Understanding Returns to Short Selling Using Option-Implied Stock Borrowing Fees☆

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Abstract

Measures of short sale constraints and short selling activity strongly predict stock returns. This apparently exploitable predictability is difficult to explain. We partially resolve this puzzle by using measures of the stock borrowing costs paid by short-sellers. We show in portfolio sorts that the returns to short selling, net of stock borrowing costs, are much smaller than the gross returns to shorting or a typical long-short strategy. Option-implied borrowing fees, which reflect option market makers’ borrowing costs and the risks of changes in those costs, are on average only slightly higher than quoted borrowing fees. This finding indicates that the risk of changes in borrowing fee does not command a substantial risk premium. Option-implied borrowing fees predict future fees and stock returns, including returns net of quoted borrowing costs. The option-implied fee drives out other return predictors in panel regressions including option-based variables and other measures of short selling activity.

\textit{JEL Classification:} G12, G13, G14

\textit{Keywords:} Short sales, stock borrowing fee, stock lending fee, equity options

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Abstract

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1. Introduction

A large literature shows that proxies for short selling activity and short sale constraints including short interest, lending fees, utilization, days to cover, and the risk of changes in stock lending fees predict the cross-section of stock returns.\textsuperscript{1} The persistence of this predictability is a puzzle. One possible explanation is that short selling is not profitable to the marginal short seller (Hong, Li, Ni, Scheinkman and Yan 2016). Alternatively, it might be that the returns to shorting are compensation for the special risks of holding short positions. One potentially important risk stems from the market practice that stock loans may be recalled at any time, forcing market participants either to cover their short positions and return the borrowed stock or else to reestablish their stock loans at a possibly much higher borrowing fee (D’Avolio 2002 and Engelberg, Reed, and Ringgenberg 2018). Focusing on a different risk, Drechsler and Drechsler (2016) argue that short-sellers have concentrated portfolios and that the abnormal returns to stocks with high stock borrowing fees reflect the compensation that short sellers require for bearing the risk of undiversified short positions. These two risks are potentially related because a diversified portfolio of short positions should attenuate the importance of a sudden change in the borrowing fee for one particular stock.

A seemingly unrelated literature shows that differences between certain option implied volatilities predict the cross-section of stock returns (Bali and Hovakimian, 2009; Cremers and Weinbaum, 2010; and Xing, Zhang, and Zhao, 2010). A common interpretation of this predictability is that demand pressure in the options market due to informed trading alters option prices and implied volatilities but is only slowly reflected in stock prices, causing the option implied volatility measures to predict returns.\textsuperscript{2} This is puzzling, because option prices are readily available to all market participants.

We present a number of results that address the returns to shorting, possible explanations for its persistence, and the finding that differences between implied volatility measures predict


\textsuperscript{2} Related research by Ofek, Richardson, and Whitelaw (2004) finds that deviations from the usual put-call parity relation predict returns, controlling for stock lending fees. They interpret the findings as consistent with a framework in which stock and options markets are segmented and equity markets are “less rational” (p. 307) so that this information is reflected in stock prices with a delay.
stock returns. First, we use portfolio sorts to show that the returns to short selling net of the costs of borrowing stocks are much smaller than the gross returns, and not significantly different from zero. This finding differs from the existing literature, which typically concludes that the net returns to shorting remain large (Geczy, Musto, and Reed, 2002; Jones and Lamont, 2002; Ofek, Richardson, and Whitelaw, 2004; Cohen, Dieter, and Malloy, 2007; and Drechsler and Drechsler, 2016). One reason why our results differ from those in the existing literature is that we use the fees paid by ultimate stock borrowers, for example hedge funds and option market makers, while most of the literature uses the fees received by the ultimate lenders. The fees paid by ultimate borrowers differ from those received by ultimate lenders due to the substantial markups charged by prime brokers.

Second, we exploit the fact that stock borrowing costs are reflected in option prices to compute option-implied borrowing fees using put-call pairs. The option-implied borrowing fees strongly predict changes in fees. This finding indicates that the implied fee is a forward looking measure of the expected borrowing fee during the remaining life of the option pair.

Third, the option-implied fee also reflects any risk premium that option market makers require for bearing the risk of borrowing fee changes. Obviously, if the borrowing fee is constant or has very low volatility, then this risk premium should be non-existent or small. However, if the borrowing fee is volatile and covaries with some measure of systematic risk, then option market makers may be compensated for bearing this risk. As a result, the average difference between the option-implied borrowing fee and the average quoted borrowing fee over the life of the option is an estimate of the risk premium for the risk of borrowing fee changes. Our results show that this risk premium is small.

Fourth, the option-implied borrowing fees we compute are excellent predictors of stock returns during the subsequent week (month). If we include the option-implied borrowing fee in predictive regressions it (and utilization) predict the cross-section of stock returns, while short interest and short fee risk do not. After we net out the costs of borrowing stock, the indicative fee also no longer negatively predicts returns but the option-implied borrowing fee still has predictive power.

Fifth, in our sample long-short strategies based on the implied volatility spread and skew exhibit significant performance gross of borrowing fees. However, after adjusting for the cost of selling short, the performance of these strategies is attenuated by more than 50% and the point
estimates are no longer statistically significant. Indeed, the relevant $t$-statistics are less than or equal to one. This result indicates that the seemingly unrelated strategies based on option prices are not exploitable after taking into account the cost of borrowing stock.

Sixth, the implied volatility spread and skew no longer predict returns once we include the option-implied borrowing fee and utilization in predictive regressions. The natural interpretation of this result is that the implied volatility spread and skew predict stock returns not because they reflect informed option market demand that has not yet been reflected in stock prices, but rather because they proxy for stock borrow costs that are typically omitted when implied volatilities are computed. Omitting stock borrowing fees when they are non-zero leads to errors in computing implied volatilities. These errors are correlated with the omitted borrowing fees.

In these analyses we use indicative fee data from Markit. This variable estimates the fees that would be paid by a hedge fund or other short seller to borrow a stock from surveys of participants on both sides of the market for stock loans. These fee data differ from those used in the existing literature. To understand how our fee data differ, one must recognize that prime brokers are important intermediaries in the market for borrowing and lending stock (see, for example, Kolasinski, Reed, and Ringgenberg, 2013), and that the fees paid by ultimate borrowers such as hedge funds and option market makers differ from the fees received by the ultimate lenders. In a typical case, a prime broker borrows from a lender, for example a mutual fund or pension fund, and lends to an ultimate borrower, for example a hedge fund or an option market maker who wants to short the stock, at a different fee. The existing literature typically uses measures of the fees received by ultimate lenders, not the fees paid by short sellers.\(^3\)

We begin our analyses by using the measures of the borrowing costs paid by short sellers to show that the returns to shorting net of stock borrowing costs are much smaller than the gross returns to that do not reflect borrowing costs. We sort stocks into decile portfolios based on two measures: indicative fees for new stock loans and a measure of the risk of fee changes. The equal-weighted gross returns to shorting the high fee (high fee risk) decile portfolio are 1.09% (1.06%) per month, and highly significant. However, returns to shorting the high fee (high fee

\(^3\) For example, the data used in D’Avolio (2002), Geczy, Musto, and Reed (2002), Jones and Lamont (2002), Ofek, Richardson, and Whitelaw (2004), and Cohen, Dieter, and Malloy (2007), Drechsler and Drechsler (2016), and Engelberg, Reed, and Ringgenberg (2018) are or appear to be measures of the fees received by lenders.
risk) portfolio net of the stock borrowing fees are only 0.22% (0.28%) per month, and thus are only about 20% (26%) as large as the gross returns, and are not significantly different from zero. The equal-weighted gross returns to the long-short decile ten-decile one portfolio based on sorting by fee (fee risk) are 1.43% (1.37%) per month, and also highly significant. In contrast, the net-of-stock-borrow-cost returns to the long-short portfolios are only 0.59% (0.62%) per month, just 41% (48%) of the magnitude of the gross returns. This performance is either not statistically significant or only marginally significant at conventional levels.

These results lead to a different conclusion about the net-of-borrow-cost returns to shorting compared to the existing literature. In the calculation closest to ours, Drechsler and Drechsler (2016, Table 2) sort stocks by fees and compute the net-of-fee returns to the long-short portfolio, but using the fees received by ultimate stock lenders. They find that taking account of fees has a considerably smaller impact on net-of-fee returns, and the net-of-fee returns to the long-short portfolio remain highly significant. Geczy, Musto, and Reed (2002), Jones and Lamont (2002, pp. 232-233), Ofek, Richardson, and Whitelaw (2004, p. 335), and Cohen, Dieter, and Malloy (2007, p. 2091) also conclude that returns to short selling remain large even after taking account of the fees received by lenders. Interestingly, our results that the net-of-borrow-cost returns to the high fee (high fee risk) portfolio are only 22 (28) basis points per month are roughly consistent with the results in Sadka (2010, Table 3) showing that hedge funds that specialize in short selling earn abnormal returns of only 34 basis points per month. Since the difference between the borrowing fee paid to sell short and the lending fee received by the ultimate lenders of the stocks is due to financial intermediation by the prime broker, our results indicate that the costs of this financial intermediation is an important component of short selling constraints.

Our results help resolve the puzzle that readily available measures of shorting activity and short sale constraints predict stock returns: net-of-borrow-cost returns are much smaller than gross returns, making the puzzle much less puzzling. The reduced magnitude of the returns makes explanations in terms of the costs of short covering (Hong Li, Ni, Scheinkman and Yan

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4 The proportionate impact of stock borrow fees on the long-short portfolios is not as large as the impact on the returns of the decile 10 portfolios because only one leg of each of the long-short portfolios is impacted by high stock borrowing fees.

5 Beneish, Lee, and Nichols (2015) appear to use the Data Explorers/Markit simple average fee variable SAF, which is a buy-side fee measure. They find that the returns to five of the nine anomalies they examine remain significant after taking account of stock borrowing costs.
2016) and short fee risk (Engelberg, Reed, and Ringgenberg 2018) more likely to be viable. However, our results do not eliminate the puzzle because panel regressions discussed below show that the option-implied borrowing fee and utilization have some ability to predict net-of-borrow-cost returns.

In our second set of results, we exploit the fact that option market makers are an important group of short sellers who are exposed to borrowing fees and bear the risk of changes in them. Option market makers often borrow and short-sell stock to delta-hedge their options positions. When stocks are hard to borrow the delta hedging by option market makers typically involves shorting stock. Through these net short hedging positions, option market makers bear the expected cost of borrowing stock as well as the risk of changes in the stock borrowing fee because they typically maintain the hedging positions even if stock the borrowing fee increases substantially. As a result, the option prices they quote must reflect their expected borrowing costs over the options’ lives plus any risk premium they require to compensate them for the risk of future fee changes. The option-implied borrowing fee, which reflects both the expected borrowing cost and the risk premium, can be computed from option prices using a version of the put-call parity relation that includes the borrow cost. We compute the option-implied fees and confirm that they predict change in indicative borrowing fees over the lives of the options used to compute the option-implied fees even after controlling for current quoted fees. Thus, the implied fee is a forward-looking measure of the borrowing costs to short sell stock.

Since the option-implied fee is a valid measure of future fees, we proceed to estimate the risk premium for bearing the risk of changes in the borrowing fee in our third set of results. The average difference between option-implied and realized indicative borrowing fees over the options’ lives provides an estimate of the risk premium for bearing the risk of borrowing fee changes. This idea is analogous to an approach in the interest rate literature in which the difference between the three-month interest rate and the average overnight rate during the three-month term is an estimate of the risk premium for bearing interest rate risk. A similar idea appears in the literature on the variance risk premium, where the variance risk premium is the average difference between so-called “model-free” option-implied variances and realized variances over the options’ lives (Carr and Wu, 2009).

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6 This is shown in Internet Appendix Table 4.
We estimate the risk premium using option prices from OptionMetrics and the estimates of stock borrow costs from Markit.\(^7\) Since the correlation between the option-implied borrowing fee and the indicative fee is 0.59 for daily observations despite the errors in estimating the implied fee stemming from wide option bid-ask spreads, these fee measures appear to be closely related. On average, the option-implied fees are similar to the realized indicative borrowing costs during the lives of the options from which the option-implied fees are computed. Indeed, the mean (median) estimate of the risk premium is only 31 (28) basis points per year. For hard to borrow stocks, the mean (median) estimate of the risk premium is 7 (20) basis points per year. The small average difference between the average option-implied and realized indicative borrowing fees means that the risks of borrowing stock are not severe enough to create an important risk premium reflected in the prices of exchange-traded options. Consistent with the small risk premium, correlations between borrowing fees and stock returns are low.

We also find that shortly before and just after the 2008 short-sale ban, estimates of the risk premia reflected in the borrowing costs of financial stocks were larger than the corresponding risk premia to borrow non-financial stocks. This time period is when option market makers were plausibly worried about the possible imposition or re-imposition of ban on shorting financial stocks.

During the early part of the sample period, our estimates of the risk premium for hard-to-borrow stocks might be impacted by the ability of option market makers to short stock and fail-to-deliver rather than borrow shares (Evans, Geczy, Musto, and Reed 2009). We find a small risk premium even after option market makers’ ability to short stock and failure-to-deliver ended. Thus, the locate and close-out requirements do not create a large stock borrowing risk premium.

The lack of a substantial risk premium embedded in option prices does not contradict the arguments in D’Avolio (2002) and Engelberg, Reed, and Ringgenberg (2018) that uncertainty about future stock borrowing fees might be an impediment to short sales. The risk of changes in the borrowing fee can be an impediment to short-selling even if it does not carry a large risk premium. However, in the sample of optionable stocks, while short fee risk predicts changes in the indicative fee, it does not predict stock returns once we include the option-implied

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\(^7\) An earlier version of this paper that circulated under the title “Is There a Risk Premium in the Stock Lending Market: Evidence from Equity Options” used synchronized intra-day stock and option quotes to compute the option-implied lending fees. The results in that version of the paper are similar to those in the current version.
fee and other variables in the predictive regressions, but the option-implied borrowing fee still predicts returns. Thus, while short fee risk predicts future fee changes and may impede arbitrage, the regression evidence indicates that its predictive power for stock returns is subsumed by the combination of the forward-looking option-implied fee that captures expected future fee changes and any risk premium as well as the other variables included in the predictive regressions.

Fourth, if the option-implied borrowing fees are forward-looking estimates of quoted borrowing fees then they also should predict future stock returns. We estimate predictive regressions using the option-implied borrowing fee and other covariates and find that option-implied borrowing fees predict stock returns over one-week and one-month horizons in both the full sample and a subsample of hard-to-borrow stocks. The coefficient on the option-implied borrowing fee remains significant, usually highly significant, even when other variables such as the indicative borrowing fee, utilization, short interest, and short fee risk are included in the regressions. Of all of the variables we include, the option-implied borrowing fee is the most significant predictor of stock returns. In the subsample of hard-to-borrow stocks it is the only significant predictor of weekly returns, and the option-implied fee and utilization are the only significant predictors of monthly returns. The evidence from the hard-to-borrow sample is compelling because the other potential explanations should be particularly important in this sample, and yet, there is no evidence supporting these alternatives.

Of course, since the option-implied fee is a transformation of apparent put-call parity violations that are known to predict returns (Ofek, Richardson and Whitelaw 2004), the finding that it predicts returns is not particularly surprising. However, the fact that these apparent put-call parity violations are clearly related to the expectation of future borrowing costs casts these results in a different light.

Our regression results in which we use the option-implied borrowing fee to predict stock returns are closely related to the large literature that uses measures of lending fees to predict returns. For example, Geczy, Musto and Reed (2002), Ofek, Richardson, and Whitelaw (2004), Cohen, Diether, and Malloy (2007), and Drechsler and Drechsler (2016) present evidence that lending fees negatively predict stock returns. Our results are consistent with these papers, but suggest that the option-implied borrowing fee is a better measure of shorting costs than the fees used in the literature for two reasons. First, the option implied borrowing fee is measured from
the borrower’s perspective, and second, it is a forward-looking market-based measure of expected future borrowing fees.

While these (and most of our other) results are obtained in a sample of optionable stocks rather than all stocks, the set of optionable stocks for which we compute an option-implied borrowing fee includes on average 1,625 stocks each month, which on average comprise 92% of the market capitalization of the stocks with indicative borrowing fee data available from Markit. Thus, it comprises an important set of stocks that is of great interest to most investors.

Fifth, we consider the literature showing that differences between certain option-implied volatilities predict underlying stock returns. Bali and Hovakimian (2009) and Cremers and Weinbaum (2010) find that the implied volatility spread, defined in Cremers and Weinbaum (2010) as the average difference between the implied volatilities of calls and puts with the same strike price and expiration date, positively predicts returns. Xing, Zhang, and Zhao (2010) find that the implied volatility skew, defined as the difference between the implied volatility of an out-of-the-money put and an at-the-money call, is a negative predictor of returns. The returns to decile portfolios sorted on the volatility measures and univariate panel regressions confirm that these measures predict gross returns during our sample period. However, the returns net of stock borrowing costs of the decile ten minus decile one long-short portfolio are much smaller than the gross returns, and not significantly different from zero at conventional levels.

Lastly, when we include the option-implied fee and other predictors in the panel regressions along with the implied volatility spread and skew, we find that only the option-implied fee and utilization predict weekly stock returns. In panel regressions that predict monthly returns, the option-implied fee, the indicative fee, and utilization are highly significant predictors, while the coefficient on the implied volatility skew is insignificant and the coefficient on the implied volatility spread has the wrong sign and is usually not significant. We obtain similar results when we predict net-of-borrow-cost returns, except that the coefficient on the indicative fee becomes insignificant for monthly returns.

There is a natural interpretation of our finding that the implied volatility spread and skew predict returns in portfolio sorts and univariate regressions but have almost no relevance once we include the borrowing fees in the panel regressions. The implied volatility spread and skew are based on OptionMetrics implied volatilities that are computed omitting stock borrowing fees, that is by assuming that borrowing fees are zero. Thus, the implied volatilities are computed
with errors that depend on the magnitude of the omitted borrowing fees. As a result, in the cross-section of stocks the implied volatility spread and skew are correlated with the stock borrowing fee. The findings that these implied volatility measures predict returns in univariate regressions but no longer predict returns once the option-implied borrowing fee is included in the regression specifications suggests that the implied volatility spread and skew predict returns because they are transformations of the omitted borrowing fee.

This interpretation differs from most of the current literature, which interprets the ability of the option-implied spread and skew to predict returns as evidence that informed trading occurs in the option market and impacts option prices and implied volatilities. This apparent information is not immediately reflected in stock prices, causing the option implied volatility measures to predict returns. Although we cannot fully rule out this explanation, we do show that the implied borrowing fee retains its predictive power even for observations with very low option volume. Since the implied borrowing fee remains such a useful predictor of subsequent returns for this subset of observations, explanations related to price pressure in the options market would appear to be secondary.

The balance of the paper is as follows. Section 2 describes the stock borrowing fee and option price data we use. Section 3 uses decile portfolio sorts to show that the returns to shorting net of the costs to borrow stock are much smaller than the gross returns, and not significantly different from zero. Section 4 introduces the option implied borrowing fee and describes how we compute it. This section also shows that the option-implied borrowing fee predicts future borrowing fees and that the borrowing fee risk premium is zero. Section 5 presents results of regressions in which we use the option-implied borrowing fee and other variables to predict stock returns. Section 6 presents the regression results regarding the implied volatility spread and skew. Section 7 briefly concludes.

2. Data and summary statistics

We use stock borrowing fees and other data about short selling from the Markit Securities Finance Buy Side Analytics Data Feed available from Markit, Ltd. The database includes daily data on securities borrowing and lending activity, including rebates and loan fees, the quantity on loan, the number of loans, the numbers of active brokers and lending agents, and other data. Markit obtains the information from more than 100 equity loan market participants, including
beneficial owners, hedge funds, investment banks, lending agents, and prime brokers, who
together account for approximately 85% of US securities loans (Markit, 2012). While the Markit
Securities Finance dataset includes a broader range of securities, the analysis in Section 3 is
limited to U.S. equities, and the analyses in other sections are limited to the subset of U.S.
equities that have exchange-traded options. Our sample begins in July 2006 because the data
coverage expanded significantly around that time and the data are available at daily frequency
beginning June 28, 2006. The sample ends with August 2015.

The market for borrowing stock is described in other papers, including D’Avolio (2002)
and Kolasinski, Reed, and Ringgenberg (2013). It includes three groups of participants: (i)
lenders such as mutual funds, pension funds, and insurance companies, some of which lend
through agent lenders (custodians), (ii) ultimate borrowers, for example hedge funds, proprietary
trading desks, and option market makers, and (iii) prime brokers. Typically hedge funds and
option market makers borrow the securities from their prime brokers, who in turn borrow from
the mutual funds, pension funds, and other ultimate lenders (Kolasinski, Reed, and Ringgenberg
2013, especially Figure 1). In this process the prime brokers “mark up” the fee, that is they
borrow from the original lender and then relend to the hedge fund, option market maker, or other
short seller at a higher fee, the ultimate borrowing fee.

Borrowing fees typically are not quoted directly but are derived from quoted rebate rates.
The security borrower usually provides cash collateral to the security lender, and the security
lender pays interest (the rebate rate) on the cash collateral that it holds. The borrowing fee is the
difference between the market short-term interest rate and the rebate rate paid on the cash
collateral. 8 The rebate rate can be negative when securities are hard to borrow and the borrowing
fee is high. The borrowing fee can also be negative, which occurs when the rebate rate that the
security lender pays on cash collateral exceeds the short-term interest rate. 9

8 When the security borrower provides Treasury securities as collateral the borrowing fee is quoted and the rebate
rate is derived as the difference between the short-term interest rate and the borrowing fee. During our data period
Markit used the Federal Funds Open rate as the short-term interest rate in these calculations.
9 This can occur in financing transactions motivated by the security lender’s desire to obtain access to the cash
collateral posted by the security borrower in order to invest the cash in high-yielding assets. (Each security loan is
simultaneously a loan of a security, collateralized by cash, and a loan of cash, collateralized by a security.) Pierce
(2014) describes AIG’s use of securities lending to obtain funds to invest in mortgage-backed securities prior to the
financial crisis, and Foley-Fisher, Narajabad, and Verani (2016) provide evidence that other insurance companies
continue to use securities lending to obtain funding. In both of these papers the securities being lent are bonds,
which are typically better collateral for cash loans than are stocks because bond prices are typically less variable
than stock prices. However, the summary statistics in Table I of Engelberg, Reed, and Ringgenberg (2018) indicate
The market structure in which prime brokers are typically in the middle implies that there are two fees, a buy-side fee paid by the ultimate borrower (for example, a hedge fund or option market maker) and a lender-side fee received by the ultimate lender (for example, a mutual fund). The main borrowing fee variable we use is “IndicativeFee,” which is a buy-side fee. Specifically, it is Markit’s estimate of the “The expected borrow cost, in fee terms, for a hedge fund on a given day,” based on “both borrow costs between Agent Lenders and Prime Brokers as well as rates from hedge funds to produce an indication of the current market rate” (Markit 2012).10 The Markit database also includes another buy-side fee variable called Simple Average Fee (SAF) and a corresponding Simple Average Rebate (SAR), which are the simple averages of the actual borrowing fees paid and rebates received by ultimate borrowers for ongoing short positions as of a specific date. An important limitation of SAF is that this variable is not well populated in the database—as we show below, it is available for only about 51% of the stock-date pairs for which the indicative fee is available. In addition, SAF and SAR are subject to an important selection bias because they tend to be unavailable when stocks are hard to borrow and the indicative fee is high (Internet Appendix Table 5).

The literature on stock shorting such as Drechsler and Drechsler (2016) or Engelberg, Reed, and Ringgenberg (2018) that uses lending fees generally uses one of the lender-side fee measures available in the Markit Securities Finance Database or a similar lender-side fee measure computed from a proprietary database (for example, D’Avolio, 2002; Geczy, Musto, and Reed, 2002; Ofek, Richardson, and Whitelaw, 2004; and Asquith, Au, Covert and Pathak, 2013). While such lender-side fee data are useful for many purposes, including predicting securities returns, they are not the fees paid by ultimate borrowers such as hedge funds and option market makers. As a result, using the lender-side fees to compute returns to short positions net of the fees paid to borrow stock would result in upward-biased estimates of the net of fee returns and downward-biased estimates of the borrowing costs of option market makers.

10 The full description of the data item is “The expected borrow cost, in fee terms, for a hedge fund on a given day. This is a derived rate using Data Explorers proprietary analytics and data set. The calculation uses both borrow costs between Agent Lenders and Prime Brokers as well as rates from hedge funds to produce an indication of the current market rate. It should not be assumed that the indicative rate is the actual rate a Prime Broker will quote or charge but rather an indication of the standard market cost” (Markit, 2012).
This bias will be substantial if prime brokers receive significant compensation for their market making activities in the context of equity loans.

The Markit buy-side data also include the quantity on loan (QuantityOnLoan) and the utilization rate (Utilization), defined as the ratio of the quantity on loan to the lendable quantity (LendableQuantity), both of which we use. In addition to the Markit data, we also use end-of-day option price quotes from OptionMetrics. Stock prices, returns, and dividend information (amounts and ex-dividend dates) are from the files maintained by the Center for Research in Securities Prices (CRSP) files, and we address NASDAQ delisting returns as in Shumway and Warther (1999). Our analyses use interest rates that we “imply” or infer from the prices of liquid options for stocks that are extremely easy to borrow. While we think this approach provides a more accurate estimate of borrowing costs for option market makers, the main findings do not change if the relevant LIBOR rates are used instead.

Table 1 Panel A reports various percentiles of the distributions of the Markit stock borrowing fee and rebate data, and also of several variables we compute from the Markit data, for the set of stock-dates for which a common stock appears in CRSP and an indicative fee is available in the Markit data. The first row of the table reveals that the mean indicative fee is 1.46% per year, and that this variable is positively skewed. The indicative fee is 0.25% at the first percentile, 0.375% at both the tenth and 50th percentiles, and then reaches 1.88% at the 90th percentile and 25% at the 99th percentile. In the next row the rebate is negatively skewed, being \(-24.79\%\) at the first percentile (note that large negative rebates correspond to large positive fees), \(-1.31\%\) at the tenth percentile, and \(-0.24\%\) at the 50th percentile, with a mean value of \(-0.15\%\).

The next two rows of the table contain information about the historical borrowing fee measured using simple average fee (SAF) and historical rebate measured using the simple average rebate (SAR). These data are available for only about 51% (= 3,658,261/7,193,745) of the stock-date pairs for which the indicative fee is available. The mean is only 1.02%, which is considerably less than the indicative fee mean of 1.46%. In addition, the 90th and 99th percentiles of SAF are only 1.20% and 17.34%, much less than the corresponding percentiles of the indicative fee. These differences suggest a selection bias in which SAF and SAR are less likely to be available when the indicative fee is high. We provide more evidence regarding this issue in the appendix of the paper.
The next two rows report information about utilization and short interest, both of which are also right-skewed. The mean of utilization is 19.02% compared to a median of 10.54%, and the 90th and 99th percentiles are 51.88% and 89.02%, respectively. Short interest is computed from the Markit data, and is defined as the quantity on loan divided by shares outstanding (from CRSP). After short interest comes information about the short fee risk measure introduced by Engelberg, Reed, and Ringgenberg (2018). This variable is defined as the natural log of the variance of the daily fee over the preceding 12 months, and has mean and median values of 4.36 and 3.96, respectively.11

The last two rows provide some information about the market capitalization of the underlying stocks in our sample. The typical stock is in the seventh NYSE size decile, with mean and median market capitalizations of $4,887 million and $667 million, respectively. The sample is tilted to larger stocks in CRSP because a stock is only included on a particular date if the Markit indicative fee is available on that date, market capitalization is greater than or equal to $10 million, and the stock price is greater than or equal to $5 per share. Markit provides the indicative lending fee for at least one day during each month in our sample for an average of 3,195 stocks that also satisfy our market capitalization and stock price filters.

Panel B provides the same information and some additional information about the subset of the common stocks in Panel A that are optionable and for which we compute an option-implied lending fee. This sample consists of all combinations of optionable stocks and dates for which the dividend yield is less than or equal to 5%, and there is at least one call-put pair that satisfies the following criteria: (a) the put moneyness \( K/S \) is less than or equal to 1.1; (b) there are between 15 and 90 days remaining to expiration; and (c) and the sum of the call and put bid-ask spreads divided by the stock price is less than or equal to 5%. In addition, for each option in a put-call pair, open interest is positive, the absolute delta is between 0.01 and 0.99, implied volatility is between 0.03 and 2, the bid is greater than 0.1, and the bid is less than the ask.12 The optionable stocks tend to be larger than those in the sample used in Panel A—the mean and

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11 Our short fee risk measure is not exactly the same as that used in Engelberg, Reed, and Ringgenberg (2018), because their measure is computed from lender-side fees and ours is computed from buy-side indicative fees. We are unable to replicate the Engelberg, Reed, and Ringgenberg (2018) short fee risk measure because we do not have the lender-side fees—at the time we licensed the buy-side data Markit was unwilling to license both the buy and lender-side data to the same researcher or group of researchers.

12 The requirements that the dividend yield be less than or equal to 5% and the put moneyness \( K/S \) be less than or equal to 1.1 are included to filter out calls and puts, respectively, for which early exercise is important. The other filters eliminate options with wide bid-ask spreads, low liquidity, or unreasonable prices.
median market capitalizations in Panel B are approximately 2 and 4 times as large, respectively, as the corresponding values in Panel A. After applying these filters, we compute an option-implied borrowing fee on at least one day during the month for an average of 1,625 stocks per month. The combined market capitalization of these stocks with an implied fee is 92% of the combined market capitalization of the stocks covered by Markit in Panel A for the average month.

Not surprisingly, indicative borrowing fees and short fee risk are lower for the optionable stocks. The mean and median values of utilization are slightly larger for the optionable stocks, though the 99th percentile is slightly smaller. All of the reported percentiles of short interest are greater for the optionable stocks as compared to the full sample in Panel A. This is not surprising, as option market makers often short stocks to hedge their option positions.

Panel B also contains information about the option-implied borrowing fee. Section 4 below describes how it is computed from put-call pairs using a version of the put-call parity relation that includes the borrowing fee. We use the option data to compute the option-implied borrowing fee for each date and call-put pair with between 15 and 90 days remaining to expiration, and then for each date and stock we use the median option-implied fee across the call-put pairs on that date as the estimate of the option-implied fee. The row labeled Option-implied fee, unadj. reports information about estimates of the option implied borrowing fee, without any adjustment for the bias caused by the use of a version of the European put-call parity relation with American option prices. The row labeled Option-implied fee, adjusted includes an adjustment to remove this bias, as described in Section 4.

The mean and median of the adjusted option-implied fee, 1.27% and 0.77%, are somewhat larger than the mean and median of the indicative borrowing fee reported in the first row of Panel B. However, the distribution of the option-implied fees exhibits much more dispersion than the distribution of the indicative fees—the 90th percentile is 4.73% and the 10th percentile is actually negative, −2.14%. The statistics for the unadjusted option-implied fees are similar, though the mean and all percentiles are somewhat smaller, reflecting the adjustment for early exercise. The dispersion in the option-implied fees reflects the fact that implied fees are estimated with error, some of which is microstructure “noise” stemming from the wide bid-ask
spreads in the option market.\textsuperscript{13} In the panel regressions we estimate below these measurement errors likely cause estimates of the coefficients on the option-implied fee to be biased toward zero as a result of the classic errors-in-variables bias. In general, this problem should make it more difficult to find evidence that the option-implied fee predicts changes in the subsequent indicative fees and or stock returns.

A side benefit of our approach is that it provides a way to estimate stock borrowing costs during the period before Markit began collecting borrowing fee data. The high correlations between option-implied and indicative fees, along with the fact that option-implied fees predict changes in indicative fees, show that the option-implied borrowing fees can be a useful proxy for the actual borrowing fees faced by the marginal investor.

3. Impact of borrowing fees on the performance of portfolio strategies

The literature regarding short selling frictions includes several results in which a particular measure of the cost of maintaining a short position predicts subsequent stock returns. However, this type of analysis frequently does not include an adjustment for some measure of the fees paid to maintain such positions. Taking into account the fees that must be paid to borrow stock is necessary to correctly calculate the return to a short position. Omitting the fees is analogous to computing stock returns while omitting dividends. In this section, we evaluate the performance of several simple portfolio sorts using variables measuring short selling activity. This performance evaluation includes an analysis of the returns of these strategies after incorporating borrowing fees.

In Table 2 we sort stocks into deciles based on the indicative borrowing fee. All stocks are sorted into portfolios based on the historical borrowing fee as of the close of trading day \( t \). Stocks are held from the close of trading day \( t + 1 \) until the close of trading day \( t + 22 \), to mimic the length for a typical month with 21 trading days. The reported return for each portfolio for a specific date is the average of this return for all stocks in the portfolio minus the return to the value-weighted CRSP return for the same time period. By construction, the performance measure

\textsuperscript{13} Despite these estimation errors, the unadjusted option-implied fee is highly correlated (0.59) with the indicative fee (Internet Appendix, Table 1, Panel B). The fee measures are not as highly correlated with short interest and short fee risk. In the full sample the correlations between the indicative fee and short fee risk and short interest are only 0.28 and 0.20, respectively, while in the optionable sample the correlations between the option-implied fee and and short fee risk and short interest are only 0.29 and 0.24. Despite the potential for estimation errors in option-implied fees, once we add the implied fee to panel regressions to predict stock returns most other predictors become insignificant.
for each portfolio is a moving average in which the horizon of the returns leads to 20 overlapping observations, and so, it is important to use Newey-West standard errors to adjust for this feature of the data. This approach ensures that there is a one day gap between the information used to sort stocks into the portfolios and the evaluation period for the portfolio return. This gap is important for subsequent analyses using option-implied measures because the midpoint of the quotes for the underlying stock price that are used by option market participants can be different from the actual closing price reported by CRSP. This temporary price difference generates substantial stock return predictability the next trading day according to the findings in Goncalves-Pinto, Grundy, Hameed, van der Heijden, and Zhu (2017). In addition, using the average portfolio return across all potential starting dates will eliminate any unusual results associated with end-of-month patterns.

We examine the performance of equal-weighted portfolios with the understanding that the abnormal performance results are almost always less pronounced for value-weighted portfolios (not reported). The first row of results for market-adjusted returns shows that stocks with a high indicative fee have much lower returns than stocks with a low indicative fee. The performance across portfolios exhibits a roughly monotonic pattern and the return differential between the top and bottom deciles is more than 1.43% per month. The magnitude of this estimate is similar to the 1.31% per month gross return differential reported by Drechsler and Drechsler (2016; Table 2) for portfolios sorted using the 30-day value-weighted average lending fee they use. Our estimate is associated with a $t$-statistic of 3.8 and is due largely to the low returns for stocks in the tenth decile compared to the performance of the other nine deciles. The differences between the abnormal performance for the top and bottom decile using the 4-factor model are virtually identical to the unadjusted return differentials reported in the column labeled 10-1 in Table 2. The risk-adjusted results are not reported for brevity.

The next set of results report portfolio returns after also adjusting for the indicative borrowing fee. For the row labeled Indicative fee adj., the cumulative indicative borrowing fee based on the daily indicative fee from Markit from day $t + 1$ to $t + 22$ is added to the performance of the portfolio. This adjustment accounts for the decrease in the effective performance of short positions due to the borrowing fee and its impact is concentrated in the tenth portfolio. Strikingly, adjusting for the cost of borrowing stock causes the market-adjusted return of the tenth portfolio to change from a large and highly significant $-1.09\%$ per month to
an insignificant −0.22% per month. That is, the net-of-borrow-fee return to shorting the high fee portfolio decreases from 1.09% to 0.22%, so that the net return is only 20% (=0.22%/1.09%) as large as the gross return. The performance differential in the decile ten minus decile one long-short portfolio following the indicative fee adjustment is only 41% of the magnitude without this fee adjustment, −0.59% per month instead of −1.43% per month, and the net-of-fee estimate is not statistically significant. The impact of stock borrow fees on the average return of the long-short portfolio is not as striking as their impact on the decile ten portfolio return because the fees have limited impact on the returns of the decile one portfolio, that is they have an important impact on only one leg of the long-short portfolio.14

In Panel B, we revisit this calculation of the net of fee returns using the subset of optionable stocks. We verify that this subset is sufficiently representative of the full sample to be useful for comparison purposes. Before the indicative fee adjustment, the return of the decile ten portfolio and the performance differential are 0.64% and 0.89% per month, with $t$-statistics of −2.2 and −2.9. Again, the performance differential is driven by the low returns of stocks in the tenth decile. The magnitude and statistical significance of this estimate is smaller than the analogous estimate for the full sample. In this sample, taking account of the lending fee almost completely eliminates the benefit of shorting the decile ten portfolio, as the return from shorting is reduced from 0.64% per month to an insignificant 0.10% per month. In the long-short portfolio, the fee-adjusted differential performance of 0.39% per month is less than half of the unadjusted performance, and most of the after-fee performance differential is due to decile one. This attenuation due to taking account of fees observed in the optionable sample matches the pattern for the full sample quite closely. The results indicate that the performance of the portfolio strategy is largely not exploitable once the borrowing fees used to form the portfolios in the first place are taken into account. The failure to include the realistic cost of implementing short positions in the performance evaluation overstates the performance of strategies based on short

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14 The net-of-borrow-fee long-short portfolio return slightly overstates the return that could be obtained by a sophisticated investor short selling the decile ten portfolio and purchasing the decile one portfolio. The calculation assumes that the investor lends the stocks in decile one and receives the indicative fees. In fact, an investor who holds a long position in the decile one portfolio is not guaranteed to be able to lend his or her stocks, because the average level of utilization for the stocks in this portfolio is low. Even if the holder successfully lends the stocks in the decile one portfolio, the compensation the investor receives for lending the stocks is usually less than the indicative fees we use in the calculations due to the prime broker intermediation costs.
selling. Consequently, it is much less puzzling why investors do not attempt to take greater advantage of this apparent mispricing by establishing the necessary short positions.

This pattern of substantial attenuation of return differentials is not only associated with portfolios based on the level of the borrowing fee. In Panel A of Table 3 we examine the performance of portfolios sorted using short fee risk for the full sample. This measure of indicative fee volatility is estimated as the standard deviation of the daily indicative borrowing fee during the previous year for each stock. The first set of results in Table 3 show that the return of the portfolio of stocks with high short fee risk is \(-1.06\%\) per month and highly significant. This return is 1.37\% per month less than that of the portfolio of stocks with low short fee risk. The difference in performance is statistically significant and largely due to the very low returns of stocks in the tenth decile. The 1.37\% performance differential in the decile portfolios is larger than 0.8\% per month return differential reported by Engelberg, Reed, and Ringgenberg (2018) for quintile portfolios formed using short fee risk. The larger magnitude is to be expected because the returns of the highest and lowest quintile portfolios should be less extreme than those of the highest and lowest decile portfolios that we analyze.

The results in Panel B show that the adjustment based on the indicative fee changes the returns to the decile ten portfolio from \(-1.06\%\) per month to an insignificant \(-0.28\%\) per month, that is, this adjustment reduces the returns to shorting the portfolio from 1.06\% to 0.28\%. The indicative fee adjustment attenuates the differential performance of the high versus low fee risk portfolios by more than half. A similar pattern of results is present in the optionable subset of stocks analyzed in Panel B. While the magnitude of the initial differential performance is somewhat smaller for optionable stocks, the adjustment for the indicative fee results in similar attenuations of the performance of the decile ten portfolio and the decile ten minus decile one long-short portfolio.

In general, the main finding in this section is that proper adjustment for the cost of establishing short positions dramatically reduces the effective benefits of strategies based on proxies for short selling constraints. As a result, it is difficult for the marginal institutional investor facing the indicative borrowing fee to exploit the return patterns by establishing short positions. This finding is consistent with the results in Sadka (2010, Table 3). Hedge funds that specialize in short selling earn abnormal returns of only 0.34\% per month according to Sadka (2010) and this return is much less than the gross-of-borrowing fee returns of simple strategies.
based on readily available information. It is very difficult to reconcile the performance of hedge funds that specialize in short selling with any claim that investors’ net-of-borrow-cost returns to shorting are close to the gross returns.

A remaining puzzle is the fact that retail and other institutional investors hold the high fee stocks in spite of the clear benefits to selling stocks exhibiting high borrowing fees. It is important to note that institutional investors who lend these stocks may receive a lending fee, but are not guaranteed to receive the lending fee because even for hard-to-borrow stocks utilization is typically less than 100% and their shares may not be borrowed. In addition, the fees received by lenders are typically smaller than the borrowing fees paid by ultimate borrowers such as hedge funds and option market makers.

4. Option-implied fees and the risk premium in the stock loan market

An option market maker quotes prices for call and put options. We are interested in analyzing how the stock borrowing fees that she must pay to borrow shares impact the option prices she quotes. For simplicity, we assume that the options are of the European type initially, the interest rate is constant, and the stock does not pay a dividend before the expiration of the options. The option market maker will delta-hedge by borrowing and short-selling the underlying stock, and thus must pay the stock borrowing fee. For hard-to-borrow stocks this is typically the case; that is, for hard-to-borrow stocks the option market maker’s option position is usually such that she will need to short-sell stock in order to delta-hedge her option position. We also assume that the stock lender, typically the option market maker’s prime broker, does not require the option market maker to overcollateralize the stock loan.\footnote{Hedge funds that borrow and short-sell shares are typically required to post collateral equal to at least 102% of the value of the borrowed shares, that is the prime broker keeps the proceeds of the short sale and requires the hedge fund to provide additional collateral equal to at least 2% of the value of the borrowed shares. We are told by option market makers that because their prime brokers hold all of their securities their liabilities to their prime brokers are routinely overcollaterized and they are not required to provide the additional 2%.

4.1 Borrowing fee risk premium

Consider a discrete-time setting with risky borrowing payments that are made once each day from $t$ to the expiration of the option pair $T = t + k$. The variables $S_t$ and $h_t$ are the stock price and borrowing fee at date $t$, and an investor who buys the stock at date $t$ at the price $S_t$ can lend the stock and receive $h_t S_t$ at time $t + 1$. Note that similar to an overnight interest rate, $h_t$ is quoted
at time \( t \) but \( h_t S_t \) is paid at the end of the period, time \( t + 1 \). Define \( R_{t+j}^{h} \) as \((S_{t+j}/S_t) - 1\), which does not include the claim to any borrowing fee payments. Define \( R_{t+j} \) for the same length of time as the return including the borrowing fee payments; this is the return received by the representative investor that determines stock prices and the stochastic discount factor. Of course, the risk of changes in the borrowing fee might be a priced risk because it might covary with the stochastic discount factor. Let \( M_{t+j} \) be the stochastic discount factor from period \( t \) to period \( t + j \) and let \( V_{t+j} \) be the risk-adjusted present value of \( h_{t+j-1} S_{t+j-1} \), which is the borrowing fee paid at date \( t + j \) based on \( h_{t+j-1} \) quoted at \( t+j-1 \). Also let \( r \) be the one-day interest rate and let \( \delta = 1/(1 + r) \) be the one-day discount factor.

The borrowing fee paid at date \( t + j \) is \( h_{t+j-1} S_{t+j-1} \) which is based on \( h_{t+j-1} \) quoted at date \( t + j - 1 \) and the stock price at time \( t + j - 1 \). Consider the risk-adjusted value at \( t \) of this borrowing fee:

\[
V_{t+j} = E_t[M_{t+j}(S_{t+j-1} h_{t+j-1})] = E_t[(\delta M_{t+j-1} S_{t+j-1}) h_{t+j-1}] = E_t[\delta M_{t+j-1} S_{t+j-1} E_t[h_{t+j-1}] + \text{Cov}_t(\delta M_{t+j-1} S_{t+j-1}, h_{t+j-1})] \tag{1}
\]

where the second equality uses \( M_{t+j} = \delta M_{t+j-1} \), reflecting the fact that the fee paid at time \( t + j \) is known at time \( t + j - 1 \). Divide by \( E_t[\delta M_{t+j-1} S_{t+j-1}] \) to simplify the resulting expression:

\[
\frac{V_{t+j}}{E_t[\delta M_{t+j-1} S_{t+j-1}]} = E_t[h_{t+j-1}] + \text{Cov}_t\left(\frac{\delta M_{t+j-1} S_{t+j-1}}{E_t[\delta M_{t+j-1} S_{t+j-1}]}, h_{t+j-1}\right). \tag{2}
\]

Note that \( E_t[\delta M_{t+j-1} S_{t+j-1}] \) is the present value of the underlying stock received at date \( t + j - 1 \) without any claim to borrowing fees (or dividends) before \( t + j - 1 \). If the borrowing fee is not included in the return to the representative investor then \( E_t[\delta M_{t+j-1} S_{t+j-1}] = S_t \). However, in this case the representative investor receives the borrowing fee, so the present value of the future stock price is lower than the current stock price. This situation is similar to the presence of a dividend payment.

Averaging the payments on \( k \) dates from \( t + 1 \) to \( T = t + k \),

\[
\frac{1}{T-t} \sum_{j=1}^{k} \frac{V_{t+j}}{E_t[\delta M_{t+j-1} S_{t+j-1}]} = \frac{1}{T-t} \sum_{j=1}^{k} \left( E_t[h_{t+j-1}] + \text{Cov}_t\left(\frac{\delta M_{t+j-1} S_{t+j-1}}{E_t[\delta M_{t+j-1} S_{t+j-1}]}, h_{t+j-1}\right) \right). \tag{3}
\]
Define a risk-adjusted borrowing fee \( h_Q \) to be the constant risk-adjusted borrowing fee that results in the same present value of fees as the random fees \( h_{t+j-1} \) over the next \( k \) periods. That is, \( h_Q \) solves

\[
\sum_{j=1}^{k} V_{t+j} = \sum_{j=1}^{k} E_t[\delta M_{t+j-1} h_{t+j-1} S_{t+j-1}] = \sum_{j=1}^{k} E_t[h_Q \delta M_{t+j-1} S_{t+j-1}].
\] (4)

The right-hand side can be simplified to

\[
\sum_{j=1}^{k} E_t[h_Q \delta M_{t+j-1} S_{t+j-1}] = \delta h_Q S_t \sum_{j=1}^{k} (1 - \delta h_Q)^{j-1}
\]

\[
= \delta h_Q S_t \left( \frac{1}{\delta h_Q} - \frac{(1 - \delta h_Q)^k}{\delta h_Q} \right).
\] (5)

where we used the fact that

\[
E_t[\delta M_{t+j-1} S_{t+j-1}] = \delta S_t (1 - \delta h_Q)^{j-1}.
\] (6)

The term \((1 - \delta h_Q)^{j-1}\) adjusts the present value of the future stock price for the borrowing fee payments that are not received by the representative investor. Note that for a small number of time periods and/or small \( h_Q \), the right-hand side of equation (5) is approximately \( k \delta h_Q S_t \), and that this approximation is exact if the borrowing fee is not included in the return received by the representative investor.

Using the assumption that \( h_Q \) is constant from \( t \) to \( T \) and equation (6) we have \( V_{t+j} = E_t[h_Q M_{t+j-1} S_{t+j-1}] = h_Q \delta S_t (1 - \delta h_Q)^{j-1} \). Substituting into the left-hand side of (3) and using (6) again, the left-hand side of (3) becomes

\[
\frac{1}{T-t} \sum_{j=1}^{k} E_t[\delta M_{t+j-1} S_{t+j-1}] = h_Q.
\] (7)

Thus (3) becomes

\[
h_Q = \frac{1}{T-t} \sum_{j=1}^{k} \left( E_t[h_{t+j-1}] + Cov_t \left( \delta M_{t+j-1} S_{t+j-1}, h_{t+j-1} \right) \right).
\] (8)

Moving the average of \( E_t[h_{t+j-1}] \) to the left-hand side and slightly rearranging we have an expression for the risk premium for bearing the risk of changes in the borrowing fee:
\[ h_Q - E_t \left( \frac{1}{T-t} \sum_{j=1}^{k} h_{t+j-1} \right) = \frac{1}{T-t} \sum_{j=1}^{k} \text{Cov}(E_t(\delta M_{t+j-1}S_{t+j-1}), h_{t+j-1}) \]
\[ = \frac{1}{T-t} \sum_{j=1}^{k} \text{Cov}(M_{t+j-1}S_{t+j-1}, h_{t+j-1}) \]

(9)

If date \( T \) is the expiration date of an option then the constant risk-adjusted fee \( h_Q \) on left-hand side can be computed from option prices. The average borrowing fee can be computed from realized borrowing fees over the life of the option, and the risk premium can be estimated as the average value of the difference. This approach is similar to how the volatility risk premium is often measured as the difference between implied and future realized volatilities, such as in Carr and Wu (2009).

Using the constant risk-adjusted borrowing fee \( h_Q \), the put-call parity relation for a put-call pair expiring at date \( T = t + k \) is

\[ S_t - \sum_{j=1}^{k} E_t[\delta h_Q M_{t+j-1}S_{t+j-1}] = C_t - P_t + PV(K) \]

(10)

From this, and using (6), the option-implied borrowing fee, \( h_Q^{imp} \), is given by the solution of

\[ S_t - S_t \left( 1 - (1 - \delta h_Q^{imp})^k \right) = C_t - P_t + PV(K) , \]

(11)

where we have used the fact that the borrowing fee is part of the equilibrium return to the representative investor. Rearranging,

\[ 1 - (1 - \delta h_Q^{imp})^k = \frac{S_t - C_t + P_t - PV(K)}{S_t} . \]

(12)

In this equation \( h_Q^{imp} \) is a non-linear function of the put-call parity violation and \( k \) is the number of borrowing fee payments (or periods) remaining until expiration. The solution of this equation is

\[ h_Q^{imp} = \frac{1}{\delta} \left[ 1 - \left( 1 - \frac{S_t - C_t + P_t - PV(K)}{S_t} \right)^{1/k} \right] . \]

(13)

This computation of the option-implied borrowing fee takes account of the discrete nature of lending fee payments and generates implied fees similar to an alternative simplified approach where the lending fee is a continuous flow analogous to the continuous dividend yield that appears in some versions of the Black-Scholes-Merton formula.
Turning back to the risk premium in equation (9), we can replace the first term on the left hand side with the option-implied borrowing fee based on options from $t$ to $T$. We replace the second term on the left hand side, the expected average of daily borrowing fees, with the actual average of the daily borrowing fees from $t$ to $T$. The difference on the left hand side should be positive if the stochastic discount factor covaries with the borrowing fee or if the stock return covaries with the borrowing fee to any significant extent. Of course, it is also possible that this covariance is near zero because the realized borrowing fee is largely idiosyncratic. Indeed, we have verified that the daily borrowing fee appears to be largely uncorrelated with the contemporaneous stock return as well as the next day’s stock return.

4.2 Computation of the option-implied borrowing fee

In computing the option-implied borrowing fee we must take account of the dividends on the stocks. Thus, we compute the option-implied borrowing fee using the version of the put-call parity relation that incorporates dividends,

$$S_t - S_t \left(1 - (1 - \delta h_{Q}^{\text{imp}})^k \right) - PV(D) = C_t - P_t + PV(K).$$

Equation (13) becomes

$$h_{Q}^{\text{imp}} = \frac{1}{\delta} \left( 1 - \left( \frac{S_t - C_t + P_t - PV(D) - PV(K)}{S_t} \right)^{1/k} \right).$$

where $C(t)$ and $P(t)$ are the midpoints of quoted call and put quote prices, $PV(D)$ is the present value of dividends with ex-dividend dates before the expiration date, $T - t = k$ is the time to expiration, $S(t)$ is the current stock price, and $K$ is the option strike price. For each stock and day, we use the median of the borrowing fee estimates from individual call-put pairs to reduce the impact of microstructure noise. We also restrict attention to options for which the sum of the call and put bid-ask spreads divided by the stock price is less than or equal to 5% and the stock price is greater than $5.

Actual equity options have American, not European, style exercise, and often their underlying stocks pay dividends. As described in Section 2, we minimize the impact of the biases created by the possible early exercise of American options and our use of the European put-call parity relation by restricting the sample to exclude in-the-money puts and options whose underlying stocks pay large dividends during the lives of the options. We also restrict attention to options with between 15 and 90 calendar days to expiration.
These sample restrictions do not address the fact that, when the borrowing fee is large, the fee itself can make early exercise of an American call optimal even when the stock does not pay any dividends during the life of the option. This impacts the value of an American call option, and therefore, the option-implied borrowing fees we compute using the European put-call parity relation are downward-biased. We assess the magnitude of the bias by using the binomial model to compute American option prices for a grid of borrowing fees and option volatilities, using plausible values for the moneyness, time-to-expiration, and risk-free rate. For each put-call pair, we estimate the difference between the true borrowing fee and the option-implied fee computed using equation (15) above. Repeating this for many put-call pairs, we use a regression model to estimate how the difference between the true and option-implied fees depends on the option parameters.

We find that the bias due to the use of the European put-call parity relation can be important when the borrowing fee is large and the moneyness $\ln(K/S)$ is small so that call options are well in-the-money. The regression analysis shows that the bias is not sensitive to the option volatility and is well explained by a linear function of the interaction term $\min(h \times \ln(K/S), 0)$, where $h$ is the indicative borrowing fee from Markit. We compute this linear function using the regression estimates and add the adjustment to the option-implied borrowing fees computed using the European put-call parity relation. We use these resulting adjusted option-implied borrowing fees to estimate the risk premium using equation (9) above. However, we use the unadjusted option-implied fees to predict borrowing fee changes and stock returns because the adjustment uses the indicative fee. Due to this potential for contamination, using the adjusted fees in predictive regressions would make it difficult to conclude whether the predictive ability was due to the option-implied fee or the indicative fee component of the adjustment for early exercise. We obtain similar (untabulated) results using the adjusted borrowing fees in the regressions.

By using option price bid-ask midpoints to compute the option-implied borrowing fee, we are estimating the stock borrowing fees that option market makers input into their valuation models. Specifically, the underlying assumption is that option price bid-ask midpoints are (possibly noisy) proxies for the option fair market values computed by option market makers’ valuation models. By using them, and inverting the put-call parity relation for the option-implied borrowing fee as in equation (15), we are computing the borrowing fee that option market
makers input into their valuation models, plus noise stemming from the fact that the bid-ask midpoint can be a noisy proxy for the option fair market value.\textsuperscript{16} The option-implied borrowing fees we compute are not the fees that an investor would implicitly pay by using the option market to enter into a synthetic short stock position by buying a put at the ask price and selling a call at the bid price.

To illustrate how the implied borrowing fee adjusted for early exercise is closely related to the indicative fee, we plot these two series in Figure 1 Panel A for a particular stock, AIG. Figure 1 Panel B plots the stock price for AIG during the same time period. The implied fee is not calculated when the stock price is less than $5, and therefore, the series for the implied fee has a break for the part of the financial crisis when the stock price of AIG is close to zero. The option-implied fee appears to be the indicative fee plus noise. The implied fee closely tracks the indicative fee and this linkage remains fairly tight even when the indicative borrowing fee spikes to more than 40\% per year. Note that this very high option implied fee would appear as a huge put-call parity violation in options markets if one were to use the conventional put-call parity relation that ignores the stock borrowing fee. Only by matching the implied fee series to the indicative fee series does it become obvious that apparent violations of put-call parity embedded in the option-implied fee reflect the failure to incorporate the cost of borrowing stock.

We provide more general evidence regarding the direct link between the implied borrowing fee and the indicative fee in Figure 2. Rather than plotting these two series for a particular stock like AIG, this figure presents the daily cross-sectional average of the indicative borrowing fee and the option-implied borrowing fee for hard-to-borrow stocks (utilization greater than 60\%). Again, these two series generally track each other closely during the sample period. Thus, apparent violations of put-call parity, appropriately scaled by time to expiration, reveal the critical relevance of the borrowing fee. The largest deviation between the two series occurs during the financial crisis when market making activities may have been particularly constrained. This deviation might reflect a borrowing fee risk premium reflected in the option-implied fees, or it might occur because the forward-looking option-implied fees were forecasting increases in indicative fees.

4.3 Option-implied borrowing fee predicts changes in borrowing fees

\textsuperscript{16} Option valuation models used by option market practitioners typically reflect the cost of carry, one component of which is the stock borrowing cost.
If the option-implied borrowing fee is a forward-looking estimate of the future borrowing fees then it should help predict changes in the indicative borrowing fee. Table 5 presents the results of regressions used to test this relation. We construct the estimates of the option-implied borrowing fees used in the regressions as follows.17

The unit of observation is a stock-date. For each combination of stock and date, we compute the option-implied borrowing fee from end-of-day price quotes for each call-put pair that satisfies the option filters used in constructing the optionable subset of common stocks. The calculation yields an estimate of the option-implied borrowing fee for each call-put pair.18 For each stock and date we then take the median of the option-implied borrowing fees across the available call-put pairs, resulting in an estimate of the implied borrowing fee for each stock and date.19 The current indicative borrowing fee for each stock and date is from the Market Securities Finance database, and the future borrowing fee is the average indicative fee over the life of the option. The change in the indicative borrowing fee is the difference between the future borrowing fee and the current borrowing fee.

Table 4 reports the results of regressions in which the change in the borrowing fee during the subsequent month is regressed on the indicative fee, the option-implied borrowing fee, and several other covariates. The results in the first three columns are for the full sample, while those in the last three columns are for the subset of stock-date combinations on which the stock is hard-to-borrow, where a stock is hard-to-borrow on a date if its utilization rate is greater than 60%.20 The indicative borrowing fee by itself predicts a decrease in borrowing fees, indicating some mean reversion in borrowing fees (columns 1 and 4). The results in the other columns

17 Because the change in the borrowing fee is the difference between the future fee and the current indicative fee and our regressions control for the current indicative fee, the results in Table 5 also show that the option-implied fee helps explain future fee levels. In untabulated results we confirm that the option-implied fee predicts the future level of the indicative fee by regressing future fee levels on the covariates used in Table 5. We obtain results in which (a) the estimated coefficients on the current indicative fee are equal to those reported in Table 5, plus one; and (b) coefficients on all other covariates are unchanged.
18 The criteria are: (a) $K/S$ is less than or equal to 1.1; (b) there are between 15 and 90 days remaining to expiration; and (c) and the sum of the call and put bid-ask spreads divided by the stock price is less than or equal to 5%. In addition, for each option in a put-call pair, open interest is positive, the absolute delta is between 0.01 and 0.99, implied volatility is between 0.03 and 2, the bid is greater than 0.1, and the bid is less than the ask.
19 Using the mean implied borrowing fee rather than the median fee yields similar results.
20 The utilization rate of 60% is greater than the 90th percentile of utilization in Table 1, so the hard-to-borrow sample consists of fewer than 10% of the observations. Stocks with high utilization are those for which constraints on supply are most likely to be binding, possibly leading to loan recalls, higher borrowing fees, and difficulties locating new shares to borrow when attempting to replace recalled stock loans. The possible alternative of defining a hard-to-borrow stock as one with a high lending fee is problematic, as the lending fee is used in computing the change in the lending fee that is the left-hand side variable.
show that the option-implied borrowing fee helps predict the change in the borrowing fee, controlling for both the current indicative fee and other covariates, and that the estimated coefficients are highly significant. The coefficients on the option-implied borrowing fee are larger in the subsample of hard-to-borrow stocks, which is unsurprising because the option-implied borrowing fee is larger relative to any errors in the estimates for this subsample. When both variables are included in the regression specification the coefficient on the indicative borrowing fee is larger than the coefficient on the option-implied fee, though in the sample of hard-to-borrow stocks the coefficient on the option-implied borrowing fee is almost as large as that on the indicative fee.

4.4 Borrowing fee risk premium

Table 5 provides evidence about the magnitude of the borrowing fee risk premium by reporting the mean and median of the risk premium, defined as the difference between the option-implied borrowing fee and the realized indicative borrowing fee, for various samples. The unit of observation is a stock-date. For each combination of stock and date, we compute the option-implied borrowing fee for each call-put pair used in the regressions reported in Table 4, and then take the median across the option pairs for the stock. We also adjust each of the option-implied fees for the early exercise premium as described above. For each option, we compute the average indicative borrowing fee over the remaining life of the option. The realized risk premium is the difference between the option-implied borrowing fee and this average indicative borrowing fee. The first row, Borrowing fee risk premium (adjusted), reports the mean, median, and standard deviation of the realized risk premium for the full sample and a subsample of hard-to-borrow stocks. This estimate of the risk premium is based on the adjusted option-implied fee. The $t$-statistic for the mean risk premium is in the next row. The table also reports the mean and median values of the risk premium computed from option-implied borrowing fees that are not adjusted for early exercise, the adjusted and unadjusted option-implied borrowing fees, where the option-implied borrowing fees are computed as described above, and the indicative borrowing fee. The estimates in this table indicate that the risk premium in the stock borrowing market, if there is one, is relatively modest. In the full sample the mean and median risk premia are 0.31% and 0.28% per year, respectively. There are some extreme values of the realized risk premia, so the median is probably a better measure of location than the mean, but in this case both metrics are similar. In the subsample of hard-to-borrow stocks, defined as those with utilization greater
than 60%, the mean and median values of the realized risk premium are 0.07% and 0.20% per year, respectively. The median of 0.07% is only 1% (= 0.07%/7.16%) of the median adjusted option-implied borrowing fee of 7.16% per year. The subsample of hard-to-borrow stocks is the place where we would expect to find a risk premium, if there is one, because this is the subsample for which constraints on supply are most likely to be binding, possibly leading to loan recalls, higher borrowing fees, more volatile borrowing fees, and difficulties locating new shares to borrow when attempting to replace recalled stock loans. The fact that we do not find a substantial risk premium in this subsample is compelling evidence that the risk premium in the stock borrowing market, if there is one, is small.

In Table 6 we revisit the estimates of the risk premium in the stock borrowing cost for several subsamples. First, we restrict the sample to observations from November 2008 or later because the option market maker exception to the locate and close-out requirements, permitting widespread delivery failures by option market makers, was eliminated in September 2008. The evidence in Stratmann and Welborn (2013) as well as Jain and Jain (2015, Figure 1) clearly shows that the incidence of delivery failures for optionable stocks declined dramatically in September and October 2008. As a result, the extent to which stock borrowing costs were reflected in option prices may have changed at this time. Second, we restrict the sample to observations in 2013 or later. SEC enforcement actions with respect to delivery failures began to take place in 2012, suggesting the alternative possibility that the extent to which shorting costs were reflected in option prices changed some time shortly before the start of 2013. The risk premium estimates for the sample period following November 1, 2008 as well as the sample period following January 1, 2013 are similar to the risk premium estimates for the full sample. For the hard to borrow stocks, the risk premium estimates for these subsamples are slightly smaller than their counterparts for the entire sample. Thus, any decrease in the ability of market makers to fail-to-deliver appears unrelated to the observed absence of a risk premium.

The third row of Table 6 restricts the sample to valid put-call pairs with time to expiration greater than 60 days to measure the risk premium over longer time periods. Using the option-

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21 Until 2008, options market makers were exempt from the requirement to locate a stock before short selling and certain close-out requirements, and options market makers often sold short without borrowing shares and then failed to deliver the shares (Evans, Geczy, Musto and Reed 2009, Stratmann and Welborn 2013). This reduces the costs of shorting by option market makers, and there is evidence that some of the benefit of lower shorting costs was reflected in option prices (Evans, Geczy, Musto and Reed 2009).

22 We thank Matthew Ringgenberg for suggesting that we examine this subsample.
implied borrowing cost for longer horizons allows more time during which the indicative borrowing fee could change dramatically. Again, we find no evidence of a larger risk premium for this subsample.

The remaining rows of Table 6 restrict the sample based on various option characteristics to ensure that option prices are more likely to be large relative to option trading costs and that the observed option prices are not simply stale quotes. The fourth row restricts the sample to observations for which the sum of the call and put bid-ask spreads divided by the stock price is less than or equal to 1%. Any “noise” due to wide bid-ask spreads should be less relevant for this sample. The fifth row restricts the sample to observations for which the stocks with high average prices, and presumably, higher option prices and lower relative spreads. 23 The sixth row restricts the sample to observations of put-call pairs with higher implied volatility and the seventh row restricts the sample to observations with higher average option volume during the previous month. The largest estimate of the risk premium across all of the possible subsamples is 51 basis points per year (or about 4 basis points per month). The magnitudes of these alternative estimates suggest that there may be a modest borrowing fee risk premium.

In this context, we also validate the decision to use the midpoint option prices to calculate the implied borrowing fee and the borrowing fee risk premium. In Columns 5 through 8 of Appendix Table 2, we restrict the sample of observations to those with utilization less than 60% and with short fee risk below the cross-sectional median on each date. For this sample, the average indicative fee is low and the risk premium should be trivial because the probability of a subsequent change in the indicative fee is also low. Consistent with this and our main results, the option-implied lending fees computed from option-bid ask midpoints are only slightly greater than the indicative fees. However, if the implied borrowing fee is calculated using option prices on the appropriate side of the bid-ask spread for a synthetic short stock position, then the average implied borrowing fee would be about 8%. The difference between the average implied fee and the average indicative fee for this sample would require a borrowing fee risk premium larger than the average risk premium for the stock market.

Figure 3 presents kernel regression estimates showing how the indicative fee, adjusted option-implied fee, and borrowing fee risk premium vary with utilization. While both the

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23 Merton (1973) shows that option prices are linear homogenous in underlying stock prices. Thus, holding other option characteristics fixed, higher stock prices result in higher option prices and lower relative spreads.
indicative fee and the option-implied fee increase considerably as utilization increases above 60%, the estimate of the risk premium does not follow the same pattern. Rather, it is approximately constant, and actually becomes slightly negative when utilization is very high. The indicative fee and adjusted option-implied fee remain low for utilization ranging from 0% to about 40%. The option-implied fee is slightly above the indicative fee for this range. Both variables increase rapidly above 40% utilization and the two fee measures are approximately linear in utilization once utilization is above 60%. These results indicate that the 60% utilization cut-off used to construct the hard-to-borrow subsample is reasonable. The figure also supports our conclusion that the risk premium for hard-to-borrow stocks is modest is not sensitive to this particular cut-off.

Finally, Table 7 presents evidence that there was a differential risk premium in the option-implied borrowing fees of financial stocks shortly before and immediately after the 2008 ban on shorting financial stocks. During these periods option market makers were plausibly worried about the possible imposition or re-imposition of a policy banning the short selling of financial stocks from which they might not be exempt. Thus, if a borrowing risk premium ever exists, it is likely to be found for financial stocks during this turbulent time period. The two columns in Table 7 under the heading Indicative Fee report the average indicative fee for the stocks that were banned and those that were not banned for several periods before and after the short-sale ban. While the average indicative fees for the banned stocks are slightly greater than those for the stocks that were not banned, the differences are not economically important. The next two columns report the average ex ante borrowing fee risk premium for the banned and not banned stocks, where the ex ante risk premium is defined as the difference between the option-implied and contemporaneous quoted indicative borrowing fees. The point estimates in these two columns suggest that the risk premium was elevated in the two-month periods just prior to and just after the ban on shorting financial stocks. The columns headed Difference and Diff.

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24 The 2008 ban on short selling financial stocks is discussed and analyzed by Battalio and Schultz (2011) and Boehmer, Jones, and Zhang (2013).

25 We considered an analysis of the risk premium during the ban period itself. However, new short positions in financial stocks were precluded, and so, continuing to borrow shares to maintain old short positions for these stocks became virtually costless.

26 The time periods we examine in this table are very short and the changes in indicative borrowing fees are cross-sectionally correlated. Due to these factors, the approach of estimating the risk premium as the difference between the option-implied borrowing fee and the average realized indicative fee over the life of the option used to estimate the option-implied fee that we use elsewhere in the paper is more difficult to interpret in this context.
(w/o controls) address whether the elevated risk premiums during this time period are statistically significant. The coefficient estimates and corresponding $t$-statistics in the columns headed Difference are from specifications with an indicator variable equal to one for banned financial stocks and zero for other stocks in panel regressions that explain the ex ante risk premia, controlling for market capitalization, stock return volatility estimated as the idiosyncratic volatility from a three-factor Fama-French model over the previous 21 days, and the contemporaneous stock return, which is included to control for the mechanism identified in Goncalves-Pinto, Grundy, Hameed, van der Heijden, and Zhu (2017) by which stock market price pressure causes put-call parity deviations. The coefficient estimates on the indicator variable were 0.54% (0.84%) during the two-month periods before (after) the ban, with a $t$-statistic of 2.1 (2.6). The results in the columns headed Diff. (w/o controls) are from panel regressions without the controls, and are slightly stronger. Thus, we find evidence consistent with a borrowing fee risk premium for financial stocks during times when such a risk premium is likely to be found. However, this result must be evaluated with some caution because it is also possible that the option-implied fee is high relative to the current indicative fee for the stocks that were banned because the indicative fee was expected to differentially increase in the future for these stocks. In this scenario, the true risk premium could still be close to zero even though this estimate of the risk premium is large.

5. Cross-sectional return predictability

The results in Table 4 from the preceding section show that the implied borrowing fee is a strong predictor of the change in the indicative borrowing fee during the remaining life of the option pair. Since the expected cost of a short position is likely to be a key determinant of any limits to arbitrage associated with short sales, we analyze the predictability of stock returns based on the implied borrowing fee. Table 8 presents the results of these panel regressions for various specifications. The predictive relation between the implied borrowing fee and subsequent returns is negative and highly significant. While we initially focus our attention on the full sample using weekly stock returns, we also consider the subsample of stocks with high utilization that we label as hard-to-borrow (Columns 5 through 8) and stock returns during the subsequent month (Panel B). The subsample of hard-to-borrow stocks is the group where predictability due to differences in the cost of short selling may be the most relevant.
In Column 1, the t-statistic indicates overwhelming statistical significance of the predictive relation between the implied borrowing fee and stock returns during the next week in Panel A and during the next month in Panel B. Of course, it is possible that the implied borrowing fee only reflects the current cost determined by the market for short sales for a particular stock, that is, the current indicative borrowing fee. Column 2 indicates that the predictive relation between the implied borrowing fee and subsequent returns is clearly distinct from any role associated with the current indicative fee.

Engelberg, Reed, and Ringgenberg (2018) argue that short selling risk is relevant for the cross-section of stock returns. Essentially, this hypothesis is motivated by the observation that shorting stocks with volatile borrowing fees incorporates another source of risk into the returns of short positions. In the theoretical setting of De Long, Shleifer, Summers, and Waldmann (1991), idiosyncratic risk precludes undiversified and risk averse arbitrageurs from fully correcting any potential mispricing. The ability of a risk averse and undiversified arbitrageur to move an asset's price toward its fundamental value degrades further in the presence of high idiosyncratic volatility and the findings of Wurgler and Zhuravskaya (2002) regarding index inclusions support this theory. The results of Engelberg, Reed, and Ringgenberg (2018) indicate that stocks with higher short selling risk, as measured by the estimates of fee volatility, tend to have lower subsequent stock returns. The authors suggest that the high volatility of the borrowing fee prevents short sellers from taking sufficiently large short positions to drive down the current stock price immediately and eliminate the subsequent low returns.

The estimate in Column 3 confirms that there is a strong univariate relation between short fee risk, as measured by the volatility of the indicative borrowing fee during the previous twelve months, and subsequent stock returns. However, the estimates in Column 4 indicate that in our sample of optionable stocks the predictive power of short fee risk is subsumed by the other covariates. We include other characteristics of the securities borrowing market discussed in the existing literature along with the log of market capitalization for each particular stock. Once these other measures of short sales activity are incorporated, the estimated coefficient for short fee risk becomes statistically insignificant. The predictive relation between the implied

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27 Also, as explained in footnote 8 above, our short fee risk measure is not exactly identical to that used in Engelberg, Reed, and Ringgenberg (2018) because their measure is computed from lender-side fees and ours is computed from buy-side indicative fees.
borrowing fee and subsequent stock returns does not change noticeably in magnitude or statistical significance once the other variables introduced in Column 4 compared to the estimation results in Column 2.

In Columns 5 through 8, we repeat our analysis for the subsample of dates for which a specific stock is hard to borrow, that is, dates with high utilization (above 60%) for a particular stock. To the extent that the cross-section of subsequent stock returns is influenced by the limits to arbitrage created by the properties of the market for short positions, these considerations should be more important at times where relatively high demand is more likely to generate borrowing constraints now or in the near future. The predictability of stock returns using the implied borrowing fee in this subsample is quite similar to the evidence presented in Columns 1 through 4 even though these specifications include less than 10% of the observations. In addition, with the exception of the estimated coefficients for the implied borrowing fee, the other variables of interest in Column 8 are not significant for this subsample. Apparently, the other variables measuring short selling activity in the stock market do not explain the cross-sectional pattern of expected returns in the subsample that should be the most relevant.

We also revisit all eight specifications for stock returns during the subsequent month in Panel B. The coefficient estimate for the implied borrowing fee is approximately three times larger compared to Panel A. The patterns of statistical significance for the same predictors of stock returns remain virtually unchanged compared to the analogous patterns for stock returns during the next week. With the exception of the implied borrowing fee, none of the potential predictors are statistically significant when all predictors are included for the hard-to-borrow observations. The results of these specifications indicate that the relation between the implied borrowing fee and subsequent returns is relevant even after controlling for other variables.

Since the preceding section of this paper indicates that the implied borrowing fee does not exhibit a large positive risk premium, we interpret the implied borrowing fee as a proxy for the expected cost of holding a specific short position. The explanation of stock return predictability using the implied borrowing fee readily follows from this interpretation. Essentially, the level of the expected borrowing fee, rather than the risk properties of the borrowing fee, is responsible for the observed limit to arbitrage. This explanation is clearly consistent with the basic idea that short sellers should be less likely to take large short positions whenever doing so is expensive, e.g. Miller (1977). We generalize this concept because the
expected cost of the short position during the subsequent week or month, rather than the current
daily cost of the short position, creates the limit to arbitrage. This explanation of the findings is
also consistent with the evidence that the current indicative borrowing fee is not significant
predictor of returns in many specifications. The implied borrowing fee is a better proxy of the
expected costs of short selling for the relevant horizon of typical short position. We conclude that
the expected cost of the short position is the main limit to arbitrage. The potential riskiness of the
borrowing fee may only be a second order consideration in terms of return predictability.

Thus, it appears that the expected cost of short selling as measured by the implied
borrowing fee is the dominant limit to arbitrage. In general, this finding supports the existing
literature that measures of borrowing market activity such as borrowing fees, short interest, and
the relative demand for lendable shares are typically negatively related to stock returns. The
implied borrowing fee is a better summary statistic of the various forces at work in the securities
borrowing market compared to the other measures used in the literature. At the same time, the
relation between short fee risk and returns in Engelberg, Reed, and Ringgenberg (2018) appears
to be due to the omission of other variables related to the expected cost of maintaining short
positions. The volatility of the fee does not have any predictive power after controlling
appropriately for proxies related to the expected cost of short positions.

Next, we investigate the subsequent performance of portfolios formed using the implied
borrowing fee. Following the performance evaluation approach described in Section 3, we sort
stocks into portfolios each trading day based on the implied borrowing fee. We evaluate
performance for each decile during the subsequent month after skipping one trading day. The
first row of Panel A indicates that stocks with low implied borrowing fees have higher returns
than stocks with high borrowing fees. This difference in performance is statistically significant.
The differential performance is mostly due to the low stock returns in the tenth decile compared
to the other portfolios, but there is also a clear monotonic performance pattern from decile 1 to
decile 10 for these unadjusted returns. After the indicative borrowing fee adjustment during the
evaluation period, the return to the high-fee portfolio switches from $-0.41\%$ to an insignificant
$0.04\%$ per month. The estimate of the performance differential between the top and bottom
deciles is also attenuated but to a lesser extent because only one leg of the long-short portfolio is
impacted by high borrowing fees, and the corresponding $t$-statistic is only 1.1. Of course, this
reduction in the performance differential estimate is unsurprising because the implied borrowing
fee is an estimate of the expected costs associated with maintaining a short position in the near term, and so, the differences in performance associated with the implied fee should reflect future realized fees for the most part. The pattern of attenuated performance after taking borrowing fees into account is similar to the patterns in Table 2 and Table 3 for portfolios generated using the indicative fee and short fee risk, respectively.

In Panel B, we revisit the same portfolio strategy using the implied borrowing fee and risk-adjusted performance using the four-factor model. The factor specification increases the precision of the estimate for the decile 10 portfolio and the performance differential because there are substantial loadings on the SMB factor. The abnormal performance of the decile 10 portfolio and the 10-1 performance differential are slightly larger as compared to Panel A, and the corresponding t-statistics are more than twice as large. After adjusting for the indicative fees during the next month, the abnormal performance of the decile 10 portfolio changes from −0.55% to an insignificant −0.10% per month. The abnormal performance differential is attenuated to less than half of its unadjusted magnitude, and this residual performance differential is mainly due to decile 1. The differential remains statistically significant and there is a clear monotonic pattern across the deciles. Thus, the implied borrowing cost appears to contain some information about future abnormal performance even after adjusting for the indicative borrowing fees that are realized in the future.

6. Option-based predictors of stock returns

There is also an expanding literature investigating links between option markets and stock returns using various measures of implied volatility. For instance, Bali and Hovakimian (2009) and Cremers and Weinbaum (2010) show that the average difference between the implied volatilities of calls and puts with the same strike price and expiration date, also known as the implied volatility spread, positively predicts stock returns. In addition, Xing, Zhang, and Zhao (2010) show that the implied volatility skew, the difference between the implied volatility of an OTM put and an ATM call, is a negative predictor of stock returns. A common interpretation of this predictability is that demand pressure in the options market due to informed trading alters option prices and implied volatilities but is only slowly reflected in stock prices, causing the option implied volatility measures to predict returns. An alternative interpretation starts from the observation that the implied volatilities are computed assuming that the stock borrowing fee is
zero. If the borrowing fee is not zero, then treating it as zero generates negative and positive errors in estimates of call and put implied volatilities, respectively. This suggests that the implied volatility measures might predict returns because they are transformations of the omitted stock borrowing fee, a variable that predicts gross-of-fee stock returns. Thus, the underlying source of stock return predictability associated with these measures is an open question.

In Table 10 we analyze the stock returns during the subsequent month of portfolios formed using implied volatility spread and skew. All stocks are sorted into portfolios based on a particular option-implied measure as of the close of trading day \( t \). Following the performance evaluation approach in previous sections, stocks are held from the close of trading day \( t + 1 \) until the close of trading day \( t + 22 \), to mimic the return for a typical month with 21 trading days.

When we sort on implied volatility spread, decile 1 contains the stocks with the highest spreads, and decile 10 contains the stocks with lowest (most negative) spreads. The first row of Panel A confirms that stocks with higher implied volatility spread (decile 1) have higher returns than stocks with lower volatility spread (decile 10). This difference is statistically significant and the differential performance is largely due to the low average return in the tenth decile compared to the other portfolios. While the reported estimates are not risk-adjusted, in unreported results the estimated abnormal performance differential using a four-factor model is virtually identical to the raw differential reported in the table.

After adjusting for the indicative borrowing fee in the second set of results in Panel A, the average return on the decile ten portfolio switches from \(-0.41\%\) to \(0.02\%\) per month. Approximately half of the estimated ten minus decile one performance differential disappears, what remains is due to the decile one portfolio, and this adjusted differential is not statistically significant. This pattern is due to the impact of the borrowing fee adjustment on the performance of the tenth portfolio. The observed underperformance of stocks with a high implied volatility spread is concentrated amongst stocks that have high costs for short positions. Essentially, the differential performance observed before adjusting for borrowing fees is not exploitable through short positions because the costs of borrowing faced by the marginal institutional investor are high for these stocks.

Panel B of Table 10 conducts a similar analysis for implied skew instead of implied volatility spread. Here, deciles one and ten contain the stocks with the lowest and highest skews, respectively. The first row of Panel B confirms that stocks with high implied skew have low
returns compared to stocks with low implied skew. Once again, the difference in performance between the top and bottom deciles is statistically significant and this difference is almost entirely associated with the poor performance of the tenth decile compared to all of the other deciles. In unreported results, the four-factor model yields a very similar pattern for all deciles as well as the difference in abnormal performance for the top and bottom deciles. The second set of results in Panel B incorporate the adjustment for the indicative borrowing fee. This correction alters the decile ten performance from a significant $-0.52\%$ per month to an insignificant $-0.12\%$ per month. It also reduces the performance differential to about half of its original magnitude, and it is no longer statistically significant. The adjustment for the borrowing fee has a very large impact on the performance of the tenth decile and this indicates that low unadjusted stock returns for stocks with high implied skew are not exploitable by the marginal investor via short positions.

Table 11 analyzes the same implied volatility measures using panel regressions. First, we confirm the existence of a strong univariate predictive relation between each of these implied volatility measures and subsequent stock returns. Column 1 indicates that the implied volatility spread is positively related to returns next week. Column 2 shows that implied volatility skew is negatively related to returns next week. However, when we augment this approach with the implied borrowing fee and and the indicative borrowing fee, the only consistently significant predictors of stock returns are the implied borrowing fee and the indicative borrowing fee. In Column 4, we augment the specification by including utilization, short fee risk, short interest, and market capitalization as control variables. Again, the coefficients for implied volatility spread and implied volatility skew are not significant, while the implied borrowing fee remains strongly statistically significant ($t$-statistic of about 5). Neither the implied volatility spread measure from Cremers and Weinbaum (2010) nor the implied skew measure from Xing, Zhang and Zhao (2010) are significant predictors of returns next week after controlling for borrowing fees.

Following our typical practice, we revisit these specifications for stock returns during the next month. In Column 5 and Column 6 we verify the presence of a strong univariate relation between each implied volatility spread measure and stock returns next month. If we include the measures of borrowing fees, Column 7, the two clearly significant predictors of returns related to short selling are the option-implied borrowing fee and the indicative borrowing fee. The implied
volatility spread measure is not significant in this specification and the coefficient estimate changes sign relative to the univariate relation. The implied skew measure from Xing, Zhang, and Zhao (2010) is not a significant predictor of returns and the t-statistic is almost identically zero. This pattern of coefficient estimates is virtually unchanged in Column 8 after including the additional control variables.

In Table 12 we revisit the specifications in Table 11 while adjusting subsequent stock returns for the indicative borrowing fee. This adjustment dramatically reduces the strength of the univariate relation between implied volatility spread and subsequent stock returns, Columns 1 and 5, as well as the relation between implied skew and subsequent stock returns, Columns 2 and 6. While the univariate coefficients remain statistically significant, the magnitudes of these coefficients decline by at least one half and in some cases more than two thirds. This pattern of attenuation indicates the stock return predictability associated with either of these transformations of option prices is due to the high costs of borrowing for a relatively modest number of stocks. Once the variables measuring borrowing fees are included, both implied volatility spread and implied skew are no longer significant predictors of stock returns during the next week. Instead, the implied borrowing fee and the indicative borrowing fee predict subsequent stock returns. These results reflect the same patterns of predictability for unadjusted returns that were present in Table 11. For returns during the subsequent month, the results are quite similar except the coefficient estimate for implied volatility spread changes sign once the variables reflecting borrowing fees are included. This pattern of results is not affected by the inclusion of the additional control variables in Columns 4 and 8.

To further distinguish between explanations of predictability related to price pressure in the options market and the expected costs of borrowing, Table 13 revisits the specifications in Table 11 for the subset of observations with average daily option volume of less than 100 contracts. The ability of the option-implied spread and skew to predict returns is interpreted as evidence that informed trading occurs in the option market. It is conceivable that the implied borrowing fee predicts returns only because it is a better measure of this informed trading. However, the results in Table 13 indicate that the implied borrowing fee retains its predictive power even for observations with very low option volume. Since the implied borrowing fee remains such a useful predictor of subsequent returns for this subset of observations, any explanations related to price pressure in the options market, including those related to informed
trading, would appear to be largely irrelevant. In general, these results indicate that stock return predictability related to these transformations of option prices is really a consequence of the expected cost to borrow stocks.

7. Conclusion

Measures of short selling activity and short sale constraints that are readily available to sophisticated investors predict stock returns. This finding, documented extensively in the literature, presents a puzzle. We use portfolio sorts and measures of the stock borrowing costs paid by short-sellers to show that the returns to shorting net of stock borrowing costs are much smaller than the gross returns, and not significant. This partially resolves the puzzle of the persistence of predictability based on readily available information, but does not fully eliminate the puzzle because panel regressions show that the option-implied borrowing fee continues to predict returns net of borrowing costs. The smaller magnitude of the net of borrowing cost returns also makes explanations of the puzzle in terms of trading costs and risk of borrowing fee changes more likely to be viable. For example, it seems unlikely that borrowing fee risk could fully explain the return of 109 basis points per month (≈13% per year) to shorting the decile ten stocks or the decile ten minus decile one long-short spread of 143 basis points per month (≈17% per year) in Table 2. Nevertheless, it could more plausibly explain the net of borrowing cost returns of 22 basis points for shorting decile ten and of 59 basis points for the long-short spread between the top and bottom portfolios.

We also use option implied borrowing fees to estimate the risk premium to bearing the risk of borrowing fee changes. Specifically, the average difference between the option-implied borrowing fee and the average daily borrowing fee during the life of the option pair used to compute the option-implied borrowing fee is an estimate of the borrowing fee risk premium. We find that the option-implied borrowing fees are only slight larger than the relevant realized daily borrowing fees. This result implies that the risk of borrowing stock does not create a substantial risk premium reflected in the prices of exchange-traded options. The finding is consistent with the possibility that borrowing fee risk for individual stocks is largely diversifiable and the options market is sufficiently competitive and well-capitalized to distribute this risk effectively.

It should be the case that the option-implied borrowing fee predicts the changes in the daily borrowing fee during the life of the option. Indeed, we find that the option-implied borrowing fee is a strong predictor of changes in realized indicative borrowing fees. This finding
is evidence that the option-implied borrowing fees we compute are useful forward-looking estimates of the borrowing fees during the lives of the options. Since option prices are public information readily available to all investors, these results also indicate that one valid measure of the expected cost of short selling is public information.

If the option-implied borrowing fee is a forward-looking estimate of the actual borrowing fees and the expected cost of short selling is a limit to arbitrage, then this measure should predict future stock returns. We estimate predictive regressions using the option-implied borrowing fee and find that option-implied borrowing fees predict stock returns next week and next month. This relation is highly significant even when other variables such as the indicative borrowing fee, loan utilization, short interest, and the short fee risk are included. Indeed, aside from utilization, these other measures of borrowing market activity are typically not significant predictors especially for hard-to-borrow stocks. Our results suggest that the option-implied borrowing fee is a better measure of expected costs of shorting than the lending fee and short interest commonly used in the literature. In all likelihood, this superior performance is due to the fact that the option-implied borrowing fee is a better measure of future borrowing fees during the holding period of the typical short position.

We also find that the option-implied borrowing fee is related to the literature relating option-implied volatility measures to subsequent stock returns. Cremers and Weinbaum (2010) find that the implied volatility spread is positively relate to stock returns and Xing, Zhang, and Zhao (2010) show that the implied volatility skew is negatively related to returns. If we include the option-implied borrowing fee and these other option-based predictors in predictive regressions, we obtain significant coefficients on the option-implied borrowing fee and insignificant coefficients on both the implied volatility spread and the implied volatility skew. This pattern suggests that the implied volatility measures only predict returns because they proxy for the option-implied borrowing fee. This result may have important implications for any potential explanations of these existing findings in the literature. For example, the explanation proposed by Xing, Zhang, and Zhao (2010) is that informed traders use out-of-the-money put options to exploit an informational advantage. This seems to be quite distinct from the limit to arbitrage explanation generated by the expected costs of short selling.
References


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Figure 1. Borrowing fees and stock price of AIG.
Panel A shows the adjusted option-implied and indicative fees to borrow AIG stock during the sample period from July 2006 to July 2015. The computation of the adjusted option-implied fees is described in Section 4 and the indicative fees are from Markit. The option-implied fee is not available during the period when the AIG stock price is less than $5 per share because this price level is used as a filter in constructing the optionable sample. Panel B shows the stock price of AIG from CRSP for the same time period.
Figure 2. Cross-sectional average stock borrowing fees for hard-to-borrow stocks
This figure plots the daily cross-sectional average, equally weighted, for the adjusted option-implied borrowing fee and the cross-sectional average indicative borrowing fee for the hard-to-borrow stocks. The sample on each date consists of the set of optionable stocks with utilization greater than 60% in CRSP that match to a valid put-call pair in Optionmetrics and an indicative borrowing fee in Markit. The option-implied fees are adjusted to take account of early exercise using the procedure described in Section 4. The filters used to identify the stocks with at least one valid put-call pair to calculate the option-implied fee are described in Section 2. The sample period is July 2006 to August 2015.
Figure 3. Stock borrowing fees and borrowing fee risk premium
This figure plots the fitted values from kernel regressions of the indicative borrowing fee, adjusted option-implied fee, and borrowing fee risk premium on utilization. The unit of observation is the combination of a stock and trading date for the optionable subset of common stocks in CRSP that match to a valid put-call pair in Optionmetrics and an indicative borrowing fee in Markit. The computation of the adjusted option-implied borrowing fee is described in Section 4. The borrowing fee risk premium is the difference between the adjusted option-implied fee and the average realized indicative fee during the life of the put-call pairs used to compute the option-implied fee. The filters used to identify the stocks with at least one valid put-call pair to calculate the option-implied fee are described in Section 2. The sample period is July 2006 to August 2015. The kernel regressions were estimated using the Stata function lpoly, with the default options of local mean smoothing and the Epanechnikov kernel.
This appendix contains additional summary statistics and supplementary results to support the findings in the paper “Understanding Returns to Short Selling Using Option-Implied Stock Borrowing Fees.”

Appendix Table 1 reports the correlation matrices for selected characteristics for the two samples used in the paper. Panel A presents the correlation matrix of the characteristics for common stocks in CRSP that also have an indicative borrowing fee in Markit, market capitalization is greater than or equal to $10 million, and stock price is greater than or equal to $5. The unit of observation is a stock-trade date. Panel B presents the correlation matrix for the sample of optionable stocks. This sample consists of the subset of stock-dates from the sample used in Panel A for which there is also a valid put-call pair in Optionmetrics used to compute an option-implied stock borrowing fee. The filters used to construct the sample of optionable stocks with a valid put-call pair are indicated in Section 2 of the paper.

Appendix Table 2 presents results showing the cost of synthetically shorting stock using the options markets for the sample of easy to borrow optionable stocks (utilization less than 60%) and a subsample of these easy to borrow optionable stocks that also have low short fee risk (short fee risk less than its cross-sectional median). The first two rows report the mean and medians of the indicative fee and the adjusted option-implied fee; these are included for comparison with the results for other samples in the paper as well as the results in the other rows of the table. The remainder of the table reports various estimates of the cost of synthetically shorting by buying put options and writing call options, assuming that the puts and calls are purchased and sold at the end-of-day ask and bid prices reported in OptionMetrics. The measure of the cost of synthetically shorting is the adjusted option-implied stock borrowing fee computed using put ask prices and call bid prices rather than bid-ask midpoints.

In the third row, for each stock-date the cost of shorting is estimated as the median option-implied fee across the available put-call pairs. In the fourth row, for each stock-date the cost of shorting is estimated as the mean option-implied fee across the available put-call pairs. In the fifth and sixth rows, for each stock date the cost is estimated as the minimum or maximum, respectively, of the option-implied fee across the available put-call pairs. For each case, the table then reports the means and medians of the stock-date medians, means, minima, or maxima, as the case may be. These results show that the cost of synthetically shorting using options markets is extremely high compared to the average borrowing fee for both samples. Indeed, the
borrowing fee risk premium estimated using the cost of synthetic shorting is implausibly large. For instance, in the easy to borrow sample with low short fee risk, we would expect this borrowing fee risk premium to be near zero. Instead, the median implied fee based on option prices at the appropriate bid and ask is about 7.8% even though the average borrowing fee is only about 0.4% for this sample.

Appendix Table 3 parallels Table 6 of the paper but provides additional statistics not reported in Table 6. In addition to reporting the adjusted option-implied borrowing fee risk premium, for each of the subsamples in Table 6 Appendix Table 3 also reports the mean and median risk premium based on the unadjusted option-implied fee, the adjusted and unadjusted option-implied borrowing fees, and the indicative fee.

Appendix Table 4 shows that option market makers’ positions in calls and puts vary with utilization. When utilization is high market makers’ net delta-hedge position will involve shorting the stock. The table is constructed by first sorting stock into deciles by utilization. Then for each decile, the first two rows of Panel A presents averages of cumulative monthly order imbalances for call and puts option types for ISE customers based on equal-weighted portfolios of stocks. The third row presents the difference (calls minus puts) in the cumulative order imbalance. These results show that for the high utilization portfolios, the customers of the market makers are typically writing calls and buying puts. Option market makers will hedge this customer demand by short selling stock. Panel B shows the mean adjusted option-implied and indicative borrowing fees for the portfolios sorted based on utilization. This strong monotonic relation indicates that the borrowing fees and utilization are closely linked. Market makers will tend to have short positions when the indicative borrowing fee is high.

Appendix Table 5 shows the gross and net-of-borrow-fee returns for the high fee (high fee risk) decile portfolio when portfolios are sorted by fee (fee risk), using different fee adjustments. The first two columns in Panel A show the average gross return and the average net-of-borrow-fee return using the indicative fee to make the adjustment; these repeat results for the decile 10 portfolio reported in Table 2 Panel A. As in Table 2 Panel A, the adjustment using the indicative fee reduces the magnitude of the return from −1.09% to −0.22%. In the third column, Historical Fee (SAF) Adj., the adjustment is implemented using the historical borrowing fee, the simple average fee (SAF) from Markit. This variable is described as “Simple average fee of stock borrow transactions from hedge funds in this security.” Using this adjustment, the
magnitude of the return is only reduced to \(-0.53\%\), larger than the net-of-borrow-fee return of \(-0.22\%\) computed using the indicative fee. But on average the historical fee variable SAF is available for only 43\% (=135/311) of the decile 10 stocks, emphasizing the potential for a specific form of selection bias in which the historical fee, SAF, tends to be unavailable when the true borrowing fee is large. The fourth column, Indicative Fee Adj. Conditional Sample, confirms the existence of such a selection bias. The net-of-borrow-fee returns in this column are computed using the indicative fee, but only using the sample of stocks for which SAF is available. The net-of-borrow-fee return in this column is \(-0.40\%\), somewhat closer to the estimate of \(-0.53\%\) based on SAF than to the estimate of \(-0.22\%\) based on the indicative fee. Much of the difference between the net-of-borrow-fee return of \(-0.53\%\) computed using SAF and the net-of-borrow-fee return of \(-0.22\%\) computed using the indicative fee is due to selection bias rather than to differences between SAF and the indicative fee when both are available.

Panel B shows corresponding results for the decile 10 portfolio when decile portfolios are formed by sorting by fee risk. As in Table 3 Panel A, the adjustment using the indicative fee reduces the magnitude of the return from \(-1.06\%\) to \(-0.28\%\). Similar to Appendix Table 5 Panel A, adjusting returns using the historical fee results in a much larger estimate of the net-of-borrow-fee return of \(-0.68\%\). But again, the historical fee based on the Markit variable SAF is available for only about 40\% of the decile 10 stocks. The fourth column, Indicative Fee Adj. Conditional Sample, adjusts performance using the indicative fee, but only includes stocks for which SAF is available. The net-of-borrow-fee return in this column is \(-0.56\%\), much closer to \(-0.68\%\) based on SAF than to the estimate of \(-0.28\%\) based on the indicative fee. Similar to the results in Panel A, most of the difference between the net-of-borrow-fee return of \(-0.68\%\) computed using SAF and the net-of-borrow-fee return of \(-0.28\%\) computed using the indicative fee is due to the selection bias of which stocks have SAF data rather than to the differences between the historical fee based on SAF and the indicative fee when both are available.