships with short selling, consistent with the notion that the availability of lendable shares and the costs of borrowing shares are two important dimensions of constraints confronted by short sellers (e.g., D'Avolio, 2002; Engelberg et al., 2018). Overall, the results suggest that F-score negatively predicts short selling activity, consistent with the view that short sellers use fundamental signals to identify and exploit overpriced stocks.

4.3. Short selling, F-score, and growth expectations

In this section, we raise the question of whether all low F-score firms are equally attractive to short sellers. The exploitation of investors' slow reactions to negative signals predicts that short sellers are only interested in low F-score firms with high market expectations. To test this prediction, we sort firm-year observations by BM ratios (i.e. growth, neutral, and value) and F-scores (i.e. low, middle, and high F-score firms as defined in Section 2.3) to form nine BM and F-score based portfolios.

Panel A in Table 4 reports the averaged market-adjusted short turnover for the nine portfolios across the sample period. We find that both growth and neutral stocks with low F-score have a significantly higher short interest than the market average, implying that short sellers are

attracted to firms whose fundamental performance is below market expectations.[8] In contrast, the short interest of value firms with low F-score is not significantly different from the market average, suggesting that short sellers are not attracted to firms whose fundamental performance is congruent with market expectations. We also show that the short interest of value firms with middle and high F-score is significantly lower than the market average. This is expected, as short selling cannot be used to exploit underpricing. We also find that the difference in short interest between growth and value firms is positive and highly significant across the three F-score portfolios, consistent with the findings of Dechow et al. (2001).

However, the short interest of growth firms with high F-score is not significantly higher than the market average, consistent with our conjecture that short sellers avoid shorting a subset of growth firms whose market expectations are congruent with the strength of fundamentals. Within growth firms, the difference in short turnover between low F-score and high F-score firms is positive (3%) and significant at less than 5% level. This evidence contrasts with the findings of Dechow et al. (2001) that all growth firms attract short shelling. Finally, the short interest associated with the portfolio of middle F-score and middle BM is indifferent from the market average, reflecting short sellers' belief that the growth prospects implied by fundamentals for firms in this particular portfolio are largely incorporated into the prices.

In Panels B and C, we use two alternative measures for growth/value, namely earnings-to-price and cash-flow-to-price. Consistent with the results in Panel A, Panels B and C also show that growth firms attract significantly higher short interest when their F-scores are relatively low. In sum, short sellers exploit investors' slow reactions to negative fundamental information, particularly when such information contradicts investors' strong beliefs about growth prospects.

[8] In unreported results, we estimate returns to the nine BM and F-score sorted portfolios. We find similar results to Piotroski and So (2012) that the value-growth strategy is only profitable when expectation errors are large.

Notwithstanding, the results of the portfolio analysis may be biased due to omitted firm characteristics. To mitigate this concern, we follow Piotroski and So (2012) and use the Fama and MacBeth (1973) procedure to estimate the following cross-sectional regression:

$$\begin{aligned} Mkt\_adj\_SH_i = {} & \beta_1 F1_i + \beta_2 F2_i + \beta_3 F3_i + \beta_4 F1_i \times Growth_i + \beta_5 F1_i \times Neutral_i + \beta_6 F2_i \times Growth_i \\ & + \beta_7 F2_i \times Value_i + \beta_8 F3_i \times Neutral_i + \beta_9 F3_i \times Value_i + \beta_{10} Size_i + \beta_{11} Mom_i + \varepsilon_i \end{aligned} \quad (2)$$

The intercept in Equation (2) is suppressed to ensure non-collinearity among different F-score groups. The dependent variable is the market-adjusted short interest defined as before. *F1*, *F2*, and *F3* are dummy variables with values of one if a firm's F-score is less than or equal to three, between four and six, or greater than or equal to seven, respectively, and zero otherwise. *Growth*, *Neutral*, and *Value* are dummy variables with values of one if the firm's BM ratio is the bottom 30%, the middle 40%, and the top 30% of BM at the fiscal year-end, respectively, and zero otherwise. We annually and independently rank firm size (*Size*) and momentum (*Mom*) into deciles and include their decile ranks in Equation (2) to mitigate the impact of intertemporal distribution changes in the two variables.

In Equation (2), the coefficients on *F1*, *F2*, and *F3* measure the impact of F-score on short turnover for a specific value/growth portfolio when market expectations implied by firms' BM ratios are congruent with the strength of their fundamentals. The coefficients on the six interaction terms measure the differential effects of F-score on the short selling for the firms that are likely to suffer from expectation-based errors in a given value/growth portfolio. Similar to our earlier analysis, we also use earnings-to-price and cash-flow-to-price as alternative measures of value/growth.

Table 4 reports the average coefficients estimated from annual cross-sectional regressions. Column (1) in Table 4 shows that the coefficients on *F1*, *F2*, and *F3* are significantly negative, implying that firms whose fundamental performance is congruent with market

expectations are less likely to attract short sellers. The coefficients on the three interaction terms (i.e. F1×Growth, F1×Neutral and F2×Growth) are significantly positive, indicating that stocks with fundamental performance below market expectations are likely to be short sold. However, the remaining three interaction terms (i.e. F2×Value, F3×Neutral, and F3×Value) are significantly negative, as short selling cannot be used to exploit stocks with the potential of underpricing. Finally, in columns (2) and (3) we document similar results when we use E/P and cash-flow-to-price. In sum, our results suggest that short sellers exploit overpricing by selling stocks whose growth prospects are overestimated by the market.

4.4. Short selling and future returns

Rational pricing and mispricing disagree on the ability of short selling activity to influence the future returns of low F-score firms. Rational pricing emphasizes that negative fundamental information is fully impounded into prices. Consequently, a low F-score is a reflection of low risk and, hence, associated with low future returns. However, the mispricing argument suggests that markets are slow to fully incorporate negative fundamental information into prices, leading to overpricing. The exploitation of overpricing by short sellers would increase the speed of price adjustments to negative signals. Therefore, high levels of short interest should reduce or even eliminate the ability of low F-score to predict returns.

We formally test the price impact of short selling by confining our analysis to low F-score firms and low F-score firms with low BM ratios, which are likely to be of interest to short sellers[9]. We first sort low F-score firms into quintiles based on their market-adjusted short

[9] Investors can react to strong fundamental signals in two ways: either by reducing shorting or by increasing purchasing. However, it is more likely that investors do not have a short transaction planned for strong fundamental firms, causing more intense purchases rather than less intense shorting. Unfortunately, we cannot observe the long transactions of the short sellers in our sample, which make the response of short selling upon strong fundamental signals hard to interpret.

turnover and then calculate the difference in returns between the bottom quintile (Q1: lightly shorted) and the top quintile (Q5: heavily shorted). We also sort low F-score firms with low BM ratios into terciles on the basis of their market-adjusted short turnover and calculate the difference in returns between the bottom tercile portfolio (T1: lightly shorted) and the top tercile portfolio (T3: heavily shorted)[10]. To measure the speed at which short selling activity incorporates fundamental information into prices, we use size-adjusted returns in addition to market-adjusted returns following Piotroski and So (2012). It is appropriate in our context to use size-adjusted returns[11] because small firms are more likely to exhibit anomalous returns than large firms and short sellers have preference for large stocks. Thus, controlling for firm size enhances our confidence that short selling contributes to the price discovery process. Finally, we calculate our portfolio returns over several time horizons, including holding periods of 3, 6, 12, 15, 18, and 24 months[12], to test the short- and long-term impact of short selling on the stock price discovery process.

Table 5 reports the returns on all low F-score firms and the quintile portfolios of lightly (Q1) and heavily (Q5) shorted low F-score firms. Panel A shows that the market-adjusted returns on all low F-score firms and Q1 are negative and significant across all holding periods, while the market-adjusted returns on Q5 are only significantly negative for the six-month holding period. The market-adjusted return differential between Q1 and Q5 is also negative and highly significant across all holding periods. We obtain similar results using size-adjusted returns in Panel B. Specifically, Q1 experiences significantly negative size-adjusted returns across all horizons, while the returns on Q5 are only significant over the three-month and the

[10] We use tercile portfolios for low BM and low F-score firms to ensure that each tercile portfolio contains more than 30 stocks.

[11] Size based deciles are derived from universe-CRSP stocks. The assignment of each stock in a portfolio is based on this stock's market-cap at the end of the last calendar year (i.e. annually rebalanced). Monthly return series for each decile portfolio are provided by CRSP and we then compound returns into 3, 6, 9, 12, 15, 18, 21 and 24 months periods. We adjust the delisting returns according to Shumway (1997).

[12] Piotroski (2000) find that the outperformance of high F-score firms over low F-score firms can persist up to two years.

six-month horizons. The size-adjusted return differential is significantly negative across all holding periods. In brief, short selling largely reduces the return predictability of poor fundamentals by increasing the speed of price adjustment to negative fundamental signals.

The first row in Panel A of Table 6 shows that the market-adjusted returns on low F-score firms with low BM ratios are significantly negative. These returns are lower than those of the low F-score firms reported in Panel A of Table 5. This finding is consistent with notion that the market is slow to adjust to negative signals when the expectation about growth prospects is high (e.g., Lakonishok et al., 1994; Piotroski and So, 2012). Next, we report the returns on the tercile portfolios based on the short turnover. Panel A of Table 6 shows that the market-adjusted returns on T1 and T2 are significantly negative across almost all horizons, while the market-adjust returns on T3 are statistically insignificant. The return differential between T1 and T3 are highly significant, implying that short selling activity helps correct overpricing. The results of the size-adjusted returns in Panel B are largely consistent with those reported in Panel A. In particular, Panel B shows that, except for the nine-month horizon, T1 has significantly negative size-adjusted returns, while the returns on T3 are statistically insignificant. Over the nine-month horizon, the size-adjusted return on T3 is negative, but its magnitude is considerably smaller than that of T1. Overall, our evidence suggests that short selling activity attenuates the relation between firm fundamentals and future returns, consistent with the mispricing argument.

4.5. Evidence from a natural experiment

Thus far, we have shown that short selling activity alters the relation between firm fundamentals and future returns. To the extent that short sellers are pure arbitrageurs whose activity is motivated by the potential profits from arbitrage opportunities (e.g., Miller, 1977; D'Avolio, 2002; Engelberg et al., 2012), this evidence implies that the return predictability of

fundamentals is driven by the slow price adjustment to information. However, one may argue that since short sellers are more risk-tolerant than individual investors, short selling activity could also be driven by risk. This risk interpretation suggests that, as long as risk remains constant, existing short selling already reflects risk tolerances and should have no influence on the relation between fundamentals and future returns. To test this prediction, an ideal setting would be to include exogenous shocks, which affect short selling behavior but do not alter factor risk.

Following Chu et al. (2020), we exploit a natural experiment, namely the pilot program of Regulation SHO. This experiment creates plausibly exogenous shocks to short-sale constraints that often limit the ability of short sellers to profit from arbitrage opportunities. In addition, the program is about a regulatory change which is unlikely to be correlated with shifts in factor risk. Specifically, the Securities and Exchange Commission (SEC) adopts Regulation SHO in July 2004. Among stocks in the Russell 3000 index as of June 2004, the pilot program designates every third stock ranked by average daily trading volume (in the prior year) on each of NYSE, Amex, and NASDAQ as pilot stocks. The pilot stocks on NYSE/Amex are exempted from the uptick rule and those on NASDAQ are exempted from the bid price test from May 2005 and August 2007. As such, the pilot program makes it easier to short sell pilot stocks relative to non-pilot stocks, while the assignment of pilot and non-pilot firms is unlikely to be correlated with the loadings of stocks on risk factors due to the quasi-random selection. Thus, the program represents an ideal setting to test the risk explanation for the return predictability of fundamentals.

The risk-based explanation predicts that relaxing short-sale constraints should have no effect on the return predictability of fundamentals, while the mispricing explanation makes the opposite prediction. Specifically, the mispricing explanation suggests that: first, the return predictability of fundamentals becomes weaker for pilot firms relative to non-pilot firms

during the pilot period when short sellers could more easily short pilot stocks with the potential of overpricing; second, the reduction in the return predictability of fundamentals during the pilot period comes mainly from the short-leg portfolios with poor fundamentals; and finally, the pilot portfolio, which is formed during the pilot period and contains pilot stocks with poor fundamentals and low BM, would outperform its non-pilot counterpart portfolio. The likelihood of overpricing is high when investors tend to underweight negative fundamental signals that contradict their prior beliefs. Thus, pilot stocks with low BM and poor fundamentals could be more easily short sold during the pilot period. To the extent that short selling increases the speed at which prices adjust to negative signals, the subsequent returns of the pilot stocks would be higher than their non-pilot counterparts.

To test our predictions, we first construct F-score based pilot and non-pilot portfolios. Specifically, the high F-score pilot portfolio includes pilot stocks with F-scores between seven and nine, while pilot stocks with F-scores between zero and three are assigned to the low F-score pilot portfolio. Similarly, we construct the high and low F-score non-pilot portfolios for non-pilot firms. Within low F-score firms, we further divide the pilot and non-pilot portfolios into low, middle and high BM stocks[13]. Following Chu et al. (2020), our sample stocks are firms on NYSE/Amex in the Russell 3000 index as of June 2004[14]. In particular, we have 508 pilot stocks and 1,016 non-pilot stocks and the sample period spans from January 1980 to December 2016.[15]

To evaluate portfolio performance, we calculate one-year market-adjusted returns beginning four months following the fiscal year-end (see figure 1) for each portfolio. The return

[13] Low, middle and high BM are defined in the same way as in Section 2.2, i.e., firm-year observations with BM ratios below the 30th percentile, between the 30th and 70th percentile, and above the 70th percentile of the sample at each fiscal year-end.
[14] Diether et al. (2009) find that a significant fraction of trading volume in NASDAQ-listed stocks is executed on ArcaEx and INET, which do not enforce the bid price test. Therefore, we follow Chu et al. (2020) to exclude NASDAQ stocks in our sample.
[15] We are grateful to Professor Vivian Fang for sharing the list of pilot and non-pilot stocks with us.

predictability of F-score is measured by the difference in returns between high F-score firms (i.e., the long leg) and low F-score firms (i.e., the short leg). Using a difference-in-differences approach, our main interest is to compare the returns of the pilot portfolios with those of the non-pilot portfolios across the pre-pilot and the pilot periods. Following Chu et al. (2020), we estimate the following specification:

$$R_{i,t} = \alpha_0 + \gamma_t + \beta_1 Pilot_i \times During_t + \beta_2 Pilot_i \times Post_t + \varepsilon_{it} \quad (3)$$

where R_{it} is the one-year market-adjusted return of portfolio i (which can be the long leg, the short leg, or the long-short portfolio based on F-score) in fiscal year t, γ_t denotes time fixed effects, $Pilot_i$ is a dummy variable that is equal to 1 if portfolio i is formed on pilot firms, and zero otherwise, $During_t$ is a dummy variable that is equal to 1 if fiscal year t is 2005 or 2006 (i.e., during the pilot period of Regulation SHO), and $Post_t$ is a dummy variable that is equal to 1 if fiscal year t is after 2006. As $During_t$ and $Post_t$ is subsumed by the time fixed effects, they are dropped from the regression. The time fixed effects γ_t capture the common factors that drive the portfolio returns for both pilot and non-pilot portfolios. In these regressions, the unit of analysis is a portfolio-fiscal year observation. We estimate Equation (3) for the long leg, the short leg, and the long–short portfolios separately. β_1 is of our main interest and captures the difference in returns between pilot stocks and non-pilot stocks across the pre-pilot and the pilot periods. The coefficient estimate of β_2 is used to test the difference in returns between pilot stocks and non-pilot stocks across the pre-pilot and the post-pilot periods.

The difference-in-differences approach (Eq (3)) is used to compare the return predictability of F-score between pilot and non-pilot firms, whereas a valid basis of this comparison is that pilot firms should represent a random draw from the Russell 3000 population (Fang et al., 2016). To verify the quasi-randomness of pilot stock assignment, we compare the means of

F-score as well as each component of F-score, which is a binary signal, between pilot and non-pilot firms at the end of 2003. Panel A of Table 7 shows that the average F-score is statistically indifferent between pilot and non-pilot firms. In addition, the differences in each of nine components of F-score are economically small and statistically insignificant. As the return premium associated with F-score is measured by the difference in returns between the high and low F-score portfolios, in Panels B and C we also compare the means of F-score and each component of F-score for pilot and non-pilot stocks that fall into the two groups. The differences are again mostly small and statistically insignificant. Overall, we observe no significant difference in the characteristics of pilot and non-pilot firms prior to the announcement of the pilot program.

We also verify the validity of the difference-in-differences analysis by ruling out the possibility that the observed difference in returns is a result of a pre-existing trend (e.g., Roberts and Whited, 2012). We report the mean returns for the pilot and non-pilot portfolios in the pilot and the pre-pilot periods. The results are reported in the first six columns of Table 8. Column (3) shows that there is no difference in returns between the pilot and non-pilot portfolios in the pre-pilot period. In contrast, the return effect of the pilot program is observed during the pilot period in column (6). Thus, the results satisfy the parallel trends for pilot stocks and non-pilot stocks.

Column (7) shows the results of the mispricing predictions. First, β_1 is significantly negative for long–short portfolio returns, suggesting that the pilot program reduces the power of F-score to predict returns by 8.85% per year. Second, β_1 is significantly positive for the short-leg portfolios, but insignificant for the long-leg portfolios, implying that the reduction in the return predictability comes almost entirely from the short leg portfolios. Finally, pilot stocks with low F-score and low BM outperform their non-pilot counterparts by 12.82% per year. In contrast, β_1 is insignificant for the other two low F-score portfolios with middle and high BM,

suggesting that relaxing short-sale constraints has no material effect on the stocks which are less likely to be overvalued.

If our main results in column (7) are indeed driven by the pilot program, the difference in returns between pilot and non-pilot firms should disappear after the end of the pilot program. Column (8) shows that β_2 is insignificant across all rows, ensuring the validity of our experiment. In sum, evidence from the experiment suggests that the returns earned by short sellers stem from exploiting overvalued stocks rather than taking additional risk.

4.6. Additional analysis

4.6.1. Short selling and momentum

Our previous results show that F-score also has a positive relation with past performance. To the extent that short sellers chase downward momentum, low F-score firms would also experience higher short interest than high F-score firms. To test whether chasing momentum can explain our results, we first calculate the differences in returns between low and high F-score firms over the three-month period following fiscal year-end (i.e., the window [-4,-1] in Figure 1). We then rank the differences in returns across the sample years and separate them into two groups. The first group includes the 22 annual observations in which the underperformance of low F-score firms relative to high F-score firms is particularly large, while the second group contains the remaining 22 annual observations. If downward momentum chasing drives short interest, we would expect differences in short interest between low and high F-score firms to be larger in the first group than in the second group.

The results in Panel A of Table 9 show that the average return differential between low and high F-score firms in the first group is -6.42%. The difference in short interest between low and high F-score is statistically insignificant. In the second group, although low F-score firms

slightly underperform high F-score firms by -0.14%, the difference in short interest between low and high F-score firms is 3.49%-and highly significant. The last row in Panel A shows that the difference-in-difference (DID) in short interest and in returns between low and high F-score firms across the two groups are significantly negative. The finding that low F-score firms attract more short selling activity even when their performance is similar to high F-score firms is inconsistent with the view that short sellers chase downward momentum.

Our second test is based on the cross-sectional analysis of past returns. Similar to our previous analysis, we rank all sample firms on the basis of the three-month returns over the information period (i.e. the window [-4,-1] in Figure 1) in each fiscal year. Then, we divide the firms into two groups based on the median values of the three-month returns. The first group contains stocks with high past returns (i.e., winners) and the second group consists of stocks with low past returns (i.e., losers). Each of these two groups is then divided into low, middle, and high F-scores to form six F-score and past return portfolios. If short sellers chase poor past performance, we would expect losers to have a higher short interest than winners across both high and low F-score portfolios.

Panel B of Table 9 reports the results. Column (1) shows that low F-score losers have a significantly lower short interest than low F-score winners. The difference in short interest is negative (-3.80%) and highly significant (*t*-value = -2.68). Furthermore, low F-score winners have the highest short interest in the six portfolios. This evidence contradicts the momentum based explanation, which predicts more short selling activity in low F-score losers. Instead, this finding is consistent with our hypothesis that short sellers exploit the overpricing arising from a subset of low F-score stocks that may have performed well in the past despite deteriorated fundamentals. In the middle and high F-score portfolios, differences in short interest between losers and winners are all insignificant, implying that short selling activity is

not driven by poor past performance. Overall, our findings indicate that short sellers are contrarian traders.

4.6.2. Short selling and investor sentiment

In this section, we examine the interaction between short selling and investor sentiment. Baker and Wurgler (2006) argue that, in periods of high investor sentiment, speculative demand induces stock prices to deviate further and more frequently from fundamental values. Consistent with this argument, Stambaugh et al. (2012) find that the returns on the short-leg of most asset-pricing anomalies are significantly lower in high sentiment periods. If the relationship between fundamentals and future returns is driven by mispricing, overpricing should be more prevalent when sentiment is high. This, in turn, would imply that high sentiment periods provide short sellers with greater opportunities to exploit overpriced firms. As such, we predict a positive association between the exploitation of overpricing and investor sentiment. To test this prediction, we examine the variations in short selling activity between low and high F-score firms and in the portfolio of firms with low F-score and low BM ratio across different sentiment periods. We use the investor sentiment index developed by Baker and Wurgler (2006)[16] to classify our sample years into high, medium, and low sentiment periods.

Panel A of Table 10 shows that the difference in the market-adjusted short turnover between low F-score ($mkt\_adj\_SH^{F1}$) and high F-score firms ($mkt\_adj\_SH^{F3}$) is insignificant during low sentiment periods. It also shows that the market-adjusted short turnover of low F-score firms with low BM ratios ($mkt\_adj\_SH^{F1\_lowBM}$) is positive but only significant at 10% level. However, during high sentiment periods, ($mkt\_adj\_SH^{F1}$-$mkt\_adj\_SH^{F3}$), $mkt\_adj\_SH^{F1}$ and

[16] We obtain data on the annual investor sentiment index, which is orthogonalized to macroeconomic factors, from Jeffery Wurgler's website: http://pages.stern.nyu.edu/~jwurgler/.

mkt_adj_SH^{F1_lowBM} are all significantly positive. Furthermore, the market-adjusted short turnover associated with the various portfolios is significantly higher during high sentiment periods than during low sentiment periods. In panel B, we regress mkt_adj_SH^{F1}-mkt_adj_SH^{F3}, mkt_adj_SH^{F1} and mkt_adj_SH^{F1_lowBM} separately on the Baker and Wurgler's (2006) sentiment index. All the coefficients on the sentiment index are significantly positive, implying that short sellers exploit the optimistic market beliefs during periods of high sentiment. The overall evidence suggests that short sellers help correct the overpricing induced by investor sentiment.

5. Conclusion

Numerous studies show that firm fundamentals predict returns. This evidence is often interpreted as arising from the slow price adjustments to public information. However, since the strength of fundamentals proxies for expected profitability and higher expected profitability implies a higher discount, the relation between firm fundamentals and future returns is also consistent with the risk-based argument. Fama and French (2006) argue that tests based on the valuation equations cannot differentiate between these two explanations. We overcome this limitation by investigating whether short sellers take advantage of slow-information-diffusion and whether their trading activity affects the relationship between firm fundamentals and future returns. Specifically, we examine whether short sellers use fundamental signals, proxied by F-score (Piotroski, 2000), to identify and exploit overpricing. The risk explanation predicts that changes in market expectations are fully and quickly impounded into prices and short selling activity should not alter the relation between F-score and future returns. Under the mispricing explanation, markets are slow to fully incorporate

public information and short selling activity should change the return predictability of firm fundamentals.

Consistent with the mispricing argument, we show that short selling has a negative relationship with F-score after controlling for firm-specific characteristics. We also show that short selling activity is significant in stocks whose fundamental performance is below market expectations. In contrast, short selling activity is insignificant in stocks whose fundamental performance is congruent with market expectations. Taken together, our evidence suggests that short sellers exploit the overpricing that arises from the market's underreaction to negative fundamental signals. Our results also show that short selling activity can attenuate the return predictability of fundamentals by speeding up information diffusion.

A potential challenge to our results is that if short sellers are more risk-tolerant than less sophisticated investors, then the short selling activity could be driven by risk rather than the potential profits from arbitrage opportunities. To test whether the returns earned by short sellers reflect rational risk premia or mispricing, we exploit a natural experiment, namely Regulation SHO which creates plausibly exogenous shocks to short-sale constraints but is unlikely to change factor risk. The risk-tolerance interpretation implies that as long as risk remains constant, future returns associated with fundamentals should be independent of short selling. As a result, relaxing short-sale constraints should have no effect on the return predictability of fundamentals. However, the mispricing explanation predicts the opposite. The results show that the return predictability of fundamentals is reduced for pilot stocks during the pilot period. The reduction in the predictability is mainly from the short-leg portfolios. In the short-leg portfolios, pilot firms with low BM outperform their non-pilot counterparts. Collectively, evidence from the experiment refutes the risk-based explanation and supports the view that the return predictability of firm fundamentals is driven, at least partly, by the gradual incorporation of public information into prices.

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Table 1 Preliminary results

Panel A: The characteristics of F-score-sorted portfolios

F_score	0	1	2	3	4	5	6	7	8	9
Mkt_adj_ret[0,12]	-14.42%	-7.74%	-4.67%	-2.75%	-0.80%	1.29%	2.70%	4.43%	4.43%	5.52%
Mkt_adj_SH[-1,0]	-0.38%	0.26%	3.70%	1.70%	-0.54%	-0.00%	-0.20%	-0.68%	-1.90%	-1.74%
Mkt. cap (million)	303.61	336.81	705.33	1856.14	2821.11	3257.29	3421.64	3352.44	3308.20	2537.68
BM	0.99	0.80	0.91	0.86	0.85	0.80	0.80	0.78	0.81	1.04
IO	28.31%	28.17%	32.70%	37.36%	42.33%	43.96%	44.18%	44.79%	40.36%	30.00%
Analysts	1.29	1.75	1.84	2.17	2.85	2.99	3.00	2.98	2.63	2.10
Mom	-1.01%	0.32%	2.17%	2.84%	3.79%	6.25%	9.45%	11.96%	14.43%	15.53%
Avg. obs.	17	104	189	371	496	594	547	391	172	30

Panel B: Short selling activity and stock returns in the information period and the post F-score period

	Information period					Post F-score period			
	High F-score	Middle F-score	Low F-score	High-low		High F-score	Middle F-score	Low F-score	High-low
Mkt_adj_ret	4.38%***	2.52%***	-0.10%	4.48%***	Mkt_adj_ret	4.75%***	1.01%	-4.34%**	9.09%***
[-4,-1]	(6.59)	(3.93)	(-0.11)	(5.50)	[0, 12]	(3.20)	(0.81)	(-2.21)	(6.12)
Mkt_adj_SH	-0.79%	-0.22%	1.98%**	-2.76%**	Mkt_adj_SH	-0.49%	0.06%	0.30%	-0.80%
[-1,0]	(-1.54)	(-0.46)	(1.99)	(-2.50)	[1,12]	(-1.50)	(0.22)	(0.60)	(-1.50)

This table provides the main characteristics for the F-score based portfolios. Panel A reports the main characteristics for the deciles of F-score based portfolios. Mkt_adj_ret [0,12] is market-adjusted one-year ahead returns from the fourth month following the fiscal year end. These returns are calculated from a firm's buy-and-hold returns less the CRSP buy-and-hold return over the same period. Mkt_adj_SH [-1,0] is the average market-adjusted short turnover in the third and the fourth months following the fiscal year end. The market-adjusted short turnover is calculated as a firm's short turnover less the market average short turnover in a same month. Short turnover is defined as number of shares shorted scaled by a total of share outstanding. Mkt_cap, BM, IO, and analysts are firm size, book-to-market ratio, institutional ownership, and numbers of analysts measured at the fiscal year end, respectively. Mom is a firm's past returns measured over the period starting three months prior to the fiscal year end and ending two months after the fiscal year end. Panel B reports the market-adjusted short turnover and market-adjusted returns over the information period and the post F-score period. The information period is the four-month period following fiscal year end, whereas the post F-score period is the 12-month period starting five months after the fiscal year end. High, middle and low F-score firms are defined as F-scores between zero and three, between four and six, and greater or equal to seven, respectively. Mkt_adj_ret [-4, -1] is the market-adjusted returns measured over the period from the fiscal year end to one month prior to portfolio formation. The *t*-statistics are reported in parentheses. *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 2 The relation between F-score and short selling

	(1)	(2)
F-score	-0.004**	-0.003**
	(-2.26)	(-2.49)
size		0.006**
		(2.32)
BM		-0.003*
		(-1.96)
Mom		-0.001
		(-0.16)
Illiquidity		-0.799
		(-0.12)
σ		0.046***
		(3.81)
IO		0.032***
		(3.08)
DP		-0.094***
		(-4.31)
Analyst		-0.001
		(-0.19)
Cons	0.017	-0.052***
	(1.57)	(-9.03)
Adjusted R^2	0.13	0.26

This table reports the relation between F-score and short selling estimated using Fama and MacBeth (1973) regressions. The coefficients are the time-series means of cross-sectional regression. *F-score* measures the strength of firm fundamentals (Pitroski, 2000). The dependent variable $Mkt\_adj\_SH_i$ is the market-adjusted short turnover for firm *i* between three and four months following the fiscal year end. $Size_i$ and BM_i are firm *i*'s market value and the book-to-market ratio at the fiscal year-end, respectively. Mom_i is firm *i*'s past 6-month buy-and-hold return ending up to the second month following the fiscal year end. $Illiquidity_i$ is calculated as the monthly average of the daily ratio of absolute stock return to dollar volume over a three-month period including the month of fiscal year end and the subsequent two months. σ_i is a volatility measure calculated as the difference between the highest and lowest prices during the three month period scaled by the highest price. IO_i is the percentage of institutional ownership in firm *i* at the end of fiscal year. DP_i is firm *i*'s cash dividend yield (i.e., cash dividend paid per share divided by stock price). $Analyst_i$ is the number of analysts following firm *i* at the fiscal year end. Newey-West (1987) adjusted *t*-statistics are reported in parentheses. *,**, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 3 Short selling, F-score, and growth opportunities

Mkt adj SH [-1,0]	Low F-score	Middle F-score	High F-score	Low- high
Panel A: F-score against BM				
Low BM (Growth)	3.10%***	1.22%**	0.10%	3.00%**
	(2.93)	(2.45)	(0.18)	(2.47)
Middle BM (Neutral)	2.03%**	-0.24%	-0.77%*	2.80%**
	(2.12)	(-0.52)	(-1.74)	(2.55)
High BM (Value)	-0.89%	-1.75%***	-1.90%***	1.00%*
	(-0.96)	(-3.32)	(-4.02)	(1.68)
Low-high	3.99%***	2.97%***	2.02%***	
	(4.07)	(7.32)	(8.25)	
Panel B: F-score against Earnings/Price				
Low E/P (Growth)	1.14%**	0.94%*	-0.40%	1.57%**
	(2.30)	(1.78)	(-0.74)	(2.03)
Middle E/P (Neutral)	0.80%	-0.13%	-0.92%*	1.72%*
	(1.19)	(-0.21)	(-1.88)	(1.92)
High E/P (Value)	1.09%	-1.12%**	-1.00%**	2.10%*
	(0.55)	(-2.25)	(-1.98)	(1.89)
Low-high	0.04%	2.06%***	0.60%**	
	(0.02)	(4.82)	(2.37)	
Panel C: F-score against Cash-Flow-to-Price				
Low cash-flow-to-price	3.52%**	3.42%*	-0.38%	3.90%**
	(2.22)	(1.73)	(-0.64)	(2.02)
Middle cash-flow-to-price	0.12%	-0.11%	-0.10%	0.22
	(0.27)	(-0.25)	(-0.12)	(1.00)
High cash-flow-to-price	-0.83%	-1.16%**	-1.31%***	0.50
	(-1.46)	(-2.53)	(-3.94)	(0.88)
Low-high	4.35%**	4.59%**	1.00%*	
	(2.53)	(2.27)	(1.80)	

This table reports the market-adjusted short interest for the F-score and value/growth sorted portfolios. *Mkt_adj_SH* is the market-adjusted level of short turnover for the period starting three months and four months following the fiscal year end. We sort firms independently by their BM ratios (i.e. growth (top 30%), neutral (middle 40%), and value (bottom 30%) and their F-scores to form nine BM and F-score based portfolios. High, middle and low F-score firms are defined as F-scores between zero and three, between four and six, and greater or equal to seven, respectively. Panel A reports the averaged market-adjusted short turnover for the nine portfolios across our 44 sample years. In Panels B and C, we use earnings-to-price and cash-flow-to-price ratios as alternative measures for value and growth. Earnings, cash flows, and prices are based on fiscal year end values. Newey-West (1987) adjusted *t*-statistics are reported in parentheses. *,**, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 4 Cross-sectional analysis

	(1) BM	(2) EP	(3) CFP
F1	-0.0606***	-0.0539***	-0.0547***
	(-3.79)	(-5.37)	(-4.73)
F2	-0.0670***	-0.0536***	-0.0634***
	(-3.73)	(-5.86)	(-5.22)
F3	-0.0692***	-0.0576***	-0.0693***
	(-3.73)	(-5.34)	(-5.44)
F1* Growth	0.0319**	0.0359**	0.0353***
	(2.34)	(2.42)	(3.18)
F1* Neutral	0.0159*	0.0186	0.0238**
	(1.80)	(1.36)	(2.10)
F2*Growth	0.0129**	0.0108*	0.0259*
	(2.02)	(1.72)	(1.81)
F2*Value	-0.0070**	-0.0073	-0.0069*
	(-2.00)	(-1.61)	(-1.66)
F3*Neutral	-0.0040*	-0.0073***	-0.0095*
	(-1.96)	(-3.58)	(-1.76)
F3*Value	-0.0044*	-0.0014	-0.0061
	(-1.75)	(-0.48)	(-1.56)
Size (decile)	0.0068***	0.0066***	0.0070***
	(5.59)	(6.50)	(6.05)
Mom(decile)	0.0018	0.0002	0.0008
	(1.57)	(0.17)	(0.62)
Adjusted-R^2	0.09	0.10	0.08

This table reports average coefficients estimated from the following cross-sectional model:

$$\begin{aligned} Mkt\_adj\_SH_i = {} & \beta_1 F1_i + \beta_2 F2_i + \beta_3 F3_i + \beta_4 F1_i \times Growth_i + \beta_5 F1_i \times Neutral_i \\ & + \beta_6 F2_i \times Growth_i + \beta_7 F2_i \times Value_i + \beta_8 F3_i \times Neutral_i \\ & + \beta_9 F3_i \times Value_i + \beta_{10} Size_i + \beta_{11} Mom_i + \varepsilon_i \end{aligned}$$

The dependent variable *Mkt_adj_SH* is the market-adjusted level of short turnover for the period starting three months and four months following the fiscal year end. *F1*, *F2* and *F3* are dummy variables with values of one if a firm's F-score is less than or equal to three, between four and six, or greater than or equal to seven, respectively, and zero otherwise. *Growth*, *Neutral* and *Value* are dummy variables with values of one if the firm's BM ratio is the bottom 30%, the middle 40% and the top 30% of BM at the fiscal year-end, respectively, and zero otherwise. We annually and independently rank firm size (*Size*) and momentum (*Mom*) into deciles and include their decile ranks in the above equation to mitigate the impact of intertemporal distribution changes in the two variables. In columns (2) and (3), we also use earnings-to-price and cash-flow-to-price as alternative measures for value/growth. Earnings, cash flows and prices are based on the values at fiscal year end. The Newey-West (1987) adjusted *t*-statistics are reported in parentheses. *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 5 Future returns of low F-score firms following short selling

Panel A Market adjusted returns								
Time horizons	[0,3]	[0,6]	[0,9]	[0,12]	[0,15]	[0,18]	[0,21]	[0,24]
Low F-score	-1.25*	-3.88***	-3.90**	-4.34**	-4.14**	-5.57**	-4.34**	-3.37**
	(-1.89)	(-2.97)	(-2.13)	(-2.21)	(-1.98)	(-2.40)	(-2.32)	(-2.01)
Q1 (lightly shorted)	-1.74**	-6.30***	-7.25***	-7.20***	-9.19***	-12.75***	-13.80***	-13.60***
	(-2.28)	(-5.18)	(-4.03)	(-3.18)	(-3.74)	(-4.38)	(-3.97)	(-3.55)
Q5 (heavily shorted)	-0.14	-2.84**	-2.93	-1.78	-0.46	-1.50	0.51	3.73
	(-0.16)	(-2.36)	(-1.60)	(-0.91)	(-0.19)	(-0.50)	(0.14)	(0.92)
Diff. Q1-Q5	-1.61**	-3.46***	-4.31***	-5.41***	-8.73***	-11.25***	-14.32***	-17.32***
	(-2.02)	(-3.40)	(-3.04)	(-3.85)	(-3.91)	(-3.99)	(-4.30)	(-4.20)
Panel B Size-adjusted returns								
Time horizons	[0,3]	[0,6]	[0,9]	[0,12]	[0,15]	[0,18]	[0,21]	[0,24]
Low F-score	-1.28***	-3.81***	-5.41***	-6.22***	-6.14***	-7.16***	-9.75***	-6.80***
	(-2.77)	(-5.46)	(-5.70)	(-6.50)	(-6.45)	(-7.30)	(-6.89)	(-6.05)
Q1 (lightly shorted)	-1.98***	-6.00***	-8.86***	-9.17***	-11.06***	-13.81***	-20.93***	-17.00***
	(-3.84)	(-8.25)	(-8.23)	(-6.80)	(-6.36)	(-7.02)	(-3.24)	(-6.78)
Q5 (heavily shorted)	-0.10	-2.81***	-3.58**	-2.90	-1.50	-2.33	-2.34	2.48
	(-0.14)	(-2.91)	(-2.44)	(-1.60)	(-0.75)	(-0.98)	(-1.16)	(0.75)
Diff. Q1-Q5	-1.87**	-3.18***	-5.27***	-6.26***	-9.56***	-11.52***	-18.59***	-19.60***
	(-2.30)	(-2.89)	(-3.42)	(-3.86)	(-4.00)	(-4.04)	(-5.63)	(-4.75)
Avg. no. of stocks	121	121	121	121	120	118	118	118

This table reports the market- and size-adjusted returns for low F-score stocks with different short selling activity. We sort low F-score firms into quintile by their market-adjusted short turnover over the period from third month to the fourth months after fiscal-year end (i.e., Q1 (lightly shorted) through Q5 (heavily shorted)). Buy-and-hold returns are calculated across 3, 6, 9, 12, 15, 18, 21, and 24 months from the end of the fourth month after fiscal-year end. Panels A and B report the market-adjusted and the size-adjusted returns, respectively. The market return is calculated from the value-weighted market index. The size-adjusted returns are calculated as a raw buy-and-hold return subtracting correspondent size portfolio's return in a same holding period. We use market-cap-based size decile portfolios provided by CRSP. The last row reports the average number of stocks in each quintile portfolio. The returns are reported in percentage. The Newey-West standard adjusted *t*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6 Future returns of firms with low F-score and low BM following short selling

Panel A Market adjusted returns								
Time horizons	[0,3]	[0,6]	[0,9]	[0,12]	[0,15]	[0,18]	[0,21]	[0,24]
Low F-score &low BM	-1.20*	-4.32***	-4.82**	-7.27***	-7.61***	-10.00***	-9.81***	-11.06***
	(-1.70)	(-3.28)	(-2.56)	(-3.79)	(-3.63)	(-4.70)	(-3.72)	(-3.90)
T1 (lightly shorted)	-1.75*	-5.80***	-8.25***	-9.98***	-13.50***	-18.15***	-19.86***	-20.52***
	(-1.77)	(-4.32)	(-5.06)	(-5.10)	(-6.63)	(-7.07)	(-6.35)	(-6.00)
T2	-1.54	-4.13***	-5.43***	-6.48***	-8.47***	-12.65***	-15.72***	-17.25***
	(-1.48)	(-2.83)	(-3.00)	(-3.28)	(-3.68)	(-4.61)	(-4.73)	(-4.60)
T3 (heavily shorted)	0.22	-2.02	-3.15	-2.79	-0.41	-0.71	0.34	2.06
	(0.17)	(-1.17)	(-1.42)	(-1.23)	(-0.14)	(-0.20)	(0.07)	(0.45)
Diff. T1-T3	-1.98*	-3.78**	-5.10**	-7.19***	-13.09***	-17.44***	-20.17***	-22.61***
	(-1.73)	(-1.98)	(-2.49)	(-3.02)	(-4.77)	(-5.38)	(-4.94)	(-4.85)
Panel B Size-adjusted returns								
Time horizons	[0,3]	[0,6]	[0,9]	[0,12]	[0,15]	[0,18]	[0,21]	[0,24]
Low F-score & low BM	-1.38**	-4.33***	-6.00***	-8.74***	-9.63***	-11.34***	-11.56***	-13.27***
	(-2.06)	(-4.80)	(-4.54)	(-6.16)	(-6.00)	(-7.17)	(-8.56)	(-6.25)
T1 (lightly shorted)	-2.06**	-5.88***	-9.38***	-11.33***	-15.06***	-19.22***	-20.02***	-23.56***
	(-2.04)	(-5.02)	(-6.75)	(-6.45)	(-8.56)	(-9.65)	(-5.10)	(-8.56)
T2	-1.69*	-3.70***	-5.56***	-6.66***	-8.42***	-11.68***	-12.68***	-16.96***
	(-1.84)	(-2.93)	(-3.56)	(-3.80)	(-4.30)	(-4.98)	(-5.20)	(-5.29)
T3 (heavily shorted)	0.30	-2.26	-3.84**	-2.74	-1.83	-1.64	0.23	0.74
	(0.26)	(-1.54)	(-2.03)	(-1.58)	(-0.72)	(-0.50)	(0.86)	(0.18)
Diff. T1-T3	-2.36**	-3.62*	-5.54**	-8.54***	-13.22***	-17.52***	-20.25***	-24.42***
	(-1.98)	(-1.94)	(-2.53)	(-2.91)	(-4.50)	(-5.26)	(-4.99)	(-5.13)
Avg. no. of stocks	54	54	54	54	53	52	52	52

This table presents the market- and size-adjusted returns to low F-score firms with low BM across different levels of short selling activity. We sort these firms into terciles by the market-adjusted short turnover over the period from the third month to the fourth month after fiscal-year end. Buy-and-hold returns are calculated across 3, 6, 9, 12, 15, 18, 21, and 24 months from the end of the fourth month after fiscal-year end. We sort our stocks into terciles on the basis of market-adjusted short turnover (i.e., T1 (lightly shorted), T2 and T3 (heavily)). Panels A and B reports the market-adjusted returns and the size-adjusted returns, respectively. The market return is calculated from the value-weighted market index. The size-adjusted returns are calculated as a raw buy-and-hold return subtracting correspondent size portfolio's return in a same holding period. We use the market-cap-based size decile portfolios provided by CRSP. The last row reports the average number of stocks in each quintile portfolio. The returns are reported in percentage. The Newey-West adjusted *t*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 7 Comparing firm characteristics between pilot and non-pilot firms

	Panel A: Whole sample Pilot (N=492) Non-pilot(N=980)	Diff.	Panel B: High F-score group Pilot (N=134) Non-pilot (N=264)	Diff.	Panel C: Low F-score group Pilot t (N=48) Non-pilot (N=127)	Diff.
F-score	5.522	0.100	7.352	0.002	2.754	0.143
	5.423	(1.14)	7.351	(0.03)	2.609	(1.23)
1. Signal of positive net income	0.917	0.024	0.985	-0.007	0.687	0.023
	0.893	(1.45)	0.992	(-0.69)	0.664	(0.29)
2. Signal of positive cash flow from operation	0.943	0.027	1.000	0.004	0.625	0.033
	0.916	(1.55)	0.996	(0.71)	0.592	(0.39)
3. Signal of cash flow from operation greater than net income	0.863	0.031	0.947	-0.010	0.646	0.029
	0.833	(1.52)	0.950	(-0.44)	0.616	(0.36)
4. Signal of growth in net income	0.606	0.008	0.932	-0.029	0.225	0.050
	0.597	(0.31)	0.962	(-1.29)	0.174	(0.68)
5. Signal of a decrease in leverage	0.679	0.002	0.925	-0.003	0.166	-0.078
	0.677	(0.07)	0.928	(-0.09)	0.245	(-1.03)
6. Signal of an increase in liquidity	0.492	-0.028	0.702	-0.016	0.272	0.212
	0.520	(-0.88)	0.718	(-0.31)	0.189	(0.80)
7. Signal of no new common/preferred stock issue	0.096	-0.008	0.183	0.008	0.026	-0.026
	0.104	(-0.44)	0.175	(0.19)	0.053	(-0.67)
8. Signal of an increase in gross margin	0.512	-0.026	0.844	0.001	0.162	0.010
	0.538	(-0.94)	0.843	(0.03)	0.152	(0.15)

9. Signal of an increase in asset turnover	0.583	0.014	0.910	0.050	0.200	-0.004
	0.569	(0.50)	0.859	(1.45)	0.203	(-0.05)

This table compares pilot and non-pilot firms in terms of F-score and each component of F-score at the end of 2003. The sample consists of non-pliot and pilot firms from the pilot program on NYSE/Amex. Panel A reports the means of F-score as well as each component of F-score, which is a binary signal, for non-pilot and pilot firms and their differences over the full sample. Panel B reports the means of F-score and each component of F-score for non-pilot and pilot firms as well as their difference, for stocks that are in the high and low F-score portfolios. The definitions of nine components of F-score are shown in Appendix 1. *t*-statistics are presented in parentheses below the difference of means.

Table 8 Difference-in-differences analysis based on a natural experiment

	(1) Pilot pre	(2) Non-pilot pre	(3) Diff	(4) Pilot during	(5) Non-pilot during	(6) Diff	(7) DiD (β_1)	(8) DiD (β_2)
Long-short portfolios	0.0268	0.0115	0.0153	0.0855	0.1587	-0.0732**	-0.0885**	0.0102
			(0.55)			(-2.38)	(-2.46)	(0.13)
Long portfolios	0.1082	0.0972	0.0110	0.0031	-0.0214	0.0245**	0.0135	0.018
			(0.78)			(2.21)	(0.82)	(0.09)
Short portfolios	0.0914	0.0957	-0.0043	-0.0824	-0.1802	0.0977**	0.1020***	-0.0084
			(-0.21)			(2.34)	(2.79)	(-0.12)
Low F-score & low BM	0.1066	0.0807	0.0259	-0.0613	-0.2101	0.1487**	0.1228**	-0.0096
			(0.88)			(2.48)	(2.31)	(-0.10)
Low F-score & Middle BM	0.0717	0.0942	-0.0225	-0.1346	-0.0734	-0.0611	-0.0386	0.0497
			(-0.22)			(-0.61)	(-0.26)	(0.61)
Low F-score & High BM	0.1135	0.1172	-0.0037	-0.0811	-0.1765	0.0954	0.0991	-0.0874
			(-0.03)			(1.12)	(1.32)	(-1.43)

This table presents the results based on the difference-in-differences analysis. The two estimates (β_1 and β_2) from the regression $R_{i,t} = \alpha_0 + \gamma_t + \beta_1 Pilot_i \times During_t + \beta_2 Pilot_i \times Post_t + \varepsilon_{it}$ is reported for F-score based portfolios. The variable R_{it} is the one-year market-adjusted return of portfolio i (which can be the long leg, the short leg, or the long-short portfolios based on F-score) in fiscal year t, γ_t denotes time fixed effects, $Pilot_i$ is a dummy variable that is equal to 1 if portfolio i is formed on pilot firms, $During_t$ is a dummy variable that is equal to 1 if fiscal year t is 2005 or 2006 (i.e., during the pilot period of Regulation SHO), and $Post_t$ is a dummy variable that is equal to 1 if fiscal year t is after 2006. One-year market adjusted returns are calculated from four months following the fiscal year-end (see figure 1). The mean portfolio returns for non-pilot and pilot stocks in the pre-pilot period and the during-pilot period, as well as their difference (pilot minus non-pilot) in these two periods, are reported from columns (1) to (6). The coefficient β_1 is the difference in these two differences (one in the pre-pilot period and the other in the during-pilot period).The coefficient estimate of β_2 is used to test the difference in returns between pilot stocks and non-pliot stocks in the post-pilot period, relative to that in the pre-pilot period, is statistically significant. Long-short portfolios means a long position in high F-score (i.e., between seven and nine) portfolio and a short position in low F-score (i.e., between zero and three) portfolio. Within low F-score firms, we further form three pairs of portfolios, namely pilot (non-pilot) stocks with low BM, pilot (non-pilot) stocks with middle BM, and pilot (non-pilot) stocks with high BM. Low, middle and high BM are defined as firm-year observations with BM ratios below the 30th percentile, between the 30th and 70th percentile, and above the 70th percentile of the sample at each fiscal year end. The sample consists of 1,016 non-pilot and 508 pilot stocks that are traded on NYSE/Amex. The sample period is January 1980 to December 2016. Robust *t*-statistics are presented in parentheses below the coefficient estimates and are only presented for differences in mean returns and the coefficients β_1 and β_2 for brevity. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 9 Short selling and momentum

Pane A: Time-series analysis				
	Ret [-4,-1]	Mkt_adj_SH[-1,0]		
The first group: large negative returns btw low and high F-score	-6.42%***	1.29%		
	(-7.93)	(1.29)		
The second group: small negative returns btw low and high F-score	-0.14%	3.49%***		
	(-0.36)	(2.71)		
Diff	-6.28%***	-2.19%**		
	(-6.96)	(-2.10)		
Panel B: Cross-sectional analysis				
Mkt_adj_SH [-1,0]	Low F-score	Middle F-score	High F-score	Low- high
Losers	-0.02%	-0.07%	-1.02%**	0.99%*
	(-0.09)	(-0.13)	(-2.01)	(1.68)
Winners	3.77%**	-0.30%	-0.57%	4.37%***
	(2.58)	(-0.61)	(-1.18)	(2.71)
Loser-winner	-3.80%***	0.22%	-0.45%	
	(-2.68)	(0.49)	(-1.25)	

This table reports short selling activity associated with past returns. In Panel A, we rank differences in returns between low and high F-score firms over the three-month period following fiscal year end (i.e. [-4,-1] in Figure 1) and separate our sample years (1972-2016) into two groups. The first group includes the 22 annual observations in which the underperformance of low F-score firms relative to high F-score firms is particularly large, while the second group contains the remaining 22 annual observations. Ret [-4,-1] is the difference in buy-and-hold returns between the low and high F-score firms over the three month period. *Mkt_adj_SH* [-1,0] is the market-adjusted short turnover over the period from three to four months following the fiscal year end (i.e.[-1,0]). Panel A shows the difference-in-difference (DID) of short interest and returns between low and high F-score firms across the two groups. In Panel B, we rank all sample firms on the basis of the three-month returns over the information period (i.e. the window [-4,-1] in Figure 1) in each fiscal year. Subsequently, we divide the firms into two groups with an equal number of observations. The first group contains stocks with higher past returns (i.e., winners) and the second group consists of stocks with lower past returns (i.e., losers). Each of these two groups is then divided into low, middle and high F-scores to form six F-score and past return portfolios. We report the market-adjusted short interest for the six portfolios. *t*-statistics are reported in parentheses. *,**, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 10 Short selling and investor sentiment

	Panel A: States of investor sentiment		
	(mkt_adj_SH^{F1}-mkt_adj_SH^{F3})	mkt_adj_SH^{F1}	mkt_adj_sh^{F1_lowBM}
High sentiment	0.0721**	0.0479**	0.0741***
	(2.56)	(1.98)	(3.00)
Middle sentiment	0.0033	0.0031	0.0261**
	(0.07)	(1.63)	(2.06)
Low sentiment	0.0005	-0.0006	0.0123*
	(0.20)	(-0.16)	(1.69)
High-Low	0.0716**	0.0485**	0.0518**
	(2.35)	(2.06)	(2.60)
	Panel B: Time-series regressions		
Dep. Variable	(mkt_adj_SH^{F1}-mkt_adj_SH^{F3})	mkt_adj_SH^{F1}	mkt_adj_sh^{F1_lowBM}
Sentiment Index	0.0358**	0.0479*	0.0386***
	(2.53)	(1.96)	(2.74)
Constant	0.0231**	-0.0005	0.0364**
	(1.99)	(-0.03)	(2.11)
Adj_R^2	0.12	0.04	0.05

This table reports the short selling activity across different sentiment periods. The differences in the market-adjusted short turnover between the low (F1) and high (F3) F-score is denoted as (mkt_adj_SH^{F1}-mkt_adj_SH^{F3}). The market-adjusted short turnover for low F-score firms is denoted as mkt_adj_SH^{F1}. The market-adjusted short turnover for low F-score firms with low BM ratio is denoted as mkt_adj_SH^{F1_lowBM}. We use the investor sentiment index developed by Baker and Wurgler (2006) to classify our sample years into periods of high, medium, and low investor sentiment. In Panel A, we report the market-adjusted short turnover across the three sentiment states. In panel B, we regress (mkt_adj_SH^{F1}-mkt_adj_SH^{F3}), mkt_adj_SH^{F1} and mkt_adj_SH^{F1_lowBM} separately on the Baker and Wurgler's (2006) sentiment index. *t*-statistics are reported in parentheses. *,**, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Appendix 1 Construction of F-score

Piotroski's (2000, 2005) F-score is the sum of nine binary variables that collectively measure the firm's financial strength. We follow Fama and French (2006) in defining the F-score variables. Each of these variables contributes one point if the following criteria is satisfied and zero otherwise.

1. Positive net income before extraordinary items.

2. Positive cash flow from operations:

> a. If a firm files a statement of working capital, we define cash flow from operation as the funds from operations minus other changes in working capital (if available). Funds from operation is the sum of earnings before extraordinary items, income statement deferred taxes, and equity's share of depreciation expense. Equity's share of depreciation expense is calculated as depreciation expense times the ratio of market capitalization to the sum of market capitalization and the difference between total assets and book value of equity. Book value of equity is defined as total assets less liabilities plus deferred taxes and investment tax credits less preferred stocks liquidity value (if available) or preferred stock redemption value (if available), or preferred stocks carrying value (if available).
>
> b. If a company files a statement of cash flows, we define cash flow from operations as net cash flow from operating activities.
>
> c. For all other cases, we define cash flow from operations as the sum of funds from operations and changes in working capital.

3. Cash flow from operations greater than net income, i.e. (2)>(1).

4. Increase in net income (scaled by total assets) from the prior fiscal year-end: net income before extraordinary items divided by total assets.

5. Decrease in leverage from prior fiscal year-end: leverage is defined as long-term debt divided by total assets.

6. Increase in liquidity (current ratio) from prior fiscal year-end: liquidity is defined as the ratio of current assets to current liabilities.

7. No new common or preferred stock issued over the previous year: if sales from common and preferred stocks are zero.

8. Increase in gross margin from prior fiscal year-end: gross margin is defined as one less the ratio of cost of goods sold to sales.

9. Increase in asset turnover from prior fiscal year-end: asset turnover is defined as the ratio of sales to total assets at the beginning of the year.

Appendix 2 Variable definition

Variable	Definition
$Size_i$	Firm *i*'s market capitalization at the fiscal year end in logarithm form.
BM_i	Firm *i*'s market book-to-market ratio at the fiscal year end
Mom_i	Firm *i*'s past 6-month buy-and-hold return ending two months after the fiscal year end.
$Illiquidity_i$	Firm i's illiquidity ratio defined as the monthly average of the daily ratio of absolute stock return to dollar volume over a three-month period including the month of fiscal year end and the subsequent two months (e.g. Amihud, 2002).
σ_i	Firm *i*'s volatility defined as the differences between the highest and lowest prices over a three-month period including the month of fiscal year end and the subsequent two months period scaled by the highest price.
IO_i	Firm *i*'s percentage of institutional ownership at the end of fiscal year. The data on institutional holdings is available on quarterly basis. If firms have fiscal year ends in months other than January, March, June, September and December, we use the quarter of the 13-F filing.
DP_i	Firm *i*'s cash dividend yield i.e., cash dividend paid per share divided by stock price at the fiscal year end.
$Analyst_i$	Firm *i*'s number of analysts following at the fiscal year end.
$Mkt\_adj\_SH_i$	The market-adjusted level of short turnover for firm *i* for the period starting three months ending four months after the fiscal year end. The raw short turnover is defined as the number of shares shorted as a percentage of shares outstanding. Then, the market-adjusted short turnover (*mkt_adj_SH*), is defined as raw the firm's short turnover in a given month minus the market average short turnover in a same month.
Mkt_adj_ret[0,12]	Firm *i*'s market-adjusted buy-and-hold returns, i.e., the firm's buy-and-hold returns less the CRSP value-weighted buy-and-hold return, over a 12-month period starting four months following the fiscal year-end
Size_adjusted_return	The size-adjusted returns are calculated as a raw buy-and-hold return subtracting correspondent size portfolio's return in a same holding period. We use the market-cap-based size decile portfolios provided by CRSP.
Pilot	A dummy variable is equal to 1 if a portfolio is formed on pilot firms, and zero otherwise.
During	A dummy variable is equal to 1 if a fiscal year is 2005 or 2006 (i.e., during the pilot period of Regulation SHO) and zero otherwise.
Post	A dummy variable is equal to 1 if a fiscal year is after 2006 and zero otherwise.