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# Daily short interest, idiosyncratic risk, and stock returns ☆

Andrea S. Au[a,*], John A. Doukas[b,c], Zhan Onayev[d]

[a]State Street Global Advisors' Global Enhanced Equities Group, Boston, MA, USA
[b]Graduate School of Business, Old Dominion University, Norfolk, VA 23529-0222, USA
[c]Judge Business School, Cambridge University, Cambridge CB2 1AG, UK
[d]State Street Global Advisors' Advanced Research Center, Boston, MA, USA

## Abstract

This paper examines the relation between short selling and returns and the impact of arbitrage costs on short sellers' behavior. Using daily UK short selling data, we find that stocks with low short interest levels experience significant positive returns on both an equal- and value-weighted basis. Economic theory predicts that short sellers avoid establishing positions in stocks with high idiosyncratic risk. Our results indicate a negative relation between short interest and returns among high idiosyncratic risk stocks and that short selling activity is mostly concentrated in low idiosyncratic risk stocks where it is less costly to arbitrage fundamental risk.


*JEL classification:* G12; G14; G15

*Keywords:* Short-sale; Idiosyncratic risk

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*Corresponding author.
*E-mail addresses:* andreau@alum.mit.edu (A.S. Au), jdoukas@odu.edu (J.A. Doukas), zhan_onayev@ssga.com (Z. Onayev).

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## 1. Introduction

The impact of short selling on asset prices has been of growing interest among academics, regulators, and investors over the recent past. Proponents of short selling consider it an essential feature of the efficient functioning of security markets.[1] While the finance literature has addressed the role of short sellers, most of the empirical analysis involves US data. The US evidence remains mixed. For example, although previous research suggests that there is a negative relationship between short selling and future firm performance,[2] more recent studies, Asquith, Pathak, Ritter (2005) and Cohen, Diether, Malloy (2007), point out that this relation is weak and driven mostly by a few small firms.

Using a unique 3-year daily UK equity loan dataset, the evidence in this paper augments a growing body of the empirical literature on short selling in several ways. First, we examine the effects of short selling on stock returns using daily short interest level and availability data. In contrast to previous studies that have limited their analyses on the long-term relation between short selling and asset prices, mainly due to unavailability of daily data, the use of daily short interest data in this study allows us to examine the short-term impact of high short interest on asset prices. Second, we investigate whether short sellers refrain from shorting stocks with high idiosyncratic risk (arbitrage cost). Third, due to regulatory and market differences, US evidence may not be indicative of behavior outside of a US market setting. While there are a few studies that analyze the impact of short sale regulations on stock return distributions using international data (e.g., Aitken, Frino, McCorry, Swan, 1998; Biais, Bisiere, Decamps, 1999; Poitras, 2002), they do not address how idiosyncratic risk influences the behavior of short sellers. Finally, studying the effect of short selling on stock returns outside the US avoids the criticism that observed regularities may be a function of data mining. The UK, the center of European financial activity and the second largest capital market in the world, is a natural testing ground for the price effects of short selling and the understanding of short sellers' behavior.

In the US, historically only monthly short interest data have been available (e.g., Asquith and Meulbroek, 1995; Aitken, Frino, McCorry, Swan, 1998; Dechow, Hutton, Meulbroek, Sloan, 2001; Desai, Ramesh, Thiagarajan, Balachandran, 2002; Asquith, Pathak, Ritter, 2005). Although more recently a few papers have used a measure of available shares for shorting, these papers analyze sample data from single lenders over short time periods (e.g., see D'Avolio, 2002; Geczy, Musto, Reed, 2002; Cohen, Diether, Malloy, 2007). Moreover, since the SEC has only recently made daily short sales flow data available, as compared to the monthly short interest level data, studies analyzing this daily data only encompass a limited history (e.g., Diether, Lee, Werner, 2008). As a result, none of these studies examines daily market short interest level and availability data. Instead, they have analyzed combinations of monthly level data, daily flow data, and/or institutional ownership or single lender samples as a proxy for availability levels.

Moreover, due to the lack of uptick and bid–ask rules, the "locate and borrow" constraint is arguably the most important short sale constraint in the UK. To test the

[1]Friedman (1953) and Fama (1965) argue that security prices must reflect fundamental values because even if irrational investors misprice securities, profit-seeking rational investors will arbitrage the mispricing, causing prices to revert to fundamentals. Recent empirical evidence by Jones and Lamont (2002) and Bris, Goetzmann, Zhu (2007) supports the theory that short sellers help maintain fair prices and efficient markets.

[2]For example, see Asquith and Meulbroek (1995), Desai, Ramesh, Thiagarajan, Balachandran (2002), and Christophe, Ferri, Angel (2004).

"locate and borrow" constraint in the US, however, previous research has focused on using institutional ownership as a proxy for shares available to borrow. Chen, Hong, Stein (2002) and Nagel (2005) argue that stocks with low institutional ownership are more likely to be short sale constrained. D'Avolio (2002), the only paper that uses loan data to test whether institutional ownership affects the ability to locate and borrow shares, examines data from one lender, a depository for mutual funds that mainly invests in large-cap stocks, and covers the five quarters beginning with the second quarter of 2000. He finds that institutional ownership explains, on average, 55% of the cross-sectional variation in that lender's supply of loanable shares.

Like D'Avolio, we examine shares available for shorting. Our paper adds to this literature, by examining a longer time period of just over 3 years, and relying on loan data that span the entire market rather than just a single lender. Using this market availability measure, as opposed to using an institutional ownership proxy or a partial availability measure, we can accurately test the "locate and borrow" constraint directly. Our research, using fairly large daily transactions short selling data, complements prior empirical studies that have revealed a number of interesting patterns relying on monthly short interest data.

Our evidence shows that while stocks with low levels of short interest experience significant positive abnormal returns on both an equal- and value-weighted basis, equally weighted portfolios composed of highly shorted stocks exhibit positive but statistically insignificant abnormal performance. These results are inconsistent with much of the historical US evidence, which demonstrates that heavily shorted stocks tend to have negative performance. However, since our analysis only uses a short 3-year sample it may not be representative of a general relation between short interest and returns or hold for extended period. Another reason for this difference may be the uniqueness of the UK dataset used in this study. The use of daily short interest data, as compared to monthly data, allows us to examine the short-term impact of high short interest on asset prices in contrast to previous studies that limited their focus on longer term short interest data. D'Avolio, one of the few US papers that has examined daily data, finds that although recalls are rare on average, recall risk increases with high volume and low availability. His findings are consistent with our argument that the incidence of short squeezes is higher for stocks with high turnover (volume scaled by shares outstanding) and high short interest to available shares.

Consistent with Asquith, Pathak, Ritter (2005), we find that value-weighted portfolios of highly shorted stocks do not significantly underperform the market, as measured by the intercepts from three-factor time series regressions. While all intercepts of the value-weighted portfolios are positive and insignificant at conventional levels, their magnitude decreases with increased short selling. We argue that positive abnormal performance may be caused by short squeezes, a liquidity demand from short sellers covering their positions. In light of our finding that smaller and less liquid securities with high short interest are more likely to experience large positive abnormal returns in the short term, this explanation seems to be plausible.

An even more important result of our analysis is that idiosyncratic risk, a deterrent to arbitrage, might be correlated with mispricing. Specifically, our results show a negative relation between short interest and abnormal returns among stocks with high idiosyncratic risk. Consistent with Shleifer and Vishny (1997), who argue that idiosyncratic risk deters arbitrage, leading to persistent mispricing, our evidence suggests that short selling is mostly concentrated in stocks with low idiosyncratic risk because it is less costly to arbitrage

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fundamental risk. An interesting implication of this finding is that exogenous economic shocks in asset markets could have amplifying effects on asset prices when short selling activity is limited due to high arbitrage costs.

Evidence from recent studies suggests that idiosyncratic risk (IR) may indicate a trading opportunity instead of a trading impediment. Ang, Hodrick, Xing, Zhang (2006) and Spiegel and Wang (2006) find that IR in the US market plays an important role in determining future returns, even after controlling for trading frictions. Specifically, Ang, Hodrick, Xing, Zhang (2006) show that stocks with high idiosyncratic volatility are systematically overpriced, suggesting that high idiosyncratic risk deters short selling. Spiegel and Wang (2006), however, find the opposite result: stocks with high idiosyncratic volatility are systematically underpriced. If idiosyncratic risk indeed determines returns, then, it would affect demand for shorting, leading to a positive relation between short interest and idiosyncratic risk. That is, if idiosyncratic risk is driving low short interest, an inverse relationship between idiosyncratic and low short interest should exist, especially among low shorted stocks. In contrast, we find that in this group of stocks the relation between short interest and idiosyncratic risk is negative. Among high short interest stocks the relation is positive, but not statistically significant. Overall, our findings are consistent with Ang, Hodrick, Xing, Zhang (2006) implying that short interest might be an important source in identifying mispricing.

The remainder of the paper is organized as follows. In the next section, we provide a brief comparison of the differences between the US and UK shorting market and present an overview of the relevant literature. We describe our data and sample selection procedure in Section 3, and report our empirical results in Section 4. Section 5 contains a brief summary and concluding remarks.

## 2. Short selling market overview and related literature

### 2.1. Short selling market overview

Short selling in the UK, is regulated by the Financial Services Authority (FSA) whose laws on short selling are less stringent than those in the US. In the US, regulatory restrictions on short sales are responsible for making shorting more costly and more difficult than going long.[3] For example, the US imposes settlement rules that aid the settlement and delivery of securities, which means that short sellers must locate and borrow the stock they are selling prior to effecting short sales. In addition, a short sale can be executed only if it passes the ‘‘uptick’’ rule or ‘‘price bid’’ rule, depending where the asset is traded. These rules are generally relaxed for market-making and a variety of hedging, risk management, or arbitrage trades since strict adherence to these rules would make it difficult to carry out trades where timely execution is important, leading to reduced liquidity or increased risk. The SEC also prohibits shorting, and/or covering of shorts, on securities during periods in which this activity may greatly elevate risk, such as around secondary offerings.[4]

[3]For more information on US short sale rules see http://www.sec.gov.

[4]See the ‘‘Report on Transparency of Short Selling’’ by the International Organization of Securities Commissions (2003).

Unlike the Securities and Exchange Commission (SEC) and National Association of Securities Dealers (NASD), which have established specific rules for shorting US securities,[5] the FSA has not imposed short sale specific restrictions or controls in the UK. Rather, short sellers are bound to general market and regulatory arrangements.[6] Contrary to the US, there is no uptick rule in the UK. Similar to the US, however, short sellers of UK securities must eventually locate and borrow the stocks they are selling. CREST, the source of our short data, handles the settlement of all securities trading on the London Stock Exchange (LSE). Availability of this unique and previously untested daily UK loan data allows us to examine the relationship between short interest and stock returns. To the best of our knowledge, there is no published research that explores the link between short selling, measured by short interest relative to shares available for borrowing on a market-wide basis, and stock returns in the UK.

### 2.2. *Related literature*

Because of risks associated with short selling, many institutional and retail investors choose not to short stocks. At the same time assets managed by hedge funds, many of which regularly sell short, have grown rapidly in recent years, increasing the amount of short selling globally. Despite recent increases in both short interest data availability and academic research on all aspects of short selling, there is still disagreement among regulators, academics, and investors on the effect of short selling on financial markets.

For example, Miller (1977), Jarrow (1980), and Chen, Hong, Stein (2002) argue that when investors disagree on valuations and short selling is difficult or expensive, stocks can become overvalued. Short sale constraints lead to mispricing by preventing negative information from being impounded into stock prices. Asquith and Meulbroek (1995) find negative and significant abnormal returns for highly short sale constrained New York Stock Exchange (NYSE) stocks for the 1976–1993 period. Desai, Ramesh, Thiagarajan, Balachandran (2002) find similar evidence for NASDAQ stocks for the 1988–1994 period. D'Avolio (2002), using less than 2 years of proprietary data, focuses on the effects of rebate on borrowed stocks and discovers that low or negative rebate rates precede negative abnormal returns. Geczy, Musto, Reed (2002), using a database from a single lender for the period from November 1998 to October 1999, find a similar relationship between rebate rates and abnormal returns, but show that short sales restrictions have a mixed impact on the profitability of standard arbitrage strategies. Jones and Lamont (2002), using early 20th century US data, show that stocks that are expensive to short are overvalued. Ofek and Richardson (2003) show that short sale constraints, in the form of option lock-ups, have dramatic and persistent negative effects on subsequent stock returns, supporting the view that stock prices do not fully incorporate information under short sale constraints.

Diamond and Verrecchia (1987) explore the effects of short sale constraints on the speed of price-adjustment to private information. Their model predicts that short sale constraints impair the dissemination of positive and negative information differently. That is, information in the presence of short sale constraints has an asymmetric impact on asset prices. In the spirit of this model, recent theoretical work by Abrew and Brunnermeier

[5]For more information on US short sale rules see http://www.sec.gov.

[6]See FSA Discussion Paper 17 on Short Selling (October 2002) for more information.

(2002) and Scheinkman and Xiong (2003) shows that short sale constraints can lead to bubbles and excessive volatility. In a different line of research, He and Modest (1995), Hansen and Jaganathan (1997), Jouini and Kallal (2001), and Duffie, Garleanu Pedersen (2002) address the effect of market frictions and the magnitude of mispricing.

Due to the risks and costs associated with short selling, many have argued that the level of short selling is a good informed sentiment indicator. Indeed, US studies by Diamond and Verrecchia (1987), Fabozzi and Modigliani (1992), Asquith and Meulbroek (1995), Aitken, Frino, McCorry, Swan (1998), Dechow, Hutton, Meulbroek, Sloan (2001), and Desai, Ramesh, Thiagarajan, Balachandran (2002) all conclude that short sellers possess an ability to identify overpriced securities. Asquith, Pathak, Ritter (2005), using a more recent and comprehensive sample, confirm previous findings and demonstrate that while equal-weighted portfolios of highly shorted stocks underperform, value-weighted portfolios do not. Therefore, this evidence suggests that the level of short selling would be more informative, as a negative sentiment indicator, for a strategy that trades smaller capitalization securities.

Several studies relate arbitrage costs, measured by a security's idiosyncratic risk, to mispricing (Pontiff, 1996) and other anomalies such as index inclusion (Wurgler and Zhuravskaya, 2003), merger arbitrage (Baker and Savasoglu, 2002), book-to-market (Ali, Hwang, Trombley, 2003), and season equity offerings underperformance (Pontiff and Schill, 2004). Unlike literature that examines the role of arbitrage costs indirectly through anomalies, we study how arbitrage costs influence short sellers' trading behavior directly.

In the context of this study, we argue that idiosyncratic risk is a cost that deters arbitrage, causing the short interest anomaly. That is, unlike previous studies by D'Avolio (2002) and Nagel (2005) that suggest short selling costs are mostly related to institutional holding rather than short interest,[7] we argue that idiosyncratic risk is likely to be a very important cost to short sellers. Exploring how idiosyncratic risk influences short sellers' trading activity can help us understand whether mispricing occurs as a result of lack of short selling due to idiosyncratic risk.[8] Therefore, we are interested in discovering if short sellers are unwilling to establish short positions because of the high idiosyncratic risk of holding these positions. Our work builds on previous studies (Jones and Lamont, 2002; Lamont, 2004; Ofek and Richardson, 2003), which argue that it is unlikely that short sale costs, such as high lending fees, were the main reason for the price run-up during the dotcom bubble in the 1990s. Ofek and Richardson (2003) argue that while short sale costs were an important factor they conjecture that the relative volatility spread between internet and non-internet stocks needs to be part of a more complete explanation of internet stock price rise and fall. Finally, given that stock returns have been found to be influenced by firm size and book-to-market factors, we control for them using three-factor Fama-French regressions.

In sum, the effect of short sale constraints on stock prices is ultimately an empirical issue that requires the use of an appropriate measure of shorting demand or shorting costs while controlling for the supply of shares to borrow. Moreover, since previous studies show that

[7] Chen, Hong, Stein (2002) argue against using short interest as a proxy for either short sale costs or shorting demand. Jones and Lamont (2002) also point out that short interest represents the intersection of supply and demand for sorting a stock.

[8] Lintner (1965), Merton (1987), Malkiel and Xu (2002), and Spiegel and Wang (2006) predict and show that there is a positive relation between idiosyncratic risk and future stock returns. Ang, Hodrick, Xing, Zhang (2006), however, provide evidence of a negative relationship between idiosyncratic risk and future stock returns.

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high short interest ratios are associated with negative abnormal returns exceeding 1% per month, that last for long horizons, it raises the question why short sellers do not immediately arbitrage overvaluation away. In this study we also address this important question by analyzing the role of idiosyncratic risk as a potential deterrent to arbitrage activity.

## 3. Empirical framework

### 3.1. Data sources, sample construction and variable definitions

CRESTCo Limited operates the real-time securities settlement system for Irish, UK, Jersey, Isle of Man, Guernsey, and international securities. CREST started publishing data on daily stock lending for FTSE 350 securities as a proxy for short interest in September 2003, as a result of an FSA regulation to increase transparency in short selling. Although monthly average security information is publicly available free of charge, the daily information is only available through a subscription. In our analysis, we use a sample of daily FTSE 350 stock lending data from September 2003 through September 2006. While this dataset contains stocks that are relatively large, fairly liquid, and subject to less binding short sale constraints, our analysis is expected to result in more conservative estimates than if smaller stocks had been included. That is, exclusion of small capitalization stocks (i.e., difficult to arbitrage stocks due to high idiosyncratic risk) should work against our main hypothesis.

We obtain two stock loan variables from the CREST dataset: (1) *shares on loan*, which is a proxy for short interest, at a point in time; and (2) *shares in CREST*, which is a proxy for the availability of lendable securities.[9] It should be noted that because *shares on loan* is a stock loan measure, it is still only a good proxy for short interest since, in addition to providing shares for short selling, stock loans can also be used to insure settlement, facilitate equity repos, or take part in arbitrage activity. On the other hand, *shares in CREST* is a more accurate measure of shares available to be shorted than commonly used proxies such as shares outstanding or institutional ownership.[10] Specifically, since short sellers must borrow the shares they intend to short, *shares in CREST* is a measure of available supply. As shares shorted draw near available supply, the cost of shorting increases. Up to this point, available shares used in short sales analysis were from proprietary sources with partial market coverage.[11]

For the sake of comparison, we employ three short interest ratios to measure the degree of shorting: (1) SI_Avail is short interest (*shares on loan*) divided by *shares in CREST*; (2) SI_Float is short interest (*shares on loan*) divided by float; and (3) SI_Shrs is short interest (*shares on loan*) divided by shares outstanding. We find that all three measures are highly correlated with each other[12] and produce similar results when analyzed.

Data on stock returns, market capitalization (MktCap) in GBP millions, shares outstanding, float, and book-to-market (BM) ratios are from WorldScope and FTSE.

[9]See the CRESTCo website, http://www.crestco.co.uk, for more information.

[10]See Chen, Hong, Stein (2002) and Nagel (2005).

[11]See D'Avolio (2002).

[12]The Pearson and Spearman correlations between SI_Avail, SI_Float, and SI_Shrs are above 70% and 90%, respectively.

Float is defined as the number of freely traded shares and is calculated as shares outstanding minus closely held shares. We use weekly 1-month LIBOR rates from the Bank of England as our measure of the risk-free rate. The 1-month cumulative abnormal returns are computed relative to FTSE 350 returns and are denoted by 1M_CAR.

### 3.2. Descriptive statistics

Fig. 1 plots the time series of daily short interest over the three share measures (SI_Avail, SI_Float, and SI_Shrs) from September 2003 through September 2006. In keeping with results of Asquith, Pathak, Ritter (2005), we observe that the typical firm in the UK sample has very little short interest. Although the bulk of securities have low levels of short interest over float (Fig. 1B), the mean and median are around 3% and 2%, respectively. The 95th percentile, or the top 5% of the sample ranked by short interest over float, had an average SI_Float of around 11% in mid-2006. We find similar results for short interest to shares, SI_Shrs (Fig. 1C). The levels of short interest to available shares, SI_Avail (Fig. 1A), appear to have similar end of period statistics, although slightly higher, but more persistent through time. Also consistent with the US results, the UK short interest levels increase slightly throughout our time period, possibly due to increases in assets managed by hedge funds or evolving trading strategies.

It is interesting to note that the trends of short interest and the market seem to move in opposite directions and this is most pronounced when examining the 95th percentile. Specifically, we notice that increases in aggregate short interest, graphically, seem to be associated with decreases in market prices. The evidence supports the notion, set forth by Shleifer and Vishny (1997), that the actions of informed traders do not dampen overreaction caused by other investors. In the US, Lamont and Stein (2004) find a highly negative correlation between short interest ratios and NASDAQ market returns. Asquith, Pathak, Ritter (2005), replicating this research over a longer time period for both the NYSE-AMEX and NASDAQ samples, also report negative, although smaller in magnitude, correlations between short interest and market returns.

## 4. Empirical results

### 4.1. Univariate analysis

Table 1, Panel A reports mean and median statistics for the entire sample. Panels B, C, and D, report mean and median characteristics of firms across different percentiles of SI_Avail, SI_Float, and SI_Shrs, respectively. The most interesting pattern emerging from the short interest statistics indicates that the majority of UK firms exhibit low short interest. We find average SI_Avail of 3.7%, SI_Float of 3.3%, and SI_Shares of 3.3%.

→

Fig. 1. Distribution of short interest ratios from September 2003 through September 2006. (A) Short interest over available shares (SI_Avail). (B) Short interest over float (SI_Float). (C) Short interest over shares outstanding (SI_Shrs). The mean, median, and the 5th and 95th percentiles of short interest ratios for FTSE 350 stocks (left axis) and the level of the FTSE 350 price (right axis) for each trading day from September 2003 through September 2006. The short interest ratios are defined as follows: SI_Avail is short interest, *shares on loan*, divided by *shares in CREST*; SI_Float is short interest, *shares on loan*, divided by float; and SI_Shrs is short interest, *shares on loan*, divided by shares outstanding. Float represents the number of freely traded shares, and it is calculated as shares outstanding minus closely held shares. Data from CRESTCo Limited.

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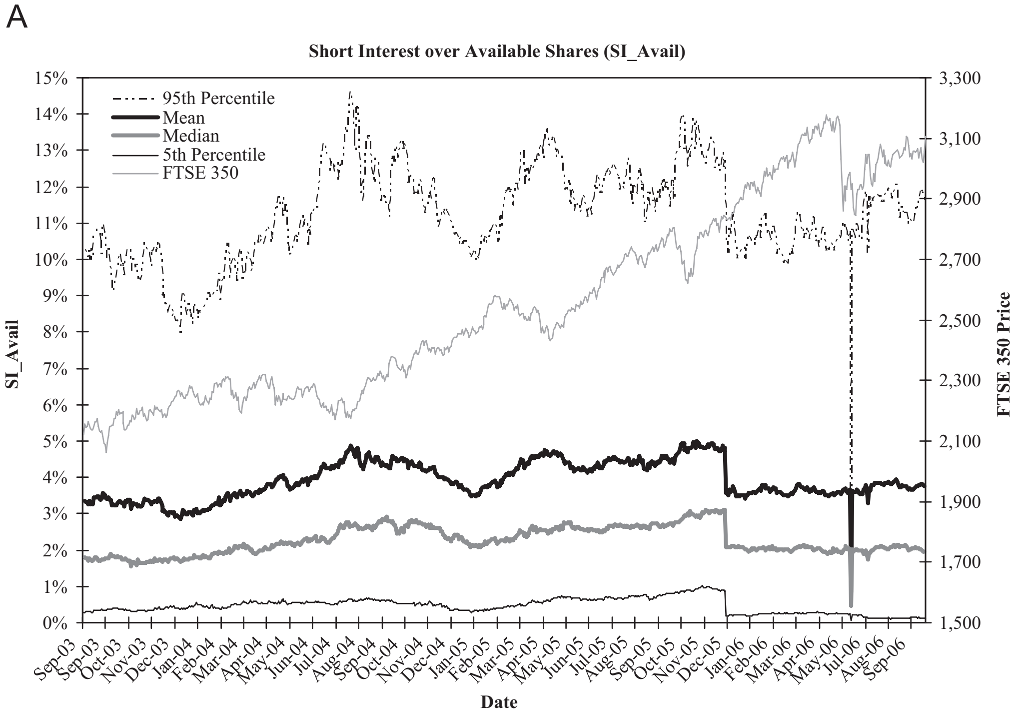
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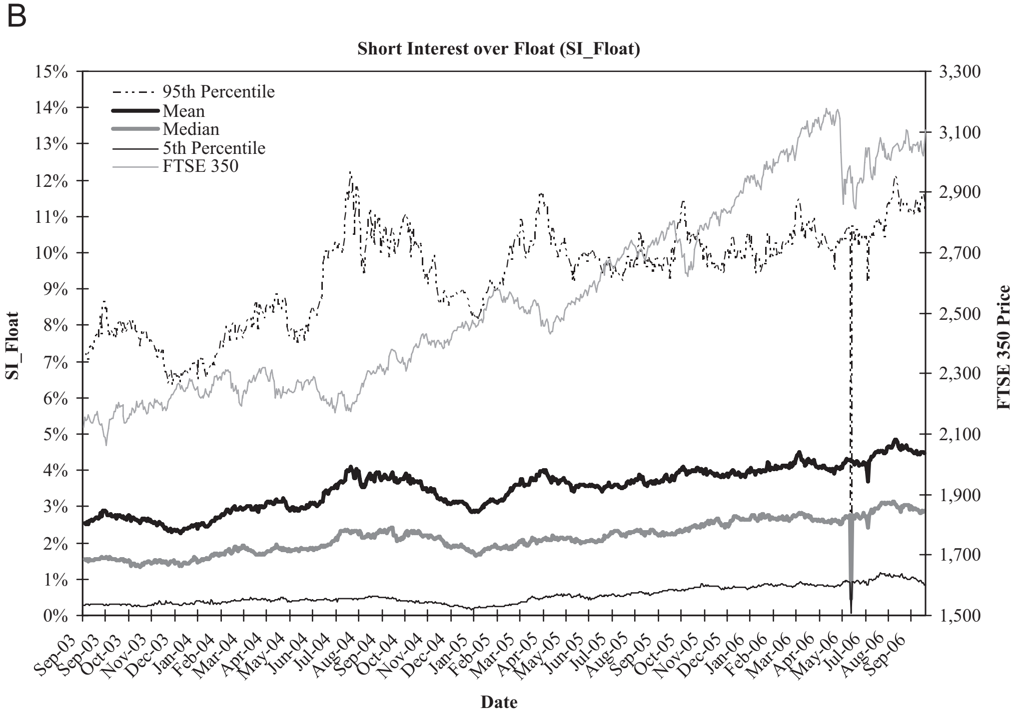
Short Interest over Available Shares (SI_Avail)
95th Percentile
Mean
Median
5th Percentile
FTSE 350
SI_Avail
FTSE 350 Price
Date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Mean
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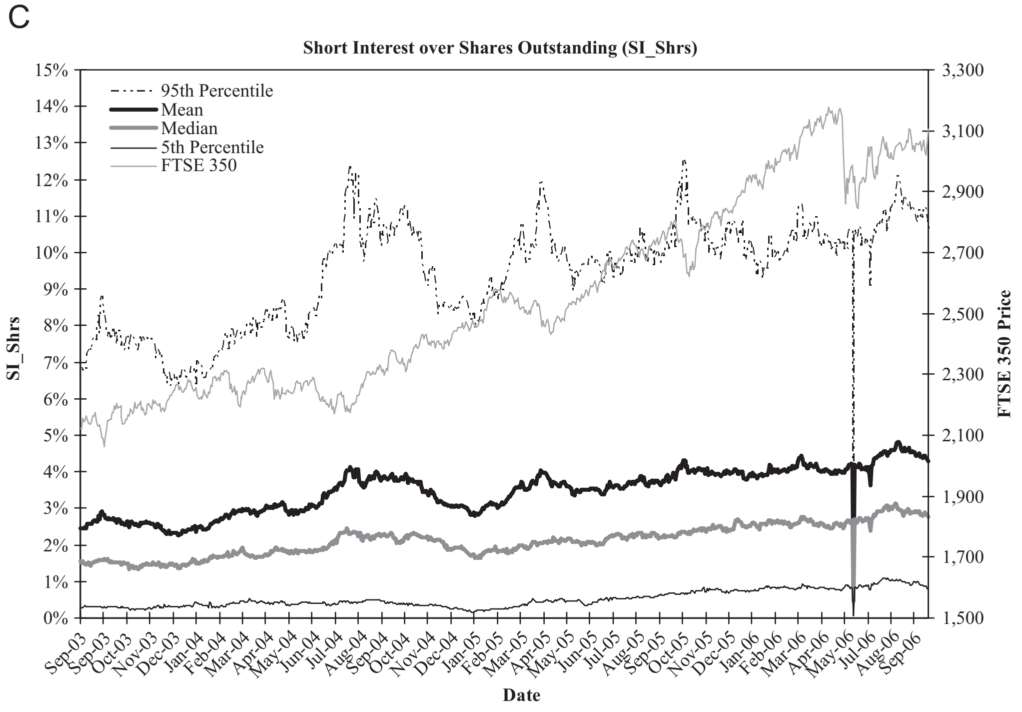


Fig. 1. (*Continued*)

Hence, the UK evidence is in line with the recent US results of Asquith, Pathak, Ritter (2005) who find that the average short interest ratios for the NYSE-AMEX and NASDAQ samples are around 1.5% and 2.5% in the later part of 2002. Highly shorted firms (in the 95th percentile), however, have an average (median) SI_Avail of 11.1% (11.1%), SI_Float of 11.7% (10.8%), and SI_Shrs of 11.8 (10.8%).

The mean and median firm size (MktCap) decreases as the SI_Avail, SI_Float and SI_Shares ratios increase, suggesting that firms with high levels of short interest tend to be smaller in size. For example, Panel B (SI_Avail) shows that firms in the 5th percentile have a mean (median) market value of £713.8 (£725.5), while firms in the 95th percentile portfolio have a mean (median) market value of £463.9 (£426.3).

Our results suggest that the heavily shorted firms also tend to exhibit higher BM ratios than less shorted firms. For instance, Panel B (SI_Avail) reports that the firms in the 5th percentile portfolio have a mean (median) BM ratio of 0.91 (0.47). Firms in the 95th percentile have a mean (median) market BM ratio of 3.55 (1.68) implying that, on average, during our sample period investors tended to short value stocks more heavily than growth stocks. Another interesting finding, reported in Table 1, is that the 1-month subsequent abnormal returns (1M_CAR) are mostly positive. Similar results are reported in Panels C (SI_Float) and D (SI_Shrs). These results also hold for longer holding horizons.

Fig. 2 plots average short interest ratios for percentile portfolios created based on 1-month forward abnormal returns (CARs). Weekly short interest ratios are measured 1 day prior to CAR portfolio formation. The mean short interest ratios at varying CAR percentiles, shown in Fig. 2, indicate a slightly U-shaped relationship between forward

Table 1
Average of daily short interest ratio portfolio statistics

This table presents descriptive statistics by percentile of short interest ratio by day. The variables are defined as follows: SI_Avail is short interest, *shares on loan*, divided by *shares in CREST*; SI_Float is short interest, *shares on loan*, divided by float; SI_Shrs is short interest, *shares on loan*, divided by shares outstanding; MktCap is market capitalization in GBP millions; BM is book value per share divided by price; and 1M_CAR is the forward 1-month cumulative abnormal return computed against the FTSE 350. The sample covers all UK firms in FTSE350 for the period from September 2003 to September 2006. Data from CRESTCo Limited.

(A) Short interest for the total sample

| | SI_Avail (%) | SI_Float (%) | SI_Shrs (%) | MktCap | BM | 1M_CAR (%) |
|---|---|---|---|---|---|---|
| Mean | 3.7 | 3.3 | 3.3 | £517.2 | 4.17 | 0.4 |
| Median | 2.2 | 2.2 | 2.2 | £432.4 | 0.90 | 0.1 |
| Std. dev. | 4.8 | 3.2 | 3.9 | £336.5 | 12.56 | 6.6 |

(B) Short interest over available shares (SI_Avail)

| SI_Avail portfolios | SI_Avail (%) | SI_Float (%) | SI_Shrs (%) | MktCap | BM | 1M_CAR (%) |
|---|---|---|---|---|---|---|
| 0 (low) | | | | | | |
| Mean | 0.1 | 0.2 | 0.2 | £610.2 | 1.27 | 1.5 |
| Median | 0.1 | 0.2 | 0.2 | £667.9 | 0.45 | 0.5 |
| Std. dev. | 0.1 | 0.1 | 0.1 | £344.8 | 8.74 | 5.0 |
| 5 | | | | | | |
| Mean | 0.4 | 0.5 | 0.5 | £713.8 | 0.91 | 0.4 |
| Median | 0.4 | 0.5 | 0.5 | £725.5 | 0.47 | 0.2 |
| Std. dev. | 0.2 | 0.2 | 0.2 | £388.1 | 4.41 | 5.7 |
| 25 | | | | | | |
| Mean | 1.1 | 1.0 | 1.0 | £563.4 | 4.61 | 0.5 |
| Median | 1.0 | 1.0 | 1.0 | £479.7 | 0.59 | 0.2 |
| Std. dev. | 0.3 | 0.3 | 0.3 | £342.8 | 13.96 | 6.6 |
| 50 | | | | | | |
| Mean | 2.2 | 1.9 | 1.9 | £511.0 | 4.86 | 0.6 |
| Median | 2.1 | 1.9 | 1.9 | £426.8 | 0.93 | 0.3 |
| Std. dev. | 0.3 | 0.5 | 0.5 | £329.2 | 14.20 | 5.7 |
| 75 | | | | | | |
| Mean | 4.5 | 3.9 | 3.8 | £457.4 | 5.25 | 0.5 |
| Median | 4.4 | 4.0 | 3.9 | £375.3 | 1.15 | −0.1 |
| Std. dev. | 0.6 | 0.9 | 1.0 | £327.4 | 16.30 | 8.3 |
| 95 | | | | | | |
| Mean | 11.1 | 9.3 | 9.1 | £463.9 | 3.55 | 0.3 |
| Median | 11.1 | 9.6 | 9.6 | £426.3 | 1.68 | 0.1 |
| Std. dev. | 1.2 | 2.2 | 2.5 | £280.5 | 7.50 | 7.8 |
| 100 (high) | | | | | | |
| Mean | 31.5 | 14.2 | 13.1 | £741.2 | 3.63 | 0.1 |

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Table 1 (*continued*)

(B) Short interest over available shares (SI_Avail)

| SI_Avail portfolios | SI_Avail (%) | SI_Float (%) | SI_Shrs (%) | MktCap | BM | 1M_CAR (%) |
|---|---|---|---|---|---|---|
| Median | 25.9 | 11.9 | 11.8 | £640.5 | 3.13 | 0.0 |
| Std. dev. | 22.2 | 6.6 | 7.1 | £537.1 | 5.86 | 9.4 |

(C) Short interest over float (SI_Float)

| SI_Float portfolios | SI_Avail (%) | SI_Float (%) | SI_Shrs (%) | MktCap | BM | 1M_CAR (%) |
|---|---|---|---|---|---|---|
| 0 (low) | | | | | | |
| Mean | 1.0 | 0.2 | 0.2 | £511.2 | 1.07 | 1.4 |
| Median | 0.5 | 0.2 | 0.2 | £425.5 | 0.44 | 0.9 |
| Std. dev. | 1.5 | 0.2 | 0.2 | £316.1 | 4.88 | 6.4 |
| 5 | | | | | | |
| Mean | 0.8 | 0.6 | 0.6 | £594.3 | 2.15 | 0.4 |
| Median | 0.7 | 0.5 | 0.5 | £508.3 | 0.54 | 0.2 |
| Std. dev. | 0.7 | 0.2 | 0.3 | £368.3 | 7.65 | 6.7 |
| 25 | | | | | | |
| Mean | 1.5 | 1.2 | 1.2 | £540.7 | 4.59 | 0.6 |
| Median | 1.4 | 1.1 | 1.1 | £455.8 | 0.61 | 0.5 |
| Std. dev. | 0.6 | 0.3 | 0.3 | £330.9 | 13.89 | 6.5 |
| 50 | | | | | | |
| Mean | 2.7 | 2.2 | 2.3 | £476.7 | 5.96 | 0.3 |
| Median | 2.5 | 2.2 | 2.2 | £381.6 | 0.99 | 0.1 |
| Std. dev. | 1.0 | 0.5 | 2.0 | £326.1 | 17.96 | 6.1 |
| 75 | | | | | | |
| Mean | 5.0 | 4.4 | 4.3 | £494.5 | 4.24 | 0.1 |
| Median | 4.9 | 4.5 | 4.4 | £404.2 | 1.26 | −0.1 |
| Std. dev. | 1.4 | 0.9 | 1.1 | £327.5 | 12.92 | 6.2 |
| 95 | | | | | | |
| Mean | 11.7 | 9.5 | 9.2 | £530.4 | 3.27 | −0.3 |
| Median | 10.8 | 9.8 | 9.7 | £452.4 | 1.68 | −0.3 |
| Std. dev. | 3.5 | 1.3 | 1.9 | £327.1 | 5.59 | 7.8 |
| 100 (high) | | | | | | |
| Mean | 20.2 | 17.8 | 17.2 | £462.7 | 3.15 | 0.8 |
| Median | 19.4 | 17.4 | 16.7 | £416.9 | 1.87 | 0.4 |
| Std. dev. | 5.4 | 4.1 | 4.2 | £306.8 | 6.23 | 8.2 |

(D) Short interest over shares outstanding (SI_Shrs)

| SI_Shrs portfolios | SI_Avail (%) | SI_Float (%) | SI_Shrs (%) | MktCap | BM | 1M_CAR (%) |
|---|---|---|---|---|---|---|
| 0 (low) | | | | | | |
| Mean | 1.0 | 0.4 | 0.2 | £401.1 | 4.47 | 1.2 |

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Table 1 (*continued*)

(D) Short interest over shares outstanding (SI_Shrs)

| SI_Shrs portfolios | SI_Avail (%) | SI_Float (%) | SI_Shrs (%) | MktCap | BM | 1M_CAR (%) |
|---|---|---|---|---|---|---|
| Median | 0.7 | 0.3 | 0.1 | £315.4 | 0.44 | 0.7 |
| Std. dev. | 1.3 | 0.4 | 0.2 | £340.1 | 12.27 | 6.7 |
| 5 | | | | | | |
| Mean | 0.9 | 0.6 | 0.5 | £599.7 | 2.10 | 0.6 |
| Median | 0.7 | 0.5 | 0.5 | £542.6 | 0.59 | 0.3 |
| Std. dev. | 0.8 | 0.4 | 0.2 | £355.5 | 7.42 | 6.5 |
| 25 | | | | | | |
| Mean | 1.5 | 1.2 | 1.2 | £532.2 | 5.23 | 0.5 |
| Median | 1.4 | 1.1 | 1.1 | £448.0 | 0.64 | 0.2 |
| Std. dev. | 0.7 | 0.4 | 0.3 | £328.4 | 16.62 | 6.3 |
| 50 | | | | | | |
| Mean | 2.7 | 2.2 | 2.2 | £460.9 | 5.79 | 0.3 |
| Median | 2.5 | 2.2 | 2.2 | £367.1 | 0.98 | 0.1 |
| Std. dev. | 1.3 | 0.7 | 0.4 | £319.2 | 16.55 | 6.4 |
| 75 | | | | | | |
| Mean | 5.1 | 4.3 | 4.3 | £472.3 | 3.76 | 0.2 |
| Median | 4.8 | 4.5 | 4.5 | £391.2 | 1.33 | −0.1 |
| Std. dev. | 2.4 | 1.0 | 0.9 | £319.1 | 9.34 | 6.1 |
| 95 | | | | | | |
| Mean | 11.8 | 9.5 | 9.5 | £531.2 | 2.63 | −0.1 |
| Median | 10.8 | 9.8 | 9.8 | £458.4 | 1.76 | −0.1 |
| Std. dev. | 4.1 | 1.5 | 1.4 | £330.9 | 3.84 | 7.7 |
| 100 (high) | | | | | | |
| Mean | 19.1 | 17.2 | 20.8 | £506.7 | 2.84 | 0.9 |
| Median | 18.9 | 17.1 | 17.1 | £446.8 | 1.61 | 0.4 |
| Std. dev. | 5.8 | 5.1 | 21.9 | £342.0 | 6.48 | 7.8 |

abnormal returns and current short sale ratios. As revealed in Panel A, this relation is slightly more pronounced when stocks are equally weighted.

Fig. 3 presents equal-weighted and value-weighted mean 1M_CAR for portfolios shorted by SI_Avail (Panel A) and SI_Float (Panel B) percentiles. As in Fig. 2, we compute 1-month forward abnormal returns for portfolios formed based on the previous day's short interest. We generally observe that as short interest, measured by SI_Avail and SI_Float, increases, forward abnormal returns decrease. A similar relation between abnormal returns and short interest is observed for the SI_Shrs ratio, not reported here for the sake of brevity. That is, a strategy of longing low SI_Avail, SI_Float, or SI_Shrs stocks

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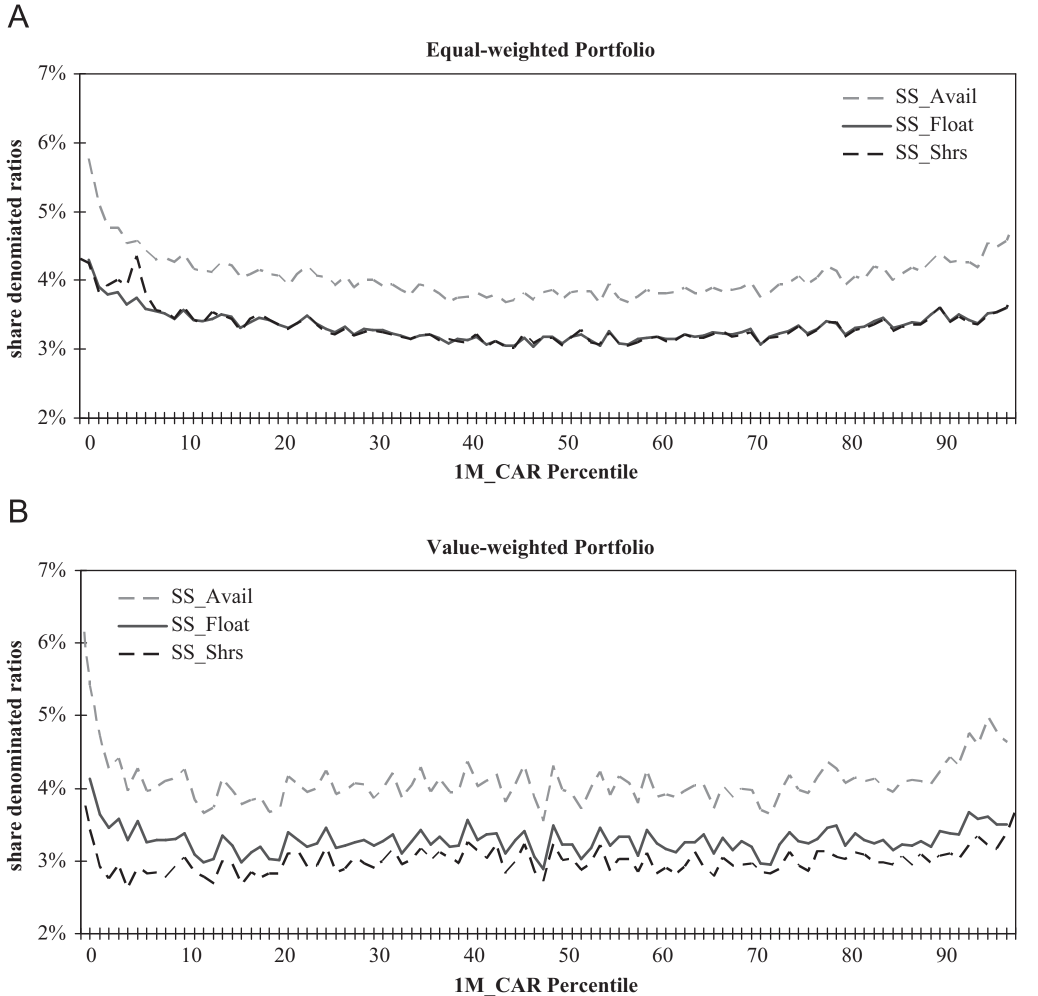


Fig. 2. Short interest ratio levels and abnormal return percentiles. (A) Equal-weighted portfolio. (B) Value-weighted portfolio. Equal-weighted (Panel A) and value-weighted (Panel B) mean of daily SI_Avail, SI_Float, and SI_Shrs by 1-month forward return percentiles from September 2003 through December 2005. The variables are defined as follows: SI_Avail is short interest, *shares on loan*, divided by *shares in CREST*; SI_Float is short interest, *shares on loan*, divided by float; SI_Shrs is short interest, *shares on loan*, divided by shares outstanding; and 1M_CAR is the forward 1-month cumulative abnormal return computed against the FTSE 350. Data from CRESTCo Limited.

and shorting high SI_Avail, SI_Float, or SI_Shrs stocks, is likely to yield positive portfolio spreads.[13]

Surprisingly, however, we do not find that heavily shorted firms underperform the market either for equal-weighted or value-weighted portfolios. There are at least three reasons that extremely heavily shorted firms could experience positive abnormal

[13]These results also hold for 2- and 3-month holding horizons.

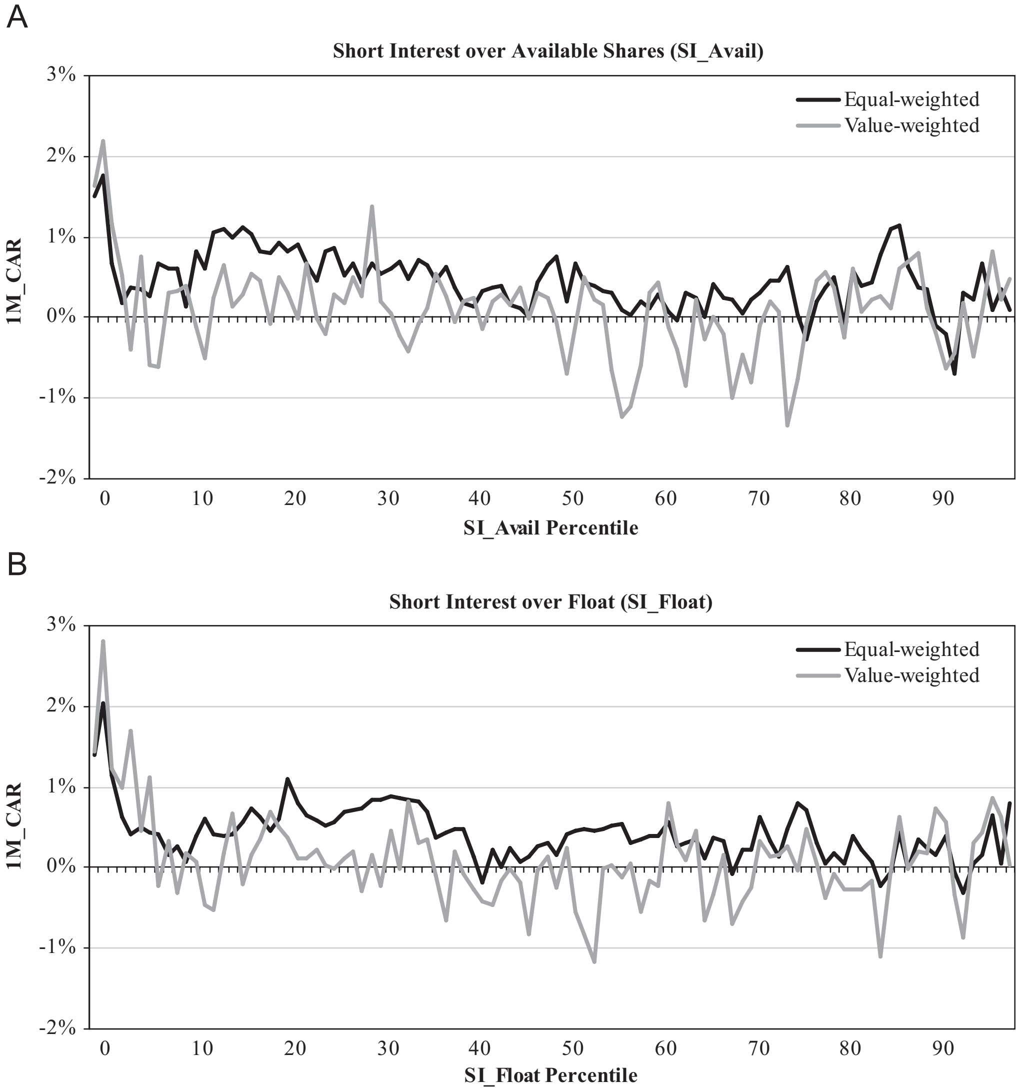


Fig. 3. One-month cumulative abnormal return and short interest percentiles. (A) Short interest over available shares (SI_Avail). (B) Short interest over float (SI_Float). This figure graphs the equal-weighted and value-weighted mean of SI_Avail (Panel A) and SI_Float (Panel B) by 1M_CAR percentiles from September 2003 through December 2005. SI_Avail is short interest, *shares on loan*, divided by *shares in CREST*; SI_Float is short interest, *shares on loan*, divided by float; and 1M_CAR is the forward cumulative abnormal return computed against the FTSE 350. Data from CRESTCo Limited.

performance. First, investors may overreact to good news relative to what is suggested by their fundamentals, resulting in short-term mispricing that would be subsequently corrected by the market. Second, the observed reversal pattern could be explained by the higher incidence of short squeezes associated with larger levels of short interest. Finally, the lack of short selling restrictions in the UK may improve market efficiency and reduce mispricing, relative to the US market, which is subject to short selling restrictions.

### 4.2. Multivariate analysis

Based on the results reported above, we can see that the relationship between short interest and forward abnormal returns is negative but non-monotonic. In fact, at extremely high levels of short interest the relationship becomes positive. In this section we explore this relationship further using a time-series regression framework. First, we examine the abnormal returns of portfolios created based on differential levels of shorting. For this purpose, we form equal- and value-weighted portfolios for different levels of SI_Avail or SI_Float and compare their risk-adjusted returns (alphas). For the sake of brevity, only SI_Avail results are reported since results from both measures are similar. One would expect heavily shorted stocks to be associated with negative alphas, indicating that the price of stocks declines with short selling reflecting short sellers' gain.[14] Short sellers earning abnormal returns may be consistent with views of market efficiency if short sellers are relatively more informed, through research or inside information. In the case of our analysis, although CREST makes average monthly loan data publicly available, daily loan information is currently only available through a subscription.

The portfolio abnormal returns are estimated from the Fama-French three-factor model:

$$R_{pi(t)} - R_{f(t)} = \alpha + \beta_1(R_{m(t)} - R_{f(t)}) + \beta_2\mathrm{SMB}(t) + \beta_3\mathrm{HML}_{(t)} + \varepsilon_{pi(t)}$$

The three zero investment portfolios that proxy as risk factors in our implementation of Fama and French are the market risk premium (MRP) computed as $R_{m(t)}$, where the market is defined as the FTSE 350 minus $R_{f(t)}$, where $R_{m(t)}$ is a long return of the market portfolio and $R_{f(t)}$ is the risk-free rate; the size factor (SMB) is the return on a portfolio of small MktCap stocks minus the return on a portfolio of large MktCap stocks; and the book-to-market factor (HML) is the return on a portfolio of high BM stocks minus the return on a portfolio of low BM stocks. We form these portfolios using the approach outlined by Fama and French (1993, 1996). $R_{i(t)}$ is the 1-week total return for security $i$ in time $t$. The factor loadings ($\beta_1$, $\beta_2$, and $\beta_3$) are the slopes in the time-series regression, while $\alpha$ is the intercept of the regression line and $\varepsilon$ is the error term. The intercept measures abnormal returns.

In Table 2 we report the regression results for both equal- and value-weighted portfolios formed based on cross-sectional ranking of their constituents by short interest based on SI_Avail. We report the equal-weighted results in Panel A and value-weighted results in Panel B. The quintile portfolios are formed every Wednesday based on that day's SI_Avail.[15] The dividend-adjusted returns are measured using Wednesday through the following Tuesday closing prices.

The results in Table 2 show that abnormal returns generally decrease with increases in short interest levels. Consistent with our previous results, this relationship is not monotonic. Equal-weighted results in Panel A show that portfolios of stocks with low short interest, such as Portfolios 1 and 2, exhibit positive and statistically significant weekly abnormal returns. The lowest SI_Avail portfolio (Portfolio 1) earns 0.16% weekly abnormal profit. In contrast, more heavily shorted stocks, such as Portfolios 4 and 5,

[14]This return does not account for short selling transactions costs such as the cost to borrow (rebate rate).

[15]For a robustness check, we performed sorts based on Friday's SI_Avail. The results of these sorts are very similar and are available upon request.

Table 2
Short interest and stock returns

This table reports time series regression coefficients for both equal- and value-weighted portfolios formed based on cross-sectional ranking of their constituents by short interest based on SI_Avail. SI_Avail is short interest, *shares on loan*, divided by *shares in CREST*; SI_Float is short interest. We estimate three factor models on equal-weighted portfolios in Panel A and on value-weighted portfolios in Panel B. These portfolios are formed weekly using middle-of-week SI_Avail quintiles. The estimated model is $R_{i(t)}-R_{f(t)}=\alpha+\beta_1(R_{m(t)}-R_{f(t)})+\beta_2\mathrm{SMB}_{(t)}+\beta_3\mathrm{HML}_{(t)}+\varepsilon$, where $R_{i(t)}$ is return, $R_{f(t)}$ is weekly 1-month LIBOR, $R_{m(t)}$ is the market return (FTSE 350), $\mathrm{MPR}_{(t)}$ is the market risk premium defined as $R_{m(t)}-R_{f(t)}$, $\mathrm{SMB}_{(t)}$ is the size factor and $\mathrm{HML}_{(t)}$ is the book-to-market factor. SMB and HML portfolios are formed last trading day of a calendar year and held for 1 year. Equal-weighted (Panels A) and value-weighted (Panels B) portfolios are created by sorting middle-of-week SI_Avail and assigned to quintile portfolios. The procedure is repeated every week. *P*-values are listed below the regression coefficients. *Two-tailed probability < 0.10; **two-tailed probability < 0.05; ***two-tailed probability < 0.01. Data from CRESTCo Limited.

(A) Equal-weighted portfolios

| Portfolio | Intercept × 100 | $\beta_1$ MRP | $\beta_2$ SMB | $\beta_3$ HML | Adj $R^2$ | $N$ |
|---|---|---|---|---|---|---|
| 1 | 0.155*** | 1.028*** | 0.787*** | 0.077 | 85.5 | 141 |
| Low SI_Avail | 0.004 | <0.0001 | <0.0001 | 0.296 | | |
| 2 | 0.101* | 1.005*** | 0.679*** | 0.145* | 81.33 | 141 |
| | 0.097 | <0.0001 | <0.0001 | 0.084 | | |
| 3 | 0.023 | 1.003*** | 0.567*** | −0.015 | 81.73 | 141 |
| | 0.701 | <0.0001 | <0.0001 | 0.850 | | |
| 4 | 0.058 | 0.983*** | 0.277** | −0.036* | 76.17 | 141 |
| | 0.403 | <0.0001 | 0.016 | 0.702 | | |
| 5 | 0.033 | 1.052*** | 0.362*** | −0.010 | 74.13 | 141 |
| High SI_ Avail | 0.668 | <0.0001 | 0.005 | 0.925 | | |

(B) Value-weighted portfolios

| Portfolio | Intercept × 100 | $\beta_1$ MRP | $\beta_2$ SMB | $\beta_3$ HML | Adj $R^2$ | $N$ |
|---|---|---|---|---|---|---|
| 1 | 0.149** | 0.903*** | 0.154 | −0.045 | 70.98 | 141 |
| Low SI_Avail | 0.042 | <0.0001 | 0.199 | 0.649 | | |
| 2 | 0.055 | 0.934*** | −0.004 | 0.341*** | 78.44 | 141 |
| | 0.382 | <0.0001 | 0.968 | 0.000 | | |
| 3 | −0.099* | 1.032*** | 0.122 | −0.063 | 84.36 | 141 |
| | 0.080 | <0.0001 | 0.187 | 0.413 | | |
| 4 | −0.067 | 1.046*** | 0.000 | −0.081 | 83.40 | 141 |
| | 0.262 | <0.0001 | 0.997 | 0.323 | | |
| 5 | 0.065 | 1.075*** | −0.075 | 0.022 | 80.83 | 141 |
| High SI_ Avail | 0.330 | <0.0001 | 0.494 | 0.813 | | |

(c) Mean spread (low SI_Avail–high SI_Avail)

| | Spread × 100 | Standard error | *T*-stat | $N$ |
|---|---|---|---|---|
| Equal weighted | 0.1474 | 0.0006 | 2.5254 | 141 |
| Value weighted | 0.0484 | 0.0009 | 0.5268 | 141 |

realize positive but statistically insignificant abnormal returns. The abnormal return of the highest SI_Avail portfolio (Portfolio 5) is positive 0.03% and is statistically insignificant at conventional levels. Overall, as also shown in Panel C, equal-weighted regression results suggest that portfolios formed from stocks with low SI_Avail outperform portfolios consisting of stocks with high levels SI_Avail.

In accord with the results in Panel A, value-weighted low SI_Avail portfolios, reported in Panel B, tend to outperform high SI_Avail portfolios. The magnitude of abnormal returns for the low short interest value-weighted portfolio (Portfolio 1) is comparable to that for an equally-weighted portfolio and is statistically significant at the 5% level. The intercept of Portfolio 1 is 0.15, implying that an abnormal profit of 15 basis points per week can be earned from investing in a value-weighted portfolio of low SI_Avail stocks. The highest SI_Avail portfolio (Portfolio 5) also exhibits a positive, but statistically insignificant, abnormal return. The mean spread between low SI_Avail and high SI_Avail value-weighted portfolios, reported in Panel C, is positive (0.05), but statistically insignificant ($t$-value of 0.5268).

We also performed a similar analysis using SI_Float instead of SI_Avail. The portfolios are ranked based on cross-sections of their constituents by short interest based on SI_Float. Even for equal- and value-weighted portfolios, not reported here, based on SI_Float, a noisier measure of lendable supply, we still find positive and statistically significant abnormal returns for stocks with low short interest (Portfolio 1). The high SI_Float (Portfolio 5) portfolio, consistent with the equally-weighted results, exhibits a positive and statistically insignificant abnormal return.

Turning to the factor loadings (slope coefficients) of highly shorted stocks, the results indicate that they have relatively high systematic market (MRP) risk. In addition, we observe that they load positively on SMB and tend to have a negative covariation with high book-to-market stocks (i.e., tilt towards growth stocks) especially in value-weighted portfolios.

Based on their positive and significant intercepts, it appears that stocks with low short interest (Portfolio 1) are overvalued relative to the market.[16] However, since negative information about these stocks is not instantaneously incorporated into prices, stocks with low short interest realize positive abnormal performance over short horizons. Our results also show that short sellers do not realize significant gains from the heavily shorted stocks (Portfolio 5). This may be due to the daily disclosure of UK short selling activity that allows investors to form hedge portfolios. A possible explanation for the different impact of short selling on stock prices is that short sellers' positions are imperfectly hedged in the case of low shorted stocks (i.e., the variance of these stocks' return is unhedgeable) while they do not appear to be prohibited from hedging their positions for the highly shorted stocks (Portfolio 5). That is, idiosyncratic risk, which makes arbitrage costly, may deter short sellers from correcting mispricing in the low shorted stock portfolio.

If price appreciation is systematic, why do not investors go long on stocks with low short interest to take advantage of it and bring prices to equilibrium? To answer this question, it is necessary to examine the relation between idiosyncratic risk and short interest among low-shorted stocks. We address this issue in Section 4.4.

Overall regression results show that both equal- and value-weighted portfolios composed of low short interest stocks earn positive abnormal returns. The magnitude of the abnormal returns is slightly larger for equal-weighted portfolios. Contrary to US evidence, we also find that highly shorted stocks do not underperform the market.

[16]The overvaluation could not be attributed to size and book-to-market since we account for these effects.

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Our results suggest that a systematic strategy of short selling does not appear to be profitable in the UK.

### 4.3. Short selling and idiosyncratic risk

As mentioned above, a plausible explanation of why stocks with low short interest are overvalued relative to stocks with high short interest is that stocks with low short interest are likely to be associated with higher idiosyncratic risk. High idiosyncratic risk, then, would cause a short position to be imperfectly hedged. As a result, short sellers would avoid establishing positions in high idiosyncratic risk stocks, leading to low short interest and overvaluation. One way to test this hypothesis is to examine the relation between idiosyncratic risk and abnormal returns for stocks with different levels of short interest. This relationship would imply that stocks with high idiosyncratic risk should have lower short interest and experience positive performance. If this conjecture is valid, we also expect to find stocks with high short interest to have lower idiosyncratic risk. For this group of stocks, short sellers would face lower arbitrage costs in hedging their positions and, therefore, causing prices to trade not far from fundamental values. Consequently, if idiosyncratic risk is driving low short interest, we also expect to observe an inverse relation between idiosyncratic risk and short interest. While we do not have borrowing cost data to test this hypothesis directly, we look at the relation between short interest and idiosyncratic risk later in the paper. However, if there is a systematic relation between idiosyncratic risk and returns, then both low and high short interest stocks should display the same sensitivity to idiosyncratic risk.

If idiosyncratic risk is responsible for the overvaluation of stocks with low short interest, we should find greater overvaluation (alphas) in portfolios with higher idiosyncratic risk. To test this prediction, we construct equally- and value-weighted portfolios based on SI_Avail and idiosyncratic risk. First, we sort stocks by SI_Avail and assign them into quintile portfolios. Next, within each SI_Avail portfolio, we sort stocks based on idiosyncratic risk. Idiosyncratic risk is computed as the standard deviation of the residual from the three-factor Fama-French model. The regressions are run daily with a rolling estimation window of 100 days. Although this analysis yields 15 portfolios, for the sake of brevity we only report results for six portfolios: three IR portfolios for the top SI_Avail quintile and three for the bottom SI_Avail quintile.

In Table 3, Panel A we report alphas and loadings from Fama-French regressions for the equal-weighted portfolios. As predicted, the abnormal returns of the portfolios formed from low SI_Avail (bottom SI_Avail quintile) and high IR (top IR tercile) stocks exceed abnormal profits earned by stocks with low SI_Avail and lower levels of IR (bottom and mid IR terciles). In fact, the alpha of the portfolios containing stocks with the lowest SI_Avail and highest IR (Portfolio (1,3)) is positive 0.27% and is statistically significant at the 1% level. The remaining two low SI_Avail portfolios, Portfolios (1,1) and (1,2), exhibit positive but statistically insignificant alphas, suggesting that idiosyncratic risk is responsible for overvaluation of stocks with low short interest. Examining the alpha of the high SI_Avail portfolio, the evidence indicates that regardless of IR stocks with high SI_Avail exhibit statistically insignificant alphas. While alphas for Portfolio (5,1) and Portfolio (5,2) are positive, the alpha for Portfolio (5,3) is negative, implying that heavily shorted stocks with high idiosyncratic risk tend to underperform.

Table 3
Short interest, idiosyncratic risk, and stock returns

This table reports coefficients of ordinary least squares across portfolios formed based on SI_Avail and idiosyncratic risk (IR). The estimated model is $R_{i(t)}-R_{f(t)}=\alpha+\beta_1(R_{m(t)}-R_{f(t)})+\beta_2\text{SMB}_{(t)}+\beta_3\text{HML}_{(t)}+\varepsilon$, where the variables are defined as follows: $R_{i(t)}$ is return; $R_{f(t)}$ is weekly 1-month LIBOR; $R_{m(t)}$ is the market return (FTSE 350); $\text{SMB}_{(t)}$ is the size factor; and $\text{HML}_{(t)}$ is the book-to-market factor. First, stocks are sorted by middle-of-week SI_Avail and assigned to quintile portfolios. Next, within top and bottom SI_Avail quintile, stocks are sorted by IR and assigned into three portfolios. As a result, we obtain six portfolios with equal number of stocks. SI_Avail is short interest, *shares on loan*, divided by *shares in CREST*. IR is a standard deviation of the residual from the Fama-French regression using 90-day rolling history. Panel A presents results of the estimation for equal-weighted portfolios and Panel B presents results for the value-weighted ones. *P*-values are listed below the correlation numbers. *Two-tailed probability < 0.10; **two-tailed probability < 0.05; ***two-tailed probability < 0.01. Data from CRESTCo Limited.

(A) Equal-weighted portfolios

| SI_Avail portfolio | IR portfolio | Intercept × 100 | Market | SMB | HML | Adj $R^2$ | $N$ |
|---|---|---|---|---|---|---|---|
| 1 (low) | 1 | 0.060 | 1.071*** | 0.439*** | 0.243*** | 87.88 | 141 |
| | (low) | 0.232 | <0.0001 | <0.0001 | 0.001 | | |
| | 2 | 0.099 | 0.978*** | 0.909*** | 0.065 | 70.01 | 141 |
| | | 0.228 | <0.0001 | <0.0001 | 0.564 | | |
| | 3 | 0.266*** | 1.027*** | 1.037*** | 0.032 | 71.57 | 141 |
| | (high) | 0.002 | <0.0001 | <0.0001 | 0.780 | | |
| 5 (high) | 1 | 0.101 | 0.802*** | 0.022 | 0.189** | 70.46 | 141 |
| | (low) | 0.130 | <0.0001 | 0.838 | 0.039 | | |
| | 2 | 0.068 | 1.110*** | 0.206 | −0.100 | 70.25 | 141 |
| | | 0.454 | <0.0001 | 0.169 | 0.423 | | |
| | 3 | −0.107 | 1.282*** | 0.817*** | −0.205 | 57.82 | 141 |
| | (high) | 0.439 | <0.0001 | 0.001 | 0.276 | | |

(B) Value-weighted portfolios

| SI_Avail portfolio | IR portfolio | Intercept × 100 | Market | SMB | HML | Adj $R^2$ | $N$ |
|---|---|---|---|---|---|---|---|
| 1 (low) | 1 | 0.156 | 0.880*** | 0.050 | 0.075 | 52.75 | 141 |
| | (low) | 0.138 | <0.0001 | 0.771 | 0.603 | | |
| | 2 | 0.200 | 0.943*** | 0.266*** | −0.028 | 50.03 | 141 |
| | | 0.089 | <0.0001 | <0.0001 | 0.860 | | |
| | 3 | 0.225* | 1.199*** | 1.002*** | −0.153 | 58.92 | 141 |
| | (high) | 0.078 | <0.0001 | <0.0001 | 0.380 | | |
| 5 (high) | 1 | 0.087* | 0.806*** | −0.273* | 0.189 | 65.87 | 141 |
| | (low) | 0.255 | <0.0001 | 0.031 | 0.113 | | |
| | 2 | 0.031 | 1.287*** | −0.124 | −0.065 | 69.41 | 141 |
| | | 0.778 | <0.0001 | 0.490 | 0.664 | | |
| | 3 | 0.030 | 1.450*** | 0.640** | −0.408 | 50.02 | 141 |
| | (high) | 0.855 | <0.0001 | 0.019 | 0.072 | | |

Table 3, Panel B presents estimates from Fama-French regressions for the value-weighted portfolios. The results, while weaker, are consistent with equal-weighted results in Panel A. The alpha associated with the portfolio from stocks with low short interest and high idiosyncratic risk, Portfolio (1,3), is highest but is only statistically significant at the 10% level.

Next, we test the prediction of the idiosyncratic risk hypothesis using a cross-sectional approach. Each day stocks are independently sorted into quintile portfolios based on the previous day's IR and SI_Avail, resulting in 25 interaction portfolios. Panel A of Table 4 reports annualized average returns of these 25 portfolios, rebalanced daily. As hypothesized, a portfolio that contains stocks with high IR and low SI_Avail strongly outperforms other portfolios with an annualized return of 51.5%. However, the extreme portfolio that consists of stocks with low IR and high SI_Avail, yields an annualized return of 26%. Moreover, as shown in the last column, an equal-weighted portfolio that buys stocks with high IR and low SI_Avail and shorts stocks with low IR and low SI_Avail earns an annualized return spread of 25.3%. On the other hand, the return of the arbitrage portfolio that buys stocks with high IR and high SI_Avail and sells stocks with low IR and high SI_Avail is only 1.8% per year. While the overall relation between IR and returns is positive (10.3%), it is both statistically and economically much stronger among low SI_Avail stocks.

Finally, it interesting to note, that the return spread of high SI_Avail and low SI_Avail portfolios we observe increases with the level of IR. For example, the spread for the entire sample is −8.1% while for high IR stocks (Portfolio 5) it is 23.6%. This provides additional support to our earlier findings that the outperformance of low SI_Avail stocks is largely concentrated among stocks with high IR.

Subsequently we estimate a daily regression of stock returns on IR for stocks with extremely high or low levels of short interest. Specifically, we construct two extreme portfolios: high SI and low SI. The high SI portfolio is composed of the top 20% of stocks ranked based on the previous day's SI_Avail. The low SI portfolio includes the bottom 20% of stocks based on the previous day's SI_Avail. For each portfolio, we run daily a cross-sectional regression of daily return on previous day's IR. In our regression analysis, we control for the influence of transactions costs on trading with the following proxies: size, liquidity, institutional ownership, and book-to-market. SIZE is the natural logarithm of market capitalization; ILLIQ is a 5-day Amihud (2002) illiquidity measure; IO is a proxy for institutional ownership, which is computed as a natural logarithm of *Shares in CREST*; and BM is book-to-market.[17]

Panel B of Table 4 presents Fama-MacBeth estimates for low SI and high SI portfolios. In these regressions we standardize all explanatory variables through demeaning and division by their standard deviations. As predicted, for stocks with low SI_Avail the coefficient of the IR variable is positive and statistically significant at 1% level, implying that idiosyncratic risk is a significant determinant of cross-sectional returns for low SI_Avail stocks. This finding is consistent with our main hypothesis that overvaluation is the outcome of idiosyncratic risk that deters arbitrage activity. That is, short sellers' reluctance to establish positions in high idiosyncratic risk stocks results in mispricing. Indeed, to the extent that idiosyncratic risk is only a measure of arbitrage costs, then this result suggests that low short interest stocks earn higher returns because of higher arbitrage costs, in agreement with Pontiff (1996, 2006) who argues that idiosyncratic risk is the largest cost faced by arbitragers. The fact that the other three variables, proxying for

[17] In the spirit of previous studies (Pontiff, 1996, 2006; Mendenhall, 2004), these variables are included in the regressions analysis to account for non-idiosyncratic risk factors that could also inhibit short sellers' trading.

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Table 4
Daily returns by idiosyncratic risk and short interest

Panel A reports annualized mean daily returns for 25 portfolios, formed by independently sorting stocks in five quintile portfolios based on previous day's IR and SI_Avail. The sorts are performed daily. *T*-statistics are listed below the mean estimates. Panel B reports Fama-MacBeth estimates from the daily multivariate cross-sectional regressions. The regressions are estimated for two groups of stocks: low SI_Avail and high SI_Avail. The low and high SI_Avail portfolios contain the bottom and top 20% of stocks based on SI_Avail, respectively. SI_Avail is a short interest, *shares on loan*, divided by *shares in CREST*. The estimated model is $R_{i(t)} = \alpha + \beta_1 \mathrm{IR}_{(t-1)} + \beta_2 \mathrm{SIZE}_{(t-1)} + \beta_3 \mathrm{ILLIQ}_{(t-1)} + \beta_4 \mathrm{IO}_{(t-1)} + \beta_5 \mathrm{BM}_{(t-1)} + \varepsilon$, where the variables are defined as follows: $R_{i(t)}$ is the 1-day stock return; $\mathrm{IR}_{(t)}$ is a standard deviation of the residual from the Fama-French regression using 90-day rolling history; $\mathrm{SIZE}_{(t)}$ is a natural logarithm of market cap; $\mathrm{ILLIQ}_{(t)}$ is a 5-day Amihud's illiquidity measure; $\mathrm{IO}_{(t)}$ is a proxy for institutional ownership, which is computed as a natural logarithm of *shares in CREST*; and $\mathrm{BM}_{(t)}$ is book-to-market. All independent variables are standardized. *T*-statistics are listed below the mean estimates. Data from CRESTCo Limited.

(A) Annualized mean portfolio returns of portfolios independently sorted on IR then SI_Avail

| SI_Avail portfolio | Idiosyncratic risk | | | | | | Spread (high–low) |
|---|---|---|---|---|---|---|---|
| | 1 (low IR) | 2 | 3 | 4 | 5 (high IR) | All | |
| 1 | 26.20 | 30.69 | 32.46 | 36.24 | 51.49 | 33.94 | 25.29 |
| Low SI_Avail | *3.85* | *4.30* | *4.19* | *4.13* | *5.47* | *5.01* | *2.18* |
| 2 | 22.23 | 33.15 | 29.88 | 36.40 | 33.46 | 30.23 | 11.23 |
| | *3.56* | *4.90* | *3.82* | *4.24* | *2.91* | *4.50* | *0.86* |
| 3 | 18.71 | 22.48 | 32.44 | 23.65 | 39.09 | 25.90 | 20.38 |
| | *3.07* | *3.41* | *4.14* | *2.87* | *3.83* | *3.81* | *1.71* |
| 4 | 19.12 | 23.99 | 31.67 | 30.75 | 25.75 | 25.83 | 6.63 |
| | *3.44* | *3.61* | *4.20* | *3.81* | *2.52* | *3.83* | *0.57* |
| 5 | 26.14 | 24.77 | 24.20 | 26.91 | 27.91 | 25.92 | 1.77 |
| High SI_Avail | *4.22* | *3.89* | *3.02* | *2.93* | *2.63* | *3.52* | *0.14* |
| All | 22.79 | 26.94 | 29.21 | 29.70 | 33.12 | 28.35 | 10.33 |
| | *3.89* | *4.43* | *4.21* | *3.98* | *3.96* | *4.28* | *1.01* |
| Spread | −0.06 | −5.92 | −8.27 | −9.33 | −23.58 | −8.02 | |
| (high–low) | *−0.01* | *−0.62* | *−0.74* | *−0.73* | *−1.66* | *−0.80* | |

(B) Fama-MacBeth regression estimates of the sensitivity of returns to idiosyncratic risk and transactions costs for extreme short interest quintile portfolios

| SI_Avail portfolio | *N* | Fama-MacBeth estimates | | | | |
|---|---|---|---|---|---|---|
| | | IR × 100 | SIZE × 100 | ILLIQ × 100 | IO × 100 | BM × 100 |
| 1 | 684 | 0.053 | 0.011 | −0.002 | −0.010 | 0.017 |
| Low SI_Avail | | *3.87* | *0.88* | *−0.10* | *−0.74* | *1.63* |
| 5 | 684 | 0.015 | 0.035 | −0.012 | −0.019 | 0.023 |
| High SI_Avail | | *0.74* | *2.55* | *−0.14* | *−1.53* | *2.20* |

trading frictions, enter this regression with insignificant coefficients provides additional support for this viewpoint.

For heavily shorted stocks, however, the coefficient of IR is still positive, but statistically insignificant. Consistent with our hypothesis, this result suggests that when short sellers

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find it less costly to hedge idiosyncratic risk security prices are less likely to trade far from fundamental values. As for the control variables, SIZE, and BM are statistically significant at the 1% level. SIZE and BM positive loadings, suggest that short sellers tend to short more heavily stocks with larger capitalization and higher book-to-market ratios. Regression results using weekly data are comparable and are not reported here.

Finally, one can argue that the idiosyncratic risk measure is a proxy for differences of opinion and, hence, our results are consistent with the Miller (1977) prediction. However, the positive coefficient of the idiosyncratic risk variable in the regression for the less-shorted (low SI_Avail) sample of stocks does not support Miller's hypothesis.[18]

### 4.4. *Idiosyncratic risk and short interest*

While our evidence thus far suggests that short selling behavior is constrained by idiosyncratic risk and, therefore, culpable for stock overvaluation persistence, it does not refute the argument that idiosyncratic risk could affect the shorting demand. The implication of this viewpoint could be consistent with Ang, Hodrick, Xing, Zhang (2006) and Spiegel and Wang (2006) who show that IR is an important determinant of future returns. It is possible, however, that investors prefer shorting high IR stocks because such a trading strategy presents them with a good trading opportunity. In this case we should observe a positive relation between short interest and idiosyncratic risk for both low- and high-short interest stock portfolios. To address this issue we perform a robustness test by relying on portfolios formed on short interest, not returns. In other words, this test allows us to examine directly whether idiosyncratic risk is driving low short interest.

We employ regression analysis using stocks from two extreme SI portfolios to evaluate the consistency of the relation between IR and SI while we control for the effects of size (SIZE) and illiquidity (ILLIQ) on the concentration of SI_Avail. That is, we examine whether idiosyncratic risk is driving low short interest by regressing SI_Avail on IR, controlling for SIZE and ILLIQ effects. Table 5 demonstrates that the relation between short interest and idiosyncratic risk is negative, contrary to the prediction of IR's being the sole determinant of cross-sectional returns.[19] This new evidence is consistent with our return-based portfolio results, reported in Table 4, and Ang, Hodrick, Xing, Zhang (2006) who show that stocks with high idiosyncratic volatility are systematically overpriced, suggesting that high idiosyncratic risk deters short selling. However, our findings contradict Spiegel and Wang (2006), who find that stocks with high idiosyncratic volatility are systematically underpriced, implying that idiosyncratic risk has an inverse influence on short selling activity. As expected, the evidence for high short interest stocks shows that idiosyncratic risk does not explain short interest. Hence, our findings imply that short interest might be an important factor in identifying mispricing in the UK market.

In sum, the main finding in this paper is that high idiosyncratic risk stocks tend to earn large abnormal returns because short sellers systematically under allocate capital to these stocks because they find it too costly to hedge their idiosyncratic risk. The mispricing of high IR stocks seems to have its origins in overconfident individual investors who value

[18]This result is consistent with the evidence of Doukas, Kim, Pantzalis (2006).

[19]One may attribute this relationship to a supply driven preference by lenders charging more for these stocks, as they may be more risky to lend. However, risky to lend stocks should be stocks loaded with high idiosyncratic risk that would be unattractive to investors.

Table 5
Fama-MacBeth regression estimates of the sensitivity of short interest to idiosyncratic risk

This table reports Fama-MacBeth estimates from the daily multivariate cross-sectional regressions. The regressions are estimated for two groups of stocks: low SI_Avail and high SI_Avail. The low and high SI_Avail portfolios contain the bottom and top 20% of stocks based on SI_Avail, respectively. SI_Avail is a short interest, *shares on loan*, divided by *shares in CREST*[‡]. The estimated model is $\text{SI\_Avail}_{(t)} = \alpha + \beta_1 \text{IR}_{(t-1)} + \beta_2 \text{SIZE}_{(t-1)} + \beta_3 \text{ILLIQ}_{(t-1)} + \varepsilon$, where the variables are defined as follows: $\text{SI\_Avail}_{(t)}$ is a daily measure of short interest defined above, $\text{IR}_{(t)}$ is a standard deviation of the residual from the Fama-French regression using 90-day rolling history; $\text{SIZE}_{(t)}$ is a natural logarithm of market cap; and $\text{ILLIQ}_{(t)}$ is a 5-day Amihud's illiquidity measure. All independent variables are standardized. *T*-statistics are listed below the mean estimates. Data from CRESTCo Limited.

| Portfolio | *N* | Fama-MacBeth estimates | | |
|---|---|---|---|---|
| | | IR × 100 | SIZE × 100 | ILLIQ × 100 |
| 1 | 684 | −0.006 | 0.034 | −0.035 |
| Low SI_Avail | | *−3.73* | *26.46* | *−26.50* |
| 5 | 684 | 0.016 | −0.068 | −0.435 |
| High SI_Avail | | *0.75* | *−3.65* | *−32.95* |

these stocks by exclusively relying on their own precision of information.[20] This is a plausible explanation given that institutional investors are prevented from shorting stocks with high idiosyncratic risk. Alternatively, the mispricing of high idiosyncratic risk stocks could also arise out of the combination of a change in sentiment on the part of the irrational traders, and a limit to arbitrage from the rational ones. In the presence of weak arbitrage forces, another explanation for this phenomenon could be associated with insider purchases and share repurchases if they believe the mispricing will worsen in the near future. This, of course, is an issue that warrants future investigation.

## 5. Conclusion

We set out to explore the relationship between short selling and stock returns for UK stocks and the impact of arbitrage costs on the behavior of short sellers. In agreement with previous studies, we find that stocks with low short interest, based on three short interest measures, have significant positive abnormal returns and outperform more heavily shorted stocks. However, contrary to US evidence, which suggests that stocks with high short interest significantly underperform, portfolios made up of heavily shorted stocks exhibit positive but statistically insignificant abnormal returns on both an equal- and value-weighted basis. It is important to note, however, that given our 3-year sample history, these results may not hold for longer time periods or varying market conditions and an analysis using a larger dataset may be warranted. Exploring the relation between short interest and returns using short interest data over a longer period of time is a natural subject for future research.

Our results indicate that idiosyncratic risk, a deterrent to arbitrage, is correlated with mispricing. Specifically, there is a negative relation between short interest and abnormal

[20] See Hirshleifer and Teoh (2003) and Daniel, Hirshleifer, Subrahmanyam (1998).

returns among stocks with high idiosyncratic risk. Consistent with Shleifer and Vishny (1997), who argue that idiosyncratic risk deters arbitrage leading to persistent mispricing, our evidence suggests that short selling activity is mostly concentrated in stocks with low idiosyncratic risk because it is less costly to arbitrage fundamental risk.

In addition, we conduct multivariate tests to better understand how different costs limit short selling activity. Our results suggest that idiosyncratic risk, a cost borne both by short and long arbitrage positions, is a greater deterrent to short selling than are transactions and short sale costs. These results are in line with the view that fewer arbitrage resources are directed to high idiosyncratic stocks and offer an explanation for the persistent mispricing among these stocks. Our findings are consistent with both Pontiff (1996) and Shleifer and Vishny (1997) who conjecture that mispricing is mostly prevalent among high idiosyncratic risk stocks.

The results of this study have important implications for the use of short interest in building investment signals. Our finding that the relationship between short interest ratios and returns is non-monotonic suggests that the common practice of using short interest as a linear signal may not be optimal. Specifically, the inclusion of idiosyncratic risk in short interest investment strategies may improve portfolio results. Another implication of our research is that exogenous economic shocks in asset markets could have amplifying effects on asset prices when short selling activity is limited due to high arbitrage costs. Finally, our results imply that reporting of short selling transactions to the public at higher frequencies may be beneficial for the orderly functioning of markets and investors.

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