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SHORT SELLING RISK

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ABSTRACT

Short sellers face unique risks, such as the risk that stock loans become expensive and the risk that stock loans are recalled. We show that these short selling risks affect prices among the cross-section of stocks. Stocks with more short selling risk have lower returns, less price efficiency, and less short selling.

JEL classification: G12, G14

Keywords: short selling risk, equity lending, market efficiency, limits to arbitrage, over-the-counter markets, short sale

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[†] Comments welcome.

"Some stocks are hard to borrow. Herbalife is not, especially, but it is *risky* to borrow…If Carl Icahn were to launch a tender offer, say, it might get a lot more expensive to short Herbalife, and the convertible trade would become considerably less fun."

Matt Levine, Former Investment Banker, Bloomberg

Short selling is a risky business. Short sellers must identify an arbitrage opportunity, borrow shares in the equity lending market, post collateral, and pay a loan fee each day until the arbitrage closes. In addition to the standard risks that many traders face, such as a margin calls and regulatory changes, short sellers also face the risk of loan recalls and the risk of changing loan fees. To date, the existing literature has viewed these risks as a static cost to short sellers, and empirical papers have shown that static impediments to short selling significantly affect asset prices and efficiency.[1] The idea in the literature is simple: if short selling is costly, short sellers may be less likely to trade; and as a result, prices may be biased or less efficient (e.g., Miller (1977), Diamond and Verrecchia (1987) and Lamont and Thaler (2003)).

In this paper, we examine the costs of short selling from a different perspective. Specifically, we show that the *dynamic* risks associated with short selling result in significant limits to arbitrage. In particular, stocks with more short selling risk have lower future returns, less price efficiency, and less short selling.

Consider two stocks – A and B – that are identical in every way except their short selling risk. Specifically, stock A and stock B have identical fundamentals and they have identical loan fees and number of shares available *today*. However, *future* loan fees and share availability are

[1] To test the impact of impediments to short selling, existing studies have examined a wide variety of potential measures of short sale constraints including regulatory action (Diether, Lee, and Werner (2009); Jones (2008); Boehmer, Jones, and Zhang (2009); Battalio and Schultz (2011)), institutional ownership (Nagel (2005); Asquith, Pathak, and Ritter (2005)), the availability of traded options (Figlewski and Webb (1993), Danielsen and Sorescu (2001)), and current loan fees (Jones and Lamont (2002); Cohen, Diether, and Malloy (2009)). However, all of these are static measures of short sale constraints (i.e., they examine how conditions *today* constrain short sellers), while we focus on the dynamics of short selling constraints (i.e., we examine how the risk of changing *future* constraints impacts short sellers).

more uncertain for stock B than for stock A. In other words, there is considerable risk that future loan fees for stock B will be higher and future shares of stock B will be unavailable for borrowing. Since higher loan fees reduce the profits from short selling and limited share availability can force short sellers to close their position before the arbitrage is complete, a short seller would prefer to short stock A because it has lower short selling risk. In this paper, we present the first evidence that uncertainty regarding future short sale constraints is a significant risk and we show that this risk affects trading and asset prices.

We define two natural measures of the ex-ante risks faced by a short seller at the time she initiates her position. The first measure, *Recall Risk*, is the variance of supply used in the lending market and is meant to capture uncertainty about supply. The second variable, *Fee Risk*, is the variance of prior lending fees and is meant to capture uncertainty about fees. These measures are motivated by a literature that finds considerable risk in lending fees and supply. In the equity loan market, the lender can recall shares, and existing evidence suggests that approximately 2% of loans are recalled in any month (D'Avolio (2002)); as a result, short sellers are subject to the constant threat of their stock loans being reduced or eliminated before the arbitrage is complete (i.e., *Recall Risk*). Furthermore, evidence suggests that loan fees can be volatile. In our sample, the time series standard deviation of annualized loan fees is 118 basis points and these loan fees can be extreme; the 99^{th} percentile of loan fees in our panel is 1,479 basis points. Thus, short sellers always face the possibility that loan fees may move against them (i.e., *Fee Risk*).

We next examine whether these short selling risks affect arbitrage. If short selling risk limits the ability of arbitrageurs to trade and correct mispricing, then it should be related to returns, market efficiency, and short selling activity. We find that it is. First, we show that both

Fee Risk and *Recall Risk* are related to future returns: a long-short portfolio formed based on *Fee Risk* earns a 9.7% annual three-factor alpha. The same portfolio based on *Recall Risk* earns 8.6% annually. Higher short selling risk appears to limit the ability of arbitrageurs to correct mispricing, and as a result, these stocks earn predictably lower future returns.[2]

We also find that both *Fee Risk* and *Recall Risk* are associated with decreased price efficiency. We examine the Hou and Moskowitz (2005) measure of price delay and find that short selling risk is associated with significantly larger price delay, even after controlling for loan market conditions at date *t* (Saffi and Sigurdsson (2011)). A one standard deviation increase in *Fee Risk* is associated with a 6.4% increase in price delay and a one standard deviation increase in *Recall Risk* is associated with a 1.7% increase in price delay. In other words, the risk of future short selling constraints is associated with decreased price efficiency today, independent of short constraints that may exist at the time a short position is initiated.

Of course, if short selling risk is truly a limit to arbitrage, then we would expect this risk to affect trading activity. To examine this, we use the announcement of a merger as an exogenous shock to short sales demand and we examine short interest in the acquiring firm over the next 20 days. Consistent with the traditional merger arbitrage strategy (Mitchell, Pulvino, and Stafford (2004)), we find that acquisition announcements are associated with a dramatic increase in short selling. We then examine short interest in two different samples of firms: one with high short selling risk and a matched sample of control firms that have low short selling risk but are similar along other dimensions. We find that arbitrageurs short significantly less when short selling risk is high. In fact, while the unconditional mean short interest following a merger announcement is 4.86% of shares outstanding, we find that short interest is 1.32 percentage

[2] This result is consistent with models of limits to arbitrage. For example, the model in Schleifer and Vishny (1997) predicts that stocks that are riskier to arbitrage will exhibit greater mispricing and have higher average returns to arbitrage.

points lower when short selling risk is high. In other words, short selling risk leads to significantly less short selling by arbitrageurs.

Finally, we turn to a wholly different source of data to investigate the implications of short selling risk. If short selling risk matters, a risk-averse short seller would be willing to pay a premium for a contract that has a guaranteed fee and a fixed term. We estimate the premium on a fixed-term contract using prices from publicly traded options, and we find that the loan fee implied from a 30-day options position also predicts lower returns, less price efficiency, and less short selling. In other words, we find that the premium short sellers are willing to pay to avoid fee risk and recall risk is related to the cross-section of returns.

Of course, it is natural to expect that the risks we describe here could be correlated with other well-known predictors of returns. For example, Ang, Hodrick, Xing, and Zhang (2006) show that high idiosyncratic volatility is associated with low future returns. We find that our results still hold after controlling for other known predictors of returns, including the bid-ask spread and idiosyncratic volatility.

Overall, our results make several contributions. Most importantly, we are the first paper to show that uncertainty regarding future short selling constraints acts as a significant limit to arbitrage; we show that higher short selling risk is associated with lower future returns, decreased price efficiency, and less short selling activity by arbitrageurs. In addition, we show that short selling risk is particularly high when there are extreme returns, indicating that short selling risk may have an adverse correlation with returns. Finally, we note that these findings may help explain existing anomalies, including the low short-interest puzzle (Lamont and Stein (2004)) and the short interest return anomaly (Boehmer, Huszar, and Jordan (2009)).

The remainder of this paper proceeds as follows: Section I briefly describes the existing literature, Section II describes the data used in this study, Section III characterizes our findings, and Section IV presents our summary and conclusion.

I. Background

Although we consider short sale constraints from a dynamic perspective, a long literature has considered these constraints from a static perspective. In this section, we briefly discuss existing work concerning short sale constraints and limits to arbitrage.

On the theoretical side, papers have argued that short sale constraints can have an economically significant effect on asset prices (e.g., Miller (1977), Harrison and Kreps (1978), Diamond and Verrecchia (1987)). In addition, empiricists have investigated multiple forms of short selling constraints, including regulatory restrictions and equity loan fees.

Several papers have analyzed the effect of short sale constraints by examining changes in the regulatory environment. For example, Diether, Lee, and Werner (2009) examine the effects of the Reg SHO pilot and find that short-selling activity increased when the uptick rule was lifted. Boehmer, Jones, and Zhang (2013) find that the U.S. short selling ban reduced market quality and liquidity. More broadly, Beber and Pagano (2013) find that worldwide short selling restrictions slowed price discovery.

The equity loan market also provides an opportunity for researchers to study the impact of short sale constraints. Using loan fees from the equity loan market, Geczy, Musto, and Reed (2002) suggest that short selling constraints have a limited impact on well-accepted arbitrage portfolios such as size, book-to-market, and momentum portfolios. Using institutional ownership as a proxy for supply in the equity loan market, Hirshleifer, Teoh, and Yu (2011) examine the relation between short sales and both the accrual and net operating asset anomalies. They find that short sellers do try to arbitrage mispricings, but short sale constraints appear to limit their ability to arbitrage them away.

Several papers abstract away from specific short sale constraints and instead use the general fact that short selling is more constrained than buying to examine possible asymmetries in long-short portfolio returns. Stambaugh, Yu, and Yuan (2011) examine a variety of anomalies and find that they tend to be more pronounced on the short side, consistent with the idea that short selling is riskier, thereby leading to less short selling by arbitrageurs. In a related paper, Stambaugh, Yu, and Yuan (2012) note that idiosyncratic volatility is negatively related to returns among underpriced stocks but is positively related to returns among overpriced stocks.

Finally, Pontiff (2006) argues that idiosyncratic risk makes arbitrage more costly, and Duan, Hu, and McLean (2010) show that for high short interest stocks, a one standard deviation increase in idiosyncratic risk is associated with a 1% decrease in future returns. The results are consistent with the hypothesis that higher idiosyncratic risk leads to less arbitrage activity by short sellers.

In this paper, we identify and examine a previously unexplored limit to arbitrage: the risk that future lending conditions might move against a short seller. We hypothesize that arbitrageurs may be less willing to short when future lending conditions are less certain. As a result, short selling risk may impact returns, price efficiency, and trading volume.

II. Data

To test the ideas discussed above, we combine daily equity lending data with data from the Center for Research in Security Prices ("CRSP"), Compustat, Thomson Reuters, SDC Platinum, and OptionMetrics, as discussed in detail below.

A. Equity Lending Data

The equity lending data used in our analyses come from Markit. The data are sourced from a variety of contributing customers including beneficial owners, hedge funds, investment banks, lending agents, and prime brokers; the market participants that contribute to this database are believed to account for the majority of all equity loans in the U.S. The initial database includes information on a variety of overseas markets and share classes. However, we exclude data on non-U.S. firms, ADRs, and ETFs, and we drop firms that have a stock price below $5 or a market capitalization below $10 million at the beginning of our sample period. The resulting database includes approximately 6.7 million observations at the firm-day level for over 4,500 U.S. equities over the 5.5-year period from July 1, 2006 through December 31, 2011.

The equity lending database includes several variables from the equity loan market. Of primary interest are shares borrowed *(Short Interest)*, the active quantity of shares available to be borrowed (*Loan Supply*), the active utilization rate (*Utilization*), the weighted average loan fee across all shares currently on loan (*Loan Fee*), the weighted average loan fee for all new loans over the past day (*New Loan Fee*), and the weighted average number of days that transactions have been open (*Loan Length*). A stock's *Loan Supply* represents the total number of shares that institutions are actively willing to lend, expressed as a percentage of shares outstanding. The *Utilization* is the quantity of shares loaned out as a percentage of *Loan Supply*. Finally, *Loan Fee*, often referred to as *specialness*, is the cost of borrowing a share in basis points per annum.

We use *Loan Fee* and *Utilization* to define two measures of short selling risk. The first measure, *Fee Risk*, is the natural log of the variance of the daily *Loan Fee* over the past 12 months. The second variable, *Recall Risk*, is the natural log of the variance of the daily *Utilization* over the past 12 months. In Table A.I of the appendix we examine the connection between these ex-ante measures of risk and ex-post realized short selling risk. We find that higher values of our ex-ante risk measures do indeed predict adverse changes in the associated variables, loan fees, and loan supply.

Panel A of Table I contains summary statistics for the equity lending database. For the typical firm, approximately 18% of outstanding shares are available to be borrowed and around 4% of shares outstanding are actually on loan at any given point. The median loan fee is only 11 basis points per annum; however, it is well known that loan fees exhibit considerable skewness, as indicated by the mean of 85 basis points and the 99^{th} percentile of 1,479 basis points. The median loan is open for approximately 65 days, highlighting the fact that short sellers often hold their position open for several months and thus are exposed to loan fee changes. Of course, the magnitude of loan fees may seem small when compared to other risks faced by arbitrageurs, especially when looking at the median loan fee of 11 bps. However, the 99th percentile of loan fees in our sample is 14.79% per year; as discussed in Kolasinski, Reed, and Ringgenberg (2013), loan fees can increase to levels that significantly decrease the profitability of nearly any trade.

In addition to the equity lending data discussed above, we use publicly available data from the SEC website to add information on failures to deliver in the equity lending market.

Failures to deliver occur when shares are not delivered by the standard three-day settlement date (often referred to as *t*+3); the SEC provides the aggregate net balance of shares that failed to be delivered on each date. The data provide information on the cumulative number of shares that have not been delivered, which does not necessarily indicate the number of new failures on any given date, as some failed positions may persist for several days. If the net balance of failed shares is below 10,000 for a given firm, the SEC does not release any information and we record a balance of zero failures for that day. As shown in Table I, failures to deliver (*Qty. Failures*) are relatively rare with a mean of 0.36% of shares outstanding and a median of 0.00% of shares outstanding.

B. Data Compilation

We match the equity lending database at the firm-day level with information from CRSP, Thomson Reuters, SDC Platinum, and Computstat. From CRSP we add closing stock prices, closing ask and bid prices, shares outstanding, volume, and daily returns, including dividend distributions. From Thomson Reuters we add institutional ownership from quarterly 13F filings. We then add merger announcement dates, SIC codes, and deal financing information from SDC Platinum. Finally, from Compustat we add the natural log of the market-to-book ratio. We define book equity as total shareholder equity minus the book value of preferred stock plus the book value of deferred taxes and investment tax credit. If total shareholder equity is missing, we calculate it as the sum of the book value of common and preferred equity. If all of these are missing, we calculate shareholder equity as total assets minus total liabilities. Panel B of Table I contains summary statistics for the CRSP and Thomson Reuters data. The mean market capitalization for the firms in our sample is $3.77 billion and the median market capitalization is $0.46 billion.

C. Option Implied Loan Fees

Finally, for all firms in our sample with exchange traded options, we download option prices from OptionMetrics. We drop those contracts with fewer than 7 days to maturity, negative bid-ask spreads, bid-ask spreads greater than 30%, zero open interest, or missing implied volatility. We use these option prices to estimate the cost of a synthetic short position with a guaranteed fee and a fixed term according to the following parity equation:

$$Call_{i,t} - \mathrm{Put}_{i,t} = S_{i,t} - K\times e^{-r(T-t)} - \mathrm{EEP} - \textstyle\sum_j D_{i,j} \times e^{-r(T-t)}, \quad (1)$$

where S is closing stock price for stock i on date t, $D_{\mathrm{i,j}}$ represents all j dividends paid on stock i from date t until expiration at date T, *Call* is the closing midpoint of call prices, *Put* is the closing midpoint of put prices, and *EEP* is the early exercise premium for puts calculated as in Barone−Adesi and Whaley (1987).

The implied loan for a short position with a guaranteed loan fee and fixed term is calculated by solving equation (1) for the implied risk-free rate, r, and then solving for the difference between the prevailing market forward risk-free interest rate at date t with maturity τ and the implied r for options expiring in month τ, i.e., $Option\ Implied\ Fee_{i,t} = r_f - r_{option,t,\tau}$. For most firms, there are multiple option contracts in existence at any point in time that vary by strike and time to maturity. We focus on options with greater than 6 days to maturity but fewer than or equal to 30 days and we calculate *Option Implied Fee* as the median implied (annualized) loan fee from all contracts with maturities of 6 to 30 days inclusive.

If short selling risk matters, a risk-averse short seller would be willing to pay a premium for a contract that has a guaranteed fee and a fixed term. In Table II, we examine the relation between our option implied loan fees and the actual loan fees from our equity lending database. As shown in Panel A, the mean actual loan fee for stocks with traded options is 57 basis points while the mean *Option Implied Fee* is 60 basis points. While the 1st percentile of our option implied loan fee is negative, this is also true for actual loan fees for these stocks as shown in Table II. Similarly, the mean, median, and 99th percentile match the empirical distribution we observe in the lending market.

In Panel B we examine the correlation between our option implied loan fee and actual loan fees. The correlation is 0.67, suggesting that equity lending market conditions strongly influence option prices. In addition, we also examine the relation between option implied loan fee and our measures of short selling risk: *Fee Risk* and *Recall Risk.* As expected, the three variables are positively correlated. In other words, option market prices reflect the willingness of short sellers to pay a premium to avoid *Fee Risk* and *Recall Risk.*[3]

III. Results

In this section, we define two natural proxies for the risks faced by short sellers and we examine whether short selling risk impacts prices and trading by arbitrageurs. We also examine the premium a risk-averse short seller would be willing to pay for a contract that has a guaranteed fee and a fixed term and we find that this premium is related to prices and trading. Overall, our findings suggest that higher short selling risk is a significant limit to arbitrage.

[3] In Table A.I of the appendix, we show that *Fee Risk* and *Option Implied Fee* both forecast future loan fee increases and we show that *Recall Risk* and *Option Implied Fee* both forecast future recalls.

A. Does Short Selling Risk Impact Arbitrageurs?

Short sellers face a number of a number of risks. In equilibrium, arbitrageurs should be compensated for the risk they take (e.g., Shleifer and Vishny (1997)). In this section, we begin by showing that high short selling risk is associated with future returns. We then show that high short selling risk is associated with decreased price efficiency and less short selling by arbitrageurs.

A.1. Short Selling Risk and Future Returns

To start, we form simple portfolios formed by conditioning on our risk measures. Specifically, each month we form portfolios by first sorting firms into quintiles using the previous month's short selling risk. These equal-weighted portfolios are then held for one calendar month and the exercise is repeated.

Figure 1 shows a strong relation between short selling risk and future returns. In particular, stocks in the low short-risk quintile earn monthly returns of 0.75% to 0.93% per month, and stocks in the high short-risk quintile earn monthly returns of between 0.00% and 0.10% per month. The long-short portfolio formed by buying stocks with low short risk and shorting stocks with high short risk earns 0.65% to 0.93% per month. Overall, Figure 1 shows a close connection between short selling risk and future returns.

Of course, a key concern is whether our results are a form of the well-established relation between short sales and future returns. Several papers have shown that high short interest predicts low future returns (e.g., Seneca (1967); Figlewski (1981); Senchack and Starks (1993); Boehmer, Huszar, and Jordan (2009); Rapach, Ringgenberg, and Zhou (2014)).

To address this issue, we first sort by short selling risk, and then we sort on short interest. The mean returns to these portfolios are shown in Table III, which expands upon the results in Figure 1. In Panel A, the conditioning variable is the previous month's *Fee Risk* (the natural log of the variance of firm *i*'s loan fees over the preceding 12 months). The first column shows mean portfolio returns to a strategy that goes long firms with *Fee Risk* in the lowest quintile and short firms with *Fee Risk* in the highest quintile. As shown in column 1 (*All*), the long-short portfolio earns a mean monthly return of 0.93%, which is statistically significant at the 1% level. In the remaining columns of Table III, Panel A, we show the returns for a strategy that first sorts on *Fee Risk* and then sorts on short interest. Interestingly, a strategy that buys stocks with low *Fee Risk* and shorts stocks with high *Fee Risk* earns positive returns in each of the five short interest quintiles, although not surprisingly the results are not statistically significant in the first quintile where short interest is extremely low. The last column of Table III, Panel A displays the well-known relation between short interest and future returns; in each row of the last column it is clear that a strategy that buys stocks with low short interest and shorts stocks with high short interest earns positive returns. However, our results also highlight a new finding: the relation between short interest and future returns is strongest when short selling risk is high.

Similarly, in Panel B we examine the relation between *Recall Risk* (the natural log of the variance of firm *i*'s supply utilization over the preceding 12 months) and future returns. Once again, the first column (*All*), shows mean portfolio returns for a strategy that goes long firms with *Recall Risk* in the lowest quintile and short firms with *Recall Risk* in the highest quintile. The positive and statistically significant mean return of 0.65% suggests that firms with high *Recall Risk* earn significantly lower future returns than firms with low *Recall Risk*. The results are statistically significant in quintiles two and five, and positive but insignificant in the others.

Overall this indicates that that *Recall Risk* has a contribution to returns independent of short interest.

Finally, in Panel C we examine the relation between our *Option Implied Fee* measure (the implied fee on a fixed term option contract) and future returns. Consistent with the results above, we find a positive and statistically significant mean return of 0.71% for a strategy that goes long firms with *Option Implied Fee* in the lowest quintile and short firms with *Option Implied Fee* in the highest quintile. Once again we find that even after conditioning on the level of short interest, all of the portfolios earn positive returns except for the first quintile. Overall, we find that *Option Implied Fee* has an independent influence on future returns. Taken together, Panels A, B, and C indicate that arbitrageurs are being compensated for the risk they take on their short positions.

While the results in Table III suggest that short selling risk significantly impacts prices, it is possible that our portfolio sorts inadvertently sort on other common risk factors. Table IV repeats the portfolio exercise with Fama and French (1993) three factor alphas.[4] In all three panels the results confirm the findings in Table III. Long-short portfolios formed by conditioning on our short selling risk measures earn three-factor alphas ranging from 0.72% to 0.81%. We also the find that the results generally remain significant after conditioning on the level of short interest. Moreover, in Panels A and C we again find that the well-known negative relation between short interest and future returns is strongest when short selling risk is high. In other words, Table IV, as with Table III, is consistent with models of limits to arbitrage; we find that the returns to short selling are largest when arbitrage is risky.

[4] Monthly Fama-French factors are from Kenneth French's website.

Finally, we adopt the regression approach of Boehmer, Jones, and Zhang (2008) to control for more firm characteristics.[5] In particular, we run monthly Fama-MacBeth (1973) regressions of the form:

$$Ret_{i,t+1} = \alpha + \beta_1 Short\ Interest_{i,t} + \beta_2 Short\ Selling\ Risk_{i,t} + Controls + \varepsilon_{i,t+1}, \qquad (2)$$

where the dependent variable is the buy and hold return percent over the subsequent month, excess of the one-month risk-free rate, and the independent variables include short interest, measures of short sale constraints, and control variables. *Short Interest*$_t$ is the quantity of shares borrowed as of the last day of the month for each firm, normalized by each firm's shares outstanding, *Market / Book* is the log of the market-to-book ratio from Compustat, *Market Cap* is the log of market capitalization, *Idio. Volatility* is the log of idiosyncratic volatility calculated using the monthly standard deviation of the residual from a Fama-French three-factor regression, *Bid-Ask* is the log of the closing bid-ask spread calculated as a fraction of the closing mid-point, and *Return*$_{t\text{-}1}$ is the return on each stock lagged by one month.

Our contribution is to introduce three new measures of an arbitrageur's short selling risk: *Fee Risk*, *Recall Risk*, and *Option Implied Fee*. The results are shown in Table V with standard errors shown below the parameter estimates in italics calculated using Newey-West (1987) standard errors with three lags.[6] In all models, the coefficient on *Short Interest* is consistent with Boehmer, Jones, and Zhang (2008); we find that short sales activity, as measured by *Short Interest*, is negative and statistically significant. In other words, high levels of short selling are associated with future price decreases.

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[5] While we follow a similar approach to Boehmer, Jones, and Zhang (2008), our specification includes several differences. First, we use a different sample period then Boehmer, Jones, and Zhang (2008) and we examine a different set of firms (we examine the entire CRSP universe of equities while they focus on NYSE firms). Moreover, we use a measure of *Short Interest* as an independent variable, while they use *Short Volume*.

[6] Per Greene (2002) we set the lag length = $T^{\frac{1}{4}} = 66^{\frac{1}{4}} \approx 3$; however, the results are robust to alternative lag choices.

In models (1) and (2) we add our first proxy of short selling risk, *Fee Risk*. In both models the negative and statistically significant coefficient on *Fee Risk* is consistent with the hypothesis that short selling risk is a significant limit to arbitrage. In particular, we find in model (1) that a one standard deviation increase in *Fee Risk* is associated with a 33 basis point decrease in future monthly returns (a decrease of approximately 3.9% per year). In other words, on average, the returns to short selling are larger in the presence of greater short selling risk.

In models (3) and (4) we add our second proxy for short selling risk, *Recall Risk*. Again, the negative and statistically significant coefficient on *Recall Risk* in model (3) is consistent with the hypothesis that short selling risk acts as a significant limit to arbitrage. A one standard deviation increase in *Recall Risk* is associated with a 39 basis point decrease in future monthly returns (a decrease of approximately 4.7% per year).

Finally, in models (5) and (6) we include *Option Implied Fee*, our measure of the price a short seller would be willing to pay to avoid *Fee Risk* and *Recall Risk*. In both models, the results are consistent with the results discussed above: higher *Option Implied Fee* is associated with significantly lower future returns. In model (6), we include the level of the actual *Loan Fee* so that our *Option Implied Fee* variable measures the *premium* short sellers would be willing to pay to avoid short selling risk. We find that a one standard deviation increase in *Option Implied Fee* is associated with a 16 basis point decrease in future monthly returns (a decrease of approximately 1.88% per year).

Overall, the findings in Tables III through V suggest that higher short selling risk limits the ability of arbitrageurs to correct mispricing; as a result, stocks with high short selling risk earn predictably lower future return. Moreover, it is worth noting that we control for the current loan fee in models (2), (4), and (6). In other words, our results show that the risk of future short selling constraints impacts returns even after controlling for current short sale constraints.

This evidence also sheds light on an unresolved puzzle. Several papers have shown that high short interest predicts low future returns (Seneca (1967); Figlewski (1981); Senchack and Starks (1993); Asquith, Pathak, and Ritter (2005); Boehmer, Huszar, and Jordan (2009); Rapach, Ringgenberg, and Zhou, (2014)), and thus it is puzzling that publicly available short interest data continue to have return predictability. Our results show that this puzzle is particularly strong among stocks with high short selling risk; Table III, Panel A shows that a low minus high short interest portfolio earns 0.41% monthly among low short selling risk stocks, but 1.16% monthly among high short selling risk stocks. Although the existing literature has been unable to fully explain the puzzle with static short selling constraints (e.g., Cohen, Diether, and Malloy (2009)), our paper suggests that *dynamic* constraints (i.e., short selling risk) may help explain more of the puzzle. In other words, short sellers continue to earn abnormal returns, in part, because short selling is risky.

A.2. Short Selling Risk and Price Efficiency

Of course, if short selling risk is a limit to arbitrage it may also decrease price efficiency. In this section, we use our proxies for short selling risk to test whether more short selling risk is associated with less price efficiency. We first estimate the Hou and Moskowitz (2005) measures of price efficiency by regressing the weekly returns of stock *i* on the current value-weighted market return and four lags of the value-weighted market return. Intuitively, the coefficients on lagged market returns are a measure of price delay; if the return on stock *i* instantaneously reflects all available information, then the lagged returns should have little explanatory power. Specifically, for each stock *i* and year *y*, we estimate the following regression:

$$ret_{i,t} = \alpha + \beta_1^{i,y} r_{m,t} + (\sum_{j=1}^{4} \delta_j^{i,y} r_{m,t-j}) + \varepsilon_{i,t}, \tag{3}$$

where $ret_{i,t}$ is the return on stock *i* in week *t* and $ret_{m,t}$ is the value-weighted market return from CRSP in week *t*. We then calculate two measures of price delay, labeled D1 and D2, as follows:

$$D1_{i,y} = 1 - \frac{R^2_{[\delta_1=\delta_2=\delta_3=\delta_4=0]}}{R^2} \tag{4}$$

where the denominator is the unconstrained R^2 and the numerator is the R^2 from a regression where the coefficients on all lagged market returns are constrained to equal zero, and

$$D2_{i,y} = \frac{\sum_{j=1}^{4} |\delta_j^{i,y}|}{|\beta_1^{i,y}| + \sum_{j=1}^{4} |\delta_j^{i,y}|} \tag{5}$$

where β and δ are the regression coefficients shown in equation (3). We then test to see if our proxies for short selling risk are associated with increased price delay (i.e., worse price efficiency). To do this, we estimate the following panel regression, similar to Saffi and Sigurdsson (2011):

$$PriceDelay_{i,y} = \alpha + \beta_1 ShortSellingRisk + \beta_2 LoanFee + \beta_3 LoanSupply + Conrols + \varepsilon_{i,y}. \tag{6}$$

The results are shown in Table VI. We include year fixed effects and all models contain robust standard errors clustered by firm. Saffi and Sigurdsson (2011) examine the relation between price efficiency and contemporaneous short sale constraints and they find that firms with high loan supply tend to have significantly better price efficiency. The statistically significant negative coefficient on *Loan Supply* confirms the findings of Saffi and Sigurdsson (2011). However, we also find that uncertainty regarding *future* short sale constraints is associated with decreased price efficiency. In models (1) and (2), the positive and statistically significant coefficient on *Fee Risk* indicates that higher uncertainty about future loan fees is associated with a significantly larger price delay for the measure calculated in equation (4). Specifically, a one standard deviation increase in *Fee Risk* is associated with a 6.4% increase in price delay relative to its unconditional mean.[7] Similarly, in models (3) and (4) we find that higher *Recall Risk* is associated with significantly larger price delay. A one standard deviation increase in *Recall Risk* is associated with a 1.7% increase in price delay relative to its unconditional mean.[8] In other words, the risk of *future* short selling constraints is associated with decreased price efficiency *today*, independent of short constraints that may exist at the time a short position is initiated.

Finally, in models (5) and (6) we examine the relation between efficiency and *Option Implied Fee*. In model (5), the positive and significant coefficient on *Option Implied Fee* implies that when arbitrageurs are willing to pay a premium to avoid short selling risk, price delay is higher. A one standard deviation increase in *Option Implied Fee* is associated with a 2.6% increase in price delay.[9] In model (6), after controlling for the actual loan fee, we find that the coefficient on *Option Implied Fee* is no longer significant. Given the high correlation between *Option Implied Fee* and the actual loan fee, this result is not surprising.

[7] The natural log of *Fee Risk* has a standard deviation of 3.25 and the Hou and Moskowitz price delay measure has an unconditional mean of 0.32; therefore, 6.4% = (0.0063 * 3.25) / 0.32.
[8] The natural log of *Recall Risk* has a standard deviation of 2.31; therefore, 1.7% = (0.0024 * 2.31) / 0.32.
[9] *Option Implied Fee* has a standard deviation of 5.26; therefore, 2.6% = (0.0016 * 5.26) / 0.32.

Taking the results in Table VI together, a general pattern emerges: higher short selling risk is associated with decreased price efficiency. Moreover, this result is especially strong for our *Fee Risk* and *Recall Risk* measures.

A.3. Short-Selling Risk and Trading by Arbitrageurs

Thus far we have found that short selling risk affects prices and we have argued that this is the case because short selling risk is a limit to arbitrage. In this section, we present direct evidence of the effect of short selling risk on an arbitrageur's behavior using one of the most common arbitrage strategies employed by short sellers: merger arbitrage.

Specifically, we use the announcement of a merger as an exogenous shock to short sales demand for the acquiring firm and we examine short interest for two groups of firms: those with high short selling risk (i.e., the treatment group) and a matched sample of firms that have low short selling risk but are similar along other dimensions. Specifically, we form a matched sample using the Mahalanobis metric with eight matching variables, including market capitalization, volume divided by shares outstanding, and the loan fee, all measured 20 days prior to the merger announcement and all transformed by the natural log. We also include indicator variables for the exchange on which a stock trades, an indicator for whether a stock has listed options, and indicators for whether the merger was a stock-only deal or a diversifying merger. We define assignment into the treatment group using *Short Selling Risk*, which is either *Fee Risk* (model (1)), *Recall Risk* (model (2)), or *Option Implied Fee* (model (3)), where *Fee Risk* is an indicator variable that equals one if the variance of loan fees over the past 12 months is in the top decile of all firms and zero otherwise, *Recall Risk* is an indicator variable that equals one if the variance of utilization over the past 12 months is in the top decile of all firms and zero otherwise, and *Option Implied Fee* is an indicator variable that equals one if the loan fee implied by option contracts is ranked in a higher decile than the actual loan fee in the month preceding the merger.

Consistent with the traditional merger arbitrage strategy, merger announcements are associated with a dramatic increase in short selling (Mitchell, Pulvino, and Stafford (2004)). However, the results in Table VII show that arbitrageurs short significantly *less* when short selling risk is high. Following merger announcements, we see a significant increase in short selling for both the treatment and control groups; however, short selling increases by significantly less in the treatment group. Specifically, the coefficient of -1.32 in model (1) suggests that short interest is 1.32 percentage points lower following the announcement of an acquisition when *Fee Risk* is high; compared to the unconditional mean short interest of 4.86% in acquirers, this represents a 27.1% decrease in trading by arbitrageurs. Similarly, in model (2) we examine *Recall Risk* and we find that short selling is 0.88 percentage points lower when *Recall Risk* is high. In addition, model (3) confirms our result using our *Option Implied Fee* measure. The coefficient estimate indicates that short selling is 0.59 percentage points lower when *Option Implied Fee* is high. In other words, the results show that short selling risk is a significant limit to merger arbitrage.

Of course, one concern with a matched sample is that unobserved characteristics could impact both short sales demand and assignment into the treated group. As with all matched samples, we caution that our results are sensitive to the included and excluded matching variables. However, to examine the robustness of our result, we calculate the Rosenbaum (2002) bounds, which measure the impact an unobserved characteristic must exert to change our inference regarding the treatment effect. The results are displayed in Panel A of Table VII where

Γ measures the maximum departure from the case with no omitted variable bias that could occur without changing our inference.

In model (1), the Γ of 1.5 suggests that an unobserved characteristic would have to increase the odds of treatment assignment by 50% to overturn our inference regarding the impact of short selling risk. Thus, while the Rosenbaum bounds suggest that our result in model (1) is not immune to the potential impact of unobserved heterogeneity, it suggests that the unobserved characteristic, if it exists, must exert a sizable impact to overturn the conclusion. Similarly, in models (2) and (3), the Γ of 1.3 and 1.2 suggest that an unobserved characteristic could overturn our findings, but it would have to increase the odds of treatment assignment by 30% and 20%, respectively.

Accordingly, we are careful to highlight that our matched sample results should be observed with some caution, but the evidence is strongly consistent with the hypothesis that short selling risk is associated with significantly lower short selling activity by arbitrageurs. Finally, we report balance statistics in Panel B. The mean absolute bias ranges between 1.2% and 2.4%, indicating that our treatment and control groups are similar along our matching dimensions.

We note that the result in Table VII relates to a long-standing question in the existing short selling literature. Several papers find it puzzling that investors do not short sell stocks in larger amounts (e.g., Lamont and Stein (2004) and Duarte, Lou, and Sadka (2006)). Our results here suggest that short sellers trade less when short selling risk is high. In particular, Table VII shows that short interest is 1.32 percentage points lower (approximately 30%) among acquirer stocks when short selling risk is high. This suggests that short selling risk may help explain the puzzling lack of short selling found in the literature.

B. Noise Trader Risk and Short Selling Risk

In the preceding subsections, we documented and examined several unique risks faced by short sellers and we found that higher short selling risk is associated with lower future returns, less price efficiency, and less trading by arbitrageurs. In this section we explore the relationship between short selling risk and other limits to arbitrage. For example, Lamont (2012) notes that lending market conditions appear to deteriorate precisely when short sellers most want to trade, and he notes that some firms actively try to impact lending market conditions to prevent short sellers from trading. As a result, short selling risk may be related to other market conditions, and these covariances may exacerbate existing limits to arbitrage.

As a first pass, we conduct a simple analysis shown in Figures 2 and 3. We sort stocks by their past 20-day return ranking and compare their return ranking to changes in share availability and changes in loan fees. The results are striking: in Figure 2 there is a strong U-shaped pattern in loan fees, indicating that loan fees tend to increase for stocks with extreme returns. Similarly, in Figure 3 we find a strong hump-shaped pattern in loan supply, indicating that lower loan supply is associated with extreme returns. Specifically, in our sample of U.S. equities over the period July 1, 2006 through December 31, 2011, the unconditional mean loan fee is 85 basis points per annum. However, for the 2% of stocks that experienced the largest price increase over the previous 20 days, the mean loan fee is almost three times larger with a mean value of 236 basis points per annum, a movement that corresponds to nearly 40% of one standard deviation.

In fact, we find that loan fees increase significantly when past returns are in either the *highest* or the *lowest* quartile of returns. Moreover, we find that the supply of shares available to be borrowed exhibits a similar pattern. While the unconditional mean loan supply is 18% of shares outstanding, the mean loan supply is only 12% for the 2% of stocks that experienced the largest price increase over the previous 20 days, a movement that corresponds to over 40% of one standard deviation. In other words, when a short seller's position moves against her, it is also likely that it will be more difficult to borrow shares in the equity lending market.

In Table VIII, we formulate a regression specification designed to statistically test the patterns shown in Figures 2 and 3. We run an OLS panel regression of the form:

$$LendingMarketCondition_{\mathrm{i,t}} = \alpha + \beta_1 LowPastReturns_{i,t-1,t-20} + \beta_2 HighPastReturns_{i,\,t-1,t-20} + \varepsilon_{\mathrm{i,t}} \quad (7)$$

where the dependent variable, $Lending\ Market\ Condition_{\mathrm{it}}$, is either $Loan\ Fee_{i,t}$ or $Loan\ Supply_{i,t}$. The results confirm the findings: when returns are in either the lowest or the highest decile of past returns, we find that loan fees are higher and loan supply is lower. Specifically, in model (2) we find that firms in the bottom decile of past returns tend to have loan fees that are 13 basis point higher and firms that are in the top decile of past returns tend to have loan fees that are 10 basis points higher. Compared to the unconditional mean (median) loan fee of 85 bps (11 bps), these results are economically large and the latter result suggests that loan fees increase precisely when a short seller's position has moved against her. Similarly, in model (4) we find that firms in the top decile of past returns tend to have significantly lower loan supply. In fact, the statistically significant coefficient estimate of -0.7117 on $High\ Past\ Returns_i$ in model (4) suggests that loan supply levels fall when past returns are high, precisely when it is most costly for a short seller.

One potential concern with these results is that we have omitted a firm characteristic in the specification that jointly determines extreme returns and high loan fees. For example, small stocks or illiquid stocks might have high loan fees and also extreme returns. To address this issue, models (2) and (4) include firm fixed effects so that the coefficients are estimated within firm. Although the magnitude of the coefficient shrinks, the conclusion remains the same: loan fees rise when a stock's return is extremely high or extremely low and loan supply contracts precisely when a stock's return is extremely high. In other words, short selling risk is not only a limit to arbitrage on its own, but it may actually magnify other previously studied limits to arbitrage.

IV. Conclusion

Most of the short selling literature takes a static view of short selling costs: if loan fees are high or shares unavailable today, prices may be too high today. In this paper we propose a dynamic, risk-based view. Among a cross-section of approximately 4,000 U.S. stocks traded from July 2006 through December 2011, we find that long-short portfolios based on short selling risk have three-factor alphas of 70 to 80 basis points per month. Furthermore, we find that short selling risk is associated with decreased price efficiency and less short selling. Using a sample of mergers to examine short selling demand, we find 30% less short selling among acquirers with high short selling risk.

This evidence also sheds light on two puzzles in the short selling literature. Specifically, several papers have shown that high short interest predicts low future returns, and thus it is puzzling that publicly available short interest data continue to have return predictability. Our results show that this puzzle is particularly strong among stocks with high short selling risk. This finding suggests that considering dynamic constraints may explain some of the puzzle. Moreover, the literature finds it puzzling that investors do not short sell stocks in larger amounts. We find that short sellers trade less when short selling risk is high, which suggests that considering dynamic short sale constraints helps explain the low level of short selling. Taking the two puzzles together, the overall idea emerges: when short selling is risky, short sellers are less likely to trade and prices are too high.

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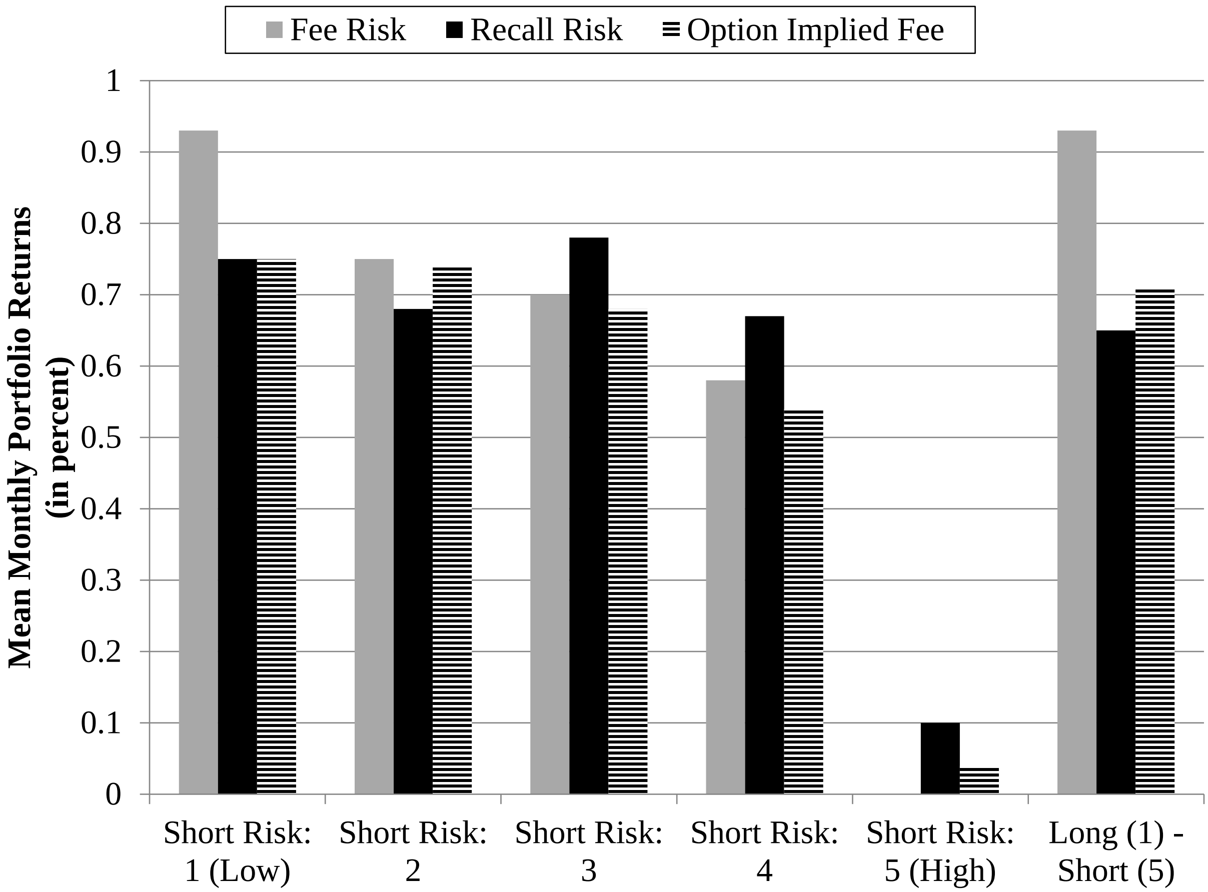

Figure 1. Mean Monthly Portfolio Returns Formed by Conditioning on Short Selling Risk. The figure displays mean monthly percentage returns for portfolios calculated over the period July 2006 through December 2011. Each month, portfolios are formed by sorting into quintiles using the previous month's short selling risk. These equal-weighted portfolios are then held for one calendar month. The solid gray bar displays returns from a portfolio formed by conditioning on the previous month's *Fee Risk*, such that firms with *Fee Risk* in the lowest (highest) quintile are assigned to the long (short) portfolio. The solid black bar displays returns from a portfolio formed by conditioning on the previous month's *Recall Risk*, such that firms with *Recall Risk* in the lowest (highest) quintile are assigned to the long (short) portfolio. The striped gray bar displays returns from a portfolio formed by conditioning on the previous month's *Option Implied Fee*, such that firms with *Option Implied Fee* in the lowest (highest) quintile are assigned to the long (short) portfolio. At the far right of the figure, we display returns from a long-short portfolio that takes a long position in the low risk portfolio and a short position in the high risk portfolio.

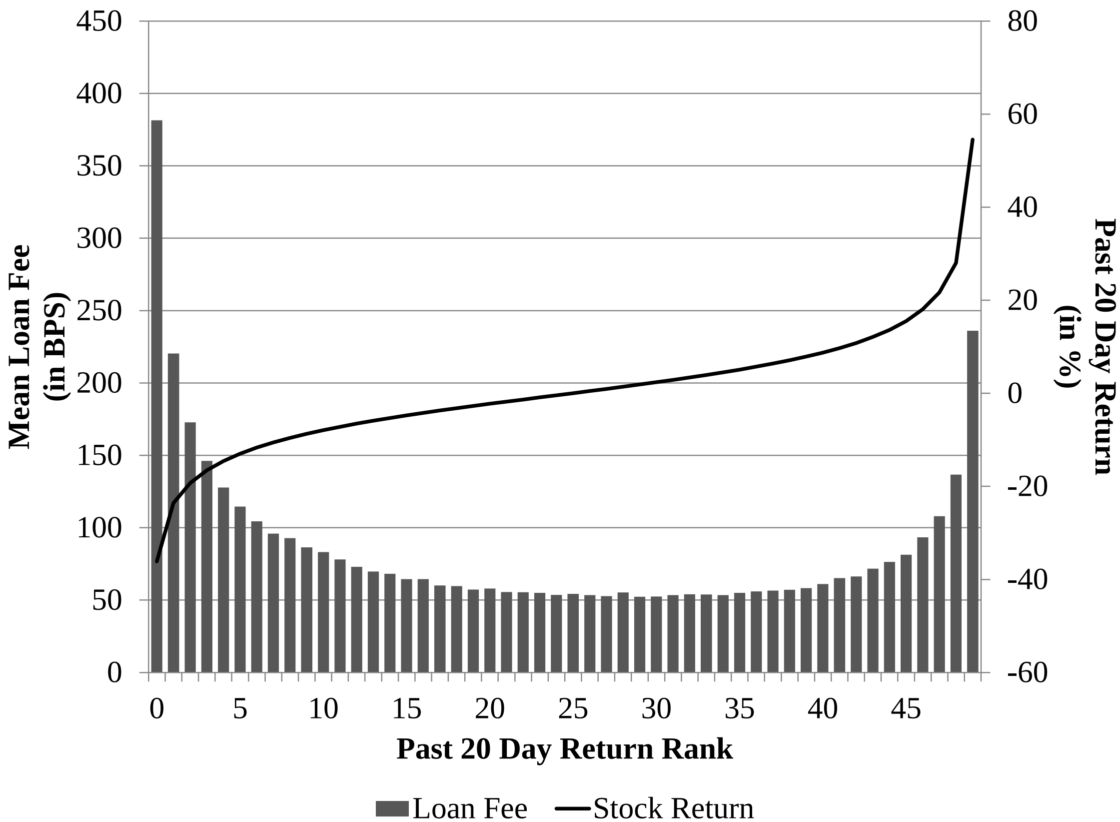

Figure 2. Mean Loan Fees Conditional on Stock Returns over the Previous 20 Days. The figure plots mean loan fees conditional on stock returns over the previous 20 days. Each day, the stock return over the previous 20 days (i.e., date *t*-1, *t*-20) is ranked into 50 equally-sized bins and then the mean loan fee or loan fee change on date *t* is calculated for each bin. In each panel the left vertical axis denotes the *Loan Fee* in basis points per annum. The loan fee measures the cost of borrowing a stock and is calculated as the difference between the rebate rate for a specific loan and the prevailing market rebate rate. The rebate rate for an equity loan is the rate at which interest on collateral is rebated back to the borrower. The right vertical axis shows the mean value of past 20-day returns in each of the 50 return bins, and the horizontal axis shows the 50 return bins.

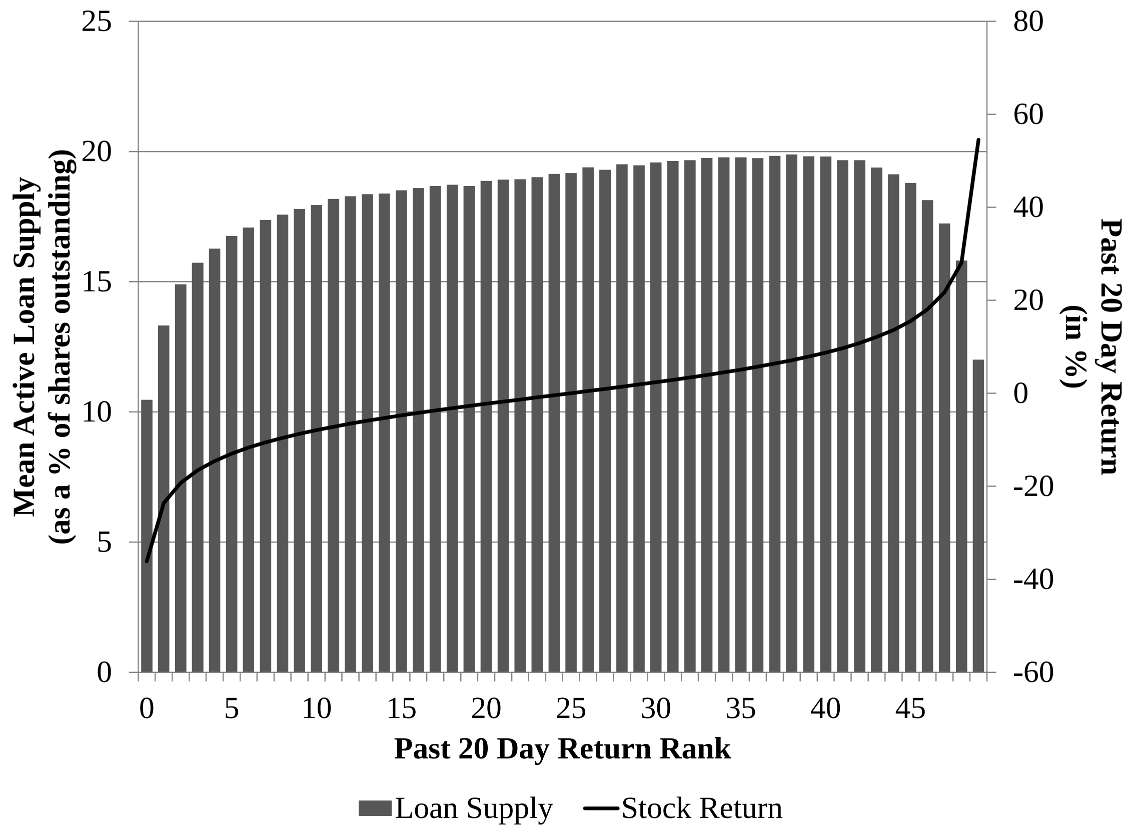

Figure 3. Mean Loan Supply Conditional on Stock Returns over the Previous 20 Days. The figure plots mean loan supply conditional on stock returns over the previous 20 days. Each day, the stock return over the previous 20 days (i.e., date *t*-1, *t*-20) is ranked into 50 equally-sized bins and then the mean loan supply or loan supply change on date *t* is calculated for each bin. In each panel the left vertical axis denotes the *Active Loan Supply* as a percentage of shares outstanding. The right vertical axis shows the mean value of past 20-day returns in each of the 50 return bins, and the horizontal axis shows the 50 return bins.

Table I
Summary Statistics

Table I shows summary statistics for the sample, which combines equity lending data from Markit with information from CRSP, Thomson Reuters, and SDC Platinum. The sample contains 6.7 million observations at the firm-day level for 4,820 U.S. equities over the period July 1, 2006 through December 31, 2011. Panel A displays the *Mean*, *Median*, *1st Percentile*, *99th Percentile*, and *Standard Deviation* values of selected equity lending variables, while Panel B displays information regarding firm characteristics using data from CRSP and Thomson Reuters. *Loan Supply* represents the total number of shares owned by institutions with lending programs, expressed as a percentage of shares outstanding. *Short Interest* is the total quantity of shares that were loaned out as a percentage of shares outstanding. *Utilization* is the quantity of shares loaned out as a percentage of shares available to be borrowed. *Loan Fee*, often referred to as *specialness*, is the cost of borrowing a share in basis points per annum. *Loan Length* is the weighted average number of days that loans have been open for each stock. *Qty. Failures* is the total quantity of shares that were not delivered as scheduled, expressed as a percentage of shares outstanding. *Market Capitalization*, *Daily Return*, and *Daily Volume as a Percentage of Shares Outstanding* are from CRSP. *Institutional Ownership* is the quantity of shares owned by institutions, as a percentage of shares outstanding, from Thomson Reuter's quarterly 13F filings.

Variable	Mean	Median	1st	99th	Standard Deviation
Panel A: Lending Market Characteristics					
Loan Supply	18.56%	19.28%	0.00%	46.42%	13.17%
Short Interest	4.43%	2.18%	0.00%	27.33%	5.99%
Utilization	13.68%	4.13%	0.00%	85.04%	20.15%
Loan Fee (all loans)	85.13 bps	11.57 bps	-12.28 bps	1,479.29 bps	372.67 bps
Loan Fee (new loans)	98.81 bps	12.79 bps	-5.74 bps	1,915.45 bps	485.83 bps
Loan Length (in days)	81.46	65.00	2.00	373.00	82.61
Qty. Failures	0.36%	0.00%	0.00%	7.27%	3.39%
Panel B: Firm Characteristics					
Market Capitalization	$3.77B	$0.46B	$0.01B	$62.81B	$16.33B
Daily Return	0.04%	0.00%	-11.07%	12.35%	4.33%
Daily Volume	0.92%	0.54%	0.00%	6.24%	1.91%
Institutional Ownership	61.13%	66.34%	0.56%	122.46%	32.10%

Table II
Implied Measures of Short Selling Risk from Option Contracts

The table shows certainty equivalent loan fees derived from Option contracts calculated as:

$$Call_{i,t} - \text{Put}_{i,t} = S_{i,t} - K \times e^{-r(T-t)} - \text{EEP} - \sum_j D_{i,j} \times e^{-r(T-t)},$$

where S is the closing stock price for stock i on date t from CRSP, $D_{i,j}$ represents all j dividends paid on stock i from date t until expiration at date T, *Call* is the closing midpoint of call prices from OptionMetrics, *Put* is the closing midpoint of put prices from OptionMetrics, and *EEP* is the early exercise premium for puts calculated as in Barone-Adesi and Whaley (1987). *Option Implied Fee* is the implied loan fee from option contracts; we use the median implied loan fee from all contracts with maturities of 6 to 30 days inclusive. The implied loan is calculated by solving the above equation for r and the loan fee is the difference between the prevailing market forward risk-free interest rate at date t with maturity τ and the implied r for options expiring in month τ, i.e., $LoanFee_{i,t} = r_f - r_{option,t,\tau}$. Panel A displays summary statistics for *Actual Loan Fee* from Data Explorers (for only those stocks that have traded options) and *Option Implied Fee*, while Panel B examines the correlations between *Actual Loan Fee*, *Option Implied Fee*, *Fee Risk*, and *Recall Risk*, where *Fee Risk* is the natural log of the variance of loan fees over the previous 12 months for each stock and *Recall Risk* is the natural log of the variance of supply utilization over the previous 12 months for each stock.

Panel A: Loan Fee Statistics

Variable	**Mean**	**Median**	**1st**	**99th**	**Standard Deviation**
Actual Loan Fee	57.38 bps	9.04 bps	-19.39 bps	1,199.70 bps	289.20 bps
Option Implied Fee	59.97 bps	7.85 bps	-851.4 bps	1,887.18 bps	526.72 bps

Panel B: Correlation Matrix

	Actual Loan Fee	Option Implied Fee	Fee Risk	Recall Risk
Actual Loan Fee	1.00			
Option Implied Fee	0.67	1.00		
Fee Risk	0.42	0.32	1.00	
Recall Risk	0.24	0.21	0.31	1.00

Table III
Monthly Mean Percentage Returns from Portfolios formed by Conditioning on Short Selling and/or Short Selling Risk

The table contains mean monthly percentage returns for portfolios calculated over the period July 2006 through December 2011. Each month, portfolios are formed by first sorting into quintiles using the previous month's short selling risk and then sorting into quintiles using the previous month's short interest. These equal-weighted portfolios are then held for one calendar month. In Panel A, the short selling risk conditioning variable is the previous month's *Fee Risk*, such that firms with *Fee Risk* in the lowest (highest) quintile are assigned to the long (short) portfolio. In Panel B, the short selling risk conditioning variable is the previous month's *Recall Risk*, such that firms with *Recall Risk* in the lowest (highest) quintile are assigned to the long (short) portfolio. In Panel C, the short selling risk conditioning variable is the previous month's *Option Implied Fee*, such that firms with *Option Implied Fee* in the lowest (highest) quintile are assigned to the long (short) portfolio. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Short Interest						***t*-test: Long - Short**
	All	**(Low) 1**	**2**	**3**	**4**	**(High) 5**	
Panel A: Fee Risk							
Fee Risk: 1 (Low)	0.93	1.05	1.56	0.79	0.58	0.64	0.41*
Fee Risk: 2	0.75	1.05	1.04	0.72	0.31	0.64	0.41*
Fee Risk: 3	0.70	0.83	0.91	0.54	0.62	0.61	0.22
Fee Risk: 4	0.58	0.94	0.90	0.41	0.31	0.33	0.61**
Fee Risk: 5 (High)	-0.00	0.71	0.30	-0.24	-0.32	-0.45	1.16***
t-test: Long - Short	0.93***	0.35	1.27***	1.03***	0.91***	1.09***	
Panel B: Recall Risk							
Recall Risk: 1 (Low)	0.75	0.45	0.93	0.85	0.71	0.81	-0.36
Recall Risk: 2	0.68	0.63	0.97	0.91	0.49	0.38	0.25
Recall Risk: 3	0.78	1.26	0.75	0.67	0.55	0.69	0.56**
Recall Risk: 4	0.67	0.90	0.95	0.57	0.56	0.40	0.50*
Recall Risk: 5 (High)	0.10	0.00	-0.21	0.38	0.42	-0.12	0.12
t-test: Long - Short	0.65***	0.45	1.13***	0.47	0.30	0.93***	
Panel C: Option Implied Fee							
Option Risk: 1 (Low)	0.75	0.64	0.97	0.74	0.65	0.68	-0.04
Option Risk: 2	0.74	0.75	0.70	0.79	0.65	0.63	0.12
Option Risk: 3	0.68	0.70	0.29	0.54	0.85	0.68	0.02
Option Risk: 4	0.54	0.77	0.51	0.59	0.60	0.07	0.70**
Option Risk: 5 (High)	0.04	0.65	0.32	-0.02	-0.22	-0.30	0.95***
t-test: Long - Short	0.71***	0.00	0.65**	0.76**	0.87**	0.99***	

Table IV
Monthly FF3 Alphas from Portfolios Formed by Conditioning on Short Selling and/or Short Selling Risk

The table contains monthly Fama-French three-factor alphas from portfolio sorts calculated over the period July 2006 through December 2011. Each month, portfolios are formed by first sorting into quintiles using the previous month's short selling risk and then sorting into quintiles using the previous month's short interest. These equal-weighted portfolios are then held for one calendar month. In Panel A, the short selling risk conditioning variable is the previous month's *Fee Risk*, such that firms with *Fee Risk* in the lowest (highest) quintile are assigned to the long (short) portfolio. In Panel B, the short selling risk conditioning variable is the previous month's *Recall Risk*, such that firms with *Recall Risk* in the lowest (highest) quintile are assigned to the long (short) portfolio. In Panel C, the short selling risk conditioning variable is the previous month's *Option Implied Fee*, such that firms with *Option Implied Fee* in the lowest (highest) quintile are assigned to the long (short) portfolio. The table displays the intercept from regressing portfolio returns, excess of the one-month risk free rate, on the contemporaneous excess market return and the SMB and HML factors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Short Interest						*t* -test:
		(Low)				(High)	Long -
	All	1	2	3	4	5	Short
Panel A: Fee Risk							
Fee Risk: 1 (Low)	0.60	0.70	1.24	0.44	0.32	0.29	0.41**
Fee Risk: 2	0.40	0.77	0.65	0.34	-0.03	0.30	0.48**
Fee Risk: 3	0.41	0.60	0.63	0.22	0.31	0.29	0.31
Fee Risk: 4	0.32	0.86	0.60	0.16	-0.02	0.03	0.83***
Fee Risk: 5 (High)	-0.22	0.68	0.07	-0.45	-0.65	-0.72	1.40***
t-test: Long - Short	0.81***	0.02	1.17***	0.89***	0.97***	1.01***	
Panel B: Recall Risk							
Recall Risk: 1 (Low)	0.50	0.32	0.86	0.51	0.35	0.45	-0.13
Recall Risk: 2	0.37	0.38	0.70	0.55	0.16	0.07	0.31
Recall Risk: 3	0.48	1.02	0.45	0.31	0.30	0.35	0.66***
Recall Risk: 4	0.38	0.73	0.62	0.24	0.24	0.07	0.66***
Recall Risk: 5 (High)	-0.22	-0.17	-0.54	0.02	0.07	-0.46	0.29
t-test: Long - Short	0.72***	0.49*	1.40***	0.50*	0.29	0.91***	
Panel C: Option Implied Fee							
Option Risk: 1 (Low)	0.27	0.32	0.51	0.19	0.19	0.32	0.00
Option Risk: 2	0.29	0.45	0.36	0.39	0.22	0.21	0.24
Option Risk: 3	0.22	0.31	-0.06	0.16	0.49	0.24	0.07
Option Risk: 4	0.02	0.34	0.03	0.11	0.17	-0.39	0.73***
Option Risk: 5 (High)	-0.48	0.21	-0.21	-0.46	-0.74	-0.57	0.78**
t-test: Long - Short	0.75***	0.11	0.72***	0.65**	0.93***	0.89***	

Table V

Cross-sectional Relation between Monthly Percentage Returns and Short Selling Risk

The table contains Fama and MacBeth (1973) regression results examining the relation between monthly returns, short sales, and short selling risk for U.S. equities over the period July 2006 through December 2011. For each model, we run 63 monthly cross-sectional regressions of the form:

$$Ret_{i,t+1} = \alpha + \beta_1 Short\ Interest_{i,t} + \beta_2 Loan\ Fee_{i,t} + \beta_3 Short\ Selling\ Risk_{i,t} + Controls + \varepsilon_{i,t+1},$$

and we take the time-series mean of the coefficients and use the standard deviation to estimate standard errors. The dependent variable (*Ret*) is the buy and hold return percent over the subsequent month, excess of the one-month risk-free rate. *Short Interest*$_{t=0}$ is the quantity of shares borrowed as of the last day of the month for each firm, normalized by each firm's shares outstanding; *Market / Book* is the log of the market-to-book ratio from Compustat; *Market Cap* is the log of market capitalization lagged by one month; *Idio. Volatility* is the log of idiosyncratic volatility calculated using the monthly standard deviation of the residual from a Fama-French three-factor regression; *Bid-Ask* is the log of the closing bid-ask spread calculated as a fraction of the closing mid-point; and *Return*$_{t-1}$ is the return on each stock lagged by one month. *Short Selling Risk* is either *Fee Risk* (models (1) and (2)), or *Recall Risk* (models (3) and (4)), or *Option Fee* (model (5) and (6)). *Fee Risk* is the natural log of the variance of loan fees over the previous 12 months for each firm. *Recall Risk* is the natural log of the variance of supply utilization over the previous 12 months for each firm. *Option Implied Fee* is the implied loan fee from option contracts with maturities between 6 and 30 days inclusive. Standard errors are shown below the parameter estimates in italics and were calculated using Newey-West (1987) standard errors with three lags. *Average* R^2 is the time-series average of the R^2 from each cross-sectional regression. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent Variable	Dependent Variable: Monthly Excess Return$_{t+1}$ (in percent)					
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.0070	0.0012	-0.0123	-0.0124	-0.0569	-0.0545
	(0.05)	*(0.05)*	*(0.05)*	*(0.05)*	*(0.04)*	*(0.04)*
Short Interest	-0.0077***	-0.0068***	-0.0060***	-0.0051***	-0.0029**	-0.0031**
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Loan Fee		-0.0013***		-0.0012***		-0.0009**
		(0.00)		*(0.00)*		*(0.00)*
Fee Risk	-0.0010***	-0.0005**				
	(0.00)	*(0.00)*				
Recall Risk			-0.0017***	-0.0016***		
			(0.00)	*(0.00)*		
Option Fee					-0.0007***	-0.0003*
					(0.00)	*(0.00)*
Market / Book	-0.0133***	-0.0133***	-0.0137***	-0.0137***	-0.0096***	-0.0106***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Market Cap	-0.0072***	-0.0070***	-0.0074***	-0.0071***	-0.0035***	-0.0035***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Idio. Volatility	0.0012	0.0015	0.0013	0.0019	-0.0009	-0.0003
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.00)*	*(0.00)*
Bid-Ask	-0.0086***	-0.0085***	-0.0095***	-0.0090***	-0.0080***	-0.0072***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Return$_t$	-0.0318***	-0.0310***	-0.0317***	-0.0322***	-0.0146	-0.0136
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*
Return$_{t-1}$	-0.0177**	-0.0175**	-0.0184**	-0.0177**	-0.0211*	-0.0262**
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*	*(0.01)*
N	180,806	178,204	183,105	178,908	96,086	85,383
Average R^2	0.059	0.061	0.059	0.061	0.069	0.074

Table VI
Price Efficiency and Short Selling Risk

The table examines the relation between Hou and Moskowitz (2005) measures of price efficiency and short selling risk for U.S. equities over the period July 1, 2006 through December 31, 2011. The dependent variable is the *D1* price delay measure from Hou and Moskowitz (2005). *Fee Risk* is the natural log of the variance of loan fees for each firm-year, *Recall Risk* is the natural log of the variance of supply utilization for each firm-year. *Option Implied Fee* is the implied loan fee from option contracts with maturities of 6 to 30 days inclusive. *Loan Fee* is the mean cost of borrowing a share in basis points per annum, divided by 100 for scale purposes; *Loan Supply* is the mean total number of shares owned by institutions that are actively available to be lent (as a fraction of shares outstanding); *Qty. Failures* is the total quantity of shares that were not delivered as scheduled; *Market Cap.* is the log of mean market capitalization for each firm-year; *Volume* is the log of mean total trading volume for each firm (as a fraction of shares outstanding); *Bid-Ask Spread* is the mean bid-ask spread; *ListedOption* is an indicator for whether a stock has listed options. All variables are annual and we include year fixed effects with robust standard errors clustered by firm shown below the estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Explanatory	**Dependent Variable: Delay Measure #1 (D1)**					
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Fee Risk	0.0063***	0.0062***				
	(0.00)	*(0.00)*				
Recall Risk			0.0024**	0.0025**		
			(0.00)	*(0.00)*		
Option Implied Fee					0.0016**	-0.0004
					(0.00)	*(0.00)*
Loan Fee		0.0002		0.0022***		0.0050***
		(0.00)		*(0.00)*		*(0.00)*
Loan Supply	-0.0016***	-0.0016***	-0.0022***	-0.0020***	-0.0016***	-0.0015***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Qty. Failures	-0.0013	-0.0014	0.0024	0.0005	0.0111***	0.0088***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Market Cap.	-0.0199***	-0.0199***	-0.0170***	-0.0174***	-0.0196***	-0.0205***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Volume	-0.0158***	-0.0158***	-0.0150***	-0.0155***	0.0066	0.0084*
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Bid-Ask Spread	0.0675***	0.0675***	0.0734***	0.0720***	0.0047	0.0027
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
ListedOption	-0.0053	-0.0054	-0.0043	-0.0055	0.0280*	0.0283*
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.02)*
N	17,102	17,102	17,220	17,177	10,036	10,034
R^2	0.376	0.376	0.380	0.378	0.177	0.179

Table VII

Impact of Short Selling Risk on Short Interest following Merger Announcements

The table examines short interest in acquiring firms following merger announcements. We form two samples, one with high short selling risk (the treatment group) and a control group formed using Mahalanobis metric matching. The matching variables include market capitalization, volume divided by shares outstanding, and the loan fee, all measured 20 days prior to the merger announcement and all transformed by the natural log. We include indicator variables for the exchange on which a stock trades (*Exchange2* and *Exchange3*); indicators for whether the merger was a stock only deal (*StockDeal*) or a diversifying merger (*Diversifying*), defined as a deal between two firms with different three digit SIC codes; and an indicator for whether a firm pays dividends (*Div. Payer*). The dependent variable is mean daily short interest (normalized by shares outstanding) over the next 20 days and the estimate shown for *Short Interest* is the average treatment effect for the treated (ATT). Treatment is defined using (1) *Fee Risk*, (2) *Recall Risk*, or (3) *Option Implied Fee*, where *Fee Risk* is an indicator variable that equals one if the variance of firm *i*'s loan fee over the preceding 250 days is in the top decile of the entire sample, *Recall Risk* is an indicator variable that equals one for firm *i* if the variance of firm *i*'s supply utilization over the preceding 250 days is in the top decile of the entire sample, and *Option Implied Fee* is an indicator variable that equals one if *Option Implied Fee* is ranked in a higher decile than the actual loan fee in the month preceding the merger. Γ measures the maximum departure from the case with no hidden bias that could occur without overturning the ATT (Rosenbaum (2002)). Panel B shows balance statistics including the mean value for treatment and control groups and the standardized bias percent for the treated sample. Robust standard errors are below the ATT in italics. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Model (1) – Fee Risk			**Model (2) – Recall Risk**			**Model (3) – Option Implied Fee**		
Panel A: Estimates									
Short Interest	-1.32***			-0.88***			-0.59**		
	(0.28)			*(0.27)*			*(0.22)*		
Γ	1.5			1.4			1.2		
N	8,167			8,167			6,522		
Panel B: Balance statistics									
Matching	**Mean**		**Treated**	**Mean**		**Treated**	**Mean**		**Treated**
Variable	**Treated**	**Control**	**Bias %**	**Treated**	**Control**	**Bias %**	**Treated**	**Control**	**Bias %**
MarketCap$_{t-20}$	0.27	0.32	-2.6	0.43	0.44	-0.6	0.84	0.90	-3.3
Volume$_{t-20}$	-13.32	-12.76	-3.0	-13.34	-12.67	-3.6	-5.22	-4.59	-4.8
Loan Fee$_{t-20}$	3.11	2.96	13.0	3.01	2.95	4.8	2.17	2.21	-3.0
Exchange 2	0.02	0.02	0.0	0.02	0.02	0.0	0.00	0.00	0.0
Exchange 3	0.52	0.52	0.0	0.51	0.51	0.1	0.43	0.43	0.1
Stock Deal	0.04	0.04	0.0	0.04	0.04	0.0	0.03	0.03	0.3
Diversifying	0.39	0.39	0.3	0.38	0.38	0.3	0.36	0.35	0.2
Div. Payer	0.65	0.65	-0.6	0.67	0.67	-0.1	0.61	0.61	0.2
Mean |Bias %|			2.4			1.2			1.5

Table VIII
Loan Market Conditions as a Function of Past 20-Day Returns

The table shows the results from an OLS panel model examining loan fees and loan supply according to the following model:

$$LendingMarketCondition_{i,t} = \alpha + \beta_1 LowPastReturns_{i,t-1,t-20} + \beta_2 HighPastReturns_{i,\,t-1,t-20} + \varepsilon_{i,t}$$

where *Lending Market Condition*$_{i,t}$ is *Loan Fees*$_{i,t}$ in models (1) and (2) and *Loan Supply*$_{i,t}$ in models (3) and (4), *Low Past Returns*$_{it}$ = 1 if firm *i* had returns in the bottom decile of all firms from date *t-1 to t-20* and = 0 otherwise, and *High Past Returns*$_{it}$ = 1 if firm *i* had returns in the top decile of all firms from date *t-1 to t-20* and = 0 otherwise. We include firm fixed effects in models (2) and (4) and month-year fixed effects in all models. Robust standard errors clustered by date are shown below the estimates in italics. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Explanatory Variable	**Dependent Variable: Loan Fee$_{i,t}$**		**Dependent Variable: Loan Supply$_{i,t}$**	
	(1)	**(2)**	**(3)**	**(4)**
Intercept	2.9073***	3.0513***	18.3234***	17.6272***
	(0.01)	*(0.01)*	*(0.17)*	*(0.17)*
Low Past Returns	0.7009***	0.1337***	-3.0116***	-0.0508***
	(0.02)	*(0.01)*	*(0.14)*	*(0.02)*
High Past Returns	0.4189***	0.0953***	-2.8617***	-0.7117***
	(0.01)	*(0.00)*	*(0.11)*	*(0.02)*
Firm Fixed Effect	*No*	*Yes*	*No*	*Yes*
Time Fixed Effect	*Yes*	*Yes*	*Yes*	*Yes*
N	4,287,629	4,287,629	4,972,250	4,972,250
Adj. R^2	0.082	0.622	0.016	0.821

Appendix for
"Short Selling Risk"

This Appendix provides additional empirical evidence to supplement the analyses provided in the text.

Table A.I
Linear Probability Model Examining the Relation between Short Selling Risk and Future Loan Market Conditions

The table shows results from a linear probability model examining the relation between Short Selling Risk and future loan market conditions. Models (1), (2), and (3) examine the likelihood that a stock will be on special next month, using a model of the form:

$$1_{i,t+1[\text{Special}]} = \alpha + \beta_1 1_{i,t[\text{Special}]} + \beta_2 Short\ Interest_{i,t} + \beta_3 Short\ Selling\ Risk_{i,t} + Controls + \varepsilon_{i,t+1}$$

and models (4), (5), and (6) examine the likelihood that loan supply for stock *i* decreases by 10% or more next month, using a model of the form:

$$1_{i,t+1[\text{Recall}]} = \alpha + \beta_1 Short\ Interest_{i,t} + \beta_2 Short\ Selling\ Risk_{i,t} + Controls + \varepsilon_{i,t+1}$$

where $1_{i,t+1[\text{Special}]}$ is an indicator variable that equals 1 if stock *i*'s loan fee exceeds 200 basis points at time *t*+1; $1_{i,t+1[\text{Recall}]}$ is an indicator variable that equals 1 if stock *i*'s loan supply decreases by 10% or more at time *t*+1; $Short\ Interest_t$ is the quantity of shares borrowed as of the last day of the month for each firm, normalized by shares outstanding; *Market Cap* is the log of market capitalization lagged by one month; and $Volume_{t-1}$ is the total trading volume for stock *i*, divided by shares outstanding, lagged by one month. *Feel Risk* (models (1) and (2)) is the natural log of the variance of loan fees over the previous 12 months for each firm. *Option Fee* (models (3) and (6)) is the implied loan fee from option contracts with 6 through 30 days to maturity. *Recall Risk* (models (4) and (5)) is the natural log of the variance of supply utilization over the previous 12 months for each firm. Standard errors are shown below the parameter estimates in italics and were calculated using standard errors clustered by firm and date. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Dependent Variable: Future Special			Dependent Variable: Future Recall		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Intercept	-0.0247***	0.0438***	0.0147	0.1085***	0.3493***	0.1439***
	(0.01)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*	*(0.03)*
$1_{[\text{Special}]}$	0.8063***	0.8044***	0.8548***			
	(0.05)	*(0.05)*	*(0.06)*			
Short Interest	0.0001***	0.0001***	0.0001***	-0.0001	-0.0000	0.0002***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Fee Risk	0.0073***	0.0067***				
	(0.00)	*(0.00)*				
Recall Risk				0.0054***	0.0039***	
				(0.00)	*(0.00)*	
Option Fee			0.0022**			0.0006*
			(0.00)			*(0.00)*
Market Cap		-0.0033***	-0.0008		-0.0128***	-0.0052***
		(0.00)	*(0.00)*		*(0.00)*	*(0.00)*
$Volume_{t-1}$		0.0012*	0.0010		0.0005	-0.0010
		(0.00)	*(0.00)*		*(0.00)*	*(0.00)*
$Volume_{t-2}$		-0.0007	-0.0011		0.0029**	0.0032*
		(0.00)	*(0.00)*		*(0.00)*	*(0.00)*
N	192,155	192,042	88,545	196,310	196,176	103,066
R^2	0.759	0.759	0.839	0.002	0.010	0.008

Table A.II
Price Efficiency and Short Selling Risk using Alternate Delay Measure (D2)

The table examines the relation between Hou and Moskowitz (2005) measures of price efficiency and short selling risk for U.S. equities over the period July 1, 2006 through December 31, 2011. The dependent variable is the *D2* price delay measure from Hou and Moskowitz (2005). *Fee Risk* is the natural log of the variance of loan fees for each firm-year. *Recall Risk* is the natural log of the variance of supply utilization for each firm-year. *Option Implied Fee* is the implied loan fee from option contracts with maturities of 6 to 30 days inclusive. *Loan Fee* is the mean cost of borrowing a share in basis points per annum, divided by 100 for scale purposes; *Loan Supply* is the mean total number of shares owned by institutions that are actively available to be lent (as a fraction of shares outstanding); *Qty. Failures* is the total quantity of shares that were not delivered as scheduled; *Market Cap.* is the log of mean market capitalization for each firm-year; *Volume* is the log of mean total trading volume for each firm (as a fraction of shares outstanding); *Bid-Ask Spread* is the mean bid-ask spread; *Listed Option* is an indicator for whether a stock has listed options. All variables are annual and we include year fixed effects with robust standard errors clustered by firm shown below the estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Explanatory	**Dependent Variable: Delay Measure #2 (D2)**					
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Fee Risk	0.0041***	0.0039***				
	(0.00)	*(0.00)*				
Recall Risk			0.0023***	0.0023***		
			(0.00)	*(0.00)*		
Option Implied Fee					0.0008*	-0.0007
					(0.00)	*(0.00)*
Loan Fee		0.0004		0.0016***		0.0038***
		(0.00)		*(0.00)*		*(0.00)*
Loan Supply	-0.0009***	-0.0009***	-0.0012***	-0.0011***	-0.0011***	-0.0010***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Qty. Failures	0.0004	0.0003	0.0024*	0.0011	0.0099***	0.0082***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Market Cap.	-0.0163***	-0.0162***	-0.0143***	-0.0146***	-0.0164***	-0.0171***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Volume	-0.0104***	-0.0105***	-0.0101***	-0.0105***	0.0041	0.0054
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Bid-Ask Spread	0.0416***	0.0416***	0.0455***	0.0445***	0.0037	0.0023
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Listed Option	-0.0026	-0.0028	-0.0020	-0.0029	0.0322**	0.0324**
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.01)*	*(0.01)*
N	17,102	17,102	17,220	17,177	10,036	10,034
R^2	0.377	0.377	0.381	0.379	0.229	0.231