# Options and the Bubble

ROBERT BATTALIO and PAUL SCHULTZ*

ABSTRACT

Many believe that a bubble existed in Internet stocks in the 1999 to 2000 period, and that short-sale restrictions prevented rational investors from driving Internet stock prices to reasonable levels. In the presence of such short-sale constraints, option and stock prices could decouple during a bubble. Using intraday options data from the peak of the Internet bubble, we find almost no evidence that synthetic stock prices diverged from actual stock prices. We also show that the general public could cheaply short synthetically using options. In summary, we find no evidence that short-sale restrictions affected Internet stock prices.

*Both authors, Mendoza College of Business, University of Notre Dame. We thank Morgan Stanley & Co., Inc. for financial support. The views expressed herein are solely those of the authors and not those of any other person or entity including Morgan Stanley. We thank an anonymous firm for providing the option data used in our analysis. We gratefully acknowledge comments from seminar participants at the University of North Carolina, the University of Notre Dame, the 2005 American Finance Association meetings, the 2005 Morgan Stanley Equity Microstructure Conference, the 2005 Western Finance Association meetings, Marcus Brunnermeier, Shane Corwin, Tim Loughran, Stewart Mayhew, Allen Poteshman, Matthew Richardson, Robert Whitelaw, and an anonymous referee.

Prices of Nasdaq-listed technology stocks rose dramatically in the late 1990s, peaked in March 2000, and then lost more than two-thirds of their value over the next two years. Many of the largest price run-ups and subsequent collapses were associated with Internet stocks. Indeed, few of these companies were profitable and most had minimal revenues. Accordingly, many observers have concluded that a bubble existed for Internet stocks in the 1999 to 2000 period and thus that prices of these stocks were irrationally high.[1]

If Internet stock prices were obviously irrationally high, why didn't rational investors sell them short and drive prices back to rational levels? Probably the simplest and most popular explanation is that traders could not borrow and short them at a reasonable cost (Ofek and Richardson (2003)). Moreover, even if investors found shares to sell short, they faced the possibility that the loaned shares would be recalled and the short positions closed before the anticipated market correction. Several authors point to other indirect constraints on short selling. For instance, deLong et al. (1990), Shleifer and Vishny (1997), and others consider the possibility that prices may move further out of line before returning to fundamentals: while well-capitalized, long-term investors may be able to weather such adverse price moves, hedge funds and other intermediaries typically face outflows of capital when they lose money over short horizons. Similarly, short-term losses can trigger margin calls for investors even if they are making correct long-term investment decisions. Finally, Abreau and Brunnermeier (2002) suggest that bubbles persist in the short and intermediate term because short sellers face synchronization risk, that is, uncertainty regarding the timing of the correction. They argue that the combination of holding costs and synchronization risk "typically cause arbitrageurs to delay acting on their information." Together, this literature suggests several reasons why rational investors would have avoided short-selling Internet stocks during the bubble.

The goal of this paper is to determine whether rational investors were able to synthetically short Internet stocks at a reasonable cost during the bubble. We first test whether short-sale restrictions are

---

[1] We use the term "bubble" throughout this paper without concluding whether the high prices of Internet stocks at that time really represented a bubble.

reflected in the prices of Internet stocks. Arbitrage normally keeps stock prices closely aligned with synthetic stock prices from the options market. If short selling is difficult or impractical, however, prices in the stock and options markets can decouple (see, for example, Lamont and Thaler (2003)). Ofek and Richardson (2003) claim that during the bubble period arbitrage opportunities from buying synthetic shares and selling the actual shares were common, which they suggest indicates that short-sale constraints for Internet stocks were sufficiently severe to affect stock prices.

We address this question bringing to bear a unique set of intraday option price data from the peak of the Nasdaq bubble. Our time-stamped quotes and trades provide two advantages. First, we can ensure that the synthetic and actual stock prices that we compare are synchronous. Second, we are able to discard quotes that, according to exchange rules, are only indicative of the prices at which liquidity demanders could have traded.

We begin by searching for evidence that Internet stocks were hard to short by comparing actual stock prices with contemporaneous prices of synthetic shares created with options. Before discarding indicative quotes, we find that 22% of our synthetic stock quotes produce apparent arbitrage opportunities. After controlling for microstructure issues, however, we find that less than 1% of the synthetic stock quotes in our sample suggest possible arbitrage opportunities. We argue that even this small proportion is likely to be grossly inflated. Surprisingly, the frequency of apparent arbitrage opportunities is higher for the nonInternet stocks in our sample than for the Internet stocks.

We then examine the costs of shorting synthetically with options. Geczy, Musto, and Reed (2002), D'Avolio (2002), and Ofek and Richardson (2003) establish that loans of the Internet stocks in their proprietary data sets were inexpensive. Each of these papers puts the costs at about 1% per year. Equity loan access varies across brokerage firms and their customers, though, so the findings of these papers are only suggestive of the general public's cost of shorting Internet stocks. On the other hand, option access is consistent across brokerages and their customers, and thus the cost of indirectly shorting Internet stocks through options is an unambiguous upper bound on the general public's cost of shorting Internet stocks.

We find that this upper bound is quite low for Internet stocks during the bubble. The expected proceeds from a synthetic short created from options on Internet stocks with 10 to 40 days to expiration and exercise prices within 5% of the stock price averages about 99.5% of the expected proceeds from an actual short sale. Longer-term options and leaps yield almost as much. Even hard-to-borrow stocks in our sample can be easily sold short synthetically, yielding proceeds that are on average only 60 basis points less than the proceeds from an actual short sale. Synthetic shorts also have an advantage that may partly offset their small additional costs: the short seller doesn't have to worry about loaned shares being recalled.

As a whole, our findings indicate that short-sale constraints were not responsible for the high prices of Internet stocks at the peak of the bubble. Investors could have sold these stocks short. Alternatively, they could have sold short synthetically using options, and this information would have been transmitted to the stock market.[2] The fact that investors did not take advantage of these opportunities to profit from overpriced Internet stocks suggests that the overpricing was not as obvious then as it is now with the benefit of hindsight.

The remainder of the paper is organized as follows. In Section I we discuss recent work on short-sale restrictions and the Internet bubble. Section II provides a description of our data. In Section III we examine whether option prices suggest that short-sale restrictions in the stock market resulted in prices for Internet stocks that were too high. We explore whether options could be used to circumvent restrictions and risks of short sales in Section IV. Finally, we provide a summary in Section V.

[2]Chakravarty, Gulen, and Mayhew (2004) analyze equity and equity option microstructure data between 1988 and 1992 and find that the equity option market's contribution to price discovery is about 17% on average. Pan and Poteshman (2004) find that in each calendar year from 1990 through 2001, equity option volume contains information about the direction that underlying stock prices will move. We confirm that the equity option market discovers underlying equity prices for our sample (results available upon request). Together, these results suggest that eventually, investors taking synthetic short positions in the options market would have driven prices of the underlying stock down.

## I. Short Sales Restrictions and the Internet Bubble

Economists have long speculated about whether the costs and restrictions of short-selling affect stock prices. Miller (1977) considers a situation in which short-sale restrictions prevent pessimistic investors from selling stock. In his model, stock prices reflect only the opinions of optimistic investors, and thus they are biased upward.[3] Diamond and Verrecchia (1981) examine this hypothesis in a rational expectations context and find that prices will not be too high on average if investors condition their pricing expectations on the fact that negative information may not be reflected in market values due to short-sale constraints.

Whether short-sale restrictions are important in practice is, of course, an empirical question. Using data on loan supply, loan fees, and recalls from a large lending intermediary for the 18 months from April 2000 through September 2001, D'Avolio (2002) shows that most stocks can be easily borrowed for short-selling at a cost of less than 20 basis points per year, with only about 9% of stock ("specials") loan fees over 1% per year. Some of these latter stocks are particularly difficult to borrow, however, and their loan fees may reach over 25% per year. Because a large proportion of lent shares come from institutions, particularly those that follow passive or indexing strategies, it is not surprising that D'Avolio (2002) finds that large company stocks and stocks with heavy institutional ownership are easiest to short. He also finds that shorting is more expensive when there is more dispersion of opinion about a stock, as proxied by turnover, greater dispersion of analyst forecasts, or more authors posting messages on the Yahoo! Finance message board within a given month. Stock loans can be recalled at any time by the owner of the stock. D'Avolio's unconditional probability of a recall is about 1% for a particular day, 2% over a month, or 18% over the entire 18-month period. The median time to reborrow the stock from another lender is nine days. Finally, D'Avolio finds that recalls do not appear to be prompted by "short squeezes."

[3]More recent theoretical analyses that investigate the relationship between market prices and short-sale constraints include Chen, Hong, and Stein (2002), Duffie, Garleanu, and Pederson (2002), Hong and Stein (2003), and Scheinkman and Xiong (2003).

Evans et al. (2003) examine short-selling constraints when options trade on the underlying stock. Options market makers are effectively allowed to sell short without borrowing the stock, and are thus important short sellers of hard-to-borrow stocks. Evans et al. show that as the costs of borrowing a stock increase, options market makers provide a larger proportion of the total short sales. The authors therefore suggest that option market makers respond to an increase in demand for synthetic short positions as stocks become harder to borrow.

Lamont and Thaler (2003) study a particular situation in which short-sale constraints are significant, namely, carveouts of tech stocks. Lamont and Thaler identify a sample of companies that conduct initial public offerings in a subsidiary with the announced intention of spinning off the rest of the subsidiary to the parent company shareholders at a later date. In six cases, the aftermarket price of the subsidiary is so high that if the same value were attached to the remaining shares owned by the parent, the implied value of the rest of the parent's assets would be negative. An example in their paper is 3Com's carveout of Palm. Each share of 3Com entitled the holder to 1 ½ shares of Palm in its upcoming spinoff. Nonetheless, Palm closed at $95.06 on its first day of trading while 3Com closed at $81.81. Lamont and Thaler attribute the apparent mispricing of Palm and other carveouts to difficulties in obtaining and shorting the stocks.

Some authors suggest that similar constraints on short sales could explain the high prices of Internet stocks in late 1999 and early 2000. For example, Ofek and Richardson (2003) examine the run-up of Internet stock prices over 1998 to 2000 and contend that while investors had widely divergent opinions about the value of Internet stocks, difficulties in shorting these stocks meant their prices reflected the beliefs of optimistic investors only. Ofek and Richardson point to three pieces of evidence to support their claim that investors were unable to short Internet stocks. First, they show that as of February 2000, the ratio of short interest to shares outstanding averaged 2.8% for Internet stocks but only 1.8% for others. Second, they find that the rebate rate for shorts, that is, the interest rate paid on the collateral for short positions, averaged 1% less for Internet stocks. In effect, short sellers paid more to short Internet stocks because they received a lower interest rate on their collateral. Finally, using a sample of closing bid and ask prices for 9,026 option pairs for three days in February 2000 along with closing trade prices for the underlying equities, they find that 36% of the Internet stocks had put-call parity violations as compared to only 23.8% of the other stocks. One reason for put-call parity violations may be that short-sale restrictions prevent arbitrage from equilibrating option and stock prices. Hence, one interpretation of the finding that there are more put-call parity violations for Internet stocks is that short-sale constraints are more frequently binding for Internet stocks.

Ofek, Richardson, and Whitelaw (2004) provide a more comprehensive comparison of the prices of stocks and options. In particular, they compare stock prices with prices of synthetic shares manufactured with options positions. The idea is that prices of synthetic shares may be lower if restrictions on short sales make it difficult or expensive to short the stock itself. The authors obtain a proprietary database of shorting costs from one financial institution for July 1999 through November 2001, and using the OptionMetrics database, they obtain closing quotes for options on individual stocks and match them with closing prices for the corresponding stocks. The authors find that the implied stock price from options is less than the actual stock price in 63% of the cases when the stock can be easily shorted. When a stock is difficult to short, the implied stock price is less than the actual stock price 76% of the time. More importantly, in some cases there are large differences between the synthetic stock price and the actual stock price. When a stock is easy to short, 5% of the synthetic stock prices are at least 1.5% less than the actual stock price. On the other hand, when the stock is difficult to short, 5% of the synthetic stock prices are at least 5.1% less than the actual stock price. Ofek, Richardson, and Whitelaw interpret these findings as evidence that short-sale constraints provide meaningful limits to arbitrage that can allow prices of identical assets to diverge.

We believe the above results are far from conclusive. In looking for arbitrage possibilities and computing synthetic share prices, both Ofek and Richardson (2003) and Ofek, Richardson, and Whitelaw (2004) use closing options quotes with time-stamps of 4:02pm and closing trades on the underlying stock that are executed no later, and possibly much earlier, than 4:00pm. In the Appendix of this paper, we show that non-synchronous prices and microstructure issues are responsible for most of the apparent arbitrage opportunities identified using the OptionMetrics IVY database.

Other research contends that short-sale constraints were not an important factor in the high prices of Internet stocks. Geczy, Musto, and Reed (2002) use data on equity loans by a custodian bank for November 1998 through October 1999 to examine the profitability of various strategies. They assume that stocks can be shorted only on the days when the custodian bank has actually lent shares and they use the rebate rates actually charged by the bank in their tests. They approximate the situation of a retail investor by only considering stocks that are not on special and the situation of an institutional investor by considering all stocks that are loaned. Geczy, Musto, and Reed find that, at least during their 1998 to 1999 sample period, investors could short dot-com stocks. Both the portfolios composed of all dot-com stocks lent by the intermediary and the portfolios composed only of dot-coms that were not on special track indices of Internet stocks closely. The specialness of the portfolio of all dot-com stocks is 1.15% when summed over the year. This cost is dwarfed by the price swings of the Internet stocks.

Mayhew and Mihov (2004) note that options lower the cost of short selling by permitting investors to take levered stock positions without borrowing the stock or posting margin. Thus, if short-sale constraints are binding, we would expect to see investors taking bearish positions in the options market with subsequent declines in stock prices when options are introduced. Mayhew and Mihov (2004) examine option listings on the Chicago Board Options Exchange between 1980 and 1997 and find no evidence in support of either prediction.

Finally, Lamont and Stein (2003) examine the relationship between historical levels of short interest and market valuations and find that total short interest tends to fall when market values near their peak. Lamont and Stein also find that the ratio of put-to-call volume displays the same countercyclical pattern, suggesting that investors do not substitute synthetic shorting for actual shorting.[4] Lamont and Stein interpret their results as evidence that the risk described by deLong et al. (1990) and Shleifer and Vishny (1997), that arbitrageurs will be forced to unwind their positions prior to market corrections, rather than short-sale constraints per se, keeps arbitrageurs from betting against bubbles.

To summarize, the literature regarding short-sale constraints and the Internet bubble is mixed. A considerable literature suggests that short-sale constraints did not contribute to the Internet bubble. Most of these analyses, however, use data generated prior to January 2000, specialized data sets that may not be representative, or aggregated statistics to reach their conclusions. In contrast, studies that use data on individual Internet and nonInternet stocks during the rise and fall of the Internet bubble arrive at the opposite conclusion. We contribute to this debate by using proprietary intraday option trade and quote data generated in the days surrounding the collapse of the Internet bubble to examine whether short-sale constraints were binding during this important period.

## II. Data

### *A. Quotes in the Stock and Options Markets*

We use option market data collected under the Options Price Reporting Authority (OPRA) Plan for Reporting of Consolidated Last Sale Reports and Quotation Information. Pursuant to this Plan, the Securities Industry Automation Corporation (SIAC) collects the last sale and quote information from each exchange, and then consolidates and disseminates it to vendors for use by retail investors and market professionals. We obtain our option market data from a large market maker that began archiving and analyzing OPRA data in January of 2000. The options in the data set are not a random sample. Instead, they are very actively traded

[4] Lakonishok, Lee, and Poteshman (2003) examine open interest and volume on CBOE options over the 1990 to 2001 period. They find that both discount brokerage and full service brokerage customers trade more calls than puts. They also show that market makers were net long put options during this period and conclude that market makers would have been willing sellers of puts on Nasdaq stocks when Nasdaq prices were at their peak.

options in which our data provider had recently started competing for order flow. Our sample consists of all options on 15 stocks for January 31, 2000 and February 1, 2000 and expands to all options on 49 stocks for February 2, 2000 through June 7, 2000. Using statistics obtained from the Options Clearing Corporation, we find that our sample options generate over one-quarter of all equity option volume in February 2000. Because of data transmission problems, we do not have data for March 31, April 6, April 19, May 17, and May 31, so we are left with 86 trading days in our sample period.

Our sample of OPRA quote and trade records contains the date, the to-the-second time, the option class and series symbols, the exchange on which the record is generated, and a message. Quotation records contain bid and ask prices while trade records contain transaction prices. We construct a National Best Bid and Offer (NBBO) from the OPRA quote records. At any given point in the day, an option series' National Best Bid (NBB) is the highest bid price from the options exchanges. The National Best Offer (NBO) is the lowest posted offer. Following Battalio, Hatch, and Jennings (2004), we exclude quotes flagged as closing quotes when calculating our NBBOs since these quotes are only indicative. For the underlying equity market, we obtain quote records from the NYSE's Trade and Quote (TAQ) database. Following Bessembinder (2003) and others, we eliminate indicative quotes and quotes associated with trading halts or designated order imbalances.

Most of our results involve option and stock quotes, so the meaning of the quotes in each market is crucial to our analysis. The firm quote rule governs quotes in the market for Nasdaq- and NYSE-listed securities. This rule mandates that specialists or market makers execute marketable orders for at least the quoted size at prices that are no worse than their quoted prices. Market makers and specialists are only exempted from this obligation if there is an order ahead or if they are in the process of changing quotes when an order arrives. Schenzler and Stoll (2005) note that in markets without automatic execution, these exemptions give market makers a chance to change their quotes to reflect new information before executing incoming market orders. Thus, if fundamental news arrives that increases the value of the security while a market order to buy is waiting to be executed, the dealer can revise his quotes upward before executing the order. Conversely, if bad news arrives before the buy order is executed, the dealer can execute the order at the old quoted price. Schenzler and Stoll note that these firm quote exceptions are intended to protect dealers from active day-traders who pick off dealers' stale quotes. Hence, it is not surprising that trading venues do not offer automatic executions under "unusual" market conditions or when quotes are either locked (the best bid price equals the best ask price) or crossed (the best bid price exceeds the best ask price).[5] To ensure that our stock quotes represent prices at which investors could actually trade, we also omit observations with locked or crossed quotes when we look for arbitrage opportunities and when we compare the costs of synthetic shares with the costs of actual shares.

While there was no SEC-imposed firm quote rule in the equity option market during our sample period, each exchange did guarantee that retail investors could automatically execute marketable orders for at least 50 contracts at or within its posted quotes during "normal" market conditions.[6] While OPRA indicates in a quote message when the market for an option on an exchange is fast (i.e., when quotes are indicative for all investors), OPRA data do not always identify indicative quotes. Quotes in the equity option market are also indicative for all market participants when they exceed prespecified maximum quote widths (see, for example, PCX Rule 6.37(4) and CBOE Rule 8.7(b)) and when they are locked or crossed. Thus, when we look at apparent arbitrage opportunities, we omit option quotes that are designated as fast, quotes with spread widths that exceed the maximum, and quotes that are locked or crossed.

[5]Indeed, the Securities Traders Association (2003) notes that, "Locked markets cause havoc in the market place. *Customer orders represented by published quotations do not get filled* when they should and, more importantly, *automated execution systems do not function* during periods when there are locked markets (emphasis added)." These sentiments are echoed by Chris Nagy, head of trading at Ameritrade, who states in a April 2003 Financial Tech interview that "when markets are locked, pricing tends to be confusing at that point, automated executions tend to halt, and you've got a somewhat dysfunctional marketplace." Indeed, even the option markets *disengage their automatic execution systems* when stock quotes become locked or crossed (see, for example, AMEX Rule 933 (f)).

[6]While there is no uniform definition of what constitutes abnormal market conditions across exchanges, they include fast or volatile market conditions, periods of time during which *quotes are locked or crossed for any series in the option class or in the underlying equity market*, periods of time surrounding significant news stories or communication or systems outages, and periods of time during which OPRA capacity is strained (See Amex Rule 933(f), CBOE Rule 6.6, PHLX Rule 1080(e), and PCX Rule 6.87(h)).

Market professionals (i.e., market makers, professional traders, etc.) do not have access to automatic execution systems during our sample period. Instead, during this period a market professional in search of liquidity had to reveal her identity and trading interest to the market maker who then decided whether or not to provide an execution at his posted price. When a market maker chose not to trade with the market professional at his posted price, the market maker was required to change his quote. This is not to say that options market makers would not trade with hedge funds and other institutions at quoted prices. Rather, the prohibition against automated execution by professionals is designed to prevent them from taking advantage of stale quotes or minor pricing discrepancies across exchanges. Institutions betting that the Internet sector was overpriced do not fall into this category.

*B. Our sample*

Table I lists our sample stocks along with the number of days that they appear in the sample and the total number of trades in their options. In total, we have 14 Internet stocks and 35 nonInternet stocks. Many of the other stocks, while not in the Internet sector, are technology stocks. These include IBM, Intel, and Microsoft. Again, the options we analyze are not a random sample: the market maker from whom we obtain the data compiled information on the most actively traded options.

**[Insert Table I]**

While there are limitations to our sample, it has a critical advantage over options data used by other researchers, namely, the data are not end-of-day data. Rather, our sample consists of intraday trades and quotes, which allows us to accurately match option quotes or trades with the corresponding stock quotes. Although our sample period is limited, it fortuitously covers the most interesting period of the Internet bubble. Internet stock prices were rising in February 2000, but in March 2000 they peaked and started to decline. The bubble "burst" in April and significant price declines continued in May 2000.

**[Insert Figure 1]**

It is critical for the rest of our analysis that our sample of Internet stocks could be traded as a proxy for the Internet sector as a whole. Figure 1 graphs values of the ISDEX index of Internet stocks along with an equally-weighted portfolio of the 14 Internet stocks in our sample. The ISDEX index consists of 50 stocks from Internet.Com's InternetStockList, a comprehensive list of companies that derive at least 50% of their revenues from the Internet. An attempt is made to select stocks for the index so as to match weights in the index to the capitalization of various Internet sectors. Size, as measured by market capitalization, and trading volume are also factors in choosing the index stocks. Futures on the ISDEX index traded on the Kansas City Board of Trade during our sample period. Our portfolio of stocks tracks the index of Internet stocks very closely: both the ISDEX index and the portfolio of our sample stocks rise dramatically in early 2000, both reach a peak in March 2000, and then both begin to decline quickly. Thus, investors who wanted to trade the Internet sector could have done so using the 14 stocks in our sample.

*C. Shorting the Internet Sector Synthetically with our Sample Options*

A synthetic share can be created by buying a call, writing a European put, lending the present value of the exercise price, and lending the present value of the dividend.[7] Of course, the puts traded on the options exchanges are American puts, so we estimate the value of European puts by subtracting the early exercise premium from the value of the American put. To synthetically purchase a share of stock, we assume we buy the call at the ask price and write the put at the bid price. Money that is lent is assumed to earn the yield that could be obtained by purchasing T-bills. Thus, a synthetic ask price for the stock is given by

$$S^{Ask}_{Synthetic} = C^{Ask} - \left(P^{Bid} - EEP\right) + e^{-r_L T} X + e^{-r_L t_D} D, \tag{1}$$

[7]This assumes that the dividend is too small for the call option to be exercised early.

where $C^{Ask}$ is the call's ask price, $P^{Bid}$ is the put's bid price, $EEP$ is the early exercise premium, $r_L$ is the T-bill lending rate, $T$ is the time to expiration, $X$ is the option's exercise price, $t_D$ is the time until the dividend, and $D$ is the dividend. Similarly, a synthetic bid price for the stock is given by

$$S^{Bid}_{Synthetic} = C^{Bid} - \left(P^{Ask} - EEP\right) + e^{-r_B T} X + e^{-r_B t_D} D \, , \tag{2}$$

where $C^{Bid}$ is the call's bid price, $P^{Ask}$ is the put's ask price, and $r_B$ is the T-bill borrowing rate.

We calculate synthetic bid and ask prices using inside bid and ask quotes at the end of each minute from 9:45am to 4pm for each day of the sample period. To construct synthetic shares we only use options with exercise prices within 5% percent of the stock price and with 10 to 40 days to expiration. We use these short-term at-the-money options because these are the options that investors prefer - open interest and trading volume are highest here. Note that longer term options trade on all of our sample stocks and synthetic shares can be constructed from these options as well.

To calculate early exercise premia, we first estimate the standard deviation for each stock-day combination using a simple average of implied standard deviations from every end-of-minute call option quote for that stock. We then use a finite difference approach with the daily implied volatility to solve the partial differential equation numerically for American and European put prices at the end of each minute. The early exercise premium is the difference between the American and European put values. The calculation of the early exercise premia is the only place where we make use of volatility estimates or the Black-Scholes (1973) model. Given that we make use of the Black-Scholes model only in the calculation of the early exercise premium, and further, the early exercise premia are a very small portion of the value of the short-term, at-the-money puts that we use, model misspecification and volatility misestimation are unlikely to pose significant problems.

We calculate interest rates from daily Treasury bill prices. Prices are obtained for bills with as close to 30, 60, 90, 120, 180, and 365 days-to-maturity as possible. We approximate lending rates from the ask quotes and borrowing rates from the bid quotes. The 30-day rate is used for option exercise prices with less than 30 days until expiration and for dividends to be paid within 30 days. For longer periods, we interpolate between rates based on maturities that are longer and shorter than the time to expiration.

Shorting an equally weighted portfolio of our sample Internet stocks is by no means an optimal strategy for an arbitrageur who believed that the Internet sector as a whole was overpriced. A trader who considers selling synthetic shares will be concerned with both the cost of selling synthetically and the correlation between the returns of the index and the portfolio of synthetic short positions. We estimate the cost of shorting each portfolio using the average difference between the synthetic bid price for each stock on February 29, 2000. Note that we use the difference between the cost of trading the synthetic and actual shares.

One of our 14 sample Internet stocks, E-Trade Group, does not appear until August 6$^{th}$ 1999. Hence, we use the period from August 6$^{th}$ 1999 through February 29$^{th}$ 2000 to estimate the correlation between portfolios of our sample Internet stocks and the ISDEX Internet index. In constructing our set of efficient portfolios, we consider all possible combinations of sample Internet stocks such that each stock is held in a proportion of one, three, or five times a minimum number of shares. Thus, for example, the holdings of every stock in our portfolio could be either 100, 300, or 500 shares, or 1,000, 3,000, or 5,000 shares. Even this restricted set includes $3^{14} = 4{,}782{,}969$ portfolios. We limit ourselves to round lot holdings in each stock, which we believe is a realistic recognition of the extra costs entailed in trading smaller bundles. We also limit ourselves to positive positions in each stock because we are using estimates of correlations; portfolios formed using both positive and negative weights ex ante may often have extreme positions in individual stocks and low correlations with the indices ex post. This is also our reason for limiting the relative size of positions to five to one. While we would be able to produce portfolios that tracked the Internet sector more closely and at a lower cost if we put no restrictions on our portfolio weights, our limited set of portfolios represents feasible strategies.

**[Insert Figure 2]**

Figure 2 shows the "efficient frontier" of correlations with the ISDEX Internet index and costs of synthetic shorting that confronted an investor who wanted to bet against the Internet sector on March 1st, 2000. The cost of shorting a stock synthetically is the difference between the bid price of the stock and the synthetic bid price. If an investor was willing to pay shorting costs of 20 basis points, it was possible to construct portfolios with ISDEX index correlations of more than 0.95 during the estimation period. If, on the other hand, the arbitrageur wanted to concentrate trading in the synthetic shares that were cheaper to trade, it was possible to hold shorting costs down to under 15 basis points and still achieve a correlation with the index of 0.90.

Of course, the correlations between the portfolios and the index are estimated ex ante. If an arbitrageur had attempted to construct a portfolio of synthetic shares to mimic an Internet index, the correlation could be lower ex post. To examine this issue, we estimate the correlation between each of our efficient portfolios and the ISDEX index in the 125 days (approximately six months) following their formation on March 1st, 2000. These correlations are plotted in Figure 3. Most of the ex ante and ex post correlations are very similar. Even the lowest ex post correlation is 0.89. Thus, an arbitrageur could do a reasonable job of mimicking the ISDEX index using the ex ante correlations between portfolios and the index.[8]

**[Insert Figure 3]**

Of course, we understate the ability of an arbitrageur to use options to bet against the Internet sector. The results we present here are based on options on the 14 sample stocks only – options were available on many other Internet stocks during this time.

## III. Do Option Prices Indicate Short-Sale Restrictions in the Stock Market?

The inability to sell short in the stock market can prevent investors from arbitraging away price differences between the stock and options markets. The rationale is as follows. Investors can duplicate shares

---

[8] We also look at ex ante and ex post efficient frontiers of trading costs and correlations with the American Stock Exchange's IIX Internet Index. Results are almost identical.

of stock in the options market by simultaneously taking long and short positions in puts and calls and either borrowing or lending cash. If the synthetic shares of stock are cheaper than the actual shares, arbitrage profits can be earned, but only if the stock can be sold short. Hence, arbitrage opportunities that involve buying synthetic shares and selling actual shares imply that the stock cannot be sold short easily and cheaply. Lamont and Thaler (2003), Ofek and Richardson (2003), and Ofek, Richardson, and Whitelaw (2004) all point to the apparent existence of arbitrage opportunities of this type as evidence of binding short-sale restrictions.

It could be the case, however, that arbitrage opportunities between stock prices and prices of synthetic shares created from options indicate that short-sale constraints in the stock market prevent arbitrage. We look for evidence of arbitrage opportunities by comparing synthetic stock prices with actual stock prices using end-of-minute quotes from 9:45 to 4:00 for all days of our sample period. We examine separately arbitrage violations in which investors can seemingly profit by purchasing synthetic shares and selling short actual shares and arbitrage violations in which investors can seemingly profit by selling short synthetically while buying actual shares in the stock market. Only the first type of arbitrage opportunity, the kind that includes selling actual shares, is implied by short-sale restrictions. As before, we use only options with 10 to 40 days to expiration with exercise prices within 5% of the stock price.

Table II describes our results. Using short-term at-the-money options, we have 2,490,562 sets of quotes that can be used to generate synthetic stock prices. As expected, in the great majority of cases there are no arbitrage opportunities. Notwithstanding, we find 225,090 instances in which it appears that an investor could buy synthetically in the options market and sell at a higher price in the stock market, and an additional 206,280 cases in which it appears that investors could buy in the stock market and sell synthetically at a higher price in the options market. When we look at Internet stocks only, 877,117 quotes can be used to generate synthetic stock prices. Of these, 102,736 suggest that arbitrage profits can be made by buying synthetic shares and selling the stock, and 92,089 suggest that arbitrage profits can be made by selling synthetic shares and buying the stock. The last column of the table reports chi-square $p$-values of tests of whether the proportion of Internet quotes that lead to arbitrage opportunities exceeds the proportion of quotes for nonInternet stocks. A significantly larger portion of Internet stock quotes leads to apparent arbitrage opportunities for each category of possible arbitrages.

**[Insert Table II]**

Even before discarding quotes that cannot be traded, the proportion of apparent arbitrage opportunities that we find is much less than that in Ofek and Richardson (2003). They find that for their sample of Internet stocks in February 2000, 36.0% of option pairs produce synthetic bids that exceed the stock price or synthetic asks that are less than the stock price. In contrast, using intraday quote data from both the stock and options markets, we find that for Internet stocks, only 22.2% of our synthetic prices imply arbitrage opportunities. Similarly, for nonInternet stocks, Ofek and Richardson find that 23.8% of their option pairs seem to create arbitrage opportunities with the stock market, whereas we find that only 14.7% of the synthetic prices from our nonInternet companies provide apparent arbitrages.

We believe that our results differ from those of Ofek and Richardson (2003) because our data are far superior. Ofek and Richardson, like Ofek, Richardson and Whitelaw (2004), use closing option quotes and last stock trade prices from the OptionMetrics Ivy database. This is arguably the best database of option prices that is publicly available and as such it has been used by numerous researchers.[9] Nevertheless, OptionMetrics matches closing stock trades that occurred no later than 4:00pm, and perhaps much earlier, with closing option quotes posted at 4:02pm. Furthermore, option market makers that post closing quotes on day t are not required to trade at those quotes on day t+1. Likewise, dealers and specialists in the underlying stocks have no obligation to execute incoming orders at the price of the most recent transaction. Hence, closing option quotes and closing stock prices obtained from the OptionMetrics database do not represent contemporaneous prices at which investors could have simultaneously traded.

[9]See Carr and Wu (2004), Cremers et al. (2004), and Ni, Pearson, and Poteshman (2004).

In the Appendix to this paper, we show that the nonsynchronous prices and microstructure biases inherent in the OptionMetrics prices can lead researchers to greatly exaggerate the frequency of put-call parity violations.

Only about half of the apparent put-call parity violations in our data are consistent with short-sale restrictions in the stock market. The inability to sell stocks short creates only one type of arbitrage opportunity, namely that investors could purchase shares synthetically and sell them at a higher price in the stock market. Table II shows, however, that when we take all stocks into account, 225,090 arbitrage opportunities require selling the stock and almost as many, 206,280, involve purchasing the underlying stock. This suggests that the arbitrage opportunities are not a result of short-sale constraints but rather are due to invalid quotes or other microstructure-related problems.

In most cases, the potential arbitrage profits appear to be small. As a check on the robustness of the arbitrage violations, we count the number of times the synthetic bid price exceeds the ask price of the stock by more than 1% or $1.00. Likewise, we count the number of times the synthetic ask price is less than the stock's bid price by more than 1% or $1.00. Most of the apparent arbitrage opportunities are eliminated by these filters. There remain 33,254 instances in which buying stock synthetically and selling it at the bid yields apparent arbitrage profits of more than 1% and 33,433 cases in which that strategy seems to yield potential profits of more than $1 per share. Similarly, there are 30,480 cases in which buying shares and selling stock synthetically in the options market yields profits in excess of 1%, and 29,962 cases in which the strategy provides profits of more than $1 per share. When we use the 1% filter, the percentage of quotes that indicate possible arbitrage opportunities is less than 2.6% of all quotes.

Both Internet and nonInternet stocks seem to provide arbitrage opportunities. The proportion of quotes that result in arbitrage opportunities is higher for Internet stocks however, and chi-square tests reveal that the proportions of both types of arbitrage opportunities are significantly larger for Internet stocks. When we restrict our attention to violations that seem to promise profits of more than 1% or $1 per share, the proportion of quotes that suggest arbitrage opportunities is again significantly larger for Internet stocks.

Are short-sale restrictions responsible for the apparent arbitrage opportunities? We have seen that apparent arbitrage opportunities are almost as likely to involve buying shares of the stock as selling them. Thus, a likely alternative explanation may be that the apparent arbitrage opportunities cannot be exploited because they result from incorrect or unusable stock or option quotes.

In Table III, we look more closely at the role of unusable quotes in the creation of apparent arbitrage opportunities. We focus on the 225,090 cases in which the synthetic ask price for the stock is lower than the actual bid price, as these are the arbitrage possibilities that could occur as a result of short-sale restrictions. The second column of the table breaks down the 225,090 apparent arbitrage opportunities into different levels of implied profit per share. More than half of them, 117,454, imply profits of less than 20¢ per share. On the other hand, 33,433 cases seem to promise arbitrage profits of more than $1 per share.

**[Insert Table III]**

The next column of the table shows the percentage of arbitrage opportunities that occur when quotes on the underlying stock are locked, that is, the bid and ask quotes are equal. In total, 4.68% of the arbitrages opportunities occur when the stock quotes are locked. The following column reports the percentage of possible arbitrages that occur when the underlying stock quotes are crossed, that is, the bid price exceeds the ask. In total, 59.12% of the remaining possible arbitrage opportunities occur when quotes are crossed and investors cannot trade the stock at quoted prices. Note that when apparent profits per share are large, the proportion of crossed quotes is larger. For example, when the apparent arbitrage implies profits of $0.90 to $1.00 per share, 81.49% of the apparent arbitrage opportunities occur when the quotes on the underlying stock are crossed. After eliminating cases in which the underlying stock quote was locked or crossed, 81,487 of the original 225,090 arbitrage possibilities remain. An even larger percentage of the arbitrage opportunities with large profits is eliminated. We also eliminate arbitrage opportunities that occur when options quotes are locked or crossed. This further reduces the number of possible arbitrage opportunities to 41,329. Again, the apparent arbitrage opportunities with large per-share profits are disproportionately eliminated.

Finally, we discard the apparent arbitrage opportunities that arise when investors could expect to trade at quoted prices because option quotes are designated as “fast market” or “wide” quotes. This leaves 34,177 apparent arbitrage opportunities, or about 1.4% of the quote observations. Thus, we eliminate 85% of the apparent arbitrage opportunities by simply discarding quotes that did not represent firm commitments to trade. Only 10,720, or 0.43% of the quotes promise profits of 10¢ per share or more.

The last column of the table provides the number of arbitrage opportunities for Internet stocks only after eliminating all potential arbitrages involving locked, crossed, fast, or wide quotes in the options market. Interestingly, the remaining arbitrage opportunities account for 1.57% of the original quotes for the entire sample, but only 0.99% for the Internet stocks in the sample. Thus, arbitrage opportunities appear to be less common for Internet stocks than for others. This is hard to reconcile with an explanation for arbitrage opportunities based on overly optimistic investors irrationally driving prices of Internet stock too high. Only 3,696 quotes for Internet stocks, or 0.42%, promise profits of 10¢ per share or more. This percentage is almost identical for the nonInternet stocks.

We therefore find that almost all of the apparent arbitrage opportunities disappear when we discard erroneous or non-binding quotes. We believe that the small number of remaining apparent arbitrage opportunities are also almost all illusory. During our sample period, trade and quote message traffic sometimes exceeded OPRA capacity, resulting in stale quotes. In addition, it takes time to make the trades necessary to take advantage of these apparent arbitrage opportunities, and real mispricings are likely to be fleeting. A further complication is that the best quotes for calls and puts used to construct a synthetic share are likely to be posted at different exchanges – there may be difficulties and time delays involved in executing trades in the stock market and possibly two separate options markets. Finally, many of these apparent opportunities may be explained by our omission of brokerage commissions and transactions costs associated with short-selling stock, or by small differences between the interest rates we use and the actual borrowing or lending rates available to possible arbitrageurs.

To summarize, our examination of possible arbitrage opportunities provides no evidence of short-sale constraints for Internet stocks. First, arbitrage opportunities that involve selling synthetic shares and buying the stock are almost as common as those that involve buying synthetic shares and selling the stock. Short-sale constraints only prevent arbitrage that involves selling stock. Second, the great majority of the observed arbitrage opportunities can be attributed to quotes that do not reflect prices that investors could expect to actually pay or receive. Finally, after removing poor quotes from the sample, apparent arbitrage opportunities are more common for nonInternet stocks than for Internet stocks, that is, for our sample of Internet stocks, there is no evidence that short-sale constraints affected prices at the bubble's peak.

## IV. Could Investors Circumvent Short-Selling Restrictions with Options?

If investors are prevented from selling stock short, they can sell short synthetically with options. Indeed, by using synthetic short sales investors avoid difficulties in borrowing stock, they do not have to restrict their short-selling to upticks (for NYSE stocks), and they do not have to worry about their stock being recalled. It is an empirical question, however, whether synthetic shorts provide a good substitute for actual short sales. For example, Lamont and Thaler (2003) show that such a strategy generated far less money than an actual short sale for their sample. In this section we begin by determining whether investors could have established large synthetic short positions in our sample of options. We then compare the proceeds available from synthetic short sales with the proceeds available from selling short directly.

As we previously noted, trading volume in our sample options constitutes over one-quarter of all volume in equity options in February of 2000. While this confirms that our options are among the most actively traded, it does not reveal whether trading in our sample options is sufficiently thick to allow investors with strong opinions to place "large" bets with options. Panel A of Table IV characterizes the relative trading volume in the sample option classes and their underlying stocks separately for Internet and nonInternet stocks during our sample period. Across the 14 Internet stocks, the relative volume of the option market averages 18.4% of the stock volume with an interquartile range of 12.43% to 20.90% of stock volume. For nonInternet stocks, the relative volume of options averages 14.62%, with an interquartile range from 9.19% to 19.27% of stock volume. An investor who wanted to trade 5% of average daily volume in Cisco (IDT Corp.) options, our most (least) active Internet stock, could have traded options on 431,887 (8,556) shares *each day*. Of course, two options, a put and call, must be traded to replicate one share. So, investors trading only 5% of Cisco (IDT Corp) options could have traded the equivalent of approximately 215,943 (4,278) shares per day. Together, the statistics in Panel A of Table IV suggest that investors could establish large positions relatively quickly during our sample period.

**[Insert Table IV]**

We use quoted prices to compare the proceeds from selling short synthetically with the proceeds from actual short sales. We believe that prices quoted in normal market conditions are an accurate measure of execution prices for options. Exchange regulations require that retail investors trading in normal markets trade at or within the NBBO. We use the volume-weighted difference between effective and quoted spreads (i.e., liquidity ratios) to evaluate the average cost of liquidity for options on Internet and nonInternet stocks during our sample period. We examine trades executed between 9:45am (after the opening rotation) and 4:00pm (before the closing rotation). We exclude trades when the execution-time bid exceeds the execution-time offer since effective half-spreads are undefined for these trades. Following Boehmer, Saar, and Yu (2005), Barclay and Hendershott (2004), and Chordia, Roll, Subrahmanyam (2001), we also exclude trades with effective spreads exceeding $5.00 as they are likely to be data errors. Complex trades (e.g., spreads and straddles) are also excluded from our sample since they are priced as a package.

Panel B of Table IV characterizes the differences between quoted and execution prices for puts and calls in our samples. Differences greater than (less than) zero suggest the average execution price paid by liquidity demanders was worse than (better than) the execution-time quotes. The mean share-weighted difference for calls across the 14 Internet stocks is \$0.0055, with an interquartile range from \$0.0015 to \$0.0088. So, on average, investors paid about half a cent more than the quoted price for calls. Across the 14 Internet stocks, the mean difference for puts is \$0.0066, while the interquartile range is from \$0.0032 to \$0.0104. For nonInternet stocks, the mean difference between execution prices and quotes is \$0.0020 for calls and -\$0.0018 for puts. Since we are using execution-time quotes to evaluate unsigned execution prices, some of which may be reported with a lag, these estimates of liquidity costs represent upper bounds.[10] These share-weighted price differences suggest that, on average, institutions and retail investors trading in fast markets are able to obtain execution prices that are very close to the posted prices. To summarize, these results indicate that quoted prices are an accurate measure of the prices that option investors could expect to pay or receive when trading options.

Having established that investors could trade large amounts of synthetic shares in the options markets and that average quoted prices are very close to actual trade prices, we now determine whether the prices of synthetic shares are such that shorting them is a good substitute for shorting actual shares of the stock. For each sample stock we calculate synthetic bid and ask prices at the end of each minute using options with 10 to 40 days to expiration and exercise prices within 5% of the stock price. We omit all observations in which the stock prices, call prices, or put prices are locked or crossed. We then calculate average ratios of synthetic to actual bid and synthetic to actual ask prices for each stock each day. Panel A of Table V reports the distributions of these daily mean ratios for each Internet stock.

**[Insert Table V]**

The grand mean of the ratio of synthetic to actual bid prices for Internet stocks, which we obtain by averaging the 14 individual stock means, is 0.996. That is, selling shares of Internet stocks synthetically

---

[10]For example, Peterson and Sirri (2003) find that estimates of effective spreads for NYSE-listed stocks in 1997 that are computed using unsigned execution prices overstate actual execution costs by up to 17%.

provides 99.6% of the proceeds that could be obtained from selling short the actual shares. The interquartile range of the 14 Internet stock means is from 0.994 to 0.997. Thus, selling short synthetically is a good substitute for an actual short sale across the individual stocks in our Internet sample. That an investor would receive slightly less by selling short synthetically than by selling short directly is not surprising. Selling short synthetically involves two transactions, writing a call and purchasing a put. Because we use bid and ask prices rather than midpoints, we implicitly incorporate the extra transaction costs involved in selling short synthetically.

These price ratios suggest that absent short-sales constraints, selling short directly is preferable. The difference in proceeds from synthetic and actual short sales is, however, exaggerated. Here we consider only one pair of options for each stock at each point in time. An investor who wishes to construct a short position in the options market could typically examine several pairs of options with different strike prices and times to expiration and choose the pair that generates the largest proceeds. In addition, synthetic shorts, unlike actual short sales, do not face the risk that borrowed shares may be recalled.

The last three columns of the table provide the distribution of the ratios of the synthetic to actual ask price. If stock prices are artificially high as a result of short-sale restrictions, it may be possible to buy shares more cheaply synthetically than directly. Lamont and Thaler (2003), for example, claim that this was the case for tech stock carve-outs. For our sample of Internet stocks it is just slightly more expensive to buy shares synthetically. The mean ratio of the synthetic to actual ask price is 1.005 for Internet stocks, with an interquartile range from 1.003 to 1.007. Buying a share synthetically costs about 0.5% more than buying the actual shares.

The next row of the table reports ratios of synthetic to actual stock prices for nonInternet stocks. For these securities, the ratios are generally closer to one. Synthetic short and long positions are even cheaper for these stocks.

Being able to sell short synthetically may have been especially important during late March and April 2000, during which time Internet stock prices were falling rapidly. Figure 4 shows the mean ratio of synthetic to actual bid prices on a daily basis over the sample period. The solid line shows the average ratio for Internet stocks while the dashed line shows the ratio for other stocks. The mean ratio is never less than 0.99 for any day. Thus, over this period investors who chose to short synthetically would receive at most 1% less than investors who sold the actual shares short.

**[Insert Figure 4]**

A critical question is whether investors could synthetically short-sell stocks that were hard to borrow. The market maker from whom we obtain OPRA data often shorts stock. When it does, a large financial institution pays it interest on the proceeds generated from shorting the stock. For shares that are easy to locate, the interest rate is 20 basis points below the federal funds rate. For hard-to-borrow stocks, the interest rate paid on the short-sale proceeds is lower. We obtain from the options market maker data that contains rebate rates for all stocks it shorted during our sample period. In the great majority of the cases the stocks are easy to locate and the rebate rate is close to the federal funds rate. We follow Geczy, Musto, and Reed (2002) and define a stock as hard to borrow on a given date if the rebate rate is at least 100 basis points lower than the typical rebate rate of 20 basis points below the federal funds rate.

By this definition, only two Internet stocks are hard to borrow at any time during our sample period. Internet Capital Group is difficult to borrow on 80 days, while Amazon is hard to borrow on seven days. Of the other sample stocks, Rambus shows up as hard to borrow every day, SAP on 29 days, Elan Plc. on 14 days, and Knight Trading on six days. Panel B of Table V shows the ratio of synthetic bid prices to actual bid prices and synthetic ask prices to actual ask prices for all hard to borrow and other stocks. A stock is only regarded as hard to borrow if it is difficult to borrow on that day. Hence, some of the Amazon.com observations are classified as hard to borrow, while some are not.

The mean ratio of synthetic to actual bids is 0.994 for the hard-to-borrow observations versus 0.998 for the others. Thus, investors could have synthetically sold short the stocks they had trouble borrowing and received almost as high a price. Of course, this comparison does not incorporate the costs of borrowing stock. The average (median) difference between the federal funds rate and the rebate rate is -2.89% (-2.42%) for our hard-to-borrow stocks, which is somewhat higher than the mean annualized cost of 1.57% for stocks on special reported by Ofek, Richardson, and Whitelaw (2004) or the 1.15% specialness cost for dot-com stocks reported by Geczy, Musto, and Reed (2002).[11] Our high average specialness cost translates into a direct shorting cost of roughly 20 basis points per month. When we consider this cost, the extra 60 basis-point cost of shorting synthetically for a month declines to roughly 40 basis points. Hence, selling short synthetically is a reasonably cost effective alternative to selling short directly when stocks are hard to borrow. Of course, we do not consider here the possibility that the borrowed stock will be recalled, which makes a synthetic short-sale all the more attractive.

The mean ratio of synthetic to actual asks is 1.006 for the hard-to-borrow stocks versus 1.003 for the others. Lamont and Thaler (2003) find for some of their sample stocks that it is cheaper to buy synthetically than to buy actual shares. In contrast, we find that even for the hard-to-borrow stocks, it is cheaper to buy shares directly.

Finally, one might take issue with the use of options with 10 to 40 days to maturity in this analysis. Table V, Panel C contains the ratio of the mean synthetic bid (ask) price to the actual bid (ask) price for options on Internet stocks with 10 to 40, 41 to 70, and 71 to 100 days to maturity and for long-term equity options (LEAPS). Since longer-term options tend to be less liquid, and thus have wider quoted spreads, we expect the ratios of synthetic to actual prices to be increasing in time to maturity. Consistent with this expectation, we find that the mean ratio of synthetic to actual bids declines from 0.996 for options with 10

[11]Interestingly, the 60 basis-point magnitude of the difference between actual and synthetic prices is very similar to the finding by Evans et al. (2003) that for every percentage point decrease in the annualized rebate rate, there is a discrepancy of 19 basis points between actual and synthetic stock prices.

to 40 days to expiration to 0.995 for options with 41 to 70 days remaining, and to 0.994 for options with 71 to 100 days to expiration and for LEAPS. So, even with longer-term options, a synthetic short position provides 99.4% of the proceeds of an actual short sale. Similarly, synthetic long positions created from options are only slightly more expensive than shares purchased directly.

To reiterate, even at the very peak of the Internet bubble, investors could have sold short synthetically and received almost as much as if they had sold the shares short. Even hard-to-borrow stocks could have been easily and cheaply sold short synthetically. Thus, there was no lack of ways in which rational investors could profit from betting against “overpriced” Internet stocks.

## V. Summary and Conclusion

It is widely believed that a bubble existed in Nasdaq stocks generally and Internet stocks in particular in the 1999 to 2000 period. Some researchers have proposed that short-selling restrictions prevented rational investors from driving prices of Internet stocks back to reasonable levels during this time. Researchers point to the presence of apparent arbitrage opportunities that involve selling actual shares and buying synthetic shares as indications that short-sale constraints were binding.

We show, however, that these apparent arbitrage opportunities are largely illusory. Our intraday data allow us to minimize nonsynchroneity problems. This alone significantly reduces the frequency of apparent arbitrage opportunities. Almost all of the remaining apparent put-call parity violations disappear when we discard locked or crossed quotes and quotes from fast options markets. In other words, the apparent arbitrage opportunities almost always arise from quotes upon which investors could not actually trade. The bottom line is that we find no evidence from apparent arbitrage opportunities that short-sale restrictions prevented investors from shorting Internet stocks.

We also show that investors could have easily shorted stock synthetically by purchasing puts and writing calls. Investors can expect to receive almost as much from a synthetic short sale as from an actual short. The extra amount lost to transaction costs from a synthetic short, about 0.5%, was dwarfed by the later decline in prices of Internet stocks. Even hard-to-borrow stocks could have been sold short synthetically to produce almost the same proceeds as an actual short. Our results suggest patient investors could have amassed sizable synthetic short positions at a reasonable cost before the Internet bubble burst. The tight linkage between the stock and options markets indicates though that sooner or later, bearish trading in the option market would have burst the Internet bubble.

Why did the Internet bubble persist as long as it did? Perhaps traders did not bet against Internet stocks because it was not obvious to them that Internet stock prices were too high – they were trying to value companies in a new industry with unprecedented levels of recent growth. In examining this question now, we academics, along with reporters and regulators, have the unfair advantage of hindsight.

## References


Abreau, Dilip, and Markus Brunnermeier, 2002, Synchronization risk and delayed arbitrage, Journal of Financial Economics 66, 341-360.

Barclay, Michael, and Terrence Hendershott, 2004, Liquidity externalities and adverse selection: Evidence from trading after hours, Journal of Finance 59, 681-710.

Battalio, Robert, Brian Hatch, and Robert Jennings, 2004, Toward a national market system for U.S. exchange-listed equity options, Journal of Finance 59, 933-962.

Bessembinder, Hendrik, 2003, Quote-based competition and trade execution costs in NYSE-listed stocks, Journal of Financial Economics 70, 385-422.

Black, Fisher, and Myron Scholes, 1973, The pricing of options and corporate liabilities, Journal of Political Economy 81, 637-659.

Boehmer, Ekkehart, Gideon Saar, and Lei Yu, 2005, Lifting the veil: An analysis of pre-trade transparency at the NYSE, Journal of Finance 60, 783-815.

Carr, Peter, and Liuren Wu, 2004, Variance Risk Premia, Working paper, Baruch College.

Chakravarty, Sugato, Huseyin Gulen, and Stewart Mayhew, 2004, Informed trading in stock and option markets, Journal of Finance 59, 1235-1257.

Chen, Joseph, Harris Hong, and Jeremy Stein, 2002, Breadth of ownership and stock returns, Journal of Financial Economics 66, 171-205.

Chordia, Tarun, Richard Roll, and Avanidhar Subrahmanyam, 2001, Market liquidity and trading activity, Journal of Finance 56, 501-530.

Cremers, Martijn, Joost Dreissen, Pascal Maenhout, and David Weinbaum, 2004, Individual Stock-Option Prices and Credit Spreads, Working paper, Cornell University.

D'Avolio, Gene, 2002, The market for borrowing stock, Journal of Financial Economics 66, 271 - 306.

de Long, J. Bradford, Andrei Shleifer, Lawrence Summers, and Robert Waldmann, 1990, Noise trader risk in financial markets, Journal of Political Economy 98, 703-738.

Diamond, Douglas, and Robert Verrechia, 1981, Information aggregation in a noisy rational expectation economy, Journal of Financial Economics 9, 221-235.

Duffie, Darrell, Nicolae Garleanu, and Lasse Pedersen, 2002, Securities lending, shorting, and pricing, Journal of Financial Economics 66, 307-339.

Evans, Richard, Christopher Geczy, David Musto, and Adam Reed, 2003, Failure is an option: Impediments to short selling and options prices, Working paper, University of Pennsylvania.

Geczy, Christopher, David Musto, and Adam Reed, 2002, Stocks are special too: An analysis of the equity lending market, Journal of Financial Economics 66, 241-269.

Hong, Harrison, and Jeremy Stein, 2003, Differences of opinion, short-sales constraints and market crashes, Review of Financial Studies 16, 487-525.

Lamont, Owen, and Jeremy Stein, 2003, Aggregate short interest and market valuations, Forthcoming, American Economic Review Papers and Proceedings.

Lamont, Owen, and Richard Thaler, 2003, Can the market add and subtract? Mispricing in tech stock carveouts, Journal of Political Economy 111, 227-268.

Lakonishok, Josef, Inmoo Lee, and Allen Poteshman, 2003, Option market activity and behavioral finance, Working paper, University of Illinois.

Mayhew, Stewart, and Vassil Mihov, 2004, Short sale constraints, overvaluation, and the introduction of options, Working paper, Texas Christian University.

Miller, E.M., 1977, Risk, uncertainty and divergence of opinion, Journal of Finance 32, 1151-1168.

Ni, Sophie, Neil Pearson, and Allen Poteshman, 2004, Stock Price Clustering on Option Expiration Dates, Working paper, University of Illinois at Urbana-Champaign.

Ofek, Eli, and Matthew Richardson, 2003, DotCom Mania: The rise and fall of Internet stock prices, Journal of Finance 58, 1113-1137.

Ofek, Eli, Matthew Richardson, and Robert Whitelaw, 2004, Limited arbitrage and short sales restrictions: Evidence from the options markets, Journal of Financial Economics 74, 305-342.

Pan, Jun, and Allen Poteshman, 2004, The information in option volume for future stock prices, Forthcoming, Review of Financial Studies.

Peterson, Mark, and Erik Sirri, 2003, Evaluation of the biases in execution cost estimation using trade and quote data, Journal of Financial Markets 6, 259-280.

Scheinkman, Jose, and Wei Xiong, 2003, Overconfidence and speculative bubbles, Forthcoming, Journal of Political Economy.

Securities Traders Association, 2003, Fulfilling the promise of the National Market System: STA's perspective on U.S. market structure.

Schenzler, Christoph, and Hans Stoll, 2005, Trades outside the quotes: Reporting delay, trading option, or trade size?, Forthcoming, Journal of Financial Economics.

Schmerken, Ivy, Nasdaq's battle over locked crossed markets, Finance Tech, April 15, 2003.

Shleifer, Andrei, and Robert Vishny, 1997, The limits of arbitrage, Journal of Finance 52, 35-55.

## Appendix

In this appendix, we discuss the difficulties that researchers face when using the OptionMetrics database to test put-call parity or to evaluate other option pricing models. Like Ofek and Richardson (2003), we find many examples of put-call parity violations in the OptionMetrics database. We show that simple screens derived from TAQ data eliminate most of the apparent violations. Even after screening the data, however, problems of nonsynchroneity between option and stock markets limit the inferences that can be made from tests using synthetic prices created solely from these data.

The OptionMetrics database contains closing quotes for equity and index options and the closing transaction price for stocks traded in the United States. For a given stock on a given day, the closing price contained in the OptionMetrics database is the price of the closing call auction (if one was conducted). If there is no closing call auction, the closing price is the price of the last transaction, even if that transaction took place hours before the close. If the security does not trade on a given day, the closing price is the midpoint of the closing bid-ask spread. Even in the best of circumstances, a serious non-synchroneity problem remains. The equity option markets cease trading at 4:02pm. Although some equity markets continue to trade after 4:00pm, specialists on the New York Stock Exchange (NYSE) and dealers in the Nasdaq market typically cease trading at 4:00pm.

Even if the times of closing prices in the options and stocks markets were to align perfectly, it is not clear that the prices would be meaningful. Option market makers are obligated to trade at posted quotes during the trading day. In contrast, option market makers posting closing quotes on day t are not required to trade with anyone at those quotes on day t+1. Likewise, dealers and specialists in the underlying stocks have no obligation to execute incoming orders at the price of the most recent transaction. Hence, closing option quotes and closing stock prices obtained from the OptionMetrics database do not represent contemporaneous prices at which investors could have simultaneously traded.

Given the general lack of recent intraday trade and quote data for equity options, we examine whether there are screens that can improve the relevance of the OptionMetrics database for use in asset pricing tests. We begin by replicating a portion of Ofek and Richardson (2003), who among other things use the OptionMetrics database to examine put-call parity violations for Internet and nonInternet stocks for three days in February 2000. Following Ofek and Richardson, hereafter OR, we obtain all of the closing stock and option prices available in the OptionMetrics database for February 2000 and we use the second volume of Morgan Stanley's Internet Company Handbook, published in June of 2000, to identify 383 Internet companies. We obtain closing quotes for options on 2,330 different stocks and closing stock prices for 7,005 stocks. OR restrict their sample to at-the-money options on nondividend-paying firms with maturities in excess of 30 days and positive open interest. Implicitly, to examine put-call parity violations OR must also eliminate call and put options that do not have a corresponding put or call option with the same maturity and exercise price. We impose similar screens on our data, assuming that options with strike prices that are within $\pm$ 10% of the closing stock price are at-the-money. We also eliminate stocks with prices less than $5 and their corresponding options, option pairs if either the put or the call has a bid-ask spread that is greater than 50% of the option price (at the midpoint), and stocks for which it is impossible to calculate the volatility of the call option because the option price is less than the difference between the stock price and the present value of the exercise price. When computing synthetic stock prices, we add back an estimate of the early exercise premium.

We use all 20 trading days in February of 2000 since OR do not state which three days are used in their analysis. On average, we have 148 more nonInternet option pairs per day than OR. For Internet stocks, our sample contains an average of 500 option pairs per day while OR have an average of 504 option pairs per day. The difference in the daily average number of option pairs in the two samples reflects, in part, the fact that we have 17 more trading days than OR.

Next, we examine the extent to which microstructure issues are responsible for the apparent put-call parity arbitrage opportunities in the OptionMetrics database. Table A1 presents our results conditional on the time to maturity of the option pairs. We present results separately for option pairs with 31 to 60 days to maturity, 61 to 90 days to maturity, and more than 90 days to maturity. The third row of Table A1 presents the raw frequency of apparent put-call parity violations for Internet and nonInternet stocks, which are comparable to the frequency of apparent arbitrage opportunities presented in Table II, Panel A in OR. Overall, we find that 3,056 of the 9,992 Internet option pairs generate apparent arbitrage opportunities (30.58%) versus 14,488 of the 53,070 nonInternet option pairs (27.30%). OR find 36.0% of their Internet option pairs and 23.8% of their nonInternet pairs generate apparent arbitrage opportunities.

**[Insert Table A1]**

We impose screens to eliminate those apparent arbitrage opportunities that investors could not have exploited. During normal business hours, stock quotes are not firm when the market is locked or crossed. We examine whether the National Best Bid equals or exceeds the National Best Offer at 4:00pm for each option pair in our sample using quote data obtained from the NYSE's TAQ database. Overall, 35.93% (16.28%) of the apparent arbitrage opportunities in Internet (nonInternet) stocks involve option pairs whose underlying stock has locked or crossed quotes at 4:00pm. Similarly, nonprofessional investors demanding liquidity in the equity option market between 9:30am (after the opening rotation) and 4:02pm are not guaranteed that their orders will execute at the posted quotes when the National Best Bid equals or exceeds the National Best Offer or when quotes exceed prespecified widths. Imposing these screens eliminates 45.05% (30.12%) of the remaining apparent arbitrage opportunities in our sample of Internet (nonInternet) stocks. The final two screens we impose focus on the integrity of the closing price obtained from the OptionMetrics database. We first eliminate apparent arbitrages for which the closing stock price is outside of the National Best Bid and Offer at 4:00pm, reasoning that the price is stale. We also discard the apparent arbitrage opportunities that vanish if the relevant 4:00pm stock quote (rather than the closing price) is used in the put-call parity calculation. After imposing all of these screens, the frequency of apparent arbitrage opportunities for option pairs with 31 to 60 days to maturity falls from 25.48% to 4.10% for Internet stocks and from 24.27% to 5.58% for nonInternet stocks. Examining the bottom two rows of Table A1 reveals that roughly half of the apparent arbitrage opportunities that survive our microstructure screens imply profits of $0.20 or less. Interestingly, after we impose our microstructure screens the frequency of apparent arbitrage opportunities is larger for the nonInternet stocks than for the Internet stocks. This is not what we would expect if the arbitrage opportunities were caused by a combination of short-sale constraints and irrationally optimistic investors in Internet stocks.

What accounts for the remaining apparent arbitrage opportunities? Recall that there is a two-minute discrepancy in the timing of the latest possible closing stock price and the closing option quotes. Without tick data it is impossible to determine the percentage of the surviving option pairs with put or call quote changes between 4:00pm and 4:02pm. To gain some insight into this problem, we examine the National Best Bid and Offer at 4:00pm and at 4:02pm for any put or call on our 14 Internet and 35 nonInternet stocks that traded on one of the 20 trading days in February 2000.

For each day in February 2000, Table A2 contains the number of option series with a trade on that day and characterizes the similarities between the National Best Bid and Offer for each of those option series at 4:00pm and at 4:02pm. Table A2, Panel A contains results for options on Internet stocks. Across the twenty trading days, 10.56% of the options had changes in their bids, 11.93% of the options had changes in their asks, and 9.28% of the options had both bids and asks that changed from 4:00pm to 4:02pm. Thus, on average 31.77% of the options on Internet stocks had one or more option quotes that changed from 4:00pm to 4:02pm. There is considerable variation in the frequency of quote revisions across days. For example, only 15.73% of the Internet options in our sample have quotes that change from 4:00pm to 4:02pm on February 1st, while over 51% of our Internet options have quotes that change on February 8th, 2000.

**[Insert Table A2]**

In the final column of Table A2, we use the midpoints of the 4:00pm and the 4:02pm National Best Bid and Offer to examine the absolute value of the two-minute return for those options with changing quotes. Overall, the average absolute two-minute return for options whose quotes change ranges from a low of 61 basis points on February 28th to a high of 503 basis points on February 18th. The daily average absolute two-minute return for Internet options with quote revisions is 144 basis points. Results for options on nonInternet stocks (available from the authors upon request) suggest quote revisions occur with roughly the same frequency in options on nonInternet stocks. Together, these results suggest many of the apparent arbitrage opportunities that survive the microstructure screens may be due to nonsynchronous stock and option prices.

In summary, researchers seeking to test arbitrage pricing relationships should proceed with caution when using closing stock prices and closing option quotes from the OptionMetrics database. By definition, neither the closing stock prices nor the closing option quotes necessarily represent prices at which liquidity-demanding investors could have simultaneously traded. This appendix proposes several microstructure screens that increase the likelihood that investors could have traded at the prices in the OptionMetrics database. Even under the best circumstances, however, stock and option prices will be two minutes apart. Using our proprietary database we demonstrate the unconditional probability that an Internet option's bid or ask (or both) changes between 4:00pm and 4:02pm exceeds 31% in February of 2000. Perhaps more important, when an Internet option's quote changes, the average absolute two-minute midpoint-to-midpoint return implied by the quote change is 144 basis points. These results suggest that even in the best-case scenario, in which stock and option prices are separated by two minutes, differences in the 4:00pm and the 4:02pm option prices are of a sufficient economic magnitude to materially distort tests that use synthetic prices created from the OptionMetrics database. Researchers using option prices from the OptionMetrics database may be better off obtaining corresponding 4:02pm stock prices from the NYSE's TAQ database. Of course, the drawback to this is that many Nasdaq- and most NYSE-listed stocks do not actively trade after 4:00pm. This will lead to wider stock market quotes, and thus, fewer rejections of put-call parity.

**Table A1**
**Apparent Arbitrage Opportunities in February 2000 using Data from OptionMetrics and TAQ**

We obtain data on all options with positive open interest on nondividend-paying stocks in February of 2000 from the OptionMetrics database. We examine each option pair (put and call with the same strike, the same maturity, and the same underlying) for which -0.1 $\leq$ ln(closing stock price from OptionMetrics/option strike price) $\leq$ 0.1 and the time to maturity is at least 31 days. There is an apparent arbitrage opportunity if either of the following conditions are met (both can be satisfied if quotes are crossed):
1. Closing Call Ask Price - Closing Put Bid Price + Early Exercise Premium + Discounted Present Value of Strike Price < Closing Stock Price, or
2. Closing Stock Price < Closing Call Bid Price - Closing Put Ask Price + Early Exercise Premium + Discounted Present Value of Strike Price.
The closing stock price is the price of the last trade on a given day or the midpoint of the closing National Best Bid and Offer (NBBO) if there are no trades on a given day, the closing option quotes are posted at 4:02pm, and the discount rate is the zero-coupon interest rate obtained from OptionMetrics. A stock is an Internet stock if it appears on the June 2000 Morgan Stanley Internet Company Handbook Master List.

| | Time to maturity | | | | | |
|---|---|---|---|---|---|---|
| | 31 to 60 days | | 61 to 90 days | | 91 days and longer | |
| | Internet | nonInternet | Internet | nonInternet | Internet | nonInternet |
| Option pairs | 3,289 | 15,478 | 1,676 | 7,879 | 5,027 | 29,713 |
| Apparent arbitrage opportunities | 838 | 3,756 | 433 | 1,909 | 1,785 | 8,823 |
| Freq. of apparent violations | 25.48% | 24.27% | 25.84% | 24.23% | 35.51% | 29.69% |
| 4pm stock NBBO (from TAQ) is locked or crossed | 272 | 646 | 154 | 241 | 672 | 1,471 |
| Locked or crossed closing option quotes | 219 | 794 | 92 | 368 | 307 | 1,378 |
| Closing option quotes are too wide | 74 | 270 | 41 | 99 | 149 | 745 |
| Closing stock price is outside of 4pm TAQ NBBO | 60 | 633 | 34 | 330 | 140 | 1,405 |
| Disappear when closing TAQ quotes are considered | 78 | 550 | 33 | 325 | 99 | 947 |
| Revised number of apparent arbitrage opportunities | 135 | 863 | 79 | 546 | 418 | 2,877 |
| Freq. of buy synthetic ask/sell close violations | 3.04% | 3.92% | 3.82%% | 5.23% | 7.94% | 7.94% |
| Freq. of buy close/sell synthetic bid violations | 1.06% | 1.66% | 0.90% | 1.70% | 0.38% | 1.74% |
| Freq. of buy synthetic ask/sell close violations > \$0.20 | 1.25% | 1.69% | 1.91% | 2.03% | 5.37% | 5.16% |
| Freq. of buy close/sell synthetic bid violations > \$0.20 | 0.46% | 0.48% | 0.30% | 0.71% | 0.04% | 0.55% |

## Table A2
## Daily Comparison of 4:00pm and 4:02pm Option Quotes from OPRA

The sample consists of all options on 15 stocks for January 31, 2000 and February 1, 2000 and expands to all options on 49 stocks for February 2, 2000 through June 7, 2000. Because of data transmission problems, we do not have data for March 31, April 6, April 19, May 17, and May 31, so we are left with 86 trading days in our sample period. Quote records are obtained from OPRA and contain the date, and the to-the-second time, the option class and series symbols, the exchange on which the record is generated, the bid and ask prices, and a message. We construct a National Best Bid and Offer (NBBO) from the OPRA quote records. At any given point in the day, an option series' National Best Bid (NBB) is the highest bid price from the options exchanges. The National Best Offer (NBO) is the lowest posted offer.

| Date | Number of option series | % with bid discrepancy only | % with ask discrepancy only | % with both bid and ask discrepancy | Absolute two-minute midpoint-to-midpoint return for discrepancy quotes (basis points) |
|---|---|---|---|---|---|
| 02/01/2000 | 89 | 4.49% | 7.87% | 3.37% | 106 |
| 02/02/2000 | 199 | 5.53% | 4.52% | 7.04% | 84 |
| 02/03/2000 | 193 | 8.81% | 11.40% | 3.63% | 91 |
| 02/04/2000 | 205 | 10.24% | 9.76% | 4.39% | 87 |
| 02/07/2000 | 178 | 20.22% | 12.92% | 15.73% | 165 |
| 02/08/2000 | 200 | 13.50% | 14.50% | 23.50% | 130 |
| 02/09/2000 | 214 | 10.75% | 17.76% | 10.75% | 100 |
| 02/10/2000 | 204 | 11.76% | 13.24% | 16.67% | 192 |
| 02/11/2000 | 219 | 9.13% | 8.68% | 6.39% | 107 |
| 02/14/2000 | 220 | 8.64% | 10.91% | 10.00% | 267 |
| 02/15/2000 | 216 | 13.89% | 20.83% | 7.41% | 144 |
| 02/16/2000 | 223 | 9.42% | 11.21% | 2.69% | 155 |
| 02/17/2000 | 215 | 13.02% | 13.95% | 6.05% | 217 |
| 02/18/2000 | 222 | 11.26% | 14.86% | 13.06% | 503 |
| 02/22/2000 | 206 | 9.22% | 7.77% | 5.83% | 64 |
| 02/23/2000 | 222 | 7.66% | 10.81% | 7.21% | 101 |
| 02/24/2000 | 217 | 8.29% | 10.14% | 16.59% | 130 |
| 02/25/2000 | 215 | 14.88% | 17.67% | 13.02% | 103 |
| 02/28/2000 | 219 | 12.79% | 9.13% | 9.13% | 61 |
| 02/29/2000 | 224 | 7.59% | 10.71% | 3.13% | 65 |
| **Average** | **205** | **10.56%** | **11.93%** | **9.28%** | **144** |

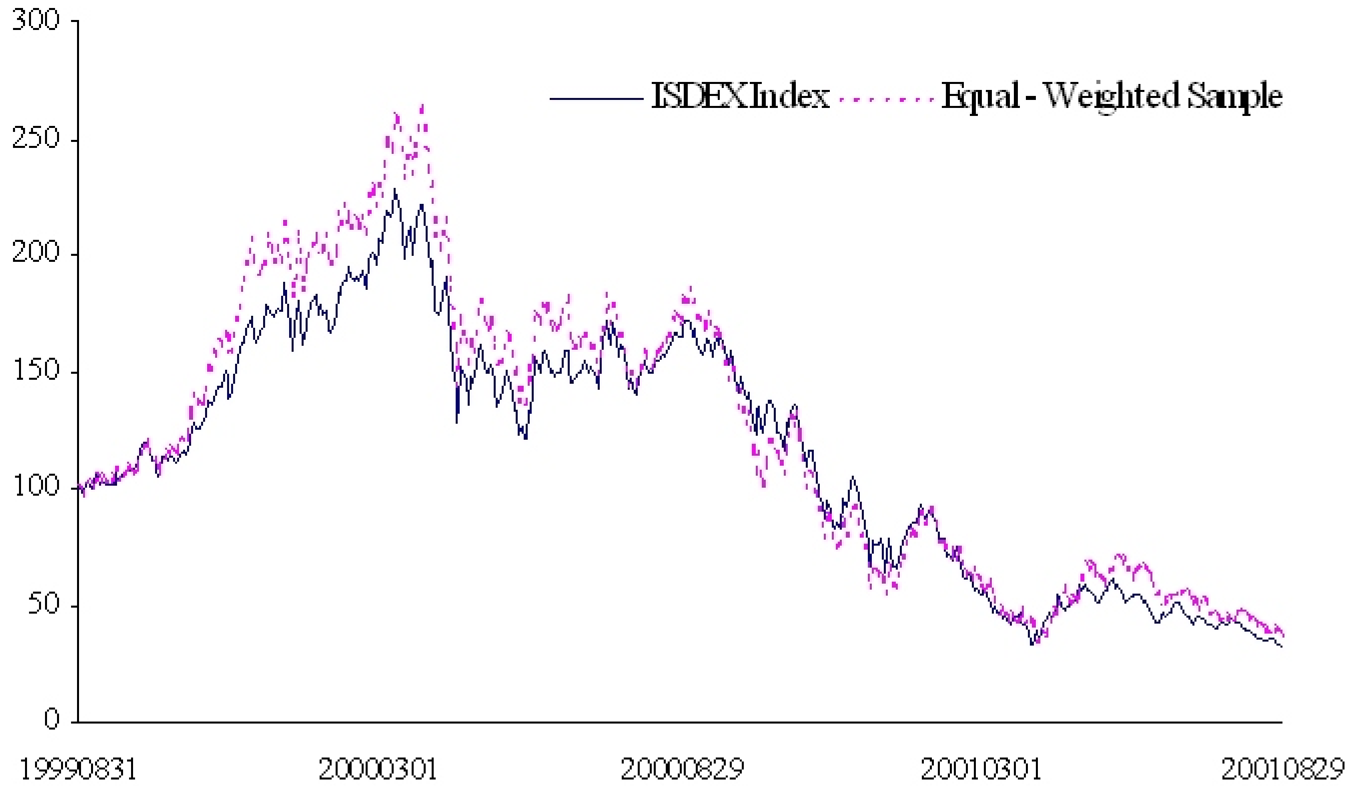


**Figure 1. Levels of the ISDEX Internet Index and an equal-weighted portfolio of our sample stocks.**

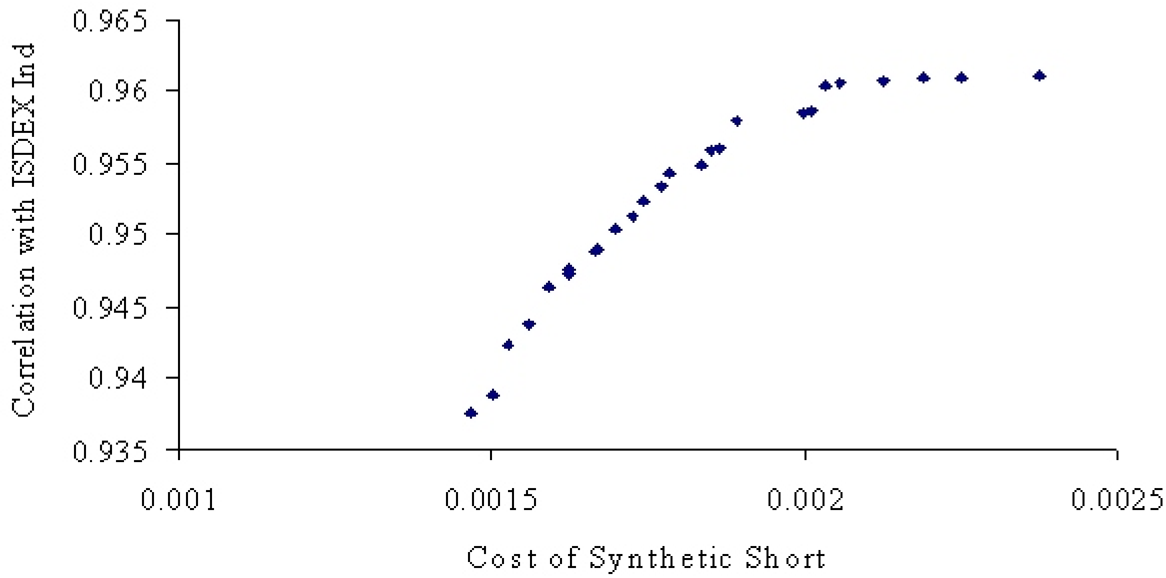


**Figure 2. Costs of portfolios of synthetic short positions and correlations of the portfolios with the ISDEX index.** Costs for a portfolio are the dollar weighted-average costs of shorting the individual stocks synthetically. These are measured as the difference between the synthetic bid and the actual bid, expressed as a proportion of the stock price.

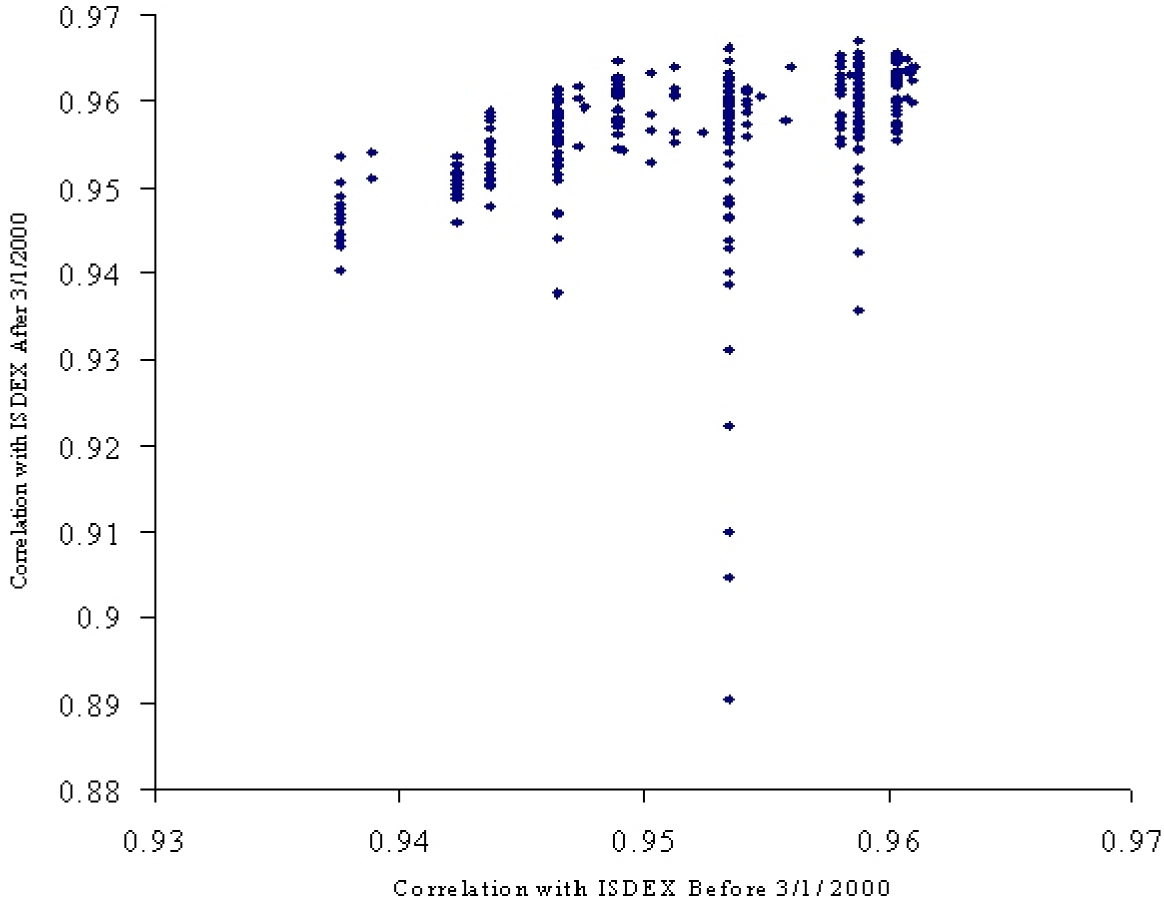


**Figure 3. Correlations between efficient portfolios of sample stocks and the ISDEX index of Internet stocks six months before and after March 1st, 2000.**

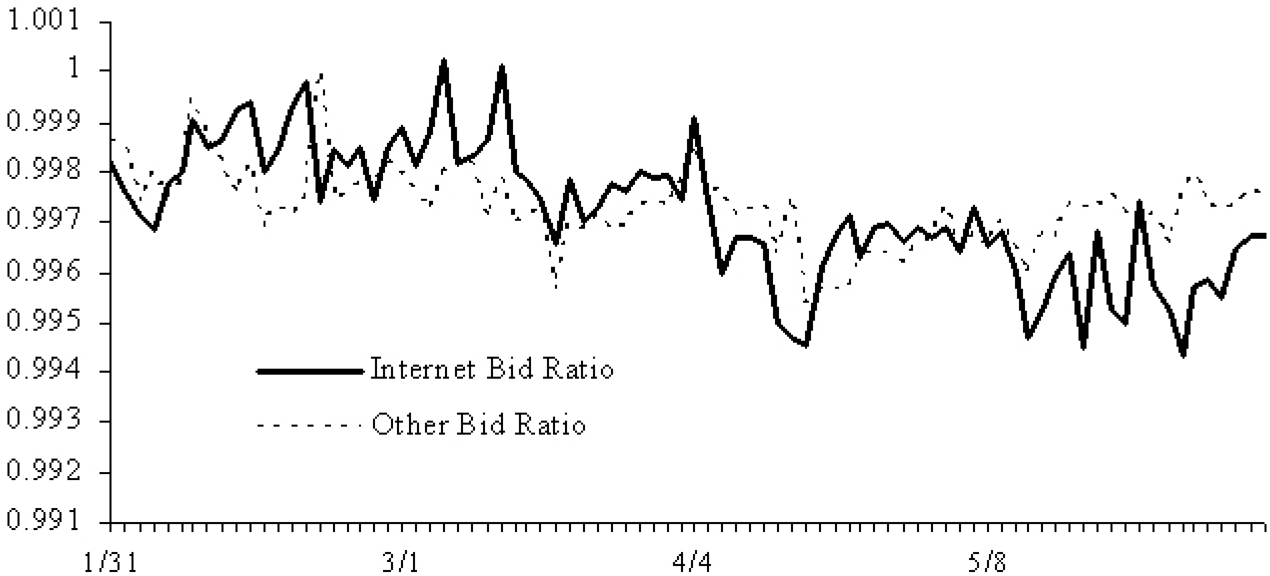


**Figure 4. Daily averages of the ratio of synthetic to actual bid prices for Internet and other stocks.**

**Table I**
**Trading Activity in Sample Option Classes**

Panel A: Number of trades in options on Internet stocks during sample period.

| Stock | Option Trades | Stock | Option Trades |
|---|---|---|---|
| Amazon | 66,218 | Internet Cap. Grp. | 35,939 |
| America Online | 187,799 | IDT Corp | 8,011 |
| Cisco | 309,632 | Inktomi | 33,416 |
| CMGI Inc. | 118,641 | Open Market | 9,884 |
| Ebay | 40,177 | Real Networks | 10,258 |
| E Trade Group | 34,650 | Siebel Systems | 33,840 |
| Exodus Comm. | 69,783 | Yahoo | 145,754 |

Panel B: Number of trades in options on nonInternet stocks during sample period.

| Stock | Option Trades | Stock | Option Trades |
|---|---|---|---|
| Analog Devices | 11,401 | Merrill Lynch | 23,705 |
| Advanced Micro | 61,898 | Microsoft | 254,105 |
| Bell Atlantic | 5,655 | Morgan Stanley | 12,968 |
| Computer Associates | 7,565 | Newmont Mining | 5,932 |
| CBS Corp | 2,061 | Network Associates | 10,056 |
| Chase Manhattan | 17,506 | Knight Trading | 45,828 |
| Conseco | 7,940 | Newbridge Network | 9,913 |
| Citigroup | 33,116 | Oracle | 136,621 |
| Elan Corp PLC. | 7,212 | Pfizer | 25,497 |
| Fannie Mae | 8,390 | Peoplesoft | 12,529 |
| Global Marine | 5,801 | Procter & Gamble | 28,129 |
| Haliburton | 10,840 | Qualcomm | 244,717 |
| IBM | 99,475 | Rambus | 62,211 |
| Intel | 180,576 | SAP Aktienges | 3,518 |
| Iomega | 2,293 | Telefonos de Mex | 4,637 |
| Kmart Corp | 6,483 | United Airlines | 5,475 |
| Level 3 Comm. | 13,486 | Xerox | 27,635 |
| McDonalds Corp. | 8,775 | | |

**Table II**
**Possible Arbitrage-Bound Violations**

At the end of each minute, synthetic purchase and sales prices for each stock are constructed using all options with exercise prices within 5% of the stock price and that have between 10 and 40 days to expiration. A buy-option/sell-stock arbitrage occurs when it is cheaper to buy the stock synthetically with options than to sell the actual shares in the market. A sell-option/buy-stock arbitrage occurs when an investor would pay less to buy the actual stock than could be received by selling the stock synthetically. The $\chi^2$ *p*-value is from a chi-square test of whether the same proportion of Internet quotes and quotes of other stocks present arbitrage opportunities.

| | Internet Stocks | nonInternet Stocks | All Stocks | $\chi^2$ *P*-value |
|---|---|---|---|---|
| # of Observations | 877,117 | 1,613,445 | 2,490,562 | |
| # of Buy Option Sell Stock Arbitrages | 102,736 | 122,354 | 225,090 | < .001 |
| # of Buy Option Sell Stock Arbitrages > 1% | 16,359 | 16,895 | 33,254 | < .001 |
| # of Buy Option Sell Stock Arbitrages > $1 | 17,111 | 16,322 | 33,433 | < .001 |
| # of Sell Option Buy Stock Arbitrages | 92,089 | 114,191 | 206,280 | < .001 |
| # of Sell Option Buy Stock Arbitrages > 1% | 14,087 | 16,393 | 30,480 | < .001 |
| # of Sell Option Buy Stock Arbitrages > $1 | 15,653 | 14,309 | 29,962 | < .001 |

## Table III
## Arbitrage Opportunities after Removing Unusable Quotes

Arbitrage opportunities are based on synthetic and actual stock prices from end-of-minute quotes. Options with 10 to 40 days to expiration and strike prices within ± 5% of the stock price are used to calculate synthetic stock prices. The sample consists of options on 14 Internet stocks and 35 other stocks for the period from January 31, 2000 through June 7, 2000.

| Per-share profitability of apparent arbitrage | # of apparent arbitrages | % with locked stock quotes | % with crossed stock quotes | % with locked and/or crossed option quotes | % with fast or wide option quotes | # of remaining apparent arbitrages in sample stocks | # of remaining apparent arbitrages in Internet stocks |
|---|---|---|---|---|---|---|---|
| $0.00 to $0.01 | 12,112 | 7.65% | 29.10% | 37.63% | 7.33% | 4,428 | 675 |
| $0.01 to $0.05 | 36,447 | 8.57% | 34.40% | 41.57% | 8.93% | 11,059 | 2,509 |
| $0.05 to $0.10 | 32,068 | 6.63% | 44.85% | 41.17% | 11.09% | 7,970 | 1,832 |
| $0.10 to $0.20 | 36,827 | 5.56% | 56.06% | 47.76% | 16.24% | 6,186 | 1,697 |
| $0.20 to $0.30 | 21,044 | 3.52% | 69.28% | 55.83% | 27.96% | 1,822 | 693 |
| $0.30 to $0.40 | 13,824 | 2.50% | 75.45% | 60.18% | 39.79% | 731 | 267 |
| $0.40 to $0.50 | 10,508 | 2.18% | 78.64% | 63.87% | 54.40% | 332 | 159 |
| $0.50 to $0.60 | 8,370 | 2.04% | 79.04% | 70.38% | 57.14% | 201 | 89 |
| $0.60 to $0.70 | 6,692 | 1.84% | 80.23% | 66.75% | 54.64% | 181 | 77 |
| $0.70 to $0.80 | 5,246 | 1.73% | 77.41% | 70.21% | 57.98% | 137 | 68 |
| $0.80 to $0.90 | 4,414 | 1.34% | 80.63% | 66.08% | 61.11% | 105 | 45 |
| $0.90 to $1.00 | 4,105 | 1.68% | 81.49% | 66.71% | 50.87% | 113 | 62 |
| > $1.00 | 33,433 | 1.42% | 78.17% | 73.69% | 51.82% | 912 | 539 |
| All | 225,090 | 4.68% | 59.12% | 49.39% | 17.31% | 34,177 | 8,712 |

**Table IV**
**Microstructure Statistics**

We examine share volume in the stock and options markets using data on 14 Internet and 35 other stocks for January 31, 2000 through June 7, 2000. Equity trading volume is the average daily share volume in the underlying stock. Relative trading volume is the average daily contract volume in the option market multiplied by 100 (the number of shares controlled by a contract) as a percentage of the average daily share volume in the underlying stock. Stock Volume is adjusted by dividing Nasdaq volume by two. In Panel B, we exclude trades when the execution-time bid exceeds the execution-time offer since effective spreads are undefined for these trades. We also exclude trades with effective spreads exceeding $5.00 as likely data errors. Complex trades (e.g., spreads and straddles) are also excluded as they are priced as a package.

Panel A. Relative trading volume.

| | Average Daily Stock Volume | Mean Ratio of Option to Stock Volume | 1st Quartile Ratio of Option to Stock Volume | 3rd Quartile Ratio of Option to Stock Volume |
|---|---|---|---|---|
| Internet Stocks | 5,505,621 | 18.40% | 12.43% | 20.90% |
| Other Stocks | 5,115,222 | 14.62% | 9.19% | 19.27% |

Panel B. Proximity of trade prices to quoted prices.

| | Mean Difference | 1st Quartile of Differences | 3rd Quartile of Differences |
|---|---|---|---|
| Internet Stock Calls | $0.0055 | $0.0015 | $0.0088 |
| Internet Stock Puts | $0.0066 | $0.0032 | $0.0104 |
| Other Stock Calls | $0.0020 | - $0.0011 | $0.0054 |
| Other Stock Puts | - $0.0018 | - $0.0056 | $0.0021 |

## Table V
## A Comparison of Synthetic and Actual Stock Prices

End-of-minute quotes from options with strike prices within 5% of the stock price are used to calculate synthetic stock prices. End-of-minute quotes for options with strike prices within 25% of the stock price are used to calculate synthetic stock prices from LEAPS (long-term equity options). The synthetic bid is the bid price of the call minus the ask price of the put plus the early exercise premium, plus the discounted value of the option strike prices plus the present value of any dividends. The synthetic ask is the ask price of the call minus the bid price of the put plus the early exercise premium, plus the discounted value of the option strike prices plus the present value of any dividends. Observations are discarded if the stock quotes, call quotes, or put quotes are locked or crossed. Borrowing and lending rates are based on bid and ask yields of Treasury bills that mature near the option's expiration. The mean ratio of synthetic to actual prices is calculated at the end of each minute. For each stock, the mean ratio of the synthetic to actual bid price and the synthetic to actual offer stock price is calculated daily. The distribution of the mean across days is reported. For the hard-to-borrow stocks and all other stocks, a simple average of all ratios across all days is reported. A stock is hard to borrow on a sample day if its rebate rate is more than 120 basis points below the federal funds rate. Values for Internet and nonInternet are across stock means. There are 14 Internet stocks and 35 nonInternet stocks. LEAPS on Internet (nonInternet) stocks traded an average of 58.6 days (78.5 days) during our sample period.

Panel A. The distribution of synthetic to actual price ratios for options with 10 to 40 days to expiration.

| | Synthetic Bid Price / Actual Bid Price | | | Synthetic Ask Price / Actual Ask Price | | |
|---|---|---|---|---|---|---|
| Stocks | Mean | 25th Percentile | 75th Percentile | Mean | 25th Percentile | 75th Percentile |
| Internet | 0.996 | 0.994 | 0.997 | 1.005 | 1.003 | 1.007 |
| Others | 0.997 | 0.996 | 0.998 | 1.003 | 1.002 | 1.004 |

Panel B. Hard-to-borrow stocks versus others.

| | Synthetic Bid Price / Actual Bid | | Synthetic Ask Price / Actual Ask | |
|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. |
| Hard-to-Borrow | 0.994 | 0.0088 | 1.006 | 0.0072 |
| Others | 0.998 | 0.0067 | 1.003 | 0.0059 |

Panel C. The distribution of synthetic to actual price ratios for longer-term options.

| | Mean Synthetic to Actual Bid | | | Mean Synthetic to Actual Ask | | | Average Years to Expiration (LEAPS) |
|---|---|---|---|---|---|---|---|
| | 41-70 Days | 71-100 Days | LEAPS | 41-70 Days | 71-100 Days | LEAPS | |
| Internet | 0.995 | 0.994 | 0.994 | 1.007 | 1.007 | 1.015 | 1.28 |
| Others | 0.997 | 0.996 | 0.996 | 1.004 | 1.004 | 1.009 | 1.26 |