Failure *is* an Option: Impediments to Short Selling and Options Prices

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Abstract

A regulatory advantage of options market makers allows them to short sell without borrowing stock. Two years of transactions by a major market maker show these failed deliveries in over half of the hard-to-borrow situations, and not a single negative-rebate loan. Despite this low cost of short exposure, options on hard-to-borrow stocks trade far from parity, implying significant profits for the market makers. This imperfect-competition equilibrium may result from economies of scale; the rule that allocates buy-ins favors higher-volume market makers, and we demonstrate that buy-in risk is disproportionately large for small market makers.

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Short sellers usually deliver borrowed shares to their buyers three days after the sale. Once delivered, the shares secure the economic value of the position; the shares can be exchanged for cash at any time. But when shares are difficult to borrow, delivery failure is an option for some well-placed market participants. Options market makers have the unique ability to short sell without locating shares to deliver, and they may choose to exercise their option to fail to deliver shares three days after the sale is made. In this case, a pledge to deliver shares made by the seller's clearing firm secures the buyer's economic position.

Making use of a two-year database of short-sales, borrowing and delivery failures from a large options market-making firm, we show one of the five largest market participants fails to deliver shares in 52% of the positions requiring delivery. However, we find that the risk of failing to deliver shares is small in our sample. Buyers rarely force market makers to deliver shares; forced deliveries, or *buy-ins*, occur in 0.12% of failed deliveries. Furthermore, buy-in prices are not statistically different from market asking prices.

Despite the low apparent risk in failing to deliver shares, the ability to short-sell cheaply can be used to profit from misalignments between stock and options markets. We show that trades taking advantage of violations of put-call parity result in profits of $70 per option contract. Furthermore, we focus on two events where stocks are hard-to-borrow and the option to fail to deliver is particularly valuable: IPO lockup expirations and merger announcements. We show that put-call arbitrage earns $58 per contract when IPO lockup trades are driving short-selling difficulty, and the trade earns $38 per contract when merger arbitrage is driving short-selling difficulty. Clearly, profits arising from put-call parity arbitrage are large.

So the question is: why don't market makers take advantage of these situations until the profits are driven to zero? Using a unique dataset form one market maker, we confirm the possibility of top market makers obtaining buy-in protection. After controlling for size, volatility and market wide short interest, we find that the market maker's proportion of short interest is not statistically related to the probability of being bought in. This protection is a barrier to entry; large options market makers face lower buy-in risk than newer, smaller market makers. We conjecture that the limited number of large options market makers prevents options prices from converging to the perfect competition equilibrium. In other words, put prices remain high in the imperfect-competition equilibrium as top options market makers collect rents on their unique ability to hedge put options without borrowing stock. However, the profits arising from put-call parity arbitrage don't take the costs of being a top market maker into account; we measure accounting profits from a particular trading strategy and not economic profits for the firm as a whole.

The rest of the paper is organized as follows. Section I explains how this paper fits into the literature. Section II describes the database. Section III presents our results, and Section IV concludes. The appendix includes a brief introduction to short selling and delivery.

I. Related Literature

In this paper, we identify the possibility of profiting from the misalignment of stock and options markets in the face of market makers' upper bound of the cost of short exposure. In so doing, this paper contributes to existing literature in three areas: short selling impediments derived from the equity lending market, the difference between predicted and observed options prices, and tests of put-call parity.

This paper is not the first to document that difficulty in borrowing stocks is related to a break down of put call parity. Lamont and Thaler (2001) find that impediments to short selling prevent traders from exploiting seemingly profitable arbitrage strategies resulting from the misalignment of stock prices in equity carve-outs. Similarly, in concurrent research, Ofek, Richardson and Whitelaw (2002) measure the relationship between increased borrowing costs and put-call disparity and find cumulative abnormal returns for arbitrage strategies involving put-call disparity exceed 65%. But, as in Jarrow and O'Hara (1989), market imperfections prevent most arbitrageurs from turning the misalignment into a profit. The put-call parity trades studied here can only be performed by market participants who can always borrow stock or else short sell without borrowing stock; in other words, rebate rates are only valid if stocks are found and borrowed. Our study has the unique advantage of a coherent approach that combines borrowing costs and feasibility for one market participant: a large options market maker.

A. The Equity Lending Market.

A number of recent papers have examined prices from the equity lending market, which are generally thought of as direct impediments to short selling. Reed (2002) uses one year of daily equity loan data to measure the reduction in informational efficiency resulting from short-sale costs. Geczy, Musto and Reed (2002) measure the impact of equity-loan prices on a variety of trading strategies involving short selling. The paper finds prices in the equity lending market do not preclude short-sellers from getting negative exposure to effects on average, but in the case of stock-specific merger arbitrage trades, short selling impediments reduce profits substantially. Cristoffersen, Geczy, Musto and Reed (2002) use the same database to study stock loans that are not necessarily related to short selling. The paper finds an increase in both quantity and price of loans on dividend record dates when the transfer of legal ownership leads to tax benefits. Using another database of rebate rates, Ofek and Richardson (2003) demonstrate that short selling is generally more difficult for Internet stocks in early 2000, and D'Avolio (2002) uses 18 months of daily data to relate specialness to a variety of stock-specific characteristics. Jones and Lamont (2002) study borrowing around the crash of 1929; the paper finds that hard-to-borrow stocks had low future returns. Finally, Duffie, Gârleanu and Pedersen (2002) formulate a model of the equity lending market.

B. Predicted and Observed Options Prices.

By relating short selling to option prices, this paper also contributes to the large literature on the difference between Black-Scholes (1973) options prices and observed option prices. MacBeth and Merville (1979) and Rubinstein (1985) show that, empirically, implied volatilities are not equal across option classes and that deviations are systematic. As in Derman and Kani (1994), these systematic deviations are commonly referred to as the volatility smile. Longstaff (1995) shows that the difference between Black-Scholes and actual option prices increase with option bid-ask spreads and decrease with market liquidity. While Longstaff's results are contested in later work (i.e. Strong and Xu (1999)), he provides a novel approach to testing the impact of market frictions on option prices. Dumas, Flemming and Whaley (1998) test a range of time- and state-dependent models of volatility meant to account for observed deviations from Black-Scholes prices. The paper concludes that these models still leave a large mean-square error when explaining market prices. Using Spanish index options, Peña, Rubio and Serna (1999) find evidence consistent with U.S. markets; they find a positive and significant contribution of the bid-ask spread to the slope of the volatility smile. Dennis and Mayhew (2000) examine the contribution of various measures of market risk and sentiment on individual index options and find that both are correlated with the smile.

C. Tests of Put-Call Parity

Some of the evidence on the impact of short-sale impediments on options prices is presented here in terms of put-call parity. Tests of put-call parity date back to Klemkosky and Resnick (1979) who find option market prices to be largely consistent with put-call parity. In a related paper that focuses on the speed of adjustment of option and stock markets, Manaster and Rendleman (1982) conclude that closing options prices contain information about equilibrium stock prices that is not contained in closing stock prices. While the implied stock price measure employed in our work differs substantially from that of Manaster and Rendleman (1982), the approach of comparing actual and implied stock prices is similar.

II. Data

We combine several databases to explain arbitrage profits in the presence of the option to fail to deliver shares. One prominent market maker provided a database of rebate rates, failing positions and net positions in addition to a database of buy-ins and their execution prices. Our data represents the experience of one market participant, and we attempt to measure the extent to which this market maker is unusual in Section III. An options database from a major clearing firm comprises daily closing prices on U.S. equity options. The term structure of interest rates is estimated using commercial paper rates from the Federal Reserve. See Appendix C for details on estimation of the short-end of the yield curve. The databases cover 1998 and 1999.

A. Options Market Maker's Rebate Rates, Fails and Buy-Ins.

A large options market-making firm has generously provided a database of their rebate rates, fails and buy-ins for 1998 and 1999. The rebate rates cover all stocks in the Russell 3000 index, and we have limited our other databases to that subset of U.S. equities using constitution lists from the Frank Russell Company. The Russell 3000 includes the 3000 largest stocks in the U.S based on May 31st market capitalization. In

1997, stocks larger than \$171.7M were included. The cutoff was \$221.9M in 1998 and \$171.2M in 1999.

The rebate rates in the database are the interest rates on cash collateral for stock loans. A discussed in Geczy, Musto and Reed (2002), rebate rates allow us to measure the difficulty in borrowing shares of a particular stock, or specialness. We construct a measure of specialness for each stock j on each date t. Specifically,

$$\text{Specialness}_{j,\,t} = \text{General Collateral Rebate Rate}_{t+3} - \text{Stock Specific Rebate Rate}_{j,\,t+3}$$

Following Geczy, Musto and Reed (2002), we estimate the general collateral rebate rate as the Federal Funds Rate minus 20 basis points (100 basis points = 1 percentage point). Specialness will be zero for most stocks, and it will be positive for specials, or hard-to-borrow stocks. Even though our market maker may not be short-selling every day in every stock, the list of rebate rates is updated daily for all stocks in the Russell 3000. The database also indicates when this market maker is failing to deliver shares on any of its short positions. In a related database, we have commissions and execution prices for all of this market maker's buy-ins.

B. Options Data

We use a proprietary database of all U.S. equity options collected by a major clearing firm. The database contains closing prices (4:02 PM ET) for exchange-traded options each day options trade from 1996 through 2001. The reporting algorithm is different from the algorithm used to record closing stock prices in the daily CRSP stock database (4:00 ET), but it ensures that our prices are close to the end-of-day prices that market makers would observe. The recorded price is either a trade or a quote, depending on whether the last trade is within the closing quoted spread. If the last trade is within the closing quoted spread, the last trade is recorded as the closing price. If not, the bid or the offer is recorded as the closing price -- whichever is closest to the last trade. If quotes differ across exchanges offering the same option, the recorded price is calculated using the National Best Bid Offer (NBBO) mid-point methodology. Specifically, the average of the highest bid and lowest ask prices across all exchanges reporting option quotes is provided. The recording algorithm ensures that options market makers' profits are not overstated. See Appendix B for a discussion of potential bias in the recording algorithm.

Three primary filters that are common elsewhere in the options literature (e.g. Dumas, Whaley and Fleming (1998) and Bakshi, Cao and Chen (1997)) are applied to the options data. First, options with times to maturity fewer than 6 days are removed due to liquidity bias. Second, we remove options quotes with prices less than $0.375 to avoid price discreteness. Third, no-arbitrage restrictions are applied to the option quotes. The no-arbitrage restrictions are explained further in Table I. In addition, we compare our options database to CRSP. If the underlying stock price included in the options database differs from the CRSP stock price or if there is no CUSIP match we remove the observation. The effects of these filters, both in isolation and sequentially, are described in Table I.

We use options trading volume data purchased from Prophet Finance, and we use the CRSP daily stock file. As shown in Table I, the intersection of the rebate and option databases contains 4,072,815 observations. After merging and filtering, we are left with 2,660,685 observations in our final database.

III. Results

Options market makers have the unique ability to short-sell without locating shares to deliver. We show how often market makers fail and how failing is related to specialness. Our next results examine situations where the option to fail is most valuable: when borrowing shares is difficult. We show that these situations are correlated with misalignments of equity and options markets. The misalignment is valuable to options market makers; they can put on the short sale when other market participants can't. Put-call parity allows us to measure the misalignments without relying on the Black-Scholes formula. Next, we measure the economic significance of these misalignments by calculating the potential profits options market makers can make by exploiting them. We measure profits from trades involving special stocks in general in addition to two cases of event-driven specialness: IPO lockups and mergers. Finally, we attempt to explain why the profit opportunities aren't competed away. We find that the incidence of failure and the expected cost of buy-ins is not sufficient to explain the continuing profit, and we attempt to measure how our data provider may have natural buy-in protection stemming from its large size.

A. Specialness and Delivery Failure

Using the database of failed deliveries from our data provider, we are able to assess the value of the option to fail in terms of how often it happens. Table II shows the likelihood of each loan category: *General Collateral, Reduced Rebate, Reduced Rebate and Fail, Fail Only and Buy-In*. *General Collateral* indicates that a stock has been loaned at the normal rebate rate; i.e. the stock is easy to borrow. *Reduced Rebate* indicates that the rebate rate is below the general collateral rate; i.e. the stock is on special. *Reduced Rebate and Fail* indicates that shares have been borrowed at a reduced rebate on part of this short position, and some shares were not borrowed. *Fail Only* indicates that no shares in this short position were borrowed. *Buy-In* indicates that delivery is being forced on some of the shares in the short position.

The table covers all Russell 3000 stocks for 1998 and 1999. As expected, a large majority, 91.24%, of daily stock loans are available at general collateral rates. The remaining 8.76% of available loans are on special; in other words, they have reduced loan rebate rates. 4.19% of the special stock/days have reduced rebate rates and borrowing continues, but this options market maker is failing to deliver at least some shares on 4.56% of the special stock/days. Clearly, failing is an important part of the story; more than half of the time the option to fail is used when stocks are on special. Any analysis of the relationship between short-sale impediments and options prices is at least incomplete, and perhaps severely biased, without consideration of the option to fail.

Market makers can fail to deliver shares, and they can provide short exposure to would-be short-sellers when stocks are hard to borrow. We measure the shift into this alternate mechanism for delivering short exposure with the following regression (p-values in parentheses):

$$\textit{(Market Maker's SI) / (Market SI)} = \underset{(0.2795)}{-0.06902} + \underset{(0.0197)}{0.04037}*\textit{Specialness}$$

Where *(Market Maker's SI) / (Market SI)* is this market maker's share of the market short interest. As the statistically significant 0.04037 indicates, as specialness increases, this market maker takes an increasing share of the market-wide short positions. Presumably, the market maker is responding to an increase in demand for synthetic short positions as market participants are precluded borrowing shares, and thus short selling in the equity market.

When specialness gets severe, rebate rates become negative. The option to fail is particularly important when rebate rates are below zero for two reasons. First, most market participants will have difficulty finding shares, giving a market advantage to options market makers who want to capitalize on put-call parity violations. In other words, the option to fail increases in value when specialness is high and when put-call parity arbitrage profits are high. Second, the options market maker will not have to pay the loan fee implied by the negative rebate. When put-call disparity is large, trading profits from writing and hedging options is large for options market makers. The details and profits of the trade are described below.

B. Specialness and Option Prices.

We expect put prices to reflect the costs of hedging including the costs of short selling. We use our measure of short-sale costs, specialness, and two measures of options prices to characterize this relationship. First, we use put-call parity to measure misalignments of stock and options markets. Second, we use a binomial tree, as in Rubinstein (1994), to measure how options mispricing relates to short-sale costs.

B.1. Put-Call Parity

The effect of short-sale costs on option prices can be seen via the European put-call parity relation. Put-call parity states that the value of a European call option plus the discounted value of the option's strike price is equal to the value of the underlying asset plus the value of a European put with the same strike price and maturity:

$$C + e^{-r\tau}K = P + S.$$

Where C is the price of a European call option on stock S with strike price K, $e^{-r\tau}K$ is the present value of K, and P is a put option with strike price K. C and P are assumed to have the same time to maturity, τ.

This relationship allows a trader to replicate the payoffs of any single instrument in the equation with the appropriate combination of the other three instruments. The stock price implied by this put-call parity relationship, or the *implied* stock price, is

$$S^i = C - P + e^{-r\tau}K.$$

For stocks with dividends paid during the life of the option, the present value of dividends is added to the right hand side of the equation.

Of course, with the American options in our sample, the possibility of early exercise makes the put-call parity relationship approximate. Simple no-arbitrage arguments can be employed to establish the following bounds on American put and call options.

$$S - K \leq C - P \leq S - e^{-r\tau}K$$

If we rearrange this relationship we can see the bounds for our measure of the implied stock price:

$$S - K(1- e^{-r\tau}) \leq S^i \leq S$$

To get a sense of how large these bounds are, we compute the average strike price and the average present value factor for our sample. We find our implied stock price to be between S and S - $0.60. In the next section we account for the early exercise bias explicitly using binomial tree pricing, but for now we reduce the effects of early exercise bias by limiting our sample. Early exercise becomes more problematic the farther the option is from maturity. We look at options for every stock trading in the sample and we isolate one option pair per stock per day; we use the pair with time to maturity closest to zero and with moneyness (S/K) closest to one. This sample provides evidence on put-call disparity's relationship to specialness with a minimum of early exercise bias.

After computing the stock price implied by put-call parity, we compute the percentage deviation of the implied stock price from the actual stock price. This is computed by subtracting the implied stock price from the actual stock price and normalizing by the actual stock price:

$$\Delta_{j,t} = \frac{S_{j,t} - S^i_{j,t}}{S_{j,t}},$$

where $S^i_{j,t}$ is the price of stock j on day t implied by put-call parity and $S_{j,t}$ is the price of stock j on day t from the stock market. We think of $\Delta_{j,t}$ as put-call *disparity*. Table III shows the distribution of this measure. It's worth noting that the distribution is tightly clustered around zero; the 5th percentile is –0.019 and the 95th percentile is 0.023.

We test the hypothesis that short selling is not associated with put-call disparity with the following regression:

$$\Delta_{j,t} = a + b\,Special_{j,t} + e_{j,t} \tag{1}$$

Where $Special_{j,t}$ is the specialness, or the reduction in stock *j*'s rebate rate on date *t*. Table IV presents coefficient estimates from the regression in (1). Panel (A) shows regression results from the whole sample, and specialness shows up in the regression with a positive and statistically significant coefficient of 0.174. In other words, specialness is a statistically significant predictor of put-call disparity, or misalignments between option and stock prices. In Section C, we will show that the statistical relationship between specialness and put-call disparity can be turned into large, economically significant profits.

Panel (B) is more refined. In this sample, we select one option pair per stock each day. This option pair holds up to scrutiny best because it is the pair with moneyness, S/K, closest to one and time to maturity closest to zero. With the new sample, we see that the coefficient on specialness is a statistically and economically significant 0.0838.

The regression in (1) pools across days and across stocks. Since the sample may include more observations on certain days, and since some days may be more volatile than others, we also run the regression in (1) independently each day. In Panel (C) of Table IV, we present the distribution of coefficients for our $Special_{j,t}$ variable when there is one cross-sectional regression per day for the 504 trading days in our sample. Similar to Fama and Macbeth (1973), the t-statistic for the average is computed by dividing the average of the coefficients by their time-series standard deviation under the assumption of independence. This cross-sectional daily regession reinforces the conclusion found in the other regression parameterizations. The statistically significant coefficient of 0.189 confirms that as specialness increases, put-call disparity also increases. In other words, in the cross-section of stocks, as specialness increases, so do stock prices in relation to options prices.

The put-call disparity relation is a percentage difference that approximates the return from simultaneously putting on short stock and long synthetic positions. The true return depends on convergence of the implied stock price and the actual stock price, and it can only be calculated upon closing out the position. The economic significance of a specialness coefficient of 0.189 is that for every percentage point decrease in the annualized rebate rate, there is a 0.189 percentage point disparity between the actual stock price and the synthetic stock price. For the average stock price in the sample, this corresponds to a difference of $0.10. In judging the economic importance of this disparity, it is important to remember that a one-percentage point decrease in the annualized rebate rate corresponds to less than one basis point decrease in the daily rebate rate.

B.2. Implied Volatilities

We measure the difference between observed and predicted options prices using implied volatilities for two reasons. First, our estimates of implied volatilities will allow us to account for the early exercise premium associated with American options that can't be captured with European put-call parity. Second, implied volatilities can be measured separately for each option, which allows us to determine the effect of specialness on calls and puts separately.

For each option, we compute the volatility implied by binomial pricing and we subtract a benchmark. Our measure of mispricing is the difference between each option's implied volatility and a normalizing measure of volatility. By employing binomial tree methods as in Rubinstein (1994), we can calculate the implied volatility of each equity option, accounting for the ability to exercise options early. Following Dumas, Fleming and Whaley (1998), we remove options with moneyness below 0.9 or above 1.1 due to their illiquid nature.

Using OLS, we try to explain this measure of mispricing with the moneyness, time-to-maturity, and specialness. The estimation results from several parameterizations of the following regression are presented in Table V.

$$\sigma^{implied} - \sigma^{benchmark} = \gamma_0 + \gamma_1 \text{Moneyness} + \gamma_2 \text{Time-to-Maturity} + \gamma_3 \text{Specialness} + \varepsilon$$

Moneyness is defined as S/K, and time to maturity ranges from 6 to 180 days. Consistent with the results for index options from Derman and Kani (1994) and Longstaff (1985), we find that implied volatility increases with moneyness. Consistent with Bakshi, Cao and Chen (1997), our regression results show that implied volatility decreases with time to maturity.

We choose two benchmarks for implied volatility. In the first set of regressions, we subtract ex-post realized volatility over the life of the option measured as the standard deviation of daily returns. In the second set, we subtract the implied volatility measured as the average of implied volatilities for all options on the given stock with the appropriate maturity date over the remaining life of the option. The realized volatility benchmark allows the measurement of specialness-induced changes that affect all of the options written on a particular stock, and the implied volatility benchmark will accurately reflect market expectations for volatility. The first benchmark allows the dependent variable to capture the height *and* the shape of the implied volatility surface while the second benchmark is meant to capture the shape of the surface.

The regressions include specialness measured with two different variables: a dummy variable and a continuous variable. The dummy variable is included to identify specialness as a market condition potentially affecting the implied volatility of all options on a particular stock, and the continuous measure is meant to measure marginal changes in options prices as short selling difficulty changes. In Panel A, we see that the specialness dummy variable is large and statistically significant for both calls and puts.

For call options, the coefficient is 0.201, and for put options, the coefficient is 0.241. The dummy variable indicates that when stocks are on special, puts and calls are more expensive. In other words, implied volatility increases with respect to the realized volatility benchmark.

The coefficient for the continuous measure of specialness in the regression on call options is 4.576, and it is statistically significant. For puts, the coefficient is 5.624, and it is again statistically significant. However, the realized volatility benchmark does not necessarily give good insight into the marginal effect of changes in specialness on the implied volatility surface. As the specialness indicator variable shows, the entire implied volatility surface rises above the realized volatility benchmark for special stocks.

When the benchmark is changed from realized volatility to average implied volatility, the effect of specialness on implied volatility decreases. For puts, the coefficients on all of the measures of specialness are statistically significant and positive. The dummy variable's coefficient is 0.019, and the continuous variable's coefficient is 0.490. Combined, these results all indicate that as stocks' specialness increases, put options become more expensive with respect to the average implied volatility for all option classes over the remaining life of the option.

When we use the implied volatility benchmark, our results are qualitatively unchanged for puts, but the sensitivity of the call options to specialness does change. The height of the volatility surface for call options decreases as the underlying becomes harder to borrow. The significant −0.021 coefficient on the specialness dummy variable indicates that call options have lower implied volatilities than the average implied volatility surface when stocks are on special by 100bps or more. Similarly, the significant coefficient on the continuous measure of specialness is –0.559, which indicates that as specialness increases, call prices decrease with respect to the implied volatility benchmark. Taken together, the results indicate that puts become more expensive and calls become cheaper as short selling difficulty increases.

The intuition for puts is straightforward; as short selling becomes more expensive or difficult (i.e. when specialness increases), hedging costs increase for put writers and the increased hedging costs are reflected in put prices. The intuition for call options derives from investors' demand for short exposure. As would-be short sellers move to options markets for short exposure as short selling in the equity market becomes difficult, they sell calls and buy puts to replicate the payoff of a short position. The increase in demand for put options and the increase in hedging costs both drive put prices up, but the increase in supply of call options from would-be short sellers drives the price of call options downward.

Taken together, Table V shows that specialness has an important effect on the volatility surface of individual stock options. For both puts and calls, implied volatility increases with respect to realized volatility when stocks become hard to borrow. Furthermore, the marginal effect of specialness on implied volatility is positive for put options and negative for call options. In unreported results, we include firm size and moneyness squared, and the results described above are unchanged in a qualitative sense. Furthermore, we ensure that our results are not driven by unusual days in the sample by estimating the above regression separately each day. Using the methodology of Fama and

Macbeth (1973), we compute the average specialness coefficient across 504 daily cross-sectional regressions. The results, presented here, are qualitatively similar to the results in Table V. With the realized volatility benchmark, the coefficient on specialness is 4.981 for calls and 5.632 for puts. With the implied volatility benchmark, the coefficient on specialness is –0.3038 for calls and 0.346 for puts. As in the previous regression results, all of the coefficient estimates for specialness are significantly different from zero. Combined, these results indicate that specialness is an important determinant of the difference between realized volatility and volatility implied by options prices.

C. Abnormal Profits

As described earlier, in hard-to-borrow situations, most investors will not be able to short-sell the stock. Nevertheless, they can synthetically replicate short positions via the options market. Market makers, selling the synthetic short position, can short-sell the underlying stock as part of a legitimate hedge. In such a case, market makers are able to profit from the apparent arbitrage between synthetic and actual stock. In this section, we will measure the profits a market maker could earn when specialness is large, and when specialness is large because of IPOs and mergers.

Proceeds from a short sale are kept by the equity lender and earn the rebate rate. While shorting the underlying asset initially gives a payoff of S, the equity lender, who pays a rebate rate, q, to the short seller, keeps these funds. Because those funds are not available for investment purposes, we can think of the investor as borrowing the value of the implied stock price, S^i, at the market interest rate r. The market interest rate, r, is greater than the rebate rate, q, and changes in this difference are measured by our specialness variable. The position is opened when the stock is on special and the American put-call parity lower bound is violated (i.e. $S^i < S$). The position is closed as soon as the prices converge or the last day the pair trades in the sample, whichever is first. In order to calculate the arbitrage profits we will use the following methodology:

$$\text{Holding-Period Profits} = \underbrace{[S(0) - S(T)]}_{\text{Short Stock Position}} + \underbrace{[S^i(T) - S^i(0)]}_{\text{Synthetic Long Position}} - \underbrace{[S(0)\sum_{t=0}^{T} r(t) - q(t)]}_{\text{Reduced Rebate Costs}}$$

Where the position is opened at t=0 and closed at t=T.

C.1. Trading Specials

The aforementioned trades are part of the obligation of options market makers. The initial trading date and the final trading date are determined by the trading counter-party; the market maker is fulfilling his obligation to provide liquidity. However, individuals with access to the equity lending market, or those who do not have to locate shares before short selling, could assume a different trading rule. In particular, when S^i is less than S and when the stock is on special, individuals could short sell stock in the stock market and buy a portfolio of options replicating a long position in the same stock. The trader could check the hard-to-borrow list to determine whether a stock was on special, and we can assume that they would know the current option prices. The long synthetic / short actual position would be closed out at convergence. If the option matures before the implied stock price converges, the last put, call and stock prices will be used to calculate the profit. We can see from Table VI that the profit is positive and statistically significant. Furthermore, the profit of 0.70 per option pair or $70 per option contract is clearly economically significant given market makers are in the unique position of capturing more profits as bid-ask spreads increase. In Section D, we provide evidence that these profits aren't competed away because smaller market makers face a disproportionately large incidence of forced deliveries, or buy-ins.

C.2. Trading IPOs

The rebate rate database used here covers a period of frequent merger and IPO activity. An exploration of the returns from shorting during these events is contained in Geczy, Musto and Reed (2002). Previous research has identified mergers and IPOs as profitable shorting events. Specifically, a number of papers have shown that a short-term trade in the days around lockup expirations is profitable because underwriting contracts generally oblige insiders not to sell their shares until a future lockup-expiration date, usually 180 days post-IPO.[1]

To assess the possible profits from this arbitrage strategy we identify put-call strike price and time to maturity matched pairs that start trading before the event day of interest and continue trading until after the event day. For IPOs, we focus on the expiration of the 180-day lockup period. We identify 364 time-to-maturity and strike-price matched put-call pairs over 36 IPOs. Each pair begins trading before the lockup

[1] See Field and Hanka (2001), Keasler (2001), Ofek and Richardson (2000), Brav and Gompers (2003) and Bradley et al. (2001).

and ends after the lockup. We assume that the t=0 position above is established on the first day that the option trades and the arbitrage profits are calculated on the last day of trading for the option

The distribution of profits from this strategy is described in Table VII. When the stock is on special, the average profit for the strategy is \$0.577 per option pair or \$57.7 per option contract. However, when it is off special, the profits are \$0.136. In these cases, market makers would also be making the bid-ask spread so that \$57.7 understates the potential profit. If the market maker were to trade only specials, the difference, \$44.1, is the value of the option to fail. In addition to its obvious economic profitability, the difference between the profitability of the market maker's IPO trade portfolio and everyone else's is statistically significant at the 1% significance level. Assuming shares of special stock can't be found, the profits for the *On-Special* IPO trades can only be realized by market participants who can short sell without an affirmative determination of future borrowability. Since market makers can short-sell without affirmative determination, the difference between the \$57.7 *On-Special* trading Profits and the \$13.6 *Off-Special* trading profits can be thought of as the value of the options market maker's option to fail to deliver stock.

In calculating this distribution we look at all options for each IPO. However, this may overweight certain IPOs for which more options are trading. As a robustness check, we calculate profits choosing only one option pair per IPO. The option pair chosen in each case expires closest to the lockup date and is closest to the money on the last day of trading. For trades when the IPO stock is special, the profit is \$0.202 per option pair, and when the IPO isn't on special, the profit is $0.054. The difference is not statistically significant at the 5% level. It is important to note that our strategy does not account for early exercise. However, early exercise is unlikely. In our sample, none of the IPOs and only three of the mergers examined declare dividends.

C.3. Trading Merger Acquirers

Jensen and Ruback (1983) and Asquith (1983) show that acquiring firms' shares decline between announcement and completion of mergers. Merger arbitrage attempts to lock in profits by short-selling shares of the acquiring firm and covering the short loan with shares of the target firm on the date of the merger.

Our strategy will be different; we will short sell acquirers' stock and buy synthetic stock in the acquiring firm in an attempt to capture misalignments between stock and options markets. We find every option trading on the acquirer's stock on the announcement date with an expiration date after the effective date of the merger. There are a total of 6338 put-call matched pairs trading around 951 mergers. We assume that the t=0 position above is established on the first day the option trades after the announcement date and the arbitrage profits are calculated on the last day of trading for the option. The distribution of profits from this strategy is shown in Table VIII. The market maker's profit for the on-special case is $0.381 per option pair or $38.1 per option contract. The profits for the off-special case are $0.083. In the one option pair per merger case, the average profit for the on-special trade is $0.325, greater than the off-special trading profits of $0.021. The two distributions are different statistically; the p-value for the t-test that the two distributions are different is less than 0.0001.

D. Why Aren't Abnormal Profits Competed Away?

D.1. The Expected Cost of Buy-Ins.

As Table II shows, buy-ins are infrequent. Only 86 positions were bought in over the 2-year period. Only 0.01% of the stock/days in the sample are bought in, but this is potentially an indication of our market maker's size. As discussed in Appendix A, the oldest fail is selected for a buy-in, and whenever a market maker's position goes from short to flat or long, the market maker's previous fail will be considered the newest fail. In other words, market makers move to the back of the line of potential buy-in candidates when their net position changes from short to long. Large market makers with more turn over will naturally move from short to long more often, reducing their probability of being bought in.

Of course, buy-ins are only problematic if execution costs are unreasonable, and they don't seem to be in our sample. Table IX describes our market maker's buy-in executions. We find that the buy-in trades are executed at prices 0.54% worse than market closing ask prices, and 0.74% worse than the ask prices implied by the average spread from 3PM to 4 PM. Statistically, the buy-in execution is not better or worse than market execution. Since buy-ins are infrequent, and execution quality is not particularly bad, buy-in risk is not a problem that would prevent options market makers from choosing to fail to deliver special stocks.

D.2. Who Gets Bought-In and Why?

In the previous section, we have shown that trading strategies involving short-selling hard-to-borrow stocks are profitable, and that being able to fail to deliver shares is a valuable option. We've also seen that the frequency and severity of buy-ins in our sample is not enough to explain the apparent profitability of failing to deliver shares in certain trades. So the question is, is the frequency and severity of buy-ins seen in our database unusually low? In other words, does our database reflect a market maker who is protected from buy-ins?

To answer the question, we predict the incidence of buy-ins in our sample, and we find that our market maker's probability of being bought in for a particular stock is not increasing in the amount of stock he shorts. Estimation results from a probit specification of the probability of our market maker being bought-in are described in Table X. As suggested by the nature of the equity lending market (see Geczy, Musto and Reed (2002)), stocks under $5 are more likely to be bought in and larger stocks are less likely to be bought in. As expected, stocks with more put option turnover have fewer buy-ins; the more frequently put positions are closed, the more frequently options market makers are net flat or long and thereby absolved of buy-in liability. Similarly, as specialness increases, so does the likelihood of a buy-in.

The interesting variables from the perspective of separating our market maker from the typical market maker's experience are fraction of short interest and failing position. As our market maker's short position increases, his net position becomes more negative. If our market maker's experience were typical, then we would expect his position to be positively correlated with the likelihood of being bought in after controlling for turnover, volatility, size, etc. However, the fraction of short interest variable is not significantly different from zero, and the point estimate is close to zero at 0.001. As this market maker's position gets larger with respect to the total number of shares being short sold, and presumably the total number of failed-delivery shares, there is no increase in this market maker's likelihood of being bought in. It is important to note that market wide short interest is included in the specification; the coefficient is positive and statistically significant, 2.535. Similarly, Panel B shows that as the market maker fails to deliver more stock, he is no more likely to be bought in on those failing positions. The coefficient on the market maker's number of failed deliveries divided by short interest is 0.009, and it is not statistically different from zero. This market maker's experience is unique; as short interest and failed deliveries increase in this market maker's account, buy-ins do not increase even though the number of buy-ins is presumably increasing market-wide. This market maker has obtained buy-in protection.

The fact that there is no increase in buy-ins as the short interest at a top market maker increases implies that a disproportionate share of buy-ins are allocated to smaller market makers. In effect, small market makers cannot fail to deliver without increased buy-in risk, making buy-in risk a barrier to entry. Competition in writing options could erode the imperfect-competition profits, but the barrier to entry becomes more severe as profits increase. In other words, top options market makers' disproportionately low buy-in risk keeps smaller options market makers from failing to deliver special stocks. Without perfect competition, put prices can remain too high with respect to put-call parity with top options market makers collecting rents via their market advantage.

IV. Conclusions

Since option market makers can short-sell without finding shares to deliver, situations arise where they have an advantage over other market participants. We describe the market makers' dispensation and measure how important it is. Furthermore, we identify the market condition where their advantage is obvious: when the option market is out of line with the stock market because short selling is difficult for most market participants.

We find that short-selling costs are a significant determinant of options price misalignments. We measure these misalignments using two methods. We measure options mispricing in a completely model-independent setting using put-call parity, and we find that specialness predicts significant deviations from parity. We then use binomial methods to relate the shape of the implied volatility surface to short-sale constraints. In both settings, we find that stock specialness significantly increases options prices.

Next, we measure whether market participants' potential profits from taking advantage of the put-call disparity predicted by specialness. Since options market makers can short-sell as a hedge when others cannot, they are in an ideal position to turn the disparity into arbitrage profits and provide liquidity to would-be short-sellers in the process. Profits from such a strategy can be large; we find statistically significant profits of $70 per contract when market makers sell synthetic short positions. Furthermore, market makers can profit from event-driven disparities. In these situations, the stocks are on special for easily identifiable reasons. We look at two such cases: IPO stocks over the lockup expiration and merger acquirers' stocks before the completion of the merger.

By selling synthetic shorts on IPO stocks, market makers can earn $57 per contract, merger acquirers lead to profits of $38 per contract.

Using data on one market maker's experience with short selling, failing to deliver and being bought in, we measure the expected costs associated with buy-ins. We find buy-in execution to be no worse than market execution, and we find that only 0.12% of failing positions are bought-in.

If buy-in costs don't explain the apparent arbitrage opportunity involving short selling, what will? We present evidence that large market makers reduce the only risk in failing to deliver, buy-in risk, by more than other participants. Controlling for turnover, volatility and size, we find that an increasing share of short interest in a stock does not increase the probability of buy-ins. We're left with an indication that top market makers receive buy-in protection beyond what would be predicted by their size and that buy-in risk for potential market entrants could be different. In equilibrium, put prices remain higher than put-call parity would imply with perfect competition.

Shares serves as security, or insurance, for a stock position; shares can be converted into cash with a sale. However, we show that market makers and clearing firms are willing to be uninsured on at least some positions; in other words, failed deliveries are common for hard to borrow stocks. Market makers fail to deliver shares and they accept delivery failures from other market makers without forcing delivery. They are foregoing position-by-position insurance in order to short sell quickly and efficiently. When market makers fail to deliver and accept failed deliveries, they are taking a portfolio approach to the insurance of their positions. Particular positions may be temporarily uninsured as delivery failure precludes a quick conversion into cash, but the portfolio of all positions won't be uninsured on average. This portfolio insurance approach to share delivery allows market makers to provide liquidity to would-be short sellers and capture arbitrage profits arising from the misalignment of stock and options markets as short-sale constraints become severe.

Appendix A:

The Details of Short Selling and Delivery

Short sellers sell stock they do not own to buyers. Exchange procedure generally requires short-sellers to deliver shares to buyers on the third day after the transaction (*t+3*). Short sellers typically borrow stock from their brokers and use the proceeds from the sale as collateral for the loan. Additionally, regulators and brokerages impose varying margin requirements on short positions. To close, or cover, the position, the short-seller buys shares and returns the shares to the lender.

A. Borrowing and Rebate Rates

Typically, a short-seller will borrow shares from his broker. Short-sellers use the proceeds from the short sale as collateral for the stock loan. The collateral earns interest, and the broker returns some of the interest to the short seller in the form of a rebate. Rebate rates are generally lower for smaller investors, but for a given investor, lower rebate rates indicate more expensive loans. The majority of loans in widely held stocks are cheap to borrow, but there are a few expensive loans in stock specials[2]. An example of the relevant cash flows is shown in Table A1.

Specials tend to be driven by episodic corporate events resulting in arbitrage opportunities for short-sellers. (See Geczy, Musto and Reed (2002) or D'Avolio (2002) for examples). Although specials are identified by their low rebate rates, the difficulty of

[2] Fitch IBCA's publicly available report: "Securities Lending and Managed Funds" estimates that the industry average spread from the fed funds rate to the general collateral rate on U.S. Equities is 21bps.

borrowing specials goes beyond an increase in borrowing costs. Only well-placed investors, e.g. hedge funds, will be able to borrow specials and receive the reduced rebate. Brokers will not borrow shares on behalf of small investors; the order to short sell will be denied. Loans in stock specials will be expensive for well-placed investors and impossible to obtain for retail investors.

B. Short-Selling When Borrowing is Difficult

Exchange rules require most market participants to demonstrate that they can obtain hard-to-borrow shares before they short sell[3]. Market makers require an affirmative determination of borrowable or otherwise attainable shares. In market parlance, the short-seller needs a *locate* before short selling. However, there is an exception to the rule. An example is NASD's rule 3370(b), which exempts the following transactions from the affirmative determination requirement: "…bona fide market making transactions by a member in securities in which it is registered as a Nasdaq market maker, to bona fide market maker transactions in non-Nasdaq securities in which the market maker publishes a two-sided quotation in an independent quotation medium, or to transactions which result in fully hedged or arbitraged positions."

[3] During our sample period, NYSE Rule 440C and NYSE Information Memorandum 91-41 require affirmative determination (a locate) of borrowable or otherwise attainable shares for members who are not market makers, specialists or odd lot brokers in fulfilling their market-making responsibilities. NASD Rule 3370 and NASD Rules of Fair Practice, Article III, Section 1, Interpretation 04 Paragraph (b)(2)(a) (See Ketchum, 1995, and SEC Release No. 34-35207), and, for the AMEX, Securities Exchange Act Release No. 27542 require also require affirmative determination of borrowable shares during the period treated in the paper (SEC Release No. 34-37773).

C. Fails and Buy-Ins

If the short sale is made on day *t*, the short seller's clearing firm generally delivers shares on day *t+3*. However, the National Securities Clearing Corporation (NSCC) procedures state: "each member has the ability to elect to deliver all or part of any short position."[4] If a clearing firm decides to deliver less than the full amount of shares to its buyers, the firm is failing to deliver shares.

If the clearing firm fails, the best-case scenario for the short seller is for the buyer's broker to allow the fail to continue as long as the short position is open. In this case, the short seller's cost of short exposure is the lost interest on the transaction amount. When borrowing shares, the short-seller would also lose the full interest income on his collateral in the case of a zero rebate rate. Economically, a failed delivery is the same as delivery of borrowed stock at a zero rebate rate as long as the buyer's broker allows the fail to continue.

In the worst-case scenario, the buyer's broker insists on delivery by filing a notice of intention to buy in with the NSCC at *t+4* in accordance with NSCC's Rule 10[5]. The notice is retransmitted from the NSCC to the seller's broker on *t+5*, and the seller has until the end of day *t+6* to resolve the buy-in liability. If the seller does not resolve the liability, a buy-in occurs: the buyer purchases shares on the seller's account to force

[4] NSCC Procedures, VII.D.2.
[5] The Securities and Exchange Commission's Customer Protection Rule requires clearing firms to possess shares in fully paid accounts. Clearing firms may attempt to acquire shares to be in compliance with the SEC's rule.

delivery[6]. If bought in, the seller will then short sell again to re-establish the short position. The short seller has to pay the execution costs of the buy-in and the following short sale every six days, in addition to the float on the purchase price[7]. Figure A1 shows the sequence of events in each scenario.

The NSCC allocates buy-ins across clearing firms and clearing firms allocate buy-ins across clients. Failing clients can protect themselves against buy-ins at both levels. Figure A2 shows the institutional structure. In the first stage, the NSCC ranks clearing firms according to the date of failed deliveries, and the NSCC allocates buy-ins to the clearing firms with the oldest failed delivery first[8]. As a result, clearing firms that frequently change from short to long net positions are less likely to be bought in.

Once the NSCC allocates buy-ins to a clearing firm, that clearing firm must allocate buy-ins among its clients. Clearing firms have discretion over this second-stage of the selection decision, and, unlike the first stage, there are no market-wide rules.

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[6] The seller's clearing firm buys shares in a buy-in for NYSE and AMEX stocks, the buyer's clearing firm buys-in shares of NASDQ stocks.

[7] There have been complaints regarding the price of shares bought-in. A limited supply of guaranteed delivery shares, combined with the transparency of the underlying purpose for the purchase may inflate prices. Second, according to NASD Regulation's general counsel Alden Adkins in Weiss (1998), "there are no hard and fast rules dictating the prices at which buy-ins can take place. But [Adkins] says the prices must be 'fair' – and that the person who sets the price must be prepared to defend it."

[8] This description provided here is a slight simplification of the actual procedure. For a more specific example of what really happens, assume that N+0 represents the date the Buy-In Notice is filed. Filing such a notice will give the firm higher priority in settlement on the first business day after filing, N+1 and on the second business day after filing, N+2, if the long position remains unfilled. On date N+1, if the position remains unfilled, NSCC submits "retransmittal notices" to the firm(s) with the oldest short position in the Buy-In stock. These notices specify the Buy-In liability for the short firm and the name of the long firm instigating the Buy-In. "If several firms have short Positions with the same age, all such Members are issued Retransmittal Notices, even if the total of their Short Positions exceeds the Buy-In position."[8] Once they receive the retransmittal notice, other settling trades may move them to a flat or even a long position in the stock but do not exempt them from their Buy-In liability. The short firm has until the end of day N+2 to resolve their Buy-In liability. Before the retransmittal notice is received, a buy-in liability is removed once a net long position of sufficient size is established.

Evidence suggests that clearing firms use their discretion; they allocate a disproportionately small number of buy-ins to protected clients.

Appendix B: Options Data Recording Biases

The options database used in this study has one price per option per day. The price is the last trade if the last trade is within the 4:00 PM EST bid-ask spread, and the price is a quote if the last trade is outside the bid-ask spread. If the last trade is above the ask, the ask is recorded, and if the last trade is below the bid, the bid is recorded.

Since price quotes are binding, and since this study measures options market makers' potential profits, our findings do not overstate profits. Market makers are unlike other market participants in that they benefit from the bid ask spread. If buying an option is part of the market maker's trading strategy, then the option would be purchased at a price below the midpoint of the bid ask spread; he would be able to purchase the option worth *p* at price *p – (spread/2)*. Similarly, the market maker can sell options worth *p* at price *p + (spread/2)*. Combined with the fact that the data-recording algorithm insures that recorded prices always fall within the bid-ask spread, we see that market makers' prices are not overstated. As Table A2 illustrates, market makers' profits are understated by no more than the spread on each trade, and it's important to emphasize that since this study's profits are computed for market makers, the understatement is a conservative measure of profits.

Appendix C:
Risk-Free Interest Rates

A database of daily risk-free interest rates is calculated using Federal Reserve 1, 7, 15, 30, 60 and 90-day AA financial commercial paper discount rates that we subsequently convert to bond equivalent yields.[9] The risk-free rate corresponding to the maturity of the option of interest is calculated by linearly interpolating between the two closest interest rates. For example, the risk-free rate for an option with maturity of 6 days would be calculated by linearly interpolating between the 1-day and the 7-day discount rates for that date.

The method of linear interpolation is an approximation to the true term structure, and the error inherent in this approximation is greatest for near-term maturities. By using the rates on commercial paper, this error in minimized relative to rates on T-bills or other fixed income instruments that are only reported for greater maturities. As a check on our procedure, we also calculate the risk-free rate with daily GOVPX data on T-bills using a procedure similar to Bakshi, Cao and Chen (1997). The option pricing regression results using T-bills are similar to the results presented here. Additionally, the correlation coefficient between the 3-month AA financial commercial paper rate and the 3-month T-bill rate reported by the Federal Reserve is 0.98. As a further check, we regress our 3-month measure on the Federal Reserve's 3-month rate from September 1997 to August 2001. The intercept is not significantly different from zero, the slope is statistically significant (the coefficient is 0.90), and the R^2 is 0.95.

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[9] Bond Equivalent Yield = (Discount/100)(365/360)/(1-(Discount/100)(Time to Maturity/360))
This is equivalent to the yield formula reported in the Wall Street Journal and is commonly used in option markets and for debt instruments with maturities of less than one year.

Table A1. Cash and Security Positions

		t	t+1	t+2	t+3	t+4
Date		***t***	***t+1***	***t+2***	***t+3***	***t+4***
Transaction		***Short-Sale***			***Delivery***	
Market Conditions	***Closing Stock Price***	$ 100.00	$ 110.00	$ 100.00	$ 100.00	$ 100.00
	Margin Requirement	15.0%	15.0%	15.0%	15.0%	15.0%
	Seller's Rebate Rate	0.0%	0.0%	0.0%	0.0%	0.0%
	Cash Interest Rate	4.2%	4.2%	4.2%	4.2%	4.2%

Case 1: Normal Borrowing and Delivery

		t	t+1	t+2	t+3	t+4
Short-Seller's Account	***Cash***					
	Transaction Proceeds	0.00	0.00	0.00	0.00	0.00
	Market Adjustment	0.00	-10.00	10.00	0.00	0.00
	Margin Requirement	-15.00	-1.50	1.50	0.00	0.00
	Total Payout	**-15.00**	**-11.50**	**11.50**	**0.00**	**0.00**
	Interest Earned	0.0018	0.0019	0.0018	0.0018	0.0018
	Securities (Economic Exposure)					
	Shares	-1	-1	-1	-1	-1
	Market Value	-100.00	-110.00	-100.00	-100.00	-100.00
Short-Seller's Broker	***Cash***					
	Securities Collateral Held	0.00	0.00	0.00	100.00	100.00
	Margin Requirement Held	15.00	16.50	15.00	15.00	15.00
	Securities (Certificates)					
	Holding (+) / Borrowing (-)	**0**	**0**	**0**	**-1**	**-1**
Buyer's Account	***Cash***					
	Cash Held	**100.00**	**100.00**	**100.00**	**0.00**	**0.00**
	Interest Earned	0.0117	0.0117	0.0117	0.0000	0.0000
	Securities (Economic Exposure)					
	Shares	1	1	1	1	1
	Market Value	100.00	110.00	100.00	100.00	100.00
Bro-ker	***Securities (Certificates)***					
	Holding (+) / Borrowing (-)	**0**	**0**	**0**	**1**	**1**

Case 2: Delivery Failure

		t	t+1	t+2	t+3	t+4
Short-Seller's Account	***Cash***					
	Transaction Proceeds	0.00	0.00	0.00	0.00	0.00
	Market Adjustment	0.00	-10.00	10.00	0.00	0.00
	Margin Requirement	-15.00	-1.50	1.50	0.00	0.00
	Total Payout	**-15.00**	**-11.50**	**11.50**	**0.00**	**0.00**
	Interest Earned	0.0018	0.0019	0.0018	0.0018	0.0018
	Securities (Economic Exposure)					
	Shares	-1	-1	-1	-1	-1
	Market Value	-100.00	-110.00	-100.00	-100.00	-100.00
Short-Seller's Broker	***Cash***					
	Securities Collateral Held	0.00	0.00	0.00	0.00	0.00
	Margin Requirement Held	15.00	16.50	15.00	15.00	15.00
	Securities (Certificates)					
	Holding (+) / Borrowing (-)	**0**	**0**	**0**	**0**	**0**
Buyer's Account	***Cash***					
	Cash Held	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Interest Earned	0.0117	0.0117	0.0117	0.0117	0.0117
	Securities (Economic Exposure)					
	Shares	1	1	1	1	1
	Market Value	100.00	110.00	100.00	100.00	100.00
Bro-ker	***Securities (Certificates)***					
	Holding (+) / Borrowing (-)	**0**	**0**	**0**	**0**	**0**

Table A2.
Bias in Market Makers' Computed Profits

Market Maker's Trade	Last Trade Price	Recorded Price in Database	Actual Execution Price	Study's Execution Price	*Understatement* of Profits on Trade
Buy	Above Ask	ask = P + (spread/2)	P - (spread/2)	P + (spread/2)	spread
	Within Spread	last trade (between bid and ask)	P - (spread/2)	between bid and ask	between 0 and spread
	Below Bid	bid = P - (spread/2)	P - (spread/2)	P - (spread/2)	0
Sell	Above Ask	ask = P + (spread/2)	P + (spread/2)	P + (spread/2)	0
	Within Spread	last trade (between bid and ask)	P + (spread/2)	between bid and ask	between 0 and spread
	Below Bid	bid = P - (spread/2)	P + (spread/2)	P - (spread/2)	spread

Figure A1. Clearing, Failing and Buying-In

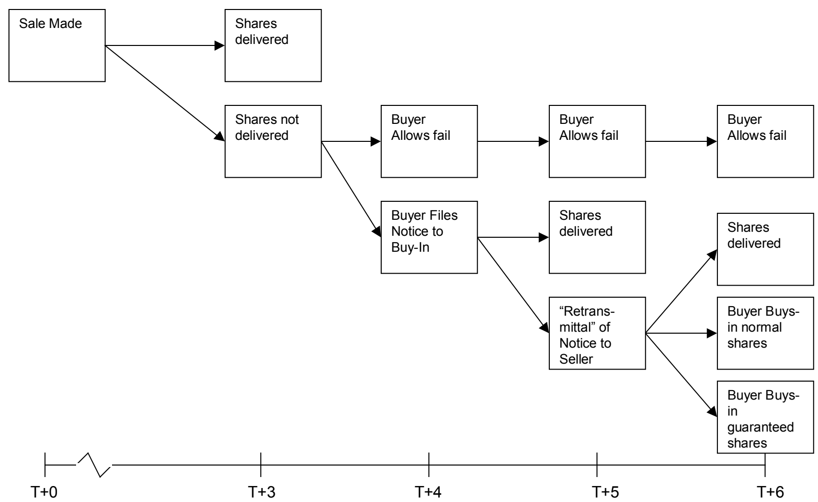
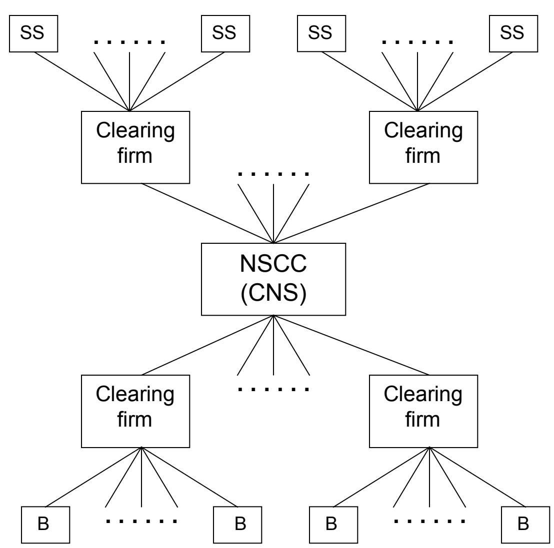


Figure A2. The Structure of Clearing Institutions



Glossary

Buy-In – Shares are purchased in the stock market on behalf of the seller to insure delivery for a buyer to whom shares are owed.

Clearing – Delivery of shares of stock from buyer to seller. A clearing firm provides clearing and settlement services for exchange members.

Continuous Net Settlement (CNS) System -- Automated book-entry accounting system that centralizes the settlement of security transactions for the NSCC.

Delivery Versus Payment (DVP) System – System allowing delivery and payment to be exchanged instantaneously. DVP is used by market participants for settlements that are not automatically handled by CNS.

Failure to Deliver – Shares are not given from seller to buyer on the settlement date.

General Collateral Rate – The prevailing interest rate earned on borrower's collateral for equity loans.

Guaranteed Delivery – Seller commits to a settlement date and allows buyer to cancel trade if delivery is not made. Delivery terms are negotiated on a trade-by-trade basis; trades often have non-standard clearing (e.g. $t+1$)

Locate – Affirmative determination that the short-seller will be able to borrow shares to deliver to the buyer. In some situations, market participants must provide a locate to the stock market maker before short-selling.

Notice of Intention to Buy-In – Indication to the NSCC that the buyer will force delivery of shares. After the notice is filed, the buyer's priority for delivery is increased. The notice of intention to buy-in can filed four days after trading if securities are not delivered.

National Securities Clearing Corporation (NSCC) -- Provides centralized clearing and settlement for the NYSE, AMEX and NASDAQ.

Hard To Borrow – Stock loans are difficult or expensive. Institutionally, certain restrictions apply unless a stock is *not* hard to borrow.

Rebate Rate – Interest rate earned by borrowers on collateral for equity loans. A rebate rate is reduced below prevailing rates when stocks are on special.

Retransmittal Notice – NSCC's indication to the seller that the buyer plans to buy-in shares. A retransmittal of the buyer's notice to buy-in to the seller. A retransmittal is sent one day after a notice of intention to buy-in has been sent if the buyer has not received shares.

Settlement – Shares are exchanged for payment.

Settlement Date -- The date on which payment is made to settle a trade. For stocks traded on US exchanges, standard settlement is three days after the trade (t+3).

Short Sale -- Sale of a security that an investor doesn't own.

Specialness - Difference between interest earned on a specific stock loan's collateral and the prevailing interest rate for stock loan collateral. The specialness of the typical stock is zero. A stock is said to be on special if specialness is positive.

Street Name – Brokerage or nominee registration as opposed to the direct account holder registration. Securities held in street name can be lent to short sellers with the permission of the owner.

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Table I. Filters

Merging of datasets and the application of specific filters throughout the paper leads to a reduction in the total number of option observations. Here, the number of observations excluded by each filter applied in isolation and in sequence is listed. Arbitrage Filters: Following Bakshi, Cao and Chen (1997), we delete observations where call prices are higher than the underlying stock prices. (C > S) We delete observations where call prices are less than the present value of payoffs if exercised. (C < S – PV(K) –PV(Div)) We delete observations where put prices are less than the current value of exercise. (P < K-S) We delete observations where put prices are above their strike prices. (P > K)

	Filters in Isolation		Filters in Sequence			
	Observations Excluded	% of Original Excluded	Observations Exlcluded	% of Original Excluded	Observations Remaining	% of Original Remaining
Original Options Sample					13,656,494	100%
Merged with Rebate Sample	4,620,579	33.83%	4,620,579	33.83%	9,035,915	66.17%
Merge with CRSP	4,362,228	31.94%	1,219,921	8.93%	7,815,994	57.23%
C,P < .375	2,291,350	16.78%	1,348,602	9.88%	6,467,392	47.36%
tau > 180	1,308,939	9.58%	730,206	5.35%	5,737,186	42.01%
tau < 6	785,112	5.75%	229,746	1.68%	5,507,440	40.33%
C > S	1,459,612	10.69%	871	0.01%	5,506,569	40.32%
C < S-PV(K)-PV(Div)	641,875	4.70%	366,147	2.68%	5,140,422	37.64%
P < K - S	383,890	2.81%	220,076	1.61%	4,920,346	36.03%
P > K	25	0.00%	19	0.00%	4,920,327	36.03%

Table II. Rebate Rates, Failure and Buy-In Frequency.

Table II presents 1998-99 rebate rate, fail and buy-in data for equities in the Russell 3000 index. Panel A. shows the overall incidence of five equity loan states in the database; General Collateral (GC), Special (S), Fail/Special (FS), Fail (F) and Buy-in (BUY) and the average rebate rate associated with each state. Special is defined as any rebate below the general collateral rate. Panel B. shows the daily frequency of each stock moving between five different equity loan states. The left-hand column shows the state of the loan on trading day T. As you move across the columns you find the relative frequency of a move from the loan state at date T to the other loan states at date T+1.

Panel A. Overall Incidence of Loan States in the Database

Loan State	Frequency	Percent	Cumulative Frequency	Cumulative Percent	Average Rebate Rate
GC	1,379,594	91.24	1,379,594	91.24	4.98
S	63,343	4.19	1,442,937	95.43	1.72
FS	59,322	3.92	1,502,259	99.36	1.50
F	9,655	0.64	1,511,914	99.99	0.34
BUY	86	0.01	1,512,000	100	0.00

Panel B. Transition Frequencies between Loan States

		T+1				
		GC	**S**	**FS**	**F**	**BUY**
T	**GC**	99.40%	0.11%	0.03%	0.46%	0.00%
	S	4.32%	92.34%	3.10%	0.23%	0.00%
	FS	0.59%	5.43%	93.65%	0.21%	0.12%
	F	52.23%	3.21%	12.76%	31.78%	0.01%
	BUY	0.00%	0.00%	77.91%	4.65%	17.44%

Table III. The Distribution of Put-Call Disparity and Specialness

Table III is constructed from a sample of 1,068,774 strike-price and maturity matched put-call observations. Put-call disparity is the difference between the stock price and the implied stock price normalized by the stock price, i.e. $(S-S^i)/S$. Specialness is defined as the difference between a general rebate rate and the specific rebate rate for a stock, so that a positive value of specialness corresponds to a hard-to-borrow situation.

	Put-Call Disparity	**Specialness (%)**	**Rebate Rate (%)**
Average	0.0016	0.48	4.68
Median	0.0021	0	4.95
Standard Deviation	0.0247	1.33	1.13
Minimum	-0.97	0	0
Maximum	0.891	5.80	5.80
5th Percentile	-0.019	0	2.00
10th Percentile	-0.011	0	4.35
90th Percentile	0.016	2.00	5.36
95th Percentile	0.023	4.60	5.43

Table IV. Implied Stock Prices and Short Sales Constraints

Using various specifications, the specialness variable is regressed on a measure of the put-call disparity, $\Delta_{j,t} = a + b\textit{Special}_{j,t} + e_{j,t}$. In panel A, all matched pairs in the sample are used. In Panel B, the regression is repeated using one option pair per stock per day. Namely, the option pair that is closest to the money and nearest term in maturity. The regression is also performed cross-sectionally on a daily basis. Panel C reports the average of the daily regression coefficients.

Panel A: Regressions using all matched pairs and the closing stock price.

Variable	Estimate	Std.Dev.	t-Stat	p-Value
Intercept	0.0007	0.00002	33.82	<.0001
Specialness	0.174	0.00149	117.06	<.0001

R-Square	0.009
Adj R-Sq	0.009
Number of Observations	1,552,405

Panel B: Regression using one, nearest term, at-the-money option pair per stock per day.

Variable	Estimate	Std.Dev.	t-Stat	p-Value
Intercept	0.0003	0.00004	7.77	<.0001
Specialness	0.0838	0.00344	24.32	<.0001

R-Square	0.0025
Adj R-Sq	0.0025
Number of Observations	233,669

Panel C: Cross-sectional daily regression.

Variable	Average	Std.Dev.	t-Stat	p-Value
Intercept	0.0005	0.002	5.42	<.0001
Specialness	0.189	0.094	45.33	<.0001

Number of Days	504

Table V. Implied Volatilities and Short-Sale Constraints

The implied volatilities of options in the sample with time to maturity of between 6 and 180 days and with moneyness between 0.9 and 1.1 are calculated using a 100-step binomial tree accounting for discrete dividends and early exercise. Put and call option pairs are matched by underlying, moneyness and time to maturity. The pairs are then separated and the regression is run using realized volatility and the average implied volatility as a baseline (calculated over the remaining life of the option). For each underlying stock, each day, subtracting the baseline normalizes the implied volatility. This difference is then regressed on moneyness, time-to-maturity and in two specifications of specialness. A Wald test is performed on the call and put coefficients for specialness and the 100 bp specialness indicator and the p-value is reported as well in the tables. ***Indicates Statistical Significance at the 0.1% Level. **Indicates Statistical Significance at the 1% Level. *Indicates Statistical Significance at the 5% Level

Panel A. Implied Volatility – Realized Volatility

	Calls			Puts		
Intercept	0.575***	0.546***	0.544***	0.485***	0.450***	0.448***
Moneyness	0.019*	0.030***	0.029***	0.092***	0.107***	0.105***
Time-to-Maturity	-0.00084***	-0.00083***	-0.00082***	-0.00082***	-0.00080***	-0.00080***
Specialness		4.576***			5.624***	
100 bp Indicator			0.201***			0.241***
Observations	771,563	771,563	771,563	771,563	771,563	771,563
Adjusted R^2	0.0108	0.0284	0.0327	0.0215	0.0759	0.0856
Put-Call. Specialness	P-Value	<0.001	<0.001			

Panel B. Implied Volatility – Average Implied Volatility

	Calls			Puts		
Intercept	-0.049***	-0.045***	-0.045***	-0.139***	-0.142***	-0.142***
Moneyness	0.079***	0.077***	0.078***	0.152***	0.154***	0.153***
Time-to-Maturity	-0.00029***	-0.00029***	-0.00029***	-0.00026***	-0.00026***	-0.00026***
Specialness		-0.559***			0.490***	
100 bp Indicator			-0.021***			0.019***
Observations	771,563	771,563	771,563	771563	771,563	771,563
Adjusted R^2	0.0025	0.003	0.0029	0.0081	0.0092	0.0091
Put-Call. Specialness	P-Value	<0.001	<0.001			

Table VI. Put-Call Arbitrage Profits

We construct the arbitrage profits of strike and time to maturity matched put-call pairs. The trading rule utilized involves only ex-ante information. Specifically, the short stock, long synthetic stock arbitrage is put on whenever the stock is on special and the implied stock price is below the American option arbitrage bound. The trade is closed out as soon as the implied stock price and the actual stock price converge. If the implied and actual stock prices do not converge, the position is closed out using prices from the last day the option traded in our sample. If the underlying asset receives a reduced rebate rate as identified by the clearing firm the stock is classified as on-special.
Panels A and B report the results using all options in the database and one option-pair per stock (the pair that is closest to the money and nearest term in maturity.

Panel A. All Options

	N	Average	Std. Dev.	t-Value	p-Value
Arbitrage Profit	3,351	0.7	0.94	43.43	< .0001

Panel B. One Option Pair Per Stock (Only that pair that is closest to the money and nearest term in maturity is retained).

	N	Average	Std. Dev.	t-Value	p-Value
Arbitrage Profit	345	0.45	0.68	12.22	< .0001

Table VII. IPO Lockup Expiration Arbitrage Profits

Profits from a long synthetic stock and short actual stock position are calculated for 448 strike-price and expiration matched put-call option pairs that trade over the lockup expiration period of 45 IPOs. The sample is divided into on-special and off-special categories. If the underlying asset receives a reduced rebate rate as identified by the clearing firm the IPO lockup expiration is classified as on-special. Panel A reports the results using all options for the IPO lockup expiration stocks. Panel B reports the results retaining only one option pair per IPO lockup expiration, specifically, the closest to the money and nearest term in maturity pair.

Panel A. All Options Trading on IPO Lockup Expiration Stocks

Category	N	Avg. Profit	Std Dev	t-Value
Off-Special	268	0.136	0.57	3.86
On-Special	180	0.577	0.88	8.79

Means Test	Variances	DF	t-Value	p-Value
Pooled	Equal	446	-6.4	<.0001
Satterthwaite	Unequal	281	-5.92	<.0001

Panel B. One Option Pair Per IPO Lockup Expiration (Only that pair that is closest to the money and nearest term in maturity is retained for each lockup expiration).

Category	N	Avg. Profit	Std Dev	t-Value
Off-Special	31	0.054	0.38	0.79
On-Special	14	0.202	0.43	1.74

Means Test	Variances	DF	t-Value	p-Value
Pooled	Equal	43	-1.15	0.2552
Satterthwaite	Unequal	22.5	-1.10	0.2835

Table VIII. Merger Arbitrage Profits

Profits from a long synthetic stock and short actual stock position for the acquiring company in a merger are calculated for 6338 strike-price and expiration matched put-call option pairs that trade over the announcement to effective date lifetime of 951 mergers. The sample is divided into on-special and off-special categories. If the underlying asset receives a reduced rebate rate as identified by the clearing firm the merger is classified as on-special. Panel A reports the results using all options trading for each acquirer. Panel B reports the results retaining only one option pair per acquirer, specifically, the closest to the money and nearest term in maturity pair.

Panel A. All Options Trading on the Merger Acquirer

Category	N	Avg. Profit	Std Dev	t-Value
Off-Special	5,404	0.083	1.09	5.60
On-Special	934	0.381	1.45	8.03

Means Test	Variances	DF	t-Value	p-Value
Pooled	Equal	6,336	-7.30	<.0001
Satterthwaite	Unequal	1,123	-5.99	<.0001

Panel B. One Option Pair Per Merger Acquirer (Only that pair that is closest to the money and nearest term in maturity is retained for each lockup expiration).

Category	N	Avg. Profit	Std Dev	t-Value
Off-Special	873	0.021	0.48	1.29
On-Special	78	0.325	0.77	3.73

Means Test	Variances	DF	t-Value	p-Value
Pooled	Equal	949	-5.02	<.0001
Satterthwaite	Unequal	82.4	-3.40	0.001

Table IX. Buy-In Execution

Table IX is constructed from 1998 and 1999 buy-in data from a major clearing firm. After merging the database with the TAQ data, there are 83 buy-in observations representing 24 stocks. The execution quality of the buy-in is examined by comparing the percentage half-spread, $\frac{S_{BUYIN} - S_{MIDPOINT}}{S_{MIDPOINT}}$, of the buy-in with the half-spread from the TAQ data $\frac{S_{ASK} - S_{MIDPOINT}}{S_{MIDPOINT}}$ under two different specifications (using the ask and the midpoint at the close and the average from 3 to 4 PM). The mean, median and standard deviation of the percentage half-spreads are reported. The statistics for the difference in execution cost, quantity of shares bought-in and trading days from buy-in to settlement are reported. A paired t-test of the difference in percentage half-spreads between buy-ins and the two specifications from the TAQ data is also reported. If multiple buy-in events are recorded on a single day, the buy-in price used in the calculations below is the quantity-weighted execution price.

	At the Close		**Avg.3 to 4PM**		**Diff. In Execution**	
	Buyin Spread	**TAQ Spread**	**Buyin Spread**	**TAQ Spread**	**At the Close**	**Avg 3 to 4PM**
Mean	0.0134	0.008	0.0163	0.0089	0.0054	0.0074
Median	0.0020	0.0044	0.0063	0.0047	-0.0026	-0.0017
Std.Dev.	0.0716	0.0152	0.0756	0.0124	0.0728	0.0744
t-stat					0.67	0.91
p-Value					0.50	0.37

	Quantity	**Trading Days**
Mean	9,659	3.01
Median	4,000	3
Std.Dev.	14,593	0.25

Table X. Determinants of Buy-Ins

The incidence of buy-ins in the sample is the dependent variable in a probit regression of the probability of being bought-in on a position. Independent variables include daily put option turnover, six-month lagged standard deviation, a binary indicator of stock price below $5, the log of the shares outstanding, an intercept term and the firm's percentage of short interest. Put option turnover is calculated as the sum of the daily volume in put options, divided by the sum of the open interest in put options. The binary price indicator takes a value of 1 for stocks with a closing bid/ask average less than or equal to $5. The fraction of short interest variable is calculated as the minimum of the firm's net position and zero (negative firm position indicates an overall short position) divided by the monthly short interest numbers. While the short interest number remains unchanged over the month, the numerator is updated on a daily basis. The marginal effect was calculated at the sample average of each quantity. For the sample observed here, there were 58 buy-in events and 30619 non-buy-in events. In using the delta-method to calculate the covariance matrix of the marginal effects and consequently to compute the chi-squared values for the marginal effects, none of the marginal effects are significant at the 5% level (two-sided test). Other variables that we included in the specification but turned out to be statistically insignificant: institutional ownership, stock turnover and failing position.

Panel A: Short Interest

Parameter	Estimate	P-Value	Average	Marg. Effect
Intercept	-0.089	0.963	1.000	-1.83E-07
Daily Std. Dev. (6 Months)	-5.108	0.166	0.051	-1.05E-05
Fraction of Short Interest	0.001	0.981	0.064	1.03E-09
Short Interest	2.535	< 0.001	0.110	5.23E-06
Price Indicator (<$5)	-0.043	0.896	0.045	-8.93E-08
Log(Shares Outstanding)	-0.223	0.039	17.379	-4.59E-07
Put Option Turnover	-0.916	0.051	1.822	-1.89E-06
Specialness	0.205	0.002	3.292	4.23E-07

Panel B: Fails

Parameter	Estimate	P-Value	Average	Marg. Effect
Intercept	-0.086	0.964	1.000	-1.79E-07
Daily Std. Dev. (6 Months)	-5.106	0.166	0.051	-1.06E-05
Fails / Short Interest	0.009	0.916	0.006	1.80E-08
Short Interest	2.535	< 0.001	0.110	5.25E-06
Price Indicator (<$5)	-0.043	0.896	0.045	-8.95E-08
Log(Shares Outstanding)	-0.223	0.039	17.379	-4.61E-07
Put Option Turnover	-0.916	0.051	1.822	-1.90E-06
Specialness	0.205	0.002	3.292	4.25E-07