Firm fundamentals, short selling, and stock returns

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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 the strength of fundamentals negatively predicts short selling. We also find that short sellers exploit the overpricing of growth firms whose fundamentals are incongruent with market expectations (i.e., growth firms with weak fundamentals). A number of tests suggest that short selling activity increases the speed of price adjustment to negative information and reduces the ability of poor fundamentals to predict returns. Our findings are consistent with the gradual incorporation of information and contradict the rational pricing explanation.

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1. Introduction

While there is ample evidence that firm fundamentals (e.g. accruals, return on equity, profitability and asset growth) 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; 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) and Chen et al. (2011) 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 observed relations between expected returns and financial strength are driven by rational or irrational pricing. To overcome this limitation, we develop a new test to assess whether short selling activity affects the relationship between the strength of fundamentals and future returns. Under the risk-based explanation, investors' revised expectations about fundamentals are instantaneously impounded into prices. Thus, if lower expected profitability is associated with lower risk, short sellers who sell firms with deteriorated fundamentals should expect lower future returns. Since market prices fully and quickly incorporate fundamental information, short selling activity should bear no relation to firm fundamentals after controlling for risk and nor should such an activity affect future returns.

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[1] For example, accruals (Sloan, 1996; Fama and French, 2006; Richardson et al., 2005), return on equity (Haugen and Baker, 1996), return on asset (Fama and French, 2006; Chen et al., 2011; Novy-Marx, 2013), asset growth (Cooper et al., 2008) and investment (Liu et al., 2009).

Under the mispricing explanation, investors slowly revise their expectations about fundamentals, particularly following the release of negative signals (DeBondt and Thaler, 1985; Barberis et al., 1998; Daniel et al., 1998; Hong and Stein, 1999)[2]. Slow revisions of expectations following negative signals would cause overpricing. When short sellers exploit overpricing, we would expect short selling activity to correlate negatively with the strength of fundamentals and positively with the speed of price adjustment to negative information.

Slow reactions to negative signals about fundamentals can also indicate that market expectations are biased, thereby causing prices to deviate from fundamental values. Several studies show that investors tend to over-extrapolate past growth and underweight negative information, which contradicts their beliefs about the firms' growth prospects (LaPorta, 1996; LaPorta et al., 1997; Dechow and Sloan, 1997; Lakonishok et al., 1994; Mohanram, 2005). Similarly, growth stocks with low Book-to-Market (BM), low earnings-to-price and low cash-flow-to-price ratios are customarily perceived to be overpriced and are therefore more likely to be short sold (Lee, 2012; Dechow et al., 2001; Curtis and Fargher, 2014). However, valuations based on price multiples completely ignore the strength of fundamentals, which measures a firm's ability to generate future cash flows. Additionally, the divergence of market expectations from fundamentals can cause substantial mispricing. For example, low price multiples combined with deteriorated fundamentals would indicate higher market expectations about growth compared to the growth prospects implied by fundamentals. Firms with such characteristics are likely to be overpriced and may generate large negative future returns (Lakonishok et al., 1994; LaPorta, 1996; Dechow and Sloan, 1997). The mispricing argument predicts that short sellers target firms with expectation errors in order to exploit overpricing. In contrast, the rational view suggests that, as market prices fully and quickly reflect public

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[2] Mispricing can persist if market frictions can 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).

information, expectation errors should not exist and short selling activity should not be related to firm fundamentals.

By using Piotroski's F-score (2000) to measure the strength of fundamentals, we first test the market response to fundamental signals. Consistent with the slow price adjustments to information, we find that the returns on low F-score firms are insignificant during the first four months following the fiscal year end and significantly negative in the subsequent one-year period. We also find a significantly negative association between F-score and short selling activity, implying that short sellers exploit overpriced low F-score firms. By using BM ratio to measure market expectations, we construct F-score and BM based portfolios to explore how short sellers exploit overpricing. The results show that short selling activity is concentrated in growth firms whose fundamentals are incongruent with market expectations (i.e., firms with low BM and low F-score). However, we find that short selling activity is insignificant in firms with high market expectations for growth (low BM) and improved fundamentals (high F-score). This finding suggests that the market requires time to revise expectations, consistent with the mispricing argument but not with the risk-based explanation.

The exploitation of overpricing also implies that short selling increases the speed of price adjustment to negative fundamental information. To test this, we separate low F-score firms into quintile portfolios according to short interest. The analysis reveals 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 separate low F-score firms with low BM ratios (i.e., the most severely overpriced firms) into terciles based on short interest. We find that the ability of F-score to predict the returns of these stocks declines with short interest, implying that short selling improves price efficiency. However, we do not expect short sellers to eliminate overpricing completely as holding short positions is costly. More specifically, short sellers may only initiate short selling when they expect price declines to be large enough to compensate

them fully for the associated costs and the risks (Diamond and Verrechia, 1987). Consistent with this argument, we find that overpricing is higher and short interest is lower when low F-score firms are smaller, have less institutional ownership and pay higher cash dividends.

Overall, our results suggest that the relationship between the strength of fundamentals and future returns arise because fundamental information is gradually impounded into prices. However, one may argue that short sellers trade low F-score firms because these firms have experienced poor past performance, i.e. short sellers are momentum traders. To test this, we compare the difference in short selling between low and high F-score firms conditional upon past performance. We find that short sellers exhibit little interest in selling low F-score firms with poor past performance, whereas low F-score firms with good past performance attract high short interest. This suggests that short sellers are contrarian traders rather than momentum traders. Another potential concern is that short sellers may move the price of low F-score firms far below fundamental values in times of economic downturns when poor performance is more likely to occur. 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 sellers are more active during high sentiment periods, indicating that short selling helps correct the overpricing induced by the speculative demand of noise traders (e.g. Shiller, 1984).

This study contributes to the literature in three ways. First, we show that short sellers trade on public information. This evidence is inconsistent with the rational pricing theories, which predict that market prices incorporate public information fully and instantaneously and that the strength of fundamentals represents a risk. Instead, our findings support the mispricing argument, which suggests that investors are slow to revise their expectations about firm fundamentals. Furthermore, our results reconcile two conflicting views on the market expectations reflected in the BM ratio (i.e., (i) the risk-based view of Fama and French (1993; 1996); and (ii) the mispricing-based view of Lakonishok et al. (1994)) and have important

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implications for the recent developments in the asset pricing literature. Specifically, the finding that short selling is concentrated in low BM firms with deteriorated fundamentals indicates that the BM ratio reflects biased market expectations about fundamentals, while the low level of short selling activity in low BM firms with improved fundamentals implies that the BM ratio represents unbiased market expectations. This evidence suggests that BM ratio is not a good proxy for future profitability, consistent with the recent findings of Fama and French (2015, p.1) that "With the additional profitability and investment factors, the value (BM) factor of the FF three-factor model becomes redundant for describing average returns in the sample we examine". Our evidence also suggests that the profitability and investment factors in the Fama and French five-factor model explain returns, at least in part, because of the ability of these two factors to capture mispricing[3].

Second, this study enhances our understanding of the trading behavior of short sellers. Prior studies show that short sellers are sophisticated and informed traders (Bernard and Thomas, 1990; Doyle et al., 2003; Desai et al., 2006; Efendi et al., 2005; Karpoff and Lou, 2010; Dechow et al., 2001; Drake et al., 2011; Christensen et al., 2014). We document evidence that short sellers are also value investors, who short sell "expensive" (low BM) stocks with prices that are significantly above fundamental values. This short selling strategy is in alignment with the central theme of value investing, which exploits stocks whose prices deviate from fundamental values (Graham and Dodd, 1934). Unlike prior studies, which consider value investing as a long position in "cheap" stocks (high BM) with improved fundamentals (e.g. Piotroski, 2000; Piotroski and So, 2012), we propose a short position for value investing (i.e., shorting low BM stocks with deteriorated fundamentals). Our evidence on the link between short selling activity and firm fundamentals provide further insights on the mechanism through which the market processes public information. Specifically, when market expectations deviate from

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[3] Also see Fama and French (2017) for international evidence.

fundamentals, investors require time to correct their expectation errors and such slow price adjustments to fundamental information, in turn, create exploitative opportunities for value investing. In particular, short sellers exploit the overpricing of growth stocks with weak fundamentals, while other market participants exploit the underpricing of value stocks with strong fundamentals (Dechow et al., 2001; Piotroski and So, 2012).

Third, we find that the trading behavior of short sellers stabilizes the market. The exploitation of negative returns in economic upturns is shown to reduce price bubbles (Diether et al., 2009; Lamont and Stein, 2004; Savor and Gamboa-Cavazos, 2011; Blau et al., 2012; Curtis and Fargher, 2014). However, short selling stocks in anticipation of negative returns in economic downturns raise a serious regulatory concern that short sellers may destabilize the market by moving prices far below fundamental values[4]. This concern resulted in temporary bans on short selling during the 2008 financial crisis across major developed markets (Beber and Pagano, 2013)[5]. Our results suggest that short sellers are not momentum traders and tend to avoid trading stocks with deteriorated fundamentals during periods of low sentiment. Instead, we find that short selling prevails in economic upturns when both sentiment and overpricing are high (e.g. Baker and Wurgler, 2006). This evidence is consistent with Stamburgh et al. (2012), who show that overpricing is unlikely to occur in economic downturns and also supports Beber and Pagno's (2013) conclusion that "at best short-selling bans have left stock prices unaffected". Overall, the regulatory concern that short sellers can destabilize the markets is largely unwarranted.

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[4] The Securities and Exchange Commission (SEC) suggested that short selling manipulates firms "uniquely vulnerable to panic" (Cox, 2008).

[5] For example, the SEC in the U.S. issued a temporary ban on the short selling of 799 financial firms in 2008 (from September 17 to October 8) in response to the sharp price declines in several financial firms. More recently, in 2010 the SEC revised Regulation SHO by restricting short-selling activity if a firm's price declines by 10% or more in a single trading day. Beber and Pagano (2013) provide more details on short selling bans during the 2008 financial crisis in the world.

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 US data for the period 1972-2016, we annually sort our stocks into portfolios based on the strength of fundamentals (F-score) and into portfolios based on price multiples. We then examine variation in short selling activity, expectation errors and future returns within and across these portfolios. Our aim is to test whether short selling affects the ability of the strength of fundamentals to predict returns.

2.1. The strength of fundamentals and market expectations

We use F-score to measure the strength of fundamentals (Piotroski, 2000; 2005). Fama and French (2006, p496) point out that F-score is a "composite measure of firm strength". Specifically, F-score is an aggregate statistic, which is based on nine financial signals that measure three dimensions of firms' financial condition: (i) profitability, (ii) change in financial leverage and liquidity, and (iii) change in operational efficiency[6] (see Appendix 1 for further details). A "good" signal contributes one point to the F-score, whereas a "bad" signal contributes zero and correspondingly, the F-scores range from zero to nine. Following prior studies (e.g., Choi and Sias, 2012; Piotroski and So, 2012), we categorize 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. F-score is a leading predictor of future returns

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[6] In F-scores, seven of nine signals are based on changes in financial condition from the last fiscal year to the current fiscal year. Strictly speaking, F-score can be interpreted as changes in fundamentals.

even after controlling for size, book-to-market, and asset growth (Piotroski and So, 2012; Choi and Sias, 2012; Fama and French, 2006). F-score can also predict future financial performance. Specifically, low F-score firms experience deterioration in future profitability, while high F-score firms incur an overall improvement in profitability (Piotroski and So, 2012). Given the strong predictability for future profitability, F-score can proxy for expected profitability (Fama and French, 2006).

BM ratio captures market expectations about future performance. Low BM firms are expected to grow faster and are therefore more "expensive" 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 realised profitability and earnings growth. In particular, low BM firms (i.e. growth firm) tend to have high future earnings growth, whereas high BM firms (i.e. value firms) are associated with low future profitability. We measure a firm's BM ratio as the book value of equity scaled by the market value of equity at fiscal year-end. Following Fama and French (1993) and Pitrioski and So (2012), we categorize firm-year observations with BM ratios below the 30th percentile, between the 30th and 70th percentile, and above the 70th percentile as growth, neural and value firms, respectively[7].

2.2. The exploitation of overpricing

Prior studies show that short sellers are informed and usually short sell stocks prior to major negative corporate events, such as negative earnings announcements (Christophe et al., 2004 and Akbas et al., 2008), 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

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[7] BM ratio is our main measure although we also include earnings-to-price and cash-flow-to-price as alternative measures in our empirical analysis.

is also evidence that short sellers possess 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. Boehmer and Wu (2013) show that short sellers exploit negative earnings surprise and mitigate negative earnings announcement drifts. 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. Departing from previous studies, we are interested in the relation between firm fundamentals and short selling, an issue that has not yet been explored in the literature. This analysis should enhance our understanding of the trading behavior of short sellers and shed light on whether the link between F-score and future returns is due to rational pricing or mispricing.

It has been widely documented that markets are slow to fully reflect public information (see, e.g., Bernard and Thomas, 1989; Doyle, 2006; Balakrishnan et al., 2010; Dichev and Piotroski, 2001; Chen et al., 1996; Gleason and Lee, 2003; Sloan, 1996; Bradshaw et al., 2006). 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 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). As slow price adjustment to negative signals about fundamentals causes overpricing, we expect short selling activity to be mainly concentrated in low F-score firms. Mohanram (2005) finds that the negative returns to growth firms are generated by a subset of growth firms with poor fundamentals. As value stocks are often ignored by the market, improvements in fundamentals are slowly reflected in their prices to induce underpricing

(LaPorta, 1996; LaPorta et al., 1997; Dechow and Sloan, 1997). Piotrioski (2000) and Piotrioski and So (2012) find that positive returns to value firms are driven by a subset of value firms with strong fundamentals. However, Fama and French (1992; 1996; 2006) find that growth firms have higher future earnings and higher growth rates than value firms, thus implying less bias in market expectations about future performance.

In the study, we link F-score with BM to reconcile two conflicting views on the market expectations reflected in BM ratios. F-score is based on the strength of fundamentals and measures the firm's ability to generate future cash flows, while BM ratios measure market expectations about earnings growth (e.g. Lee, 2014). Market expectations could be unbiased if the improved (deteriorated) fundamentals are congruent with the strong (weak) expected growth. However, when fundamentals are not strong enough to support the expected growth prospects (e.g. low F-score and low BM), it may lead to biased expectations about future performance. Such biases may cause overpricing and large negative future returns. Correspondingly, the short sellers may exploit the overpricing by selling firms whose prices are perceived to be higher than the values implied by fundamentals. Thus, we predict low BM firms to have higher short interest when their F-scores are relatively low. In contrast, high F-score combined with low BM implies that prices fully reflect the improved fundamentals. This subset of growth firms is unlikely to be attractive to short sellers, as the high growth expectations are congruent with fundamentals.

To illustrate our predictions more clearly, we define the growth expectations implied by BM and fundamentals as $\mathbf{E}$[Growth| BM] and $\mathbf{E}$[Growth| F-score], respectively. When $\mathbf{E}$[Growth| BM] is above $\mathbf{E}$[Growth| F-score], the difference in expectations is referred to as expectation errors about growth. Conversely, when $\mathbf{E}$[Growth| BM] is below $\mathbf{E}$[Growth| F-score], the difference in expectations is called expectation errors about value. That is, the market

underestimates fundamental value. The following table presents expectation errors across value/growth characteristics and the strength of fundamentals[8].

	Growth/Value based on BM		
	Growth-Low BM	Neutral BM	Value-High BM
Low F-score Weak fundamentals	E[Growth| BM]> E[Growth| F-score] Expectation errors for growth (1)	Potential expectation errors for growth (2)	E[Growth| BM]≈ E[Growth| F-score] No expectation errors (3)
Middle F-score	Potential expectation errors for growth (4)	E[Growth|BM]≈ E[Growth|F-score] No expectation errors (5)	Potential expectation errors for value (6)
High F-score Strong fundamentals	E[Growth| BM]≈ E[Growth| F-score] No expectation errors (7)	Potential expectation errors for value (8)	E[Growth| BM]< E[Growth| F-score] Expectation errors for value (9)

In this framework, portfolio (1) should have the highest short interest among the nine portfolios. Investors who have long positions in these stocks are likely to underreact to information that contradicts their beliefs about the firm's growth prospects (Mohanram, 2005; Lakonishok et

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[8] Pitroski and So (2012) use a similar table to illustrate expectation errors. We further refine these errors into expectation errors for growth and the errors for value.

al., 1994). Portfolio (9) includes stocks with expectation errors about value. This subset of value stocks is likely to be neglected by the market despite their strong fundamentals (Lakonishok et al., 1994; Piotroski, 2000; Piotroski and So, 2012). We do not expect this subset of value stocks to attract short sellers because short selling strategies cannot be used to exploit underpricing and an analogous reasoning is applicable to portfolios (6) and (8). In addition, the market expectations about the growth of the firms in portfolios (3), (5) and (7) are congruent with fundamentals, thus rendering these firms unattractive to short sellers. Therefore, we expect short selling to be concentrated in growth firms with market prices higher than fundamental values i.e. portfolios (1), (2) and (4).

Thus, by establishing links between F-score, BM and short selling, we are able to answer the following important questions: Do growth firms with different F-scores attract the same level of short interest? How can short sellers exploit overpricing? Are the market expectations reflected in BM always biased? Our central prediction is that short sellers will target firms with strong expected growth but with deteriorated fundamentals. We also expect short selling to increase the speed at which negative information is impounded into prices and, therefore, correct overpricing.

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 price and financial statement data are extracted from CRSP and Computstat, 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. Similarly, 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 is provided by the Computstat's Supplemental Short Interest File.[9] 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 raw the firm's short 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., Choi and Sias, 2012; Piotroski and So, 2012; Piotroski, 2000), we define the information period as four 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 post F-score periods.[10] Moreover, following the studies conducted by 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.

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[9] 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.
[10] We calculate returns in the post F-score period from four months following the fiscal year-end to ensure that investors have the necessary information to calculate F-score (Piotroski, 2000, 2005).

Figure 1: Timeline
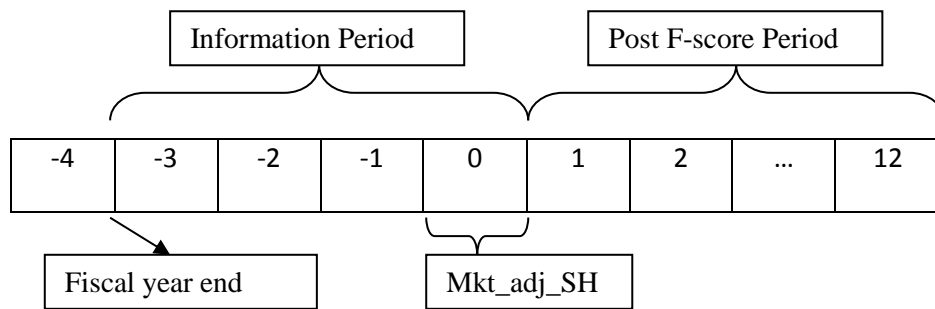
4. Results

4.1. Preliminary results

Panel A in Table 1 reports the main characteristics for the ten portfolios sorted by F-score. 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. Our results, in addition, suggest that low F-score firms are generally smaller than high F-score firms. Furthermore, we show that firms with F-score equals nine are smaller than those with F-scores between four and eight, suggesting that a subset of middle-size firms has strong fundamentals. The distribution of BM ratio exhibits an interesting pattern: 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. These findings imply that value and growth firms vary considerably in the strength of their fundamentals. Moreover, we find that high F-score firms have higher institutional ownership and more analysts following than low F-score firms. Lastly, we document a negative association between F-score and past performance (i.e., the returns over the window [-8, -2]). This implies 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. Following Choi and Sias (2012), we define low, middle and high F-score firms as firms with F-scores between zero and three, between four and six, and greater or equal to seven, respectively. The average market-adjusted returns associated with high and low F-score firms in the information period are 4.38% and -0.11%, respectively. These findings are in support of Hong et al.'s (2000) argument that positive information is incorporated into prices faster than negative information. Correspondingly, slow reactions to negative information should attract short sellers as the price of low F-score firms is expected to decline in the future. Consistent with this conjecture, 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 firms. The difference in market-adjusted short turnover between high and low F-score firms is -2.79% and is significant at less than the 5% level. This evidence lends some support to the view that short sellers exploit the overpriced low F-score stocks. 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 suggests that short sellers do not perceive low F-score firms as being overpriced in the post F-score period.

4.2. Short selling and F-score

In the previous section, we have discussed and presented corroborating evidence to show that low F-score firms attract higher short interest than high F-score firms. 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:

$$Mkt\_adj\_SH_i = \alpha + \beta_1 F\_socre_i + \beta_2 size_i + \beta_3 BM_i + \beta_4 Mom_i +$$
$$\beta_5 illiquidit y_i + \beta_6 \sigma_i + \beta_7 IO_i + \beta_8 DP_i + \beta_9 analyst_i + \varepsilon \tag{1}$$

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 (i.e.[-1,0]). $Size_i$ 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[11]. DP_i is firm i's cash dividend yield (i.e., cash dividend paid per share divided by stock price) used as a proxy for the cost of short selling. 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). The set of control variables included in Equation (1) are previously shown to affect short selling and may also relate to risk[12]. Further details on the definition of these variables are presented in Appendix 2.

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[11] If firms have fiscal year ends other than January, March, June, September and December, we match the calendar quarter of fiscal year end with the quarter of 13-F filing.
[12] For example, institutional holdings (*IO*) and analyst following (*Analyst*) can be proxies for risk of limit-to-arbitrage (Boehmer and Wu, 2013). Our volatility (σ) and illiquidity (Illiquidity) measures can be proxies for total risk and liquidity risk, respectively.

Table 2 reports the time-series means for each coefficient and Newey-West (1987) adjusted *t*-statistics. 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. It also presents a significantly positive relationship between firm size and the market-adjusted short turnover, implying short sellers target large firms. The coefficient on BM is negative and significant, suggesting that growth stocks are more likely to attract short selling than value stocks (Dechow et al., 2001). The insignificant coefficients on the momentum and illiquidity variables suggest that the pattern of past returns and liquidity characteristics do not impact the trading behavior of short sellers. The coefficient on σ_i is positive and significant, indicating that volatile stocks are more likely to be sold short. A possible explanation for this finding is that volatile stocks experience more frequent dramatic price rallies and declines, and short sellers are able to identify when the price of these stocks deviates from their fundamental values. In the last column of Table 2, we include *IO*, *DP* and analysts as additional variables in the regression. The coefficient on F-score is still significantly negative. The coefficient on *IO* is positive and significant, reflecting the fact that institutionally owned shares are easier to short sell. We also find that *DP* is significantly and negatively associated with short interest, consistent with the view that cash dividends are a proxy for short-sale constraints (Dechow et al., 2001).

Overall, the results of this section suggest that F-score is inversely related to short selling activity. This evidence is consistent with the view that short sellers exploit overpricing and contradicts the rational pricing paradigm, which suggests that the strength of fundamentals should bear no relationship to short selling.

4.3. Short selling, F-score and growth expectations

Our finding that short selling is significantly negatively associated with F-score raises the question of whether all low F-score firms are attractive to short sellers. The exploitation of expectation errors predicts that short sellers are only interested in trading low F-score firms with high expectations for growth. However, we do not expect high short interest when growth expectations are congruent with fundamentals. To test these predictions, we sort firms by their BM ratios (i.e. growth, neutral and value) and then by their 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. The results reveal several interesting short selling patterns. 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 exploit overpricing by short selling firms whose prices are perceived to be higher than fundamental values[13]. Furthermore, we show that the short interest of value firms with low F-score is not significantly different from the market average, while the short interest of the value firms with middle and high F-score is significantly lower than the market average. These results are expected, as short selling cannot be used to exploit underpricing, which is more likely to occur in value firms (Piotroski and So, 2012; Piotroski, 2000). We also find the difference in short interest between growth and value firms to be positive and highly significant across the three F-score portfolios. This finding is consistent with Dechow et al. (2001), who show that growth firms are more attractive to short sellers than value stocks. However, growth firms with high F-score have no significant level of short interest relative to the market, consistent with our conjecture that short sellers avoid shorting high F-score firms when the improved fundamentals are congruent with high market expectations for growth. The difference in short turnover between low F-score and high F-

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[13] 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.

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. Instead, our results suggest that short sellers only exploit growth firms with weak fundamentals. Finally, we find that the short interest associated with the high F-score and low BM, middle F-score and middle BM and low F-score and high BM portfolios is not significantly different from the market average, suggesting that short sellers believe that the prices of the firms in these portfolios are aligned with fundamentals. 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.

Overall, our results are consistent with our view that short sellers exploit expectation errors about earnings growth. However, 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:

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

The intercept in Equation (2) is suppressed to ensure non-collinearity among different F-score groups. The dependent variable is the market-adjusted short interests 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.

The coefficients on *F1*, *F2* and *F3* measure the impact of F-score on short turnover for the firms whose market expectations reflected in BM are congruent with the strength of their fundamentals. The six interaction terms measure the differential effects of F-score on the short selling of firms that are likely to suffer from expectation errors. 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 and the Newey-West adjusted t-statistics.

Column (1) in Table 4 shows that the coefficients on *F1*, *F2* and *F3* are significantly negative, implying that firms whose fundamental characteristics are fully and accurately impounded into their prices are less likely to be attractive to short sellers. The coefficients on the three interaction terms (i.e. F1×Growth, F1×Neutral and F2×Growth) are significantly positive, indicating that short sellers exploit stocks with market prices perceived to be higher than fundamental values. However, the remaining three interaction terms (i.e. F2×Value, F3×Neutral, and F3×Value) are significantly negative, suggesting that short selling is less useful when strong fundamentals are not fully reflected in prices. Column (1) also shows that size is significantly and positively related to market-adjusted short interest. As short sellers need to borrow stocks from institutions, who usually hold stocks with large market capitalization, large stocks are more likely to be shortable than small stocks. The coefficient on momentum is insignificant, suggesting that the pattern of past returns has no material impact on short selling. Finally, we document similar result when we use E/P and cash-flow-to-price, instead of BM ratio, to define value/growth features (see columns (2) and (3)). Overall, our results suggest that short sellers exploit overpricing by selling firms whose prices are perceived to be higher than the fundamental values.

4.4. *Short selling and future returns*

Rational pricing and mispricing disagree on the ability of short selling activity to influence low F-score firms' future returns. Rational pricing emphasizes that negative fundamental information is fully impounded into prices and therefore low F-score represents low risk leading to low future returns. However, the mispricing argument suggests that markets are slow to fully incorporate the negative information about fundamentals. The exploitation of overpricing by short sellers would increase the speed of price adjustments to negative signals, postulating that 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[14]. We first sort low F-score firms into quintiles based on their market-adjusted short 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). In addition to market-adjusted returns, we also use size-adjusted returns[15] to take into account short sellers' preferences for large stocks over small stocks. We calculate our portfolio returns over several time horizons, including holding periods

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[14] 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.

[15] 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.

of 3, 6, 12, 15, 18 and 24 months[16], to test the short- and long-term impact of short selling on the stock price discovery process.

Table 5 reports the returns on 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 over all of the 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, suggesting that short selling largely reduces the predictability of low F-score to returns. We obtain similar results using size-adjusted returns in Panel B. Specifically, we find that Q1 experiences significantly negative size-adjusted returns across all horizons, while the returns on Q5 is only significant over three-month and the six-month horizons. The size-adjusted return differential is significantly negative across all holding periods, implying that short selling increases the speed of price adjustment to negative signals about fundamentals.

Table 6 reports the returns on the tercile portfolios of low F-score firms with low BM ratios. The first row in Panel A shows that the market-adjusted returns on low F-score firms with low BM ratios are significantly negative and larger in magnitude than those of the low F-score firms reported in Panel A of Table 5. This finding is consistent with the presence of market expectation errors about the growth prospects of low F-score firms. When fundamentals are far worse than the market expectations, investors will have greater difficulties in timely correcting their priors, leading to persistent negative returns (Lakonishok et al., 1994; Choi and Sias, 2012; Piotroski and So, 2012). Additionally, Panel A shows that the market-adjusted returns on T1 and T2 are significantly negative for almost all horizons, while the market-adjust returns on T3 are statistically insignificant. The return differential between T1 and T3 are highly significant,

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[16] Piotroski (2000) find that the outperformance of high F-score firms over low F-score firms can persist up to a two-year period

implying that short sellers help correct overpricing. The results of the size-adjusted returns in Panel B are largely consistent with those reported in Panel A. Panel B shows that, with the exception of the nine-month horizon, T1 generates 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 that short sellers are able to change the ability of low F-score to predict returns is consistent with the mispricing-based argument.

4.3. Additional analysis

4.3.1. Short selling and momentum

Our previous results show that low F-score firms have poor past performance, while high F-score firms have good past performance. If short sellers chase downward momentum, low F-score firms should experience higher short interest than high F-score firms. To test the momentum-based explanation, 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). Subsequently, we 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 that 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 7 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 positive (1.29%), but 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 positive (3.49%) and highly significant. The last row in Panel A shows the difference-in-difference (DID) of short interest and returns between low and high F-score firms across the two groups. We find that the DID in returns and the DID in short interest are negative and significant. The finding that low F-score firms attract more short selling activity when they underperform 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. 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. If short sellers chase poor past performance, we would expect losers to have higher short interest than winners across both high and low F-score portfolios.

Panel B in Table 7 reports the results. Column (1) shows that low F-score losers have 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). Low F-score winners have the highest short interest in the six portfolios. This evidence contradicts the momentum based explanation, which predicts short selling activity to be concentrated in low F-score losers. Instead, this finding is consistent with our hypothesis that short sellers exploit overpriced low F-score stocks. Specifically, our results imply that a subset of low F-score stocks may have performed well in the past, but such good performance is not sustainable due to deteriorated fundamentals. The overpricing in this subset of low F-score stocks, therefore, attracts short sellers. 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 rather than momentum traders.

4.3.2. Short selling and investor sentiment

In this section, we examine the interection 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 offer short sellers greater opportunities to exploit overpriced low F-score 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 associated with low and high F-score firms and low F-score firms with low BM ratio across different sentiment periods. We use the investor sentiment index introduced by Baker and Wurgler (2006)[17] to classify our sample years into high, medium, and low sentiment periods.

Table 8 provides the results. Panel A 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. During high sentiment periods, ($mkt\_adj\_SH^{F1}$-$mkt\_adj\_SH^{F3}$),

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mkt_adj_SH^{F1} and 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 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.

4.3.3. Short-sale constraints

Although short selling activity attenuates overpricing in low F-score firms, short-sale constraints may prevent short sellers from fully eliminating overpricing. In a perfect market with no restriction on short selling, equilibrium stock prices should be jointly set by sellers (including short sellers) and buyers with heterogeneous beliefs. However, with short-sale constraints, pessimistic investors are unable to short the stock to the extent they desire. This causes an upward bias in the equilibrium price and low future returns. For a given amount of divergence in expectations, the greater the constraint on short sales, the greater is the price and return bias (e.g., Miller, 1977; Nagel, 2004). Thus, short-sale constraints can potentially limit short sellers' ability to fully exploit the overpricing in the low F-score firms.

To test this proposition, we use four common short-sale constraint metrics: (i) the fraction of shares held by institutional investors; (ii) the number of institutions holding the shares; (iii) market capitalization; and (iv) cash dividends to price ratio. To initiate a short sale, short sellers borrow shares from institutions or brokers. Short sellers may find it difficult to short stocks with low institutional holding. Similarly, Sias et al. (2006) and Brown et al. (2013) suggest that the availability of stocks to short sellers depends on the number of institutions holding the

stocks, i.e., it is much easier for short sellers to borrow shares of a given stock when they are held by several institutions than when a single institution owns the same number of shares of that particular stock. Large stocks are also more likely to be shortable than small stocks, as institutions prefer holding large stocks (Benette et al., 2003). Finally, cash dividend-paying stocks may discourage short selling, because short sellers must repay the dividends to the original owners of the shares during the period of holding short positions (D'Avolio, 2002; Dechow et al., 2001).

We stratify low F-score firms into three portfolios based on each of the four short-sale constraint variables. We then compute the difference in the buy-and-hold market-adjusted returns and in the market-adjusted short turnover between high and low constrained portfolios. If short-sale constraints prevent short sellers from eliminating overpricing, we would expect the returns to the most constrained portfolio to be more negative than returns to the least constrained portfolio. We also expect the most constrained portfolio to have a lower level of short turnover than the least constrained portfolio.

Table 9 reports the size-adjusted returns, the market-adjusted returns and the market-adjusted short turnover for low F-score firms with different short-sale constraints. Panel A shows that the returns on low F-score firms are only negative when institutional holdings are low. The return differential between low and high institutional holdings is negative and significant. We also find that low F-score firms attract lower short interest when their institutional holdings are low, suggesting that institutional holdings affect short selling activities. In Panel B, C and D, we use alternative metrics to measure short-sale constraints. The results show that more constrained portfolios (i.e. held by few institutions, small, or high cash-dividend-to-price ratio) have more negative returns and lower short turnover than less constrained portfolios, except for the market-adjusted return differential between small and large low F-score firms. This return differential becomes negative and highly significant when we use size-adjusted returns.

Table 10 shows that the returns on low F-score firms with low BM ratios are only significantly negative when these firms are subject to high levels of short-sale constraints. We also find that these firms attract higher short interest when they are large, have greater institutional holdings and more dispersed institutional ownership. Furthermore, we show that while the return on low F-score firms with low BM ratios is significantly negative across both high and low D/P ratio portfolios, these firms generate significantly more negative returns and attract higher short interest when their D/P ratios are low. Our overall results imply that short-sale constraints limit short sellers' abilities to fully exploit overpricing.

5. Conclusion

Prior studies show that firm fundamentals predict returns (see, e.g., Richardson et al., 2005; Cooper et al., 2008; and Novy-Marx, 2013). 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 selling activity affects the between firm fundamentals and future returns. Specifically, we examine whether short sellers use public fundamental information (a proxy of the Piotroski's (2000) F-score) to 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 relationship between F-score and future returns. Under the mispricing explanation, markets are slow to fully reflect public information and short sellers' exploitation of overpricing should affect the ability of firm fundamentals to predict returns.

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 sellers use F-score information to identify overpriced stocks, inconsistent with the risk-based explanation. Specifically, we find that short selling is concentrated in firms with prices perceived to be higher than fundamental values. Further tests show that low F-score firms attract higher short interest when their past performance is strong, indicating the short sellers are contrarian traders. We also find that short sellers' exploitation of overpricing is more pronounced during high sentiment periods, implying that short selling corrects the overpricing induced by the speculative demand of noise traders. Finally, and more importantly, we show that short selling activity reduces the ability of low F-score to predict returns, implying that the relation between firm fundamentals and future returns is, at least partly, due to 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 ten F-score-sorted portfolios. Mkt_adj_ret [0,12] is market-adjusted one-year buy-and-hold-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 value-weighted 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 (i.e. [-8, -2] in Figure 1). 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. The asterisks *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 2: Short selling and F-score

	(1)	(2)	(3)
F-score	-0.004**	-0.002**	-0.003**
	(-2.26)	(-2.07)	(-2.49)
size		0.006***	0.006**
		(4.62)	(2.32)
BM		-0.008***	-0.003*
		(-3.02)	(-1.96)
Mom		0.005	-0.001
		(0.40)	(-0.16)
Illiquidity		0.128	-0.799
		(0.43)	(-0.12)
σ		0.078***	0.046***
		(4.29)	(3.81)
IO			0.032***
			(3.08)
DP			-0.094***
			(-4.31)
Analyst			-0.001
			(-0.19)
Cons	0.017	-0.341	-0.052***
	(1.57)	(-4.96)	(-9.03)

This table reports determinants of short selling estimated using Fama and MacBeth (1973) procedure. We report the time-series means for each coefficient F-score measure 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 (i.e.[-1,0]). *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) used as a proxy for the cost of short selling. *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. The asterisks *,**, 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 (i.e.[-1,0]). We sort firms by their BM ratios (i.e. growth (top 30%), neutral (middle 40%), and value (bottom 30%)) and then by their 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 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. The asterisks *,**, 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:

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

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 (i.e.[-1,0]). *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. The asterisks *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 5: The short selling and future returns of low F-score firms

	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 Newey-West standard adjusted *t*-statistics are reported in parentheses. The asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6: The short selling and future returns to low F-score firms with low BM ratios

	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 Newey-West adjusted t-statistics are reported in parentheses. The asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 7: Short selling and momentum

	Pane A: Time-series analysis		
	Ret [-4,-1]	Mkt_adj_SH[-1,0]	
The first group: large negative returns	-6.42%***	1.29%	
btw low and high F-score	(-7.93)	(1.29)	
The second group: small negative returns	-0.14%	3.49%***	
btw low and high F-score	(-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 the short selling activities associated with the momentum trading. 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 group. 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 interest for the six portfolios. The Newey-West (1987) adjusted *t*-statistics are reported in parentheses. The asterisks *,**, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 8: Short selling and investor sentiment

	$(\text{mkt\_adj\_SH}^{F1} - \text{mkt\_adj\_SH}^{F3})$	mkt_adj_SH^{F1}	$\text{mkt\_adj\_sh}^{F1\_lowBM}$
	Panel A: States of investor sentiment		
Low sentiment	0.0005	-0.0006	0.0123*
	(0.20)	(-0.16)	(1.69)
Middle sentiment	0.0033	0.0031	0.0261**
	(0.07)	(1.63)	(2.06)
High sentiment	0.0721**	0.0479**	0.0741***
	(2.56)	(1.98)	(3.00)
High-Low	0.0716**	0.0485**	0.0518**
	(2.35)	(2.06)	(2.60)
	Panel B: Time-series regressions		
Dep. Variable	$(\text{mkt\_adj\_SH}^{F1} - \text{mkt\_adj\_SH}^{F3})$	mkt_adj_SH^{F1}	$\text{mkt\_adj\_sh}^{F1\_lowBM}$
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 $\text{mkt\_adj\_SH}^{F1\_lowBM}$. We use the investor sentiment index introduced 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, In panel B, we regress (mkt_adj_SH^{F1}-mkt_adj_SH^{F3}), mkt_adj_SH^{F1} and $\text{mkt\_adj\_SH}^{F1\_lowBM}$ separately on the Baker and Wurgler's (2006) sentiment index. The Newey-West (1987) *t*-statistics are reported in parentheses. The asterisks *,**, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

Table 9: Short-sale constraints and the returns of low F-score firms

Short sale constraints variable	Market adj. return[0,12]	Size adj. return [0,12]	Market adj. short turnover[-1, 0]
Panel A : Fraction of shares held by institutions			
Low % institutions	-6.06%***	-5.37%***	-0.89%
	(-2.76)	(-2.96)	(-0.40)
High % institutions	-1.68%	-2.24%	3.07%**
	(-0.79)	(-1.46)	(2.52)
Low-high	-4.37%**	-3.13%**	-3.96%***
	(-2.13)	(-1.98)	(-2.87)
Panel B: Number of institutional shareholders			
Few institutions	-5.38%***	-5.11%**	0.88%
	(-2.85)	(-2.52)	(0.61)
Many institutions	-1.89	-2.38%	6.80%***
	(-1.03)	(-1.54)	(3.51)
Few-many	-3.48*	-2.72*	-5.08%**
	(-1.75)	(-1.69)	(-2.31)
Panel C: Market capitalization			
Small firms	-3.32%	-6.97%***	-2.54%***
	(-1.09)	(-4.37)	(-4.81)
Large firms	-2.80*	-2.53%	4.07%**
	(-1.96)	(-1.62)	(2.35)
Small-large	-0.51	-4.44%***	-6.61%***
	(-0.21)	(-2.90)	(-3.31)
Panel D: Cash dividends to price ratio			
Low Dividend/Price	-1.32%	-3.53%***	4.07%**
	(-0.77)	(-2.92)	(2.34)
High Dividend/Price	-4.75%***	-6.92%***	-2.54%***
	(-2.93)	(-4.32)	(-4.81)
Low-High	3.43%*	3.38%**	6.61%***
	(1.95)	(1.97)	(3.30)

This table reports the results on the impact of short-sale constraints on the returns and the short selling activity of low F-score firms. We use four short-sale constraint metrics: (i) the fraction of shares held by institutional investors (ii) the number of institutions holding the shares (iii) market capitalisation (iv) cash dividends to price ratio. We form three portfolios of low F-score firms based on each of the four short sale constraint variables. We then compute the difference in buy-and-hold market-adjusted and size-adjusted returns and market-adjusted short turnover between high and low constrained portfolios. The Newey-West adjusted *t*-statistics are reported in parentheses. The asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 10: Short-sale constraints of the returns of low F-score firms with low BM ratios

Short sale constraints variable	Market adj. return[0,12]	Size adj. return [0,12]	Market adj. short turnover[-1, 0]
Panel A : Fraction of shares held by institutions			
Low % institutions	-11.79%***	-12.24%***	-0.01%
	(-3.91)	(-4.34)	(0.96)
High % institutions	-1.30%	-1.86%	5.10%***
	(-0.64)	(-0.98)	(3.88)
Low-high	-10.49%***	-10.84%***	-5.11%***
	(-3.57)	(-3.36)	(-2.98)
Panel B: Number of institutional shareholders			
Few institutions	-12.15%***	-8.57%**	0.47%
	(-2.67)	(-2.01)	(1.02)
Many institutions	-1.96%	-2.52%	3.96%***
	(-1.08)	(-1.40)	(2.72)
Few-many	-10.94%**	-5.87%*	-3.49%**
	(-2.32)	(-1.68)	(-1.98)
Panel C: Market capitalization			
Small firms	-13.11%***	-15.34%***	-2.25%***
	(-3.19)	(-3.01)	(-5.30)
Large firms	-1.72%	-1.62%	5.23%***
	(-1.37)	(-1.12)	(2.43)
Small-large	-11.39%***	-13.72%**	-7.58%***
	(-2.98)	(-2.45)	(-5.79)
Panel D: Cash dividends to price ratio			
Low Dividend/Price	-2.68%*	-3.07%**	3.18%***
	(-1.76)	(-2.10)	(3.03)
High Dividend/Price	-7.34%***	-8.84%***	0.32%
	(-3.60)	(-5.42)	(0.32)
Low-High	4.66%**	5.77%**	2.87%**
	(1.98)	(2.53)	(2.42)

This table reports the results on the impact of short-sale constraints on the returns and short selling activity of low F-score firms with low BM ratio. We use four short-sale constraint metrics: (i) the fraction of shares held by institutional investors; (ii) the number of institutions holding the shares; (iii) market capitalization; and (iv) cash dividends to price ratio. We stratify low F-score firms into three portfolios based on each of the four short-sale constraint variables. We then compute the difference in the buy-and-hold market-adjusted returns and in the market-adjusted short turnover between high and low constrained portfolios. The Newey-West standard adjusted *t*-statistics are reported in parentheses. The asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Appendix 1

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
$Size_i$	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