# Liquidity and asset prices: The case of the short squeeze and the returns to the short position*

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**Abstract**

Extant literature suggests that highly-shorted firms experience negative abnormal returns because short sale constraints bias prices upward by precenting negative information from being impounded in valuation. We present a complementary risk-based model for the long-run return effect based on the notion that the high-short portfolio is uniquely subject to short-squeeze risk and test it using a sample of NYSE-AMEX stocks over the period 1988-2001. Consistent with model predictions, we find that the level of short interest is significantly related to the probability of a high subsequent positive return, a proxy for short squeeze risk. We also study broad portfolios of securities for which the Miller (1977) explanation does not apply and document an independent short squeeze effect in these portfolios. The most striking finding is that the relation between short interest and future returns exists for closed-end funds, which are short-sale constrained, but not for active ETFs, which can be created on demand and therefore carry little short-squeeze risk.

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**Abstract**

Extant literature suggests that highly-shorted firms experience negative abnormal returns because short sale constraints bias prices upward by preventing negative information from being impounded in valuation. We present a complementary risk-based model for the long-run return effect based on the notion that the high-short portfolio is uniquely subject to short-squeeze risk and test it using a sample of NYSE-AMEX stocks over the period 1988-2001. Consistent with model predictions, we find that the level of short interest is significantly related to the probability of a high subsequent positive return, a proxy for short squeeze risk. We also study broad portfolios of securities for which the Miller (1977) explanation does not apply and document an independent short squeeze effect in these portfolios. The most striking finding is that the relation between short interest and future returns exists for closed-end funds, which are short-sale constrained, but not for active ETFs, which can be created on demand and therefore carry little short-squeeze risk.

# I. Introduction

A high level of short interest is bad news for future stock returns. Figlewski (1981) finds that portfolios of stocks with a high degree of short interest underperform portfolios with low short interest. Asquith and Meulbroek (1995) and Dechow, Hutton, Meulbroek and Sloan (2001) focus on a sample of firm-years with high short interest and document a strong negative relation between stocks with high short interest and excess returns. Desai, Ramesh, Thiagarajan and Balachandran (2002) document significant negative abnormal returns to a portfolio of heavily-shorted firms on the NASDAQ market. The most puzzling feature of these results is that, contrary to the predictions of the Diamond and Verrecchia (1987) rational expectations model, these negative abnormal returns persist for at least a year subsequent to the short interest announcement. Miller (1977) suggests that short sale constraints bias prices upward by preventing negative information from being impounded into the stock price. However, aside from Jarrow's (1980) restriction on Miller's (1977) conclusions, another question arises when applying Miller's (1977) model to this problem: it is not clear that a highly-shorted stock is necessarily a stock that is short-sale constrained. In fact, we demonstrate that Exchange Traded Funds (ETFs), perhaps the most highly shorted asset class existing, are not short-sale constrained.

Thus, we propose and test an alternative risk-based explanation for the returns of high short-interest portfolios that is consistent with the empirical results cited above, but maintains that the high-short portfolio is uniquely subject to short-squeeze risk. A possible short squeeze is often mentioned as one cost to the short position, but its importance has not been fully understood. The standard stock-lending practice is that the loan must be paid on demand. This practice exposes sellers to the risk of a short squeeze (Dechow, Hutton, Meulbroek and Sloan, 2001). A squeeze occurs when the lender of the borrowed stock wants to sell, if the short seller is unable to find an alternative lender, the short-seller must repurchase the shares in the open market and repay the loan to close the position. If short covering causes a temporary imbalance in the market, then prices can rise abruptly as other shorts are forced to cover. Thus, the short squeeze imposes a liquidity cost on the short position: the short may be forced to cover in a rising market before he actually wishes to liquidate. This liquidity cost must be offset in equilibrium with a liquidity premium. In the case of a short-seller, the liquidity premium is reflected in a lower future stock price. Longs, if they possess a preference for positively skewed returns, may be willing to accept lower average returns if they think there is a chance that the a squeeze will occur and prices will rise dramatically.[1](cite popular press articles on short squeezes here)

As the risk of a short squeeze is generally negligible for most short interest levels, the effects of a possible squeeze on returns are not apparent until returns on the most highly-shorted stocks are examined. For these stocks, the probability of a short squeeze is non-zero and short squeeze risk is apparent in returns. Since short squeezes are relatively rare events, we model the effect of a potential short-squeeze on future asset prices as a peso-problem. The model predicts that an increase in the probability of a short squeeze will lower observed excess returns relative to any expected returns model that does not account for the possibility of a short squeeze. If short interest helps to predict the probability of a squeeze, the model's predictions are consistent with the empirical evidence cited above. A model of the effects of the short squeeze also helps to formally predict the cross-sectional distribution of short interest. All else equal, shorts will tend to invest in liquid securities, where the possibility of finding an alternative stock lender is greater. Thus, the fear of a short squeeze predicts the cross-sectional patterns in short interest documented in D'Avolio (2002) and Gintschel (2000).[2]

Our paper complements the recent literature identifying idiosyncratic risk as a key factor in short-sale constraints (Pontiff, 2005; Duan, Hu and McLean, 2006). However, noting that negative returns are a benefit, not a risk, to shorts, we focus on the risk of a high positive return to the short portfolio. Using short interest and other proxies for the supply of shorted shares, we build an empirical model to predict the probability of a large *positive* return (a proxy for a short squeeze), in the upcoming month. Portfolios with high predicted short squeeze risk significantly underperform. Notably, the model coefficient on short interest is positive, indicating that highly-shorted stocks are more likely to have a large *positive* return in the upcoming month. Further, the probability of a short squeeze significantly predicts future returns even in the presence of short interest and the dispersion of analysts' forecasts, a commonly-used proxy for Miller's (1977) information-based arguments.

[1] Barberis and Huang (2004) use skewness preference as an explanation for investor's continued interest in IPOs despite the well-documented underperformance of the asset class.

[2] Desai, Ramesh, Thiagarajan and Balachandran (2002) use the fear of a short squeeze argument to explain the short-sellers preference for liquid stocks in their Nasdaq sample.

To elaborate on the difference between short-squeeze effects and Miller's hypothesis, we the examine the effects of short interest on ETFs and closed-end funds. Both ETFs and closed-end funds allow investors to take short positions but it is much less likely, relative to an individual security, that investors have private information on the future returns of these diversified portfolios.[3]

ETFs and closed-end funds differ because ETFs can be created on demand and closed-end funds cannot. This property makes ETFs unique among equity-based securities: investors can short ETFs with little short-squeeze risk. (insert footnote on credit derivatives (?) as another asset class facing no short-squeeze risk) As a result, the short levels of many active ETFs are unusually large. If ETFs have lower short-squeeze risk than closed-end funds, which cannot create new shares on demand, the relation between short interest and future returns should be different across the two asset classes. Comparing the effects of short-squeeze risk on ETFs and closed-end funds, we find that short interest has the same implications for closed-end fund returns as it does for stocks, but not for ETF returns. This difference is explained by differences in the market microstructure of ETFs and closed-end funds.

Short squeeze risk is modeled in Section 2, Section 3 examines the effect of short squeeze risk for common stocks, Section 4 examines portfolio securities and Section 5 concludes.

## II. The short squeeze

There are a number of reasons why short sales are costly trades. Individual investors do not generally receive use of the sale proceeds (Danielson and Sorescu, 2001), and they must post margin to execute the trade. Even investors that do receive interest may obtain lower than market rates if the stock is on special Reed (2002). The uptick rule (SEC Rule 10a-1), constrains short sellers from executing transactions at a price below the preceding transaction price. Asquith and Meulbroek (1995), Dechow, Hutton, Meulbroek and Sloan (2001) and Chen and Singal (2003) include, but do not examine, the possibility of a short squeeze as an additional cost of shorting. Short squeezes are rare events, but there is little question that they are more likely to occur in heavily-shorted

[3] In assuming that informed traders are less likely to trade in these portfolios, I rely on Subrahmanyan (1991). Subrahmanyan (1991) concludes that the firm-specific component of adverse selection risk is diversified away in large portfolios, leaving a larger pool of uninformed liquidity traders in the market for broad portfolios.

stocks. In fact, active short sellers sometimes accuse the management of heavily-shorted companies of trying to engineer a short squeeze (Valdmanis, 2003; Lamont, 2004).

Under our short-squeeze hypothesis, the microstructure of short trading affects average returns to the long position. High short interest does not imply upwardly-biased prices but rather reflects a higher probability of a short squeeze, an added cost that must be born by the short seller. Shorts must be compensated with lower expected returns the higher the probability of a squeeze. The prediction that short-selling costs can affect the equilibrium rate of return on a security is theoretically defensible: Alexander (1993) and Kwan (1997) examine how the composition of the efficient portfolio, and hence relative prices, changes under realistic assumptions about the costs of short selling. Nyborg and Strebulaev (2004) show that the fear of a short squeeze in the secondary market can affect prices in the primary market. Gay and Manaster (1984) contend that delivery options implicit in the short position of a futures contract affect the equilibrium price of the contract. For example, the location option reduces the chance that the short will be squeezed by locally expensive storage space. Thus, the location option provides squeeze insurance to the short futures position and is one of the more general set of quality options priced into the futures contract. Absent the location option, short squeeze risk would be non-zero and priced into the contract. Like the short futures position, the short stock position enters into a contract to deliver the underlying asset in the future. Unlike the short futures position, the short stock position has no discretion over what to deliver, further, the short has no discretion over when to deliver if the long demands a recall.

## A. Short squeeze example

A short squeeze occurs because of a demand imbalance in the market for borrowed stock. Generally, a positive shock, such as an earnings announcement, in the case below initiates the squeeze, but squeezes can occur simply because of an unidentified run up in the price of a stock.[4] Formally, I define a short squeeze as a recall by the stock lender which is accompanied by an abrupt upward

[4] Dechow, Hutton, Meulbroeck and Sloan (2001) cite the 1998 short squeeze in Amazon which occurred following the announcement of a stock split. Lahart (2004) reports a short squeeze in Overstock.com that occurred after a large insider purchase.

price move. In these circumstances, recall can be costly if the short is forced to cover.[5] The price moves attributed to short squeezes can be considerable, as the following example illustrates.

On August 2, 2001, the shares of electronics manufacturer ACT Manufacturing Inc. gained 34.6% in active trading to $10.96 after the company released their second quarter earnings. Unfortunately for the shorts, most of the bad news that was expected in the earnings announcement did not emerge, as earnings were in-line with consensus expectations of the analysts surveyed by Thomson Financial's First Call division. Figure 1 illustrates the large price and volume increases that were attributed to active short covering, as short sellers were forced to cover their positions. At the time of the earnings announcement, the most recently reported short interest in ACTM was 6.6 million shares that represented a short interest ratio (shares shorted divided by average daily volume) greater than 12.

What is particularly interesting about the ACTM short squeeze is that the short sellers were fundamentally correct. After holding above $10 per share for a month, the stock price continued its gradual decline from its September 11, 2000 all-time high of $72.25. On December 21, 2001, the company filed for Chapter 11 bankruptcy protection. The stock currently trades for pennies per share on the OTC bulletin board.

### B. The short squeeze as a peso problem.

Evans (1996) presents a theoretical model of the peso problem that can used to formally characterize the effects of a short squeeze. Let $R_{t+1}$ be the return on a stock between periods $t$ and $t+1$. We can write this return as the sum of the ex-ante expected return given the information set at time $t$, and the market's forecast error or abnormal return:

$$R_{t+1} = E\left[R_{t+1}|\Omega_t\right] + e_{t+1.} \tag{1}$$

In an efficient market the abnormal return, $e_{t+1}$ should be mean zero and be uncorrelated with variables in the markets' information set, $\Omega_t$. Consider a simple case where $R_{t+1}$ can switch between two processes, indicated by changes in the discrete variable $Z = \{0, 1\}$. $Z = 0$ indicates

[5] Berenson (2001) documents a $10 million dollar loss suffered by a professional short seller in the 2000 Lernout short squeeze.

normal trading conditions and $Z = 1$ indicates a switch into a regime where a short squeeze occurs with probability 1. Let $R_{t+1}(z)$ denote the regime dependent returns when $Z_t = z$. Consider the behavior of the forecast errors, or abnormal returns, $R_{t+1}(z) - E[R_{t+1}|\Omega_t]$.

$$R_{t+1} = E[R_{t+1}(0)|\Omega_t] + \nabla E[R_{t+1}|\Omega_t] Z_{t+1} + w_{t+1} \tag{2}$$

where:

$$\nabla E[R_{t+1}|\Omega_t] \equiv E[R_{t+1}(1)|\Omega_t] - E[R_{t+1}(0)|\Omega_t]. \tag{3}$$

Returns are forecast efficiently when investors know the future trading regime with certainty. If it is known that the future regime is the normal pricing environment, $Z = 0$, then the abnormal returns from equations (1) and (2) will be equal. If a future short squeeze regime is known with certainty, then expected returns will be equal to expected returns in the normal pricing regime plus the difference between the expected returns under the short squeeze regime and the expected returns under the normal regime. In either case, if the $t + 1$ regime is known with certainty, then in an efficient market: $E[w_{t+1}|\Omega_t] = 0$.

If the $t + 1$ regime is not known with certainty, but rather must be forecast, then expected returns are equal to:

$$E[R_{t+1}|\Omega_t] = E[R_{t+1}(0)|\Omega_t] + \nabla E[R_{t+1}|\Omega_t] * E[Z_{t+1}|\Omega_t] \tag{4}$$

Substituting (2) and (4) into (1) produces the following expression for abnormal returns, $R_{t+1} - E[R_{t+1}|\Omega_t]$:

$$e_{t+1} = w_{t+1} + \nabla E[R_{t+1}|\Omega_t] * \{Z_{t+1} - E[Z_{t+1}|\Omega_t]\}. \tag{5}$$

If the market perfectly forecasts next periods regime then the second term vanishes and the errors in the regime shifting model (2) are equal to the errors in the standard model (1). However, when the future regime is unknown then the second term in (5) makes a contribution to the abnormal return.

Now consider the realized ex-post abnormal return at time $t+1$ when trading is in the normal regime (0). In this case, a short squeeze did not occur and the actual $t+1$ regime has been observed and found to be the normal trading regime (0).

$$e_{t+1}(0) = w_{t+1} + \nabla E[R_{t+1}|\Omega_t] * \{Z_{t+1} - E[Z_{t+1}|\Omega_t]\}. \tag{6}$$

Examine the second term in Equation (6): the case of ex-ante uncertainty regarding whether a short squeeze regime will occur. The first expression in the second term is the difference between the expected return in the short squeeze state (1) and the expected return in the normal state (0). Since short squeezes cause a temporary increase in buying pressure this term will be greater than zero. The second expression in the second term reflects the difference between the actual state and the expected state. Short squeezes are rare events, for most stocks and times the actual value of $Z_{t+1} = 0$. For most stocks and times therefore the expectation $Z_{t+1}$ will also be close to zero and the difference $Z_{t+1} - E[Z_{t+1}|\Omega_t]$ will be approximately zero. Hence, for most stocks and times the second expression will be close to zero and markets' can ignore the possibility of the short squeeze.

However, consider the case when the there is a non-zero expectation that a short squeeze will occur, $E[Z_{t+1}] > 0$. In this case, the expression, $Z_{t+1} - E[Z_{t+1}|\Omega_t] < 0$, and the second term on the right hand side is negative making the observed ex-post abnormal return in normal trading regime, $e_{t+1}(0)$, negative as well. This result yields Proposition 1.

**Proposition 1** *As the probability of a short squeeze increases,* $E[Z_{t+1}|\Omega_t] > 0$, *the ex-post abnormal returns relative to a benchmark asset pricing model that does not consider short squeeze risk, will decrease.*

Under this proposition, the ex-post abnormal returns will be negative the greater the ex-ante probability of a short squeeze. This statement has several implications that are consistent with studies of returns and short interest.

## C. Diversification

[I might want to say a little bit more about alternative models here. I am still thinking.]

Is short squeeze risk diversifiable? Yes, in the sense that a well-diversified portfolio of stocks should exhibit negligible short-squeeze risk, so that the unconditional expected return from holding short-squeeze risk in such a portfolio will be near zero. However, the portfolios examined in the empirical literature are not well-diversified because the portfolios are formed *conditionally* on the level of short interest in a given month. I adapt the conditional industry-momentum model of Moskowitz and Grinblatt (1999) to illustrate this effect. Consider the following multifactor linear process for stock returns:

$$\widetilde{r}_{jt} = r_f + \sum_{k=1}^{K} \beta_{jk} \widetilde{R}_{jt} + \theta_{jt}\lambda + \widetilde{\epsilon}_{jt}, \tag{7}$$

where $\widetilde{r}_{jt}$ is the return of stock $j$ at time $t$, $\widetilde{R}_{jt}$ are the returns of zero-cost portfolios that mimic the economy-wide factors, which are the source of unconditional return premia for security returns and $\beta_{jk}$ are the factor portfolio sensitivities, and $\widetilde{\epsilon}_{jt}$is stock $j's$ firm-specific return. In the context of Evans (1996) model $\lambda = \nabla E\left[R_{t+1}|\Omega_t\right]$, the size of the jump if a short squeeze occurs and $\theta_{jt} = Z_{t+1} - E\left[Z_{t+1}|\Omega_t\right]$, the difference between the actual state and the expectation of the future state of stock prices. $\theta_{jt}$, is modeled explicitly as time varying because the likelihood of a squeeze varies over time. Even though $\lambda > 0$, across a well-diversified portfolio $\theta_{jt} \approx 0$ and the well-diversified portfolio is described by the unconditional model of expected returns:

$$u = r_f + \sum_{k=1}^{K} \beta_{jk} \tilde{R}_{kt} + \tilde{\epsilon}_{jt}. \tag{8}$$

An analogy would be to describe $\lambda$ as an exposure to another less pervasive factor such as oil prices. Although not priced in the unconditional framework, it is easy to imagine building a portfolio where the $\theta_{jt}' s$ with respect to oil prices are non-zero. This is precisely what the empirical studies on short interest do; portfolios are sorted by short interest, which we show to be a proxy for exposure to short squeeze risk. Portfolios that contain low short interest exhibit no significant abnormal returns because their exposures to short-squeeze risk are approximately zero, $\theta_{jt} \approx 0$. Portfolios formed *conditionally* with stocks that have high exposure to short-squeeze risk are found to have significant negative abnormal returns. Thus, some securities face a diversifiable short squeeze risk associated with the microstructure of the securities lending markets. Empirical tests that find negative returns associated with conditionally high-risk portfolios are attributing these returns to informed trading, a link which perhaps should not be made.

### D. Discussion

The first implication of the model is that stocks will exhibit negative abnormal returns relative to a benchmark pricing model that ignores short-squeeze risk whenever the probability of a short squeeze $> 0$. If short interest is a significant predictor of squeeze risk, short interest will only have a significant effect on returns when short interest is unusually high. This is exactly the pattern of ex-post errors that were found in Asquith and Meulbroek (1995), Dechow, Hutton, Meulbroek and Sloan (2001) and in Desai, Ramesh, Thiagarajan and Balachandran (2002). An important consequence of the short squeeze model is that this pattern of abnormal returns can occur independently of whether or not the short positions represent informed trading.

The peso-problem framework illustrates the consequences of ignoring short squeeze risk on abnormal returns. When the benchmark asset pricing model always predicts the probability of a squeeze as zero, portfolios with non-zero short squeeze risk will have negative abnormal returns relative to the benchmark model. Thus, if the benchmark model contains jumps, such as Merton (1976) and Merton's risk-neutral assumption holds, the benchmark model could, if it accurately estimates the frequency and size of the jumps, capture the short squeeze effect.[6] However, relative to any benchmark model that does not contain jumps, if short squeezes exist then any portfolio with a positive expectation of a squeeze will produce negative abnormal returns.

Short activity is persistent. The first order autocorrelation coefficient on short activity, measured as either shares short or short interest is 0.94 for common stocks. Thus, the ex-ante probability of a short squeeze in any month should be fairly constant. If the ex-ante probability of a short squeeze is high, it tends to remain high from month to month. For these stocks, prices incorporate a small probability that the buying pressure which accompanies a short squeeze will drive up prices. Ex-post returns over the following month are lower if returns are benchmarked against expectations that do not control for the ex-ante probability of a squeeze. Because short interest is persistent, negative abnormal returns to high short portfolios are also persistent.

[This is tricky. What if jumps occur? I have some more work to do on this section.]

[6] Liu, Pan and Wang (2006) suggest that, in addition to risk aversion, investors possess uncertainty aversion to rare events. In their equilibrium, a rare-event risk premium exists, even when the returns generating process is known with certainty.

If a high short interest to predict the probability of a squeeze, a large positive return, then a testable hypotheses follows Proposition 1:

**Conjecture 1** *The probability of large positive return is positively related to the level of short interest.*

This conjecture is consistent with the short-squeeze model outlined above, but appears counter-intuitive under the information-based models for shorting. Because the conjecture is derived from the microstructure of the stock-lending market and is not an information-based hypothesis, it should hold for asset classes where private information risk is high (common stocks) and also for asset classes where private information risk is low (closed-end funds).

## III. Short squeeze risk in common stocks

### A. A short squeeze model

Dechow, Hutton, Meulbroek and Sloan (2001), Desai, Ramesh, Thiagarajan and Balachandran (2002) and others find that high short-interest portfolios underperform, but, by itself, short interest unlikely to be a complete measure of the probability of a squeeze. Although short interest reflects the total short demand; demand will interact with the supply of shorted shares to determine the likelihood that a squeeze occurs. To empirically implement a model for the probability of a squeeze we follow D'Avolio's (2002) empirical results on proxies for a stock on special. Specialness reflects the loan fee and hence, the 'price' determined by the interaction of demand and supply curves in the short market. As such, empirical proxies derived from D'Avolio (2002) should be useful at predicting whether a short squeeze will occur.

The two most consistently significant variables that D'Avolio (2002) found could help predict specialness were the size of the firm (market value of equity) and the percentage institutional ownership (IO) [JFE cites here?]. Both variables reflect supply effects, size reflects the gross availability of shares outstanding and institutions are much more active lenders in the short market. In addition, lenders that have more predictable demand (such as passive indexers) are valuable to the short seller because these lenders are less likely to unexpectedly cancel the loan. We use a dummy variable for a stock's inclusion in the S&P 500 index as a proxy for the participation of passive indexers in the short market. We predict short interest to be positively related to the probability of a squeeze. Size, institutional ownership and index inclusion, which all indicate a greater supply of shorted shares, will be negatively related to the probability of a squeeze.

We also include the prior month's volume, which D'Avolio (2002) found was sometimes successful in predicting a stock going on special, and the change in short interest in the prior month. Again, we are guided by D'Avolio's (2002) empirical results in this choice as he found that recall events were usually preceded by a runup in short interest in the prior month. Finally, we include the last 3 months gross return (MOM). Griffin, Harris and Topaloglu (2003) report that institutions, more so than individuals, are likely to purchase recent winners, recent returns could affect the demand for shares

As we do not possess a sample of short squeezes, we proxy for a squeeze event using an arbitrarily large positive daily return in the upcoming month. Hence, we estimate the probability of a squeeze as:

$$Prob(Return_{i,t+1} > 20\ \%) = \alpha + \beta_1 Short\ interest_{it} + \beta_2 Volume_{it} + \beta_3 \Delta Short\ interest_{it,t-1} \\ + \beta_4 Size_{it} + \beta_4 IO_{it} + \beta_5 MOM_{it} + \beta_6 S\&P_{it} + \varepsilon_{it} \quad (9)$$

where $i$ represent the return for a particular fund in short interest month $t$. Clearly, the probability of a large return, in the illustrated case, a return of 20 percent, will be related to the underlying volatility of the stock. However, Goyal and Santa-Clara (2003) find that volatility may capture return effects that we do not wish to model. As a robustness check we also estimate our squeeze model using a VAR-like risk measure, where the dependent variable is the probability of a positive $3\sigma$ event: the results are similar.[7]

[7] Results of the $3\sigma$ threshold model are presented below for closed-end funds.

## B. Estimation of the short squeeze model

The sample consists of every stock ever mentioned in the NYSE-AMEX short interest press release, whether or not the stock has short interest outstanding in the current short interest month. Beginning on January 22, 1988 the publishing date of each press release divides the sample into 167 short interest months ending on December 19, 2001. Each short interest press release contains the number of shares held short in both the current month and the previous month. If a stock is not part of a particular month's short interest press release, I first check the following month and use that month's previous short interest as the current month's short interest. If a stock is not mentioned in the current month or the following month then short interest is set to zero. Stocks never mentioned over the entire 14 year sample period are excluded as they have no probability of ever having a short squeeze.[8] The final sample consists of short interest and returns for 272,286 short interest months. Short interest is calculated as the outstanding level of short interest divided by the number of shares outstanding on the short interest announcement date. Monthly returns and abnormal returns are calculated as:

$$Abnormal\ Return = [\prod_{t=1}^{T}(1 + r_{it}) - \prod_{t=1}^{T}(1 + R_{it})] - 1 \tag{10}$$

where in $r_{it}$ and $R_{it}$ are daily stock and value-weighted monthly returns. The CRSP daily file provides data on daily returns, volumes and shares outstanding from January 1988 through December 2001. Institutional ownership is obtained from Thomsons SDC database.

Summary statistics on these data are reported in Panel A of Table 1. In any particular month about 77 percent of stocks have short positions outstanding. However, there are many similarities between the shorted stocks and the non-shorted stocks; they have similar size, institutional ownership and past returns. Surprisingly non-shorted stocks have higher average volume (though also more variable volume) and somewhat lower representation in the S&P 500. The most striking difference between the two samples is the 0.91% average monthly abnormal return difference. It is this difference that the short-squeeze model is attempting to explain.

[8] Finding stocks that are never shorted is consistent with D'Avolio's (2002) equity lending data. D'Avolio finds that these stocks tend to be small and illiquid.

Panel B presents Equation 9 estimation results. Most of the variables in the model are significant and of the predicted sign. In terms of accurately forecasting the dependent variable the most important variables are institutional ownership, size, short interest and volume. Size and institutional ownership have negative coefficients which reflect a greater supply of borrowable shares, and hence a lower probability of a squeeze. Short interest has a positive sign as predicted. High short interest indicates an increased likelihood of a *positive* return in the upcoming month. This result is not predicted by any of the current explanations for returns associated with short activity, but it is predicted by our short squeeze model. Finally, consistent with D'Avolio's (2002) explanation that conditional on the variables size and institutional ownership controlling for supply, the positive coefficient on volume represents a greater likelihood that any particular short position will be recalled, potentially triggering additional short covering.

### B.1. Results

**Short squeeze risk.** Panel C presents portfolio returns for estimated short squeeze decile portfolios. Stocks that have no short interest have zero short squeeze risk by definition and are separated out into a separate portfolio. The remaining 208,463 stock-months are sorted first according to their estimated squeeze probability from Equation 9, and for comparison purposes ten portfolios sorted by short interest. The short squeeze portfolios show a consistent pattern of declining abnormal returns with increased short squeeze risk. Portfolios with the lowest risk of a short squeeze (only 0.02%) have returns comparable to the zero short interest portfolio. Portfolios in the higher deciles for squeeze risk have economically negative abnormal returns. The highest squeeze risk portfolio has a monthly negative abnormal return of -2.57%. Note that these results occurs despite the presence, by construction, of a number of extreme positive returns in the high short squeeze portfolios.

As short interest is positively associated with the probability of a squeeze, portfolios formed by short interest alone produce the usual pattern of negative abnormal returns. Portfolio monthly abnormal returns for the highest short interest decile are -1.13 percent. However, the short squeeze model presented in Panel B does a better job, in terms of explaining cross sectional return patterns than short interest alone. We conclude that the conventional results on short interest portfolios only produce negative abnormal returns because short interest helps predict the probability of a squeeze.

Highly-shorted common stocks have a greater probability of high *positive* daily returns. This is an important finding because a relation between short interest and the positive skewness in returns is not predicted by Miller's (1977) hypothesis that highly-shorted firms lack optimists, Figlewski's (1981) contention that high short interest proxies for the level of shares that would be sold short if short-sale constraints were removed, or Diamond and Verrecchia's (1987) argument that high short interest represents a situation where informed traders have negative private information. However, such a result is consistent with the idea that the lower future returns associated with high short interest provide compensation to the short position for the risks associated with a short squeeze. The empirical fact that highly-shorted stocks produce significant negative abnormal returns can best be interpreted when short interest is used as an important explanatory variable in the probability of a squeeze. Then the squeeze probability can be used even more effectively than short interest to explain cross-sectional patterns in returns.

**Squeeze risk and dispersion** Panel D examines the interaction between dispersion and squeeze probability. Dispersion is measured as the standard deviation of analysts' forecasts of fiscal year one earnings. Dispersion is often used empirically as a measure of disagreement or the divergence of opinion. In the context of Miller (1977) dispersion is mathematically related to overpricing. When investors with negative opinions are constrained from shorting, the distribution of investors' opinions reflected in the stock price will be truncated. As the mean of a truncated series is positively related to dispersion, overpricing and the subsequent negative abnormal returns are expected to be larger the greater the dispersion of analysts' forecasts (Deither, Molloy, Scherbina, 2001). This is a joint hypothesis of Miller (1977) and analysts' forecasts as a proxy for divergence in investors' opinions. Panel D sorts the portfolio with the highest squeeze probability from Panel C into dispersion quintiles. Returns for each quintile are lower than one percent per month including the significant component of the sample has missing dispersion observations. There is no general monotonic relation between dispersion quintile and abnormal returns, however returns are lower for the two highest dispersion quintiles. Boehme, Danielson and Sorescu (2006) stress that Miller requires both short constraints and divergence of opinion. Thus, under Miller low dispersion stocks should not have negative returns. However, all portfolios, regardless of dispersion, with high squeeze probability have negative abnormal returns of greater than 1 percent per month.

The result that the highest dispersion portfolio has the largest negative abnormal returns can be interpreted as broadly consistent with Deither, Molloy and Scherbina's (2001) joint hypothesis. However, another interpretation can be inferred from D'Avolio (2002). D'Avolio discusses squeeze probability in terms of the correlation between the marginal demand for shorted shares and the marginal supply. Usually, marginal demand and supply are highly correlated, but if they become uncorrelated dislocations in the market for shorted shares can occur. When dispersion is high, revelation of good news could inform some short investors that they are very wrong and they wish to exit their positions. At the same time the good news could engender buying pressure and lenders may wish to take profits. Thus, dispersion could be a proxy for the probability of a short squeeze. Which interpretation of the return evidence is correct depends on the debatable contention that high short interest is a proxy for short constraints.

We have purposefully omitted dispersion from our squeeze probability model because of its associated with the Miller (1977) hypothesis in the literature. However, to obtain an idea of the relative effects of squeeze probability and dispersion we next calculate abnormal returns by first sorting all common stocks into dispersion quintiles and then by squeeze probability deciles, we find a large negative decile spread for all dispersion portfolios. In dispersion quintile 1 (low dispersion) the 1-10 squeeze probability spread is -0.86% (0.086% for low squeeze probability to -0.01% for high squeeze probability). In quintile 2 the decile spread is -1.56% (0.46% to -1.12%), in quintile 3 the decile spread is -1.44%(0.08% to -1.36% ), in quintile 4 the decile spread is -1.56% (-0.09% to -1.65%), in quintile 5 the decile spread is -2.48% (-0.15% to -2.63%) and when dispersion is missing the decile spread is -1.32% (0.18% to -1.14%). The salient point is that even when dispersion is low and the Miller hypothesis predicts little information-based demand for short positions, the squeeze probability can reveal significant monthly return spreads across portfolios.

### B.2. Common stocks and short interest: Alternative explanations

Table 6 presents the results of two additional tests on the relation between common stock returns and short interest. Harvey and Siddique (2000) argue that co-skewness, the scaled covariance between stock returns and squared market returns, is a priced risk factor. If the high-short portfolio exhibits greater positive co-skewness than the low-short portfolios, co-skewness risk provides an alternative explanation of the relation between short interest and abnormal returns. Hence, Panel A examines the relation between the skewness and co-skewness in common stock returns across four categories of short interest. Skewness is a more general measure of the effect of short interest on returns than the binary effects tested in the probit model. If short interest is related to the probability of a short squeeze, then high-short portfolios should exhibit positive skewness relative to low-short portfolios.

Following Dechow et al. (2001) stocks are sorted into four portfolios by short interest ($< 0.5\%$, $0.5\%$ to $1.0\%$, $1\%$ to $2.5\%$, and $> 2.5\%$). Panel A shows that high-short interest portfolio returns exhibit significantly (t-statistic = 5.70) higher positive skewness than low-short interest portfolio returns. This result is consistent with high-short stocks being exposed to a greater probability of large positive returns associated with a short squeeze. This positive skewness, and the associated occasional large positive return, can also account for the frequent endorsement of a short-squeeze strategy of going long high-short interest stocks (Hough, 2003) despite the poor average returns to this strategy.

The results in Table 6 also show that co-skewness is not a tenable alternative explanation for the relation between short interest and abnormal returns. The negative co-skewness associated with high-short stock returns is not significantly different (t-statistic = 0.10) than the negative co-skewness associated with low-short interest returns.

Diamond and Verrecchia (1987) suggest that the revelation of previously private information on the level of short interest could result in a negative market reaction at the time of the announcement. In this vein, Senchack and Starks (1993) find statistically significant negative returns subsequent to the announcement of large increases in short interest. These negative returns could contribute to the underperformance of highly-shorted stocks in the month subsequent to the announcement. Panel B of Table 6 examines this contention in our sample by calculating the two-day announcement returns around the announcement of short interest. Abnormal returns for the announcement day (day 0) and the following day (day +1) are cumulated across deciles sorted by the change in short interest from the level publicly announced in the previous month. In this replication, I cannot confirm the findings of Senchak and Starks (1993). Announcement period abnormal returns are small and insignificant across all portfolios. For stocks with the greatest positive increase in short interest, which averages 0.84% of shares outstanding, the announcement period abnormal returns are only -0.02% and not statistically significant. These results show that the effects associated with the announcement of higher levels of short interest do not explain the negative abnormal returns associated with high-short interest portfolios.

Specialness could also have a direct effect on price. Duffie, Garleanu and Pedersen (2002) model the dynamic effects of the equity lending market on price. As in the static Duffie (1996) and Fisher (2002) models, the demand for specific collateral causes the interest paid on short proceeds to be less than the market interest rate. In their dynamic model, the interest rate difference represents a benefit to equity lenders that could be capitalized into the price of the stock and their model could help explain the negative abnormal returns to the high-short portfolio.

However, specialness appears to be an incomplete explanation for the underperformance of the high-short interest stocks. Specialness is relatively rare and high levels of specialness are not generally persistent, so the effect of specialness on the performance of the high short portfolio are more likely to be complementary than complete. The 10 to 13% annual underperformance of buy and hold short portfolios found by Desai, Ramesh, Thiagarajan and Balachandran (2002) is too large to be explained by the capitalized value of specialness. A notable example comes from a study by Investment Technology Group (1998) who, after forming a high short interest portfolio, submitted the candidate portfolio to the stock-loan department of a brokerage firm to determine if the stock was borrowable and the degree of specialness in the short portfolio. They found that they could actually borrow only 23 of 39 stocks in their high-short portfolio, although this restriction did not significantly affect abnormal returns which were 17.2% annualized. For the stocks that were borrowable, the average interest rate was 2.8%, compared to 4.5% for a typical S&P 500 stock. Thus, if specialness was completely capitalized into the stock, the 1.7% interest rate difference represents only a fraction of the annual underperformance of high short interest portfolios.[9]

[9] A similar conclusion can be drawn from Beohme, Danielson and Sorescu's (2006) more recent sample of short lending fees. These fees average approximately 1.5 percent per annum in the highest decile of short interest.

## IV. Portfolios

Above we document the existence of a short squeeze effect in common stock returns. To further contrast our hypothesis with the predictions of the prevailing Miller hypothesis, we turn to examining the effects of a short squeeze on two portfolio-based assets, closed-end funds and ETFs.

### A. Closed-end funds

Empirically, we find that closed-end fund returns are significantly negatively related to short interest. This relation shows the same pattern as common stocks, with the strongest negative relation in the highly-shorted portfolios. To reach this conclusion I examine all NYSE and AMEX common stock closed-end daily fund returns from January 1988 through December, 2001. Daily returns for CRSP share code 14 (excluding ETFs which are analyzed below) are cumulated into 167 short-interest-month returns. Panel A of Table 3 presents summary statistics on short interest and returns for these funds. There are a total of 19,879 closed-end fund short interest months. However, a considerable number of closed-end funds are never shorted. These funds represent 5,513 short interest months and as they have no probability of ever having a short squeeze, are examined separately leaving 14,366 short interest months. Short interest in closed-end funds averages 0.66 percent of shares outstanding, somewhat lower than the 1.57 percent for common stocks. Unlike the common stocks in Table 1 there are more notable differences in the characteristics of shorted funds and never-shorted funds. Shorter funds are notably larger, have higher monthly volumes and institutional ownership. However, the premium (discount) to net asset value and monthly abnormal returns, while both negative, are comparable across the two groups. Many closed-end funds are non-U.S. country-specific funds, an asset class that generally underperformed domestic equities in the 1990's. This foreign stock underperformance is likely to be a contributing factor to the underperformance of closed-end funds as an asset class over the sample period.

Panel B of Table 3 estimates the probability of a short squeeze in closed-end funds. The estimating equation is similar to the common stock model presented in Equation (9) with three changes. First, rather than a fixed percentage return, the dependent variable is scaled by the standard deviation of the funds' returns. In our model, a squeeze is assumed to occur if a daily return in the short interest month is positive and larger than three standard deviations. In this sense, the model incorporates fund specific risk in a VAR like setting common to financial institutions risk management applications. Secondly, three month abnormal returns as a measure of institutional demand are dropped from the regression and replaced by premium (discount): the percentage difference between the fund price and the net asset value.[10] Many closed-end fund short positions are attempts to capture returns associated with positive deviations from fund net asset value. Hence, fund premiums are a better proxy than momentum for institutional demand in this asset class. Finally, no closed-end funds were listed by CRSP as S&P 500 constituent firms, so this variable is dropped from the analysis.

Results from estimation of the squeeze model show that short interest is positive and significantly related to the likelihood of a squeeze-like event. Squeezes are also significantly positively related to last month's trading volume and the fund premium and negatively related to firm size. Squeeze events are positively associated with institutional ownership, although the coefficient estimate is not significant at conventional levels. The explanatory power of this regression is weaker than the common stock regression and this difference reflects the different dependent variable. Estimation of some threshold raw return as a squeeze proxy provides consistently higher R-squared's for both common stocks and closed-end funds. However, we also wanted to examine a regression that controlled for asset-specific return volatility and it remains an empirical question whether squeeze probabilities estimated from the VAR model predict abnormal returns. It is this question we turn to next.

The squeeze probabilities presented in panel C of Table 3 show that we have estimated what is approximately a 95 percent VAR event with our positive $3\sigma$ event, which is somewhat higher than what we might expect if closed-end fund monthly returns were normally distributed, but a common risk cutoff in the VAR literature. Thus, closed-end fund returns exhibit the leptokurtic distribution commonly-found in stock returns. Funds are sorted into ten portfolios ranging from low squeeze probability (estimated probability = 3.87 percent) to high probability (estimated probability = 9.95 percent) and abnormal returns are calculated as both calendar time abnormal returns using the Fama and French (1993) 3 factor model as the benchmark (Column 3) and as market-adjusted abnormal returns (Column 4). For comparison purposes 3 factor model abnormal returns for 10 short interest portfolios are also presented in Column 5.

[10] Premium and discount information is obtained from Lipper.

There are two notable results in Panel C. The first is that high short interest portfolios significantly underperform. Closed-end funds with high short interest have significantly negative returns and abnormal returns compared to the low-short funds. The highest short interest portfolio has a significant negative alpha of 0.96 percent per month, while the lowest short interest portfolios have insignificant abnormal returns of 0.07 percent per month. Thus, closed-end funds exhibit the same short interest-abnormal return relation as do common stocks. Secondly, the squeeze probability model again is more efficient at sorting stocks into portfolios than short interest alone. The highest squeeze probability has a significant 3 factor alpha of -1.36 percent per month. We conclude that closed-end funds also exhibit squeeze risk. The abnormal returns to closed-end funds differ from the existing tests of highly-shorted assets because the funds are portfolios; where investors are unlikely to possess private information. The risk occurs because, as with common stocks there are a fixed number of shares outstanding and thus there is some probability that the short position could be forced to liquidate during a squeeze event. We next examine ETFs, an asset class similar to closed-end funds in that they represent equity portfolios, but different in the level of short squeeze risk.

## B. ETFs

The relation between ETF returns and short interest is interesting because of the unique nature of these securities. Exchange Traded Funds are trusts set up to track a particular index or, less commonly, a particular industry. Shares in the trust are in "continuous distribution" which means they can be created or redeemed at any time. [add more description]. The creation and redemption activity is reasonably active, at least in S&P 500 Spiders, (Elton, Gruber, Comer and Li, 2002), so, at times, the number of shares outstanding varies on a daily basis. ETFs are a useful vehicle to test the predictions of the short squeeze model because they usually track broad portfolios such as the S&P 500 (SPY) or the Nasdaq 100 (QQQ) thus, the possibility that certain investors possess private information about these securities is particularly low. Of course, ETF prices could react to a preponderance of optimistic or pessimistic traders, but because ETFs are often tied to indices, the arbitrage bounds on ETF prices should be relatively narrow. Investors could take advantage of ETF mispricing by trading in the underlying and the ETFs simultaneously. Premiums and discounts between closing Net Asset Values and ETF prices are reported in various ETF prospectuses. Frequency plots of ETF premiums and discounts show that variations of 1 percent are common and premiums and discounts of 4 percent are observed. However, because the arbitrage bounds are potentially narrow, I examine both ETF returns and ETF tracking error, where tracking error is defined as the intercept from month-by-month regressions of daily ETF returns on daily index returns.

$$ETFReturns_{it} = \alpha_i + \sum_{t=-1}^{t=+1} \beta_t IndexReturns_{it} + \varepsilon_{it} \tag{11}$$

where $i$ represents a particular ETF and the index it tracks and $t$ a particular day. The monthly intercept, $\alpha_i$, represents any systematic difference in a particular month between the ETF return and the Index return. Because the observed premiums and differences could be related to timing differences, particularly for non-U.S. ETFs, I include lead and lag coefficients in the regression specification. If ETF returns behave as common stock returns then the intercept should be negatively related to short interest. However, because of the continuous distribution of ETFs, they should be particularly good candidates for investors who wish to hedge the index-related component of their portfolio with a short position. The continuous distribution property of ETFs reduces short squeeze risk and thus, for ETFs the model predicts little or no relation between returns or tracking errors and the level of short interest.

Finding no relation between short interest and ETF returns is consistent with the short squeeze model because the continuous distribution of ETF shares eliminates most of the short-squeeze risk. However, it is also possible that because there is no significant private information trading on these portfolios, the predictions of the Miller (1977) and Diamond and Verrecchia (1987) do not hold for ETFs. Fortunately, closed-end funds are portfolios, many of which have similar holdings as ETFs, and thus investors are less unlikely to possess private information about closed-end fund returns. However, new shares of closed-end funds must be offered through an SEC filing. Thus, unlike ETFs, investors in closed-end funds face short-squeeze risk.

## C. Data

The three empirical tests in the sample use data on short selling activity, shares outstanding and security returns. I obtain data on ETF, closed-end fund and common stock returns and the value-weighted market index return from the CRSP daily files. The ETFs in the sample track indices.

Data on the levels of these indices comes from Datastream and the Morgan Stanley Capital Index website. Short interest data for ETFs is obtained from the American Stock Exchange and from Factset if the data is not available from the AMEX. Closed-end fund and common stock short interest data is obtained from the New York Stock Exchange.

The first set of empirical tests in the paper investigate whether ETF tracking error is related to short interest. Table 4 lists the 47 index-linked ETFs in the sample and the first date of available short sale data. S&P depository receipts (SPY) began trading in January 1993, but few other index-linked ETFs were introduced before August 1996, when Morgan Stanley introduced a number of country-specific index-linked ETFs. Because I intend to conduct cross-sectional analysis of short interest affects on returns and tracking errors, the sample period begins in January of 1997; the first calendar year after the introduction of the Morgan Stanley ETFs. The sample period continues through December of 2001. As ETFs increased in popularity more index-tracking ETFs were introduced.[11]

Table 4 also presents average monthly tracking errors for the ETFs in the sample. For each ETF and short interest month, I run an OLS regression of daily ETF returns against their associated daily index returns, lagged index returns and lead index returns. The coefficient on the same day index return is always the most important in predicting ETF returns, but the leads and lagged coefficients are often significant. Time-series average intercepts, $\alpha' s$, and $R^{2\prime} s$ are presented for each ETF. Popular ETFs on widely followed indices such as Spiders and Diamonds (Dow Jones Industrial Average) track their indices very closely, with $R^{2\prime} s$ of over 90 percent. However, many of the other ETFs less closely match their indices with $R^{2\prime} s$ as low as 41 percent for Morgan Stanley's Austrian country-linked ETF. Each ETFs time-series average tracking error, $\alpha$, is usually quite close to zero and never statistically significant.

Average ETF tracking error is expected to be zero because arbitrage ties the underlying value of the ETF to its index.[12] However, with costly arbitrage, the returns between ETFs and their indices

[11] One popular class of ETFs, Merrill Lynch's HOLDRS, are excluded from the analysis. HOLDRS track specific industries, but are not associated with an index available on Datastream. An example of a HOLDR is RBK, an ETF that tracks 20 stocks in the regional banking industry. HOLDRS are excluded because without index data, it is not possible to calculate tracking errors. I identified 19 HOLDRS, most of which were introduced in 2000 or 2001. Datastream index data for 10 other ETFs, that track the various Dow Jones sector indices, is incomplete or missing, so these 10 ETFs are excluded. Five other ETFs (OEF, IOO, IYJ, ELG and DSV) did not have short interest data available on AMEX or Factset.

[12] Some evidence on the magnitude of ETF tracking error is found in Hasbrouck (2002) who examines the intraday basis between ETFs and futures on the same indices.

have scope to diverge. Although average ETF tracking error is close to zero, when short interest is unusually high in a particular month, then, in that month, the short-squeeze risk in the ETF is higher than normal. In any particular month, the risk associated with highly-shorted ETFs could result in systematic differences in tracking errors. Alternatively, the continuous distribution of ETF shares could mitigate any short-squeeze risk and eliminate any relation between short interest and ETF tracking errors or returns. The next section examines this empirical question.

### D. Are Exchange Traded Fund returns related to short activity?

Panel A of Table 5 presents summary information on index-linked ETF returns and short interest. The short interest in ETFs is astounding. The average short interest is 41.5% and the maximum is over 3100 percent! The fact that there are more shares shorted than exist outstanding is due to the continuous distribution property of ETFs. However, it is also unlikely that CRSP reported shares outstanding for this variable is accurate.[13] A more reliable indicator of the level of short interest in ETFs can be observed in the short interest ratios of these securities. [Define short interest ratio here.] Short interest ratios are more reliable indicators of short activity for ETFs because the average daily volume data is accurate while shares outstanding data is suspect. The short interest ratio is calculated as the number of shares short divided by the average daily volume over the last three months. ETF short interest ratios are particularly high, averaging 11.1 with a maximum of 750. Such a high short interest ratio, by itself, is evidence that ETFs have different short sale properties than common stocks. The short squeeze risk on ETFs must be minimal else traders would not short the security so aggressively. Because ETFs are in continuous distribution and can be created or deleted as needed, they appear to have little or no short squeeze risk and thus have become extremely popular tools for shorting activity. Thus, under Proposition 1, there should be no significant relation between ETF short interest and tracking errors or abnormal returns. Alternatively, if ETF returns behave like common stock returns, then highly-shorted ETFs should have negative tracking errors or negative abnormal returns in the short interest month following the short announcement.

[13] However, a short interest that is greater than the number of shares outstanding is not unique to ETFs. Fisher (2002) reports that the short position of the on-the-run Treasury bond is often greater than the size of the bond offering. Also, neither CRSP, Bloomberg, nor AMEX appear to have reliable data on ETF shares outstanding.

Panels B and C of Table 5 examine whether the tracking error in a short interest month is related to the level of ETF short interest. Tracking error is defined as the intercept (alpha) from Equation (9). Short activity is measured by: (i) total number of shares short (Short), (ii) the percentage of shares short (Short interest) using CRSP data on shares outstanding as the denominator or (iii) the short interest ratio. ETFs are ranked into deciles for each measure of short activity and the average tracking errors for each decile are presented in Panel B. There is no consistent relation between short activity and tracking error for ETFs. Tracking error is significantly negative for decile 5 of short interest ratio rank and significantly positive for decile 6 of the short interest rank.

Panel C of Table 5 presents the results of regressions of tracking error on each of the three measures of short activity. These tests find no significant relation between monthly tracking errors and short activity. These results are consistent with the hypothesis that no significant relation exists between short interest and ETF tracking errors because ETFs have minimal short squeeze risk.

Table 5 examines tracking error because it captures potential ETF mispricing. However, for completeness, Table 6 examines the relation between ETF returns, abnormal returns and short activity. ETF abnormal returns in a short interest month are calculated as the difference between cumulative daily returns to the ETF and cumulative daily returns to the CRSP value-weighted index:

$$Abnormal\ Return = [\prod_{t=1}^{T}(1 + r_{it}) - \prod_{t=1}^{T}(1 + R_{it})] - 1 \tag{12}$$

where $r_{it}$ is the daily ETF return and $R_{it}$ is the daily CRSP value-weighted index return.

Mean monthly returns and abnormal returns are calculated for each decile for all three short activity measures. Panel A presents the average abnormal return over the short interest month for each decile for all three measures of short activity. Panel B present the same information for average returns. There is no discernible negative relation between ETF returns and short activity. Abnormal returns are generally insignificant except for positive monthly abnormal return of 0.47% for short interest decile 6, and 0.10% for short decile 10.[14] Likewise, there is no apparent pattern between ETF returns and short interest. Generally, returns in the highest deciles tend to be

[14] The significance level for such a small average abnormal return is explained by the fact that the ETFs in this decile tend to be Spiders and other ETFs that closely track the CRSP value-weighted index. Thus, the standard errors of the abnormal returns in this decile tend to be small.

greater in magnitude than returns to the smaller deciles, but the returns in the high deciles are not uniformly negative, nor do ETF returns show a monotonic decline in the level of short activity.

Short interest is not significantly related to either ETF tracking error or ETF returns. This finding could be because the continuous distribution of ETFs minimizes the risk of a short squeeze or it could be because investors have no private information on the future returns of these portfolios. The ETF results are interesting when contrasted with the closed-end fund results. Many of the ETFs mimic country indices which are highly correlated with the country-specific closed-end funds in the sample. Yet, short-squeeze risk does not seem to affect ETF returns because of the minimal short squeeze risk in ETFs. Closed-end funds are also diversified portfolios, but in contrast to ETFs, closed-end funds are not continuously distributed and could face significant short squeeze risk. Only in closed-end funds, where the possibility of a short squeeze exists, do highly-shorted portfolios exhibit negative abnormal returns.

## V. Conclusion

Unlike the long position, investors holding short equity positions face the liquidity risk of a short squeeze. Even if the risk of an actual squeeze is low, a non-zero probability of a short squeeze can affect security returns. We model short-squeeze risk as a peso-problem. The model's predictions are consistent with the empirical observation that returns are lower only for portfolios with the highest levels of short interest. For most stocks, short interest is small, the probability of a squeeze is minimal and there is no short squeeze effect on returns. However, when the probability of a short squeeze is non-zero, abnormal returns benchmarked against a model that does not control for short-squeeze risk will be negative.

The empirical results presented confirm the model's predictions. Returns of traded portfolios, where private information is likely to be less important determinants of future returns, are only related to short interest when the risk of a short squeeze exists. Exchange Traded Funds' returns are not related to short interest because the unique nature of these securities reduces the short-squeeze risk to irrelevance. However, closed-end funds, many of which have similar holdings as ETFs, have returns that are negatively related to short interest. We also find that short interest is positively related to the probability of a large positive return for both closed-end funds and common stocks and that the probability of a squeeze produces a wider spread of returns across portfolios than short interest alone. We conclude that short-squeeze risk is a complementary explanation to the specialness hypothesis of Duffie, Garleanu and Pedersen (2002). Thus, the paper's theory is intended to enhance the existing theoretical and empirical work on short selling.

Dechow, Hutton, Meulbroek and Sloan (2001) find that short positions tend to be high when fundamental ratios such as book-to-market are low. The authors ask the question whether short sellers are inadvertently loading up on unidentified risk factors such as the Fama and French (1992) book-to-market factor. To answer this question they survey sophisticated short sellers and conclude that short sellers use fundamental information to exploit mispriced securities and therefore it is unlikely that these sophisticated short sellers are inadvertently loading up on risk factors such as book-to-market. However, because the low book-to-market portfolio is heavily shorted, the book-to-market factor may be loading up on short squeeze risk. In fact, this argument will hold for any factor that relies on a long-short portfolios. If the long portfolio of any factor has a significantly different short interest than the factor's short position, the factor contains short squeeze risk that could explain part of the returns to the factor. Investigating the influence of short interest on factor portfolios is an interesting avenue for future research.

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**Table 1**
**A short squeeze model**

Short interest is defined as the number of shares shorted divided by the CRSP number of shares outstanding on the short interest announcement date. Monthly return is the return over a short interest month which is defined as the trading days between NYSE public announcements of monthly short interest.

*Panel A. Summary statistics*

| | Short interest > 0 | | Short interest = 0 | |
|---|---|---|---|---|
| Variable | Mean | Std. deviation | Mean | Std. deviation |
| Short interest | 1.57% | 2.80% | 0 | n.a. |
| Volume (000's) | 245.1 | 575.9 | 450.7 | 1,524. |
| Δ Short interest | 0.02% | 1.01% | -0.05% | 0.62% |
| Size ($000's) | 3,267 | 12,664 | 3,866 | 18,629 |
| Institutional Ownership | 46.50% | 21.6% | 45.9% | 22.5% |
| 3 month return | 3.08% | 21.8% | 3.99% | 25.8% |
| S&P 500 | 20.5% | 40.3% | 14.3% | 35.0% |
| Monthly abnormal return | -0.02% | 12.2% | 0.89% | 15.4% |
| Number of observations | 208,463 | | 63,826 | |

*Panel B. Predicting the probability of a short squeeze event in the upcoming month.*

| Independent Variables | Probability of a 20% return |
|---|---|
| Intercept | -1.38<br>(0.001) |
| Short interest | 0.03<br>(0.001) |
| Volume (000's) | 0.0003<br>(0.001) |
| Δ Short interest | -0.02<br>(0.032) |
| Size | -0.0001<br>(0.001) |
| Institutional Ownership | -1.86<br>(0.001) |
| 3 month return | 0.09<br>(0.002) |
| S&P 500 | -0.28<br>(0.001) |
| R-squared | 14.2% |

*Panel C. Abnormal returns to portfolios sorted by estimated squeeze probability.*

| Short Squeeze Portfolio | Squeeze Probability (%) | 3 Factor Model Abnormal Return (%) | Monthly Abnormal Return (%) | Corresponding short interest portfolio (%) |
|---|---|---|---|---|
| Short interest = 0 | 0.0 | | 0.89 | 0.89 |
| Short squeeze = 1 (low) | 0.02 | | 0.98 | 0.12 |
| 2 | 0.12 | | -0.13 | -0.02 |
| 3 | 0.26 | | -0.00 | -0.03 |
| 4 | 0.46 | | -0.20 | -0.07 |
| 5 | 0.71 | | -0.47 | -0.10 |
| 6 | 1.11 | | -0.57 | -0.11 |
| 7 | 1.69 | | -0.76 | -0.25 |
| 8 | 2.55 | | -1.12 | -0.38 |
| 9 | 3.93 | | -1.41 | -0.54 |
| Short squeeze = 10 (high) | 8.78 | | -2.57 | -1.13 |

*Panel D: Squeeze probability and the divergence of analysts' forecasts*

| Analyst dispersion rank | Squeeze Probability = 10 (high) | |
|---|---|---|
| | Monthly abnormal return (%) | Squeeze Probability (%) |
| Dispersion = missing | -2.31 | 9.12 |
| Dispersion = 1 (low) | -1.12 | 7.85 |
| 2 | -2.55 | 7.64 |
| 3 | -1.71 | 7.58 |
| 4 | -2.77 | 8.09 |
| Dispersion = 5 (high) | -4.26 | 9.36 |

*Panel E: Explaining returns to short interest portfolios*

T-statistics in parentheses below the coefficient estimates.

| | Short interest portfolio | | | |
|---|---|---|---|---|
| | 1=low | 2 | 3 | 4=high |
| Intercept | 0.002<br>(4.11) | 0.002<br>(0.40) | 0.001<br>(-1.14) | 0.002<br>(-1.01) |
| Squeeze Probability | -0.13<br>(-5.13) | -0.14<br>(-3.12) | -0.17<br>(-4.11) | -0.30<br>(-10.92) |
| Analysts' Dispersion | -0.000<br>(-1.39) | -0.003<br>(-2.63) | -0.003<br>(-3.35) | -0.000<br>(-1.82) |
| R-squared (%) | 0.05 | 0.06 | 0.10 | 0.52 |

**Table 2**
**Common stocks and short interest: Alternative explanations**

Panel A present the skewness and Co-skewness of stock returns in a short interest month as a function of the level of short interest. Co-skewness is calculated as in Harvey and Siddique (2000). Panel B presents average two-day (day 0 and day +1) announcement returns across short interest change deciles.

*Panel A: Skewness and co-skewness of returns*

| | Short Interest | | | |
|---|---|---|---|---|
| Skewness | <0.5% | 0.5% to 1% | 1 to 2.5% | > 2.5% |
| Univariate Skewness | 0.237 | 0.221 | 0.230 | 0.268[a] |
| Co-skewness | -0.017 | -0.007 | -0.011 | -0.017[b] |

[a] t-statistic for the difference between < 0.5% group and > 2.5% group = 5.70.
[b] t-statistic for the difference between < 0.5% group and > 2.5% group = 0.10.

*Panel B: Announcement returns and changes in short interest*

| Decile | Abnormal return (%) | Change in short interest (%) |
|---|---|---|
| 1 | 0.00 | -0.84 |
| 2 | 0.04 | -0.24 |
| 3 | 0.07 | -0.09 |
| 4 | 0.02 | -0.02 |
| 5 | -0.03 | 0.00 |
| 6 | -0.03 | 0.00 |
| 7 | 0.01 | 0.02 |
| 8 | -0.01 | 0.10 |
| 9 | -0.03 | 0.27 |
| 10 | -0.02 | 0.84 |

## Table 3
## Closed-end fund returns and short activity

The short interest ratio is calculated as the percentage of outstanding shares currently held in short positions. Data on shares short comes from the NYSE. Data on volume, market value and returns is obtained from CRSP. Lipper Analytical provided the Net Asset Value information for the calculation of closed-end fund premiums and discounts.

*Panel A. Summary statistics*

| | Short interest > 0 | | Short interest = 0 | |
|---|---|---|---|---|
| Variable | Mean | Std. deviation | Mean | Std. deviation |
| Short interest | 0.66% | 1.87% | 0 | n.a. |
| Volume (000's) | 48.4 | 73.6 | 21.7 | 50.6 |
| Δ Short interest | 0.002% | 1.01% | -0.03% | 0.19% |
| Size ($000's) | 247.9 | 353.9 | 131.5 | 132.7 |
| Institutional Ownership | 11.2% | 14.1% | 5.58% | 10.3% |
| Premium/Discount | -6.61% | 15.6% | -6.50% | 10.7% |
| Monthly abnormal return | -0.46% | 7.67% | -0.35% | 5.65% |
| Number of observations | 14,366 | | 5,513 | |

*Panel B. Predicting the probability of a short squeeze event in the upcoming month.*

| Independent Variables | Probability of a 3σ positive return |
|---|---|
| Intercept | -1.51<br>(0.01) |
| Short interest | 0.039<br>(0.01) |
| Volume (000's) | 0.00<br>(0.57) |
| Δ Short interest | -0.03<br>(0.14) |
| Size | -0.0001<br>(0.001) |
| Institutional Ownership | 0.20<br>(0.08) |
| Premium/Discount | 0.40<br>(0.01) |
| R-squared | 1.3% |

*Panel C. Abnormal returns to portfolios sorted by estimated squeeze probability.*

| Short Squeeze Portfolio | Squeeze Probability (%) | 3 Factor Model Abnormal Return (%) | Market adjusted Abnormal Return (%) | Corresponding short interest portfolio (%) |
|---|---|---|---|---|
| Short interest = 0 | 0.0 | -0.10 | -0.35 | -0.35 |
| Short squeeze = 1 (low) | 3.87 | 0.07 | -0.14 | 0.07 |
| 2 | 5.27 | 0.22 | -0.21 | -0.05 |
| 3 | 5.57 | 0.00 | -0.19 | -0.11 |
| 4 | 5.74 | -0.13 | -0.21 | -0.07 |
| 5 | 5.89 | -0.21 | -0.17 | 0.14 |
| 6 | 6.06 | -0.19 | -0.14 | -0.14 |
| 7 | 6.27 | -0.07 | -0.51 | -0.25 |
| 8 | 6.59 | -0.84 | -0.86 | -0.54 |
| 9 | 7.21 | -0.54 | -0.38 | -0.87 |
| Short squeeze = 10 (high) | 9.95 | -1.36 | -1.50 | -0.96 |

## Table 4 Index-tracking Exchange Traded Funds

MSCI is an abbreviation for Morgan Stanley Capital Index, TSX for Toronto Stock Exchange. Average tracking error is also presented for each ETF. Tracking error is defined as the intercept from a regression of:

$$\text{ETF Returns}_{\text{it}} = \alpha_{\text{i}} + \sum_{t=-1}^{t=+1} \beta_t \text{ Index Returns}_{\text{it}+\varepsilon_{\text{it}}}$$

where i is a particular ETF and t is a return month defined as the trading days between NYSE public announcements of monthly short interest.

| Ticker | Index | Short data from | Alpha | R-squared | N |
|---|---|---|---|---|---|
| DGT | Dow Jones Global Titans | October 2000 | -0.002 | 75.2 | 14 |
| DIA | Dow Jones Industrials | February 1998 | 0.003 | 93.9 | 47 |
| EWA | MSCI Australia | January 1997 | 0.016 | 44.5 | 59 |
| EWC | MSCI Canada | January 1997 | 0.009 | 49.2 | 59 |
| EWD | MSCI Sweden | January 1997 | -0.002 | 65.0 | 59 |
| EWG | MSCI Germany | January 1997 | 0.008 | 58.8 | 59 |
| EWH | MSCI Hong Kong | January 1997 | 0.006 | 51.6 | 59 |
| EWI | MSCI Italy | January 1997 | 0.000 | 68.4 | 59 |
| EWJ | MSCI Japan | January 1997 | 0.003 | 53.1 | 57 |
| EWK | MSCI Belgium | January 1997 | 0.022 | 44.4 | 59 |
| EWL | MSCI Switzerland | January 1997 | -0.003 | 47.8 | 59 |
| EWM | MSCI Malaysia | January 1997 | -0.045 | 45.0 | 58 |
| EWN | MSCI Netherlands | January 1997 | 0.000 | 60.1 | 59 |
| EWO | MSCI Austria | January 1997 | 0.047 | 41.2 | 57 |
| EWP | MSCI Spain | January 1997 | 0.024 | 64.8 | 59 |
| EWQ | MSCI France | January 1997 | 0.002 | 63.1 | 59 |
| EWS | MSCI Singapore | January 1997 | -0.024 | 44.4 | 59 |
| EWT | MSCI Taiwan | July 2000 | -0.088 | 53.4 | 18 |
| EWU | MSCI United Kingdom | January 1997 | 0.015 | 54.5 | 57 |
| EWW | MSCI Mexico | January 1997 | -0.004 | 65.0 | 58 |
| EWY | MSCI South Korea | June 2000 | -0.059 | 62.1 | 20 |
| EWZ | MSCI Brazil | January 2000 | -0.064 | 59.1 | 16 |
| EZU | MSCI European Union | December 2000 | -0.027 | 69.0 | 17 |
| FEF | Fortune e50 | October 2000 | -0.001 | 75.6 | 15 |
| FFF | Fortunet 500 | November 2000 | -0.009 | 85.8 | 15 |
| IDU | Dow Jones US Utilities | September 2000 | -0.001 | 84.5 | 16 |
| IEV | S & P Europe 350 | August 2000 | 0.013 | 61.4 | 17 |
| IJH | S & P Midcap 400 | June 2000 | 0.004 | 95.7 | 19 |
| IJR | S&P Small Cap 600 | June 2000 | -0.007 | 92.6 | 19 |
| IJS | S&P Small Cap 600 Value | September 2000 | 0.060 | 78.9 | 17 |
| IJT | S&P Small Cap 600 Growth | August 2000 | -0.010 | 74.0 | 17 |
| IKC | S&P TSX 60 | November 2000 | -.016 | 56.5 | 18 |
| IVE | S&P 500_Value | June 2000 | 0.008 | 90.0 | 19 |
| IVV | S&P 500 | June 2000 | 0.001 | 94.6 | 19 |
| IVW | S&P 500 Growth | June 2000 | 0.005 | 92.2 | 19 |
| IWB | Russell 1000 | June 2000 | 0.005 | 91.8 | 19 |
| IWD | Russell 1000 Value | June 2000 | 0.007 | 90.5 | 19 |
| IWF | Russell 1000 Growth | June 2000 | -0.005 | 93.0 | 19 |
| IWM | Russell 2000 | June 2000 | -0.009 | 94.1 | 19 |
| IWN | Russell 2000 Value | August 2000 | 0.002 | 90.0 | 17 |
| IWO | Russell 2000 Growth | August 2000 | -0.006 | 93.3 | 17 |
| IWV | Russell 3000 | June 2000 | -0.001 | 91.0 | 19 |
| IWW | Russell 3000 Value | October 2000 | 0.006 | 80.4 | 17 |
| IWZ | Russell 3000 Value | August 2000 | 0.035 | 74.0 | 17 |
| MDY | S&P Midcap 400 | January 1997 | 0.001 | 90.0 | 59 |
| QQQ | Nasdaq 100 | March 1999 | 0.003 | 95.2 | 34 |
| SPY | S&P 500 | January 1997 | 0.002 | 93.3 | 59 |

**Table 5**
**ETF Tracking error and short activity**

*Short* is the number of shares shorted on the short interest announcement date. *Short interest* is defined as the number of shares shorted divided by the CRSP number of shares outstanding on the short interest announcement date. The *Short interest ratio* is defined as the number of shares shorted divided by the average daily volume over the 3 months before the announcement date. Monthly return is the return over a short interest month which is defined as the trading days between NYSE public announcements of monthly short interest. Tracking errors are estimated month for each ETF as outlined in Table 1 and aggregated by short decile.

*Panel A. Summary statistics*

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Short | 2,419,483 | 10,216,812 | 0 | 171,793,616 |
| Short interest | 41.6% | 150.4% | 0 | 316.5% |
| Short interest ratio | 11.5 | 27.0 | 0 | 750.0 |
| Monthly return | 0.02% | 3.17% | -33.5% | 53.8% |

*Panel B. Tracking error (alpha) as a function of short activity.*

| Rank | Short | Short interest | Short interest ratio |
|---|---|---|---|
| 1 | 0.005 | 0.014 | 0.031 |
| 2 | 0.006 | -0.025 | -0.013 |
| 3 | -0.013 | 0.006 | -0.016 |
| 4 | 0.009 | -0.009 | 0.012 |
| 5 | 0.006 | 0.016 | -0.030** |
| 6 | 0.000 | 0.026** | -0.002 |
| 7 | 0.013 | -0.006 | -0.006 |
| 8 | -0.012 | 0.008 | 0.016 |
| 9 | -0.004 | -0.018 | 0.006 |
| 10 | 0.002 | -0.001 | 0.018 |

**significantly different than zero at the 0.05 level.

*Panel C. OLS regression of ETF tracking error on short activity.*

| Independent variable | Intercept (t-stat) | Coefficient (t-stat) | R-squared (%) |
|---|---|---|---|
| Short | 0.0001 | $7 \times 10^{-11}$ | 0.00 |
| | (0.24) | (0.18) | |
| Short interest | 0.002 | -0.002 | 0.04 |
| | (0.48) | (-0.76) | |
| Short interest ratio | $3 \times 10^{-5}$ | 0.0001 | 0.03 |
| | (0.01) | (0.65) | |

**Table 6**
**ETF returns and short activity**

This table presents the relation between short activity and monthly returns and monthly abnormal returns for Exchange Traded Funds. Short is the total number of shares shorted, short interest is the number of shares shorted divided by the CRSP record of shares outstanding and short interest ratio is the number of shares shorted divided by the average daily volume over the previous three months. Monthly returns are calculated by compounded daily returns over the short interest month. Monthly abnormal returns are calculated from Equation (12).

*Panel A. ETF abnormal returns as a function of short activity.*

| Rank | Short (%) | Short interest (%) | Short interest ratio (%) |
|---|---|---|---|
| 1 | 0.40 | -0.30 | 0.48 |
| 2 | 0.07 | -0.27 | -0.08 |
| 3 | -0.47 | -0.02 | 0.01 |
| 4 | 0.31 | 0.02 | 0.26 |
| 5 | 0.27 | 0.30 | -0.14 |
| 6 | -0.04 | 0.47* | 0.18 |
| 7 | 0.13 | -0.06 | -0.06 |
| 8 | -0.04 | 0.15 | 0.02 |
| 9 | 0.19 | -0.19 | -0.05 |
| 10 | 0.10** | 0.22 | 0.31 |

*significantly different than zero at the 0.10 level or ** 0.05 level

Panel B. ETF monthly returns as a function of short activity.

| Rank | Short (%) | Short interest (%) | Short interest ratio (%) |
|---|---|---|---|
| 1 | -0.09 | -0.23 | 0.37 |
| 2 | 0.36 | 0.56 | 0.42 |
| 3 | -0.11 | 0.14 | -0.36 |
| 4 | 0.24 | 0.01 | 0.43 |
| 5 | -0.28 | 1.03* | 0.09 |
| 6 | 0.92 | 0.30 | 0.32 |
| 7 | -1.09* | -0.87 | -0.89 |
| 8 | -0.67 | -1.31* | -0.28 |
| 9 | -0.02 | 1.43** | -0.07 |
| 10 | 0.98 | -0.54 | 0.39 |

*significantly different than zero at the 0.10 level or **0.05 level.