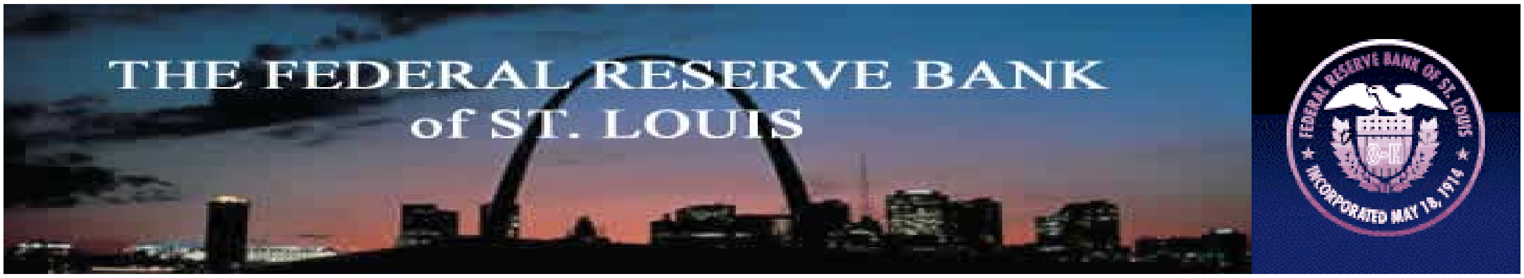

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Directly Measuring Early Exercise Premiums Using American and European S&P 500 Index Options

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Directly Measuring Early Exercise Premiums Using American and European S&P 500 Index Options

The Chicago Board Options Exchange concurrently listed European-style and American-style options on the Standard and Poor's 500 Index from April 2, 1986 through June 20, 1986. This unique time period allows for a direct measurement of the early-exercise premium in American-style index options. In this study, using ask quotes, we find average early exercise premiums ranging from 5.04% to 5.90% for calls, and from 7.97% to 10.86% for puts. Additionally, we are able to depict a potentially useful functional form of the early exercise premium. As in previous studies, we find some instances of negative early exercise premiums. However, a trading simulation shows that traders must be able to trade within the bid-ask spread to profit from these apparent arbitrage opportunities.

Directly Measuring Early Exercise Premiums Using American and European S&P 500 Index Options

Free disposal dictates that the value of an option with American-style exercise must equal or exceed the value of an otherwise identical option with European-style exercise. Because many options have American-style exercise, the size of the premium that must be paid for the right to exercise early is of interest to practitioners and researchers.

The purpose of this study is to measure early exercise premiums directly from options data on the S&P 500 Index. Although market liquidity issues complicate the task, the main contribution of this study is that early exercise premiums can be measured directly. A direct measurement is possible because of the existence of a unique time period in the history of the Standard and Poor's 500 index option. From April 2, 1986 through June 20, 1986, the Chicago Board Options Exchange listed European-style and American-style options on the Standard and Poor's 500 Index. This allows for the creation of a matched pair sample of intradaily bid and ask quotes for otherwise identical American and European options.

In this study, using midpoints from bid and ask quotes, we find smaller early exercise premiums than those reported in previous studies. We find average early exercise premiums ranging from 2.07% to 2.43% for calls, and from 0.32% to 2.76% for puts. Using ask quotes, we find average early exercise premiums largely consistent with those reported by previous studies, ranging from 5.04% to 5.90% for calls, and from 7.97% to 10.86% for puts. However, based on empirical results consistent with an inventory management argument, early exercise premiums estimated using bid-ask midpoints are most likely biased.

We are also able to depict a functional form using ask prices that could have been useful for dealers who were asked to provide a quote. Given a European ask price, the functional form can be used directly to provide an American ask price. By applying a bid-ask spread, the dealer could also generate bid prices.

Previous empirical research on early exercise has focused either on the rationality of early exercise decisions or on measuring the size of early exercise premiums. A careful measurement of the early exercise premium is important when one is studying the rational early exercise of index options [French and Maberly (1992), Diz and Finucane (1994)] or equity options [Poteshman and Serbin (2002)]. Rational early exercise decision rules for call and put options on indexes are discussed thoroughly in Diz and Finucane (1994).[1]

Rational early exercise of options can also result from the so-called "wildcard" option. The wildcard option arises because the proceeds from exercise are based on the difference between the exercise price of the option and the index level at the close of the New York Stock Exchange. Because the index option market remains open after the close of the New York Stock Exchange, option holders have an extra 15 minutes to decide whether to exercise the option. During this time, the arrival of news that affects the underlying index can make early exercise optimal.[2]

Considerable recent research has also focused on calculating the size of the early exercise premium for options on stock indexes. The first investigation into the size of the early exercise premium attempted this measurement without concurrently traded prices [e.g., Jorion and Stoughton (1989), Zivney (1991)]. Some studies use a theoretical model to estimate a European price, given an observed American price (or vice versa). Investigations employing a theoretical model to generate European option prices on equities include Whaley (1982),

[1]Essentially, rational early exercise of call options on stock indexes can occur if the annualized dividend yield received over the remaining life of the option exceeds the annualized risk-free rate of interest. Rational exercise of call options on stock indexes can also occur if there is a cluster of discrete dividends on the constituent stocks comprising the index. Early exercise for put options on stock indexes is desirable if the profit from exercising the put is sufficiently large so that the interest that could be earned by investing the profit now exceeds the possibility of an even greater profit from continuing to hold the put. See Dubofsky and Miller (2002) for a discussion of early exercise rules for call and put options on individual stocks.

[2]Fleming and Whaley (1994) provide a model to value wildcard options. Dawson (2000) reviews empirical studies of the wildcard option.

Geske and Roll (1984), and Blomeyer and Johnson (1988).

Some recent studies use observed market prices and/or theoretically concurrent prices in their calculations of early exercise premiums. These studies include Dawson (1994), Unni and Yadav (1998), and McMurray and Yadav (2000). These three studies use intradaily American and European option data for the FTSE-100 stock index to estimate the early exercise premium. However, there is an unavoidable problem inherent in the FTSE-100 data: the American and European options always have a 25-index-point difference in the exercise price of otherwise equivalent American and European options. The reason for this is that the American option strike prices on the FTSE-100 index are evenly divisible by 50. The European option strikes are evenly divisible by 25–but not by 50. Thus, exercise prices between otherwise identical American and European options on the FTSE-100 index always differ by 25 index points.

Previous studies using index and equity options have uncovered an asymmetry in early exercise premiums. Using data for American options on S&P 500 futures and European options on the S&P 500 index, Swidler and Zivney (1987) report an early exercise premium of about 4.0% for calls. Examining options on individual stocks, Sung (1995) reports an early exercise premium of 8.7% for puts. Zivney estimates that the early exercise premium for Standard and Poor's 100 index options is 3.5% for calls and 10% for puts.[3]

Finally, Lee and Nayer (2000) and McMurray and Yadav (2000) report instances of *negative* early exercise premiums, i.e., cases where the American option is selling for less than an identical European option. A negative early exercise premium is of interest because of its arbitrage implications. McMurray and Yadav (2000) find a negative early exercise premium in 32% of their call sample and 17% of their put sample, whereas Lee and Nayer

[3]Jorion and Stoughton (1989) estimate the early exercise premium is about 1 to 3 percent for both call and put options on foreign currency. This symmetry is intuitive for currency options, however, because a call option to trade Dollars for Euros is a put option to trade Euros for Dollars.

(2000) report negative early exercise premiums occur in 47% of their call sample and 58% of their put sample. In this study, we find a negative early exercise premium in 17.6% of the observed call sample and 8.7% of the observed put sample. We test these negative early exercise premiums for arbitrage profits, and find that traders must be able to trade within the bid-ask spread to profit from apparent arbitrage opportunities.

The next section is a description of the unique dataset used in this study. Following that, we present our findings on observed early exercise premiums, and we discuss the important role that liquidity plays in the data used in this study. In Section 3, we present our findings on theoretically contemporaneous early exercise premiums. In Section 4, we present regression results designed to measure early exercise premiums. Section 5 is an analysis of the determinants of the size of the early exercise premium. In Section 6, we examine a subset of the data for instances of negative early exercise premiums and discuss the implications for arbitrage trading strategies. Section 7 is a summary.

1 American and European Option Data.

The Chicago Board Options Exchange introduced options on the Standard and Poor's 500 index on July 1, 1983. These options had American-style exercise, and their ticker symbol was SPQ. On April 2, 1986, in a successful attempt to boost trading activity in S&P 500 index options, the CBOE introduced a new option on the S&P 500 index. These new options had European-style exercise, and their ticker symbol was SPX. Trading in the existing SPQ options with their American-style exercise did not cease upon introduction of the new European-style options. Instead, trading in the existing April, May, June, September, and December SPQ options was going to be allowed through their respective expiration dates.

Trading activity in the SPQ options was concentrated, however, in the June 1986 contract. After the June expiration, trading ceased for the remaining SPQ options. Therefore, the sample period from April 2, 1986 through June 20, 1986 contains cuncurrent European and American option data on the Standard and Poor's 500 index.

During the sample period, trading was active in the European-style SPX options. Total SPX call volume was 149,573 contracts, with June accounting for 88,435; total SPX put volume was 126,917 contracts, with June accounting for 80,055. However, during the sample period, trading volume for the American-style SPQ options was low. June SPQ call volume was 184 contracts, and June SPQ put volume was only 110 contracts. Consequently, the focus of this study is on quote, not trade, data.

An analysis of intradaily data tapes obtained from the CBOE reveals a total of 1,332 timestamped bid-ask quotes for SPQ calls and puts during the sample period, April 2, 1986 through June 20, 1986. Of this total, 732 are for calls and 600 are for puts. The strike prices range from 210 to 245 for both call and put options. For each of these intradaily June SPQ quote observations, the datatapes were searched for the June SPX quote with the nearest timestamp to form a pair of observed option quotes that differ only in the exercise feature.

Figure 1 displays an example of the matching technique. For each American option quote observation, $ASPQ_t$, an otherwise matching European option quote observation, $ASPX_{t+1}$ or $ASPX_{t-1}$, is selected based on its timestamp. Note that under this matching technique, the timestamp of the closest SPX quote could occur before or after the timestamp of the SPQ quote. In Figure 1, $ASPX_{t+1}$ would have been chosen because it is the closer of the two observations.

Although there were 13,503 June SPX call quotes and 9,650 June SPX put quotes, the strike prices for the SPX quotes range from 220 to 260. As a result, the strike prices in the raw matched sample range from 220 to 245. The 993 total matched pairs in the raw matched sample were screened to eliminate the following: observations with a missing bid or ask quote; observations where the ask price was greater than the bid price; observations where the days to maturity were 5 or less; observations where the matched quotes differed in time by more than one hour; observations where the bid-ask spread was greater than \$3; and observations where the SPX bid is less than the SPQ ask ("instant" arbitrage situations).

Sheikh and Ronn (1994) document the possibility of problems with the CBOE data during this particular sample period. Sheikh and Ronn (1994) report that the data in the first half-hour of the trading day could have been misrecorded. That is, a trade with a time stamp of 20 minutes after 9:00:00 could have actually occurred at 20 minutes before or after 9:00:00. As a result, observations for the first hour of trading (i.e., those before 9:30:00) are discarded. As a result of this screen and the others described above, the post-screen sample consists of 414 matched call and 321 matched put observations.

Some descriptive statistics of the post-screen dataset appear in Table I. Bid-ask midpoint prices for the SPQ American-style call options ranged from \$0.625 to \$25.00, with a mean of \$10.26. For puts, the bid-ask midpoint price ranged from \$0.125 to \$18.50, with a mean of \$4.84. Bid-ask midpoint prices for the SPX European-style options had similar ranges. For calls, the range was \$0.6875 to \$24.9375, with a mean of \$10.17. For puts, the range was \$0.09375 to \$18.625, with a mean of \$4.81.

During the sample period, the underlying S&P 500 cash index averaged 239.00. The index range in this period of 228.03 to 248.56 represents a 10% difference from low to high, approximately centered on the mean. At first, this could seem low. However, recall that this range occured in a sample period less than three months long. Six strike prices are in the sample, and days to maturity range from seven to 79.

Because volatility is the most important source of variation in option prices, we examine market volatility during the sample using a time series of implied standard deviations from options on the Standard and Poor's 100 Index (OEX). This time series is calculated by the Chicago Board Option Exchange and is available at Yahoo!©. Known by the ticker symbol

VIX, this daily time series is the implied standard deviation for a hypothetical option with a constant 30 days to maturity [Whaley (1993); Fleming, Ostdiek, and Whaley (1995)]. Using daily closing levels, VIX averaged 20.3% during our sample period. This is consistent with all of 1986, where VIX averaged 20.4%. From 1986 through 2000, VIX averaged 20.5%. Thus, in terms of market volatility, it appears that our sample period is quite ordinary. During the sample period, VIX ranged from a low around 16% to a high around 24.5%, supporting the notion that the sample contains sufficient variability.

2 SPQ and SPX Option Market Liquidity.

Even in markets with high trading volume, liquidity can be a nettlesome issue. For example, because the put-call parity relationship holds exactly for European options, Zivney (1991) argues that deviations from put-call parity using American option prices can be attributable to an early exercise premium. However, as documented by Kamara and Miller (1995), deviations from put-call parity could also reflect liquidity risk. Thus, it is possible that the early exercise premiums reported by Zivney also contained liquidity premiums.

Trading interest in European SPX options dominated American SPQ options from the inception of the SPX in April of 1986. However, because options on the S&P 500 index were in a transition from an American-style exercise to a European-style exercise, one could reasonably expect liquidity issues to be present.

In this study, there is clearly a difference in liquidity between the SPQ and SPX option markets. Potential liquidity differences motivate the way in which the dataset has been constructed for this study. In addition, liquidity differences have motivated several different measures of the early exercise premium (which are discussed below and in Section 3). A discussion of three liquidity issues follows.

2.1 The Speed of Quote Revisions.

In this study, it is implicitly assumed that the posted quotes for the SPQ and SPX were "good until updated." During the sample period, the CBOE encouraged, but did not legally require, market makers to stand by their quotes for one to five contracts.[4]

When an SPQ quote appears on the tape, it is assumed that the quote is "good" for some (albeit unknown) period of time. By matching the closest time-stamped SPX quote, we believe we have constructed a dataset that minimizes the influence of the speed of quote revisions. However, the "freshness" of the average time between changes in SPX quotes is still of interest.

For the actively traded OEX options during 1989, George and Longstaff (1993) report that quotes can be recorded as frequently as 30 times a minute for the most actively traded OEX options. George and Longstaff (1993) also report, however, that the average time between trades in their OEX sample was 366 seconds for calls, and 270 seconds for puts.

Using OEX and SPX data for late 1990 and early 1991, Etling and Miller (2000) report the median time between OEX quotes was 8 seconds for calls and 9 seconds for puts. However, the SPX market was still gaining trading interest in 1990. Etling and Miller (2000) report the median time between SPX quotes was 78 seconds for calls and 148 seconds for puts.

Examining all SPX quotes (sorted by strike and expiration date) from April 2, 1986 through June 30, 1986, the median time between quotes was 469 seconds for calls and 636 seconds for puts. If only June expiration SPX quotes are used, the median time between quotes was 390 seconds for calls and 572 seconds for puts. In the entire data set of 414 matched call observations and 321 put observations, the median quote revision time was 296

[4]In July 1989, the CBOE implemented the so-called "10-up" rule [Rule 8.51 of the CBOE Constitution and Rules (1996).] This rule requires that at all times other than the opening rotation, all market makers at a trading station must trade up to 10 contracts at either the bid or the ask price. See Hemler and Miller (1997) for an examination of this critical assumption in a sample period before the "10-up" rule.

seconds for calls and 416 seconds for puts. When the time difference between the SPQ quote and the SPX quote is constrained to be less than 10 minutes, the median time between SPX quotes was 271 seconds for calls and 371 seconds for puts.

The time difference between SPQ and SPX quotes is also of interest. In the entire sample, the average time difference between matched SPQ and SPX quotes was 430 seconds for calls, and 561 seconds for puts. The median time difference between matched SPQ and SPX call quotes was 290 seconds for calls, and 416 seconds for puts. When the time difference between the SPQ quote and the SPX quote is constrained to be less than 10 minutes, the average time between SPQ and SPX quotes was 224 seconds for calls and 270 seconds for puts. The median times in this sub-sample were 210 seconds for calls, and 241 seconds for puts.

2.2 Size of the Bid-Ask Spread.

As shown in Panel B of Table I, the average SPQ bid-ask spread in the sample was $0.78 for calls and $0.66 for puts. The average SPX bid-ask spread was $0.39 for calls and $0.28 for puts. The relative difference between spreads for calls and puts is consistent with higher call prices, on average, during the sample.

By contrast, George and Longstaff (1993) report OEX bid-ask spreads of $0.185 for calls, and $0.156 for puts. Etling and Miller (2000) report that the most actively traded OEX options had a bid-ask spread of $0.14 for calls and $0.13 for puts. Etling and Miller (2000) also report that the most actively traded SPX options had a bid-ask spread of $0.65 for calls and $0.54 for puts. In his study of equity options, Vijh (1990) reports an overall average bid-ask spread of $0.237. Vijh also reports that 32.1% of the options in his sample had a bid-ask spread of $0.125, 22.6% had a bid-ask spread of $0.25 and 10.5% had a bid-ask spread of $0.50.

There is also a clear difference between the American and European contracts with respect to the size of the bid-ask spread. On average, the American average spread is approximately twice the size of the European. This difference can be easily explained using the inventory cost argument of Amihud and Mendelson (1980), wherein the bid-ask spread is viewed as compensation for market-makers who hold undesired inventory. Indeed, the SPQ options are clearly an example of an undesirable inventory, because SPQ options were slated to disappear. As a result, market makers would tend to increase the spreads in the SPQ market.[5]

2.3 Asymmetry of the Bid-Ask Spread.

With equal liquidity between otherwise identical American and European options, one would expect to observe an early exercise premium for both bids and asks. This is because market participants should be willing to pay more, and should demand more, for an American option than for an otherwise identical European option.

However, this is clearly not the case in this sample. As shown in Panel C of Table I, an early exercise premium is observed for asks, but not for bids. In fact, a sizeable negative early exercise premium is found for both puts and calls when bid prices are compared. The "early exercise premium" using bids averaged -0.80% for calls, and -6.86% for puts. This evidence is consistent with the notion that market makers discouraged sellers of American options. Any early exercise premium existing in bid prices is swamped by the lowered bids for American options.

The SPQ spread is not only larger than the SPX spread, it is likely that their symmetry differs. Again, this can be reasonably explained by the inventory cost argument of Amihud and Mendelson (1980). To avoid acquiring undesired inventory of relatively illiquid SPQ (American) options in the first place, dealers would tend to shade down their bid prices relative to their ask prices. Ask prices would be affected more than bids if dealers faced the

[5]We are grateful to an anonymous referee for this point.

difficulty of hedging a substantial existing inventory of relatively illiquid SPQ options. As shown in Table I, there are a large number of apparently negative early exercise premiums between SPQ and SPX bid prices. The fact that the median early exercise premium using bids is negative suggests that SPQ bids are more affected by liquidity than SPQ asks. Of course, it is still possible that the average observed early exercise premium using ask prices, 5.36% for calls and 10.86% for puts, differs from the true early exercise premium.

An early exercise premium based on bid-ask midpoints is also going to be biased in this sample. Although the average observed early exercise premiums of 2.38% for calls and 2.76% for puts seem "reasonable" (in that they are positive), the SPQ bids prices certainly appear influenced by market-makers. Thus, the undesirable effects of too much American inventory almost surely biases the measurement of early exercise premiums using bid-ask midpoints.[6]

As a result of the liquidity issues in Section 2.3, we report early exercise premiums using both the bid-ask spread and ask prices in the rest of the paper.

3 Contemporaneous Early Exercise Premiums.

Although the sample consists of quotes that are matched as closely as possible in time, the quotes are not contemporaneous. In fact, the quotes can be stamped up to 60 minutes apart from each other. To examine the possible effects of noncomtemporaneous quotes on the measurement of an early exercise premium, we construct a theoretically contemporaneous European option quote at the time of the observed American option quote. Because of the well-known pricing biases of the Black-Scholes model, we attempt to construct a contemporaneous European price as precisely as possible.[7]

[6]Unni and Yadav (1998) state that the midpoint of the bid-ask spread should be used to avoid a systematic bias in the analysis of early exercise premiums. However, because of the liquid nature of the FTSE option market in the 1990s, it is very likely that the American and European bid-ask spreads in the sample used by Unni and Yadav (1998) are symmetric, rather than asymmetric.

[7]As reviewed in depth by Corrado and Miller (1996), studies by Black (1975), MacBeth and Merville

The riskless rate used in this study is the rate on the Treasury bill that expires two days before the June option expiration. Dividend adjustments were made using Black's (1975) method of subtracting the present value of all dividends to be received before option expiration from the value of the index. Based on Figlewski's (1984) findings that the near-term dividend uncertainty for the S&P 500 is insignificant, dividends are assumed known with certainty. A published daily dividend series for the S&P 500 index does not exist for each day in the sample but one was estimated as in Kamara and Miller (1995) as follows.[8]

A monthly file of the stocks in the S&P 500 index was created from the *500 Information Bulletin* published by Standard and Poor's. Then, data for ex-dividend dates, shares outstanding, and cash dividend amounts for each stock in the index were extracted from the CRSP tapes. Dividends in terms of S&P 500 index points for each trading day are then calculated and then discounted using the appropriate Treasury bill rate. Finally, to avoid any potential "staleness" in the cash index as documented by Chung (1991), a theoretical cash index level was calculated at the time of the American quote by using the prevailing S&P 500 futures price and the cash-and-carry relationship for known discrete dividends:

$$S_t = e^{-r(T-t)} F_t + e^{-r(T-t)} \sum_{i=1}^{n} D_i e^{r(T-t)} \tag{1}$$

where S_t is the theoretical cash index level, F_t is the observed futures price, and D_i is the discrete daily dividend in index points. Intradaily data for S&P futures was obtained from *Tick Data, Inc.* Panel A of Table II contains the mean values of the inputs used to calculate the two sets of theoretically contemporaneous option prices.

(1979), and Rubinstein (1985), among others, conclude that the Black-Scholes model is accurate for near-the-money options. Thus, pricing biases of the Black-Scholes model are not a significant worry in this study because it turns out that the sample consists of near-the-money options only (i.e., options with a strike within ±10% of the index level).

[8] Harvey and Whaley (1992) independently used a similar approach to calculate an S&P 100 (OEX) dividend series.

The notation in Figure 1 shows how theoretically contemporaneous quotes are calculated. Recall that for each American option quote observation, $ASPQ_t$, an otherwise matching European option quote observation, $ASPX_{t+1}$ or $ASPX_{t-1}$, is selected based on its timestamp. Note that under this matching technique, the timestamp of the closest SPX quote could occur before or after the timestamp of the SPQ quote. In Figure 1, $ASPX_{t+1}$ would have been chosen because it is the closer of the two observations.

Two early exercise premiums are calculated at the time stamp of the American option. The first early exercise premium is calculated by using the observed American option price and a European Black-Scholes option price calculated using the implied standard deviation from the nearest observed European option price, and other option inputs from the time of the observed American option price. Note that this early exercise premium includes the value of being able to exercise the option at closing NYSE prices during the wildcard period between the close of trading on the NYSE and CBOE.

The mean and median of the theoretically contemporaneous early exercise premium containing a wildcard value appear in Panel B of Table II. For calls, the mean of 5.90% using asks and the mean of 2.43% using bid-ask midpoints are about the same as the means for early exercise premiums calculated using the observed matched-pair data (Panel C of Table I). This suggests that the matched set of observed option prices generated reliable measures of the early exercise premium for calls. For puts, however, the mean of 8.43% using asks and the mean of 0.88% using bid-ask midpoints are both about 200 basis points smaller than the means for early exercise premiums calculated using the matched-pair observed data.

In addition, we calculate a theoretical early exercise premium that does not reflect a wildcard value. Specifically, we use the Barone-Adesi-Whaley (1987) American option algorithm, the European Black-Scholes price described above, and other option inputs from the time of the observed American option quote. The mean and median of this second theoretical early exercise premium are in Panel C of Table II. For both calls and puts, the mean using asks or bid-ask midpoints are equivalent, it is 0.05% for calls and about 0.75% for puts.

Theoretically, the Barone-Adesi-Whaley price minus the Black-Scholes price should be a good measure of the early exercise premium, except for the value of the wildcard option. From the results presented in Table II Panel C, we can see how much of the early exercise premium is missing if the value of the wildcard option is omitted in this sample.

For calls, the early exercise premium stems from the wildcard option and a dividend-capture strategy. Panel C of Table II shows that the dividend-capture aspect is small. This suggests that the value of the wildcard option is the empirically relevant component of the early exercise option. For puts, the early exercise value comes from the wildcard option and the potential profit from exercising the put early and investing the proceeds to expiration. Although Panel C shows that this potential benefit is much higher for puts than it is for calls, it is still only about 1/6th the size of the value of the wildcard option.

If one compares the early exercise premiums in Panel C to those calculated using bid-ask midpoints in Panel B, however, one would conclude that the wildcard option has a low value in this sample. Given the importance of the wildcard option in explaining early exercise [Diz and Finucane, (1994)], it is reasonable to believe that one should observe non-trivial wildcard option values. Therefore, the evidence above supports the notion that bid-ask midpoints are potentially unreliable in estimating early exercise premiums, in this sample.

4 The Relationship Between SPQ and SPX Quotes.

In this section, we strive to uncover the nature of the pricing relationship between the SPQ and SPX quotes that dealers appeared to be using. To uncover the relationship between American and European option prices, the following regression can be estimated:

$$(\text{American Option Price})_t = \alpha + \beta(\text{Price of an Otherwise Identical European Option})_t + \epsilon_t. \quad (2)$$

Early exercise premiums from equation (2) are estimated using the mean log relative of the fitted value of the American option price and the European price. The true value for the right-hand side variable in equation (2) is not observed, because there is a time difference between observed American and European option prices. Thus, the estimation is potentially subject to an errors-in-variable bias unless instrumental variable estimation is used. However, because the results using Two-Stage Least Squares are qualitatively similar, ordinary least squares results are reported.[9]

In Table III, four sets of results are presented. In all regressions, $\overline{R}^2$ exceeds 0.98. Panels A and B displays results from estimating equation (2) using observed bid-ask midpoints from the matched pairs, and Panels C and D contains results using ask prices. Whenever the matched quotes are less than 10 minutes apart, estimated early exercise premiums for calls are qualitatively similar to those reported in Table I. Using bid-ask midpoints, the estimated early exercise premium for calls is 2.07%. Using asks, the estimated early exercise premium is 5.04%. For puts, however, the constraint that the quotes must be observed within 10 minutes of each other results in a lower estimated early exercise premium than in the total matched sample. Using bid-ask midpoints, the estimated early exercise premium is 0.38%; using asks, the estimated early exercise premium is 9.44%.[10]

To gauge the accuracy of the estimated early exercise premiums from observed data,

[9]Instruments used in the Two-Stage Least Squares regression for the observed matched pairs are the time difference between the American and European option quotes, implied volatility from the European options, days to expiration, and moneyness. Details are available on request.

[10]The original observed matched-pair sample allows the American and European quotes to be within 60 minutes of one another. A majority of the observations have a time difference of less than 10 minutes. The average length of time between quotes in this subsample is 224 seconds for calls and 270 seconds for puts.

we also regress the observed American option quote on the theoretically contemporaneous European quote. Using bid-ask midpoints, the estimated early exercise premium differs by four basis points for calls and six basis points for puts. Using ask prices, the estimated early exercise premium is 68 basis points higher for calls, 5.72%. For puts, the estimated early exercise premium is 147 basis points lower, 7.97%.[11]

Estimated early exercise premiums from equation (2) are plotted against observed ask European option prices in Figures 2 and 3. The variability of the regression-implied percentage early exercise premium across observations is due to an intercept that is statistically significantly positive. As shown in Figures 2 and 3, the estimated percentage early exercise premium varies non-linearly with observed prices. As the observed option prices fall, the percentage early exercise premium increases. In the sample, the average prices for calls and puts were $10.26 and $4.84, respectively. From Figures 2 and 3, these mean prices translate into estimated early exercise premiums of about 2.5% for calls and 5% for puts. This translates into about $0.26 for calls and $0.24 for puts.

5 The Determinants of Early Exercise Premium Sizes.

5.1 Observed Premiums Across Moneyness and Maturity.

To begin the analysis, we subdivide the sample by two factors that should greatly influence the observed early exercise premium, days to maturity and moneyness, which is defined as $M = (S - Ke^{-rT})/S$. In the sample, days to maturity ranges from 7 to 79, a range of 72 days. We split this range evenly among three days to maturity classifications: less than or

[11]The number of observations in Panels B and D of Table III are less than in Panels A and C. This is because additional implied volatility screens were applied to the dataset to ensure reasonable Black-Scholes prices. The screens are: (1) the ISD from the ask price must be greater than the ISD from the bid price; (2) the absolute value of the ISD must differ from the starting search value of 0.20 by more than 0.0020; (3) The Black-Scholes ask price must exceed the Black-Scholes bid price; (4) the Black-Scholes bid price must be at least $0.20; and (5) The absolute value of the difference between the bid and ask ISD must be less than 0.07. These additional screens reduced the sample size to 202 call observations and 257 put observations.

equal 31 days, between 32 and 56 days, and more than 56 days.

To achieve roughly equal observation numbers across three moneyness classifications, we must split the sample into these buckets: where M is less than or equal zero, where M is between zero and 0.04, and where M is greater than 0.04. As a result, for calls we have moneyness buckets where the calls are out-of-the-money, in-the-money, and most in-the-money. For puts, we have moneyness buckets where the puts are in-the-money, out-of-the-money, and most out-of-the-money.

For different maturity classifications, Unni and Yadav (1998) find that the observed early exercise *premium* increases as options get deeper in-the-money. As shown in Table IV for different maturity levels, *percentage* early exercise premiums fall as options get deeper in the money. This result is quite robust, as it holds using means or medians for all cases using puts, and all but one using calls. In addition, across moneyness levels, Unni and Yadav (1998) find that the observed early exercise *premium* increases as maturity increases. In this study, we find the opposite. That is, the *percentage* early exercise premiums generally decrease as time to maturity increases. However, during the sample period used in this study, the American options were slated to be terminated. As the termination time draws nearer, it is possible that the liquidity of the American option market changed in such a way that higher "early exercise premiums" were observed across moneyness levels as time to maturity fell.

5.2 The Estimated Relationship for Premium Sources.

Unni and Yadav (1998) estimate regressions that include a theoretical early exercise premium generated by the Fleming and Whaley (1994) binomial method. However, the Fleming and Whaley (1994) method co-mingles all sources of early exercise values. The purpose of this section is to provide information concerning the contribution, and relative importance, of the sources of early exercise value. That is, in this section, we compare the empirical pricing relationship with the Barone-Adesi-Whaley measure to analyze how much early exercise premium is missing if only an early exercise premium based on Barone-Adesi-Whaley is used as a theoretical early exercise premium.

As discussed in Section (3), the early exercise value for calls comes from the wildcard option and a dividend-capture strategy. For puts, the early exercise value comes from the wildcard option and the potential profit from exercising the put early and investing the proceeds to expiration. The regression-implied percentage early exercise premium calculated from the linear regressions in Table III (and displayed in Figures 2 and 3) reflect all sources of the early exercise premium. The Barone-Adesi-Whaley measure ought to reflect and isolate non-wildcard sources of early exercise.

Therefore, including both measures of early exercise premiums in the same regression can be complementary, because the regression-implied percentage early exercise premiums will reflect wild card value, and the Barone-Adesi-Whaley measure will reflect non-wildcard value. The dependent variable is the percentage early exercise premium calculated using the observed American prices and theoretically contemporaneous Black-Scholes prices.

From the linear regressions in Table III, the regression-implied percentage early exercise premium varies across observations due to the intercept. For the puts, using bid-ask midpoints, however, the intercept is not statistically significant in either regression. Hence, using bid-ask midpoints, we consider the wildcard premium to be constant for puts, and the measure reflecting the wildcard is not included as a regressor. Based on Jorion and Stoughton (1989) and Unni and Yadav (1998), we include these additional regressors: dividend yield/riskless rate ratio, moneyness, days to maturity, and implied volatility.

Two sets of regression are shown in Table V, one for the entire sample and one for a sample without short-term options. The second set of results is motivated from results presented in Table IV, namely, early exercise premiums were much larger when days to maturity were less than 31. The results are sharper for the sub-sample without the short-term options.

With this regression, we are able to estimate the relative size of the sources of early exercise premiums. As shown in Table V, the Barone-Adesi-Whaley early exercise premium is not significant for call options across the whole sample, but the wildcard premium is significantly positive. For puts, both sources of the early exercise premium are highly significantly positive (t-values ranging from 2.98 to 8.73) across the whole sample. Except for moneyness, the other regressors are insignificant.

In the sub-sample, the $\overline{R}^2$ are higher in all cases, and both sources of early exercise are significantly different from zero. Using ask prices, one can see that the wildcard EEP effects are larger than, and statistically different from, the effects from the Barone-Adesi-Whaley EEP. Over the entire sample, the two effects are statistically indistinguishable.

6 Negative Early Exercise Premiums and Arbitrage.

Lee and Nayer (2000) and McMurray and Yadav (2000) report instances of *negative* early exercise premiums, i.e., cases where the American option is selling for less than an identical European option. A negative early exercise premium is of interest because it signals the presence of an arbitrage opportunity. Lee and Nayer (2000) report that negative early exercise premiums occur in 47% of their call sample and 58% of their put sample. McMurray and Yadav (2000) find a negative early exercise premium in 32% of their call sample and 17% of their put sample.[12]

Lee and Nayer (2000) further report that about 22% and 24% of the mispriced observations of call options and put options, respectively, provide profitable arbitrage opportunities even in the presence of realistic retail transaction costs. However, Lee and Nayer (2000)

[12] In the McMurray and Yadav (2000) sample, the American option and the European option do not have identical exercise prices. Thus, as they point out, "it is not possible to adopt a totally risk-free arbitrage strategy to exploit the anomaly."

must simulate a bid-ask spread from their sample of trade prices to conduct their arbitrage tests. In this study, observed bid-ask spreads are directly available to conduct arbitrage tests when an American option price is less than a European option price.

Using the original 993 combined raw matched pairs to identify the time of the American quote, the CBOE tape is scanned for two matching European quotes: the closest one before and the closest one after the American quote. In some cases, there is no European quote before the American quote. These observations are discarded, along with observations that have a missing bid or ask quote or a zero bid or ask quote. Also, based on Sheikh and Ronn (1994), observations are removed for the first hour of trading (i.e., those before 9:30:00). Unlike before, however, any length of time between the quotes is allowed and observations with instant arbitrage situations are kept, i.e., where the SPX bid is less than the SPQ ask. This slightly different screening process results in a sample of 467 call observations and 346 put observations.

The following two scenarios were considered for arbitrage trading. At the time of each observed American quote, (1) the observed American midpoint is compared to the prevailing European midpoint, and (2) the observed American ask is compared to the prevailing European bid. In both comparisons, if the American price is less than the European price, this is called an apparent arbitrage. A transaction fee of $5 per contract is assumed, and it is also assumed traders will initiate an arbitrage trade only if the price differential exceeds this fee.

It is assumed that traders "leg-on" the apparent arbitrage trade in two ways. In the first way, traders are assumed to receive price improvement on both sides of the trade. That is, the trader buys the American option at the midpoint of the current, observed bid-ask spread, and sells the European option at the midpoint of the next *observed* European quote. In the second way, trader receive no price improvement. That is, the trader buys the American option at the ask price of the current, observed quote and sells the European option at the bid price of the next *observed* European quote.

Table VI summarizes the results of these simulations. When traders use the midpoint screens, i.e., comparison (1) above, apparent arbitrage opportunities are signaled 17.6% of the time for calls and 8.7% of the time for puts. If it is assumed that traders could have traded at the midpoint of the prevailing American quote and the midpoint of the next European quote, traders would have realized an average *profit* per contract of $23 for calls and $15 for puts. If traders paid the prevailing American ask and received the next European bid, traders would have realized an average *loss* per contract of $33 for calls and $38 for puts.

If traders impose bid-ask spreads, i.e., comparison (2) above, apparent arbitrage opportunities are signaled 1.5% of the time for calls and less than 1.0% of the time for puts. If it is assumed that traders could have traded at the midpoint of the prevailing American quote and the midpoint of the next European quote, traders would have realized an average *profit* per contract of $117 for calls and $88 for puts. If traders paid the prevailing American ask and received the next European bid, traders would have realized average profits per contract of $55 for calls and $36 for puts.

The results of these simulations highlight the importance of the assumptions that the American quote is good until updated [Hemler and Miller (1997)] and of the assumed size of the bid-ask spread used to test option market efficiency [Vijh (1990)]. If the American quote is not good until updated, there is no way to conduct an arbitrage simulation using this sample because of the infrequent observations of American quotes. Traders in these simulations lost money, on average, when trades occured at the relevant bid and ask prices and the traders acted on signals based on spread midpoints. However, traders would have profited (albeit infrequently) if they had used arbitrage signals based on relevant quotes, even in the cases where trades are executed at the relevant bid and ask prices.

7 Summary.

This study uses American options on the S&P 500 index to measure early exercise premiums (EEPs). April 2, 1986 through June 20, 1986 is a unique time period at the CBOE, because American and European options traded concurrently on the S&P 500 index. Thus, an intradaily, matched-pair sample allows a direct empirical measurement of EEPs.

Several liquidity issues motivate four EEP measurements that use: observed matched-pairs, observed American prices and theoretical European prices, linear regression on observed matched-pairs with option prices less than 10 minutes apart, and linear regression with a theoretical European price. Based on empirical results consistent with an inventory management argument, EEPs estimated using bid-ask midpoints are most likely biased. Using ask prices, the four EEP measures yield EEPs ranging from 5.04% to 5.90% for calls, and from 7.97% to 10.86% for puts.

Trading in American options was slated to cease, so short-dated option prices could be reflect illiquidity. Excluding short-dated options, average EEPs using ask prices range from 1.5% to 4.7% for calls, and from 6.5% to 8.6% for puts. Excluding short-dated options, the effects from an EEP measure that includes a wildcard premium is larger, and statistically different from, the effects from an EEP measure without a wildcard premium.

Studies by Lee and Nayer (2000) and McMurray and Yadav (2000) report many instances of arbitrage-signaling *negative* early exercise premiums. McMurray and Yadav (2000) report negative early exercise premiums frequently occur, 32% of the time for calls and 17% for puts. Lee and Nayer (2000) also report frequent occurences of negative early exercise premiums, 47% of the time for calls and 58% for puts. A lower frequency of negative early exercise premiums is found in this study, 17.6% of the time for calls and 8.7% for puts. However, it is found that traders must be able to trade within the bid-ask spread to profit from these apparent arbitrage opportunities.

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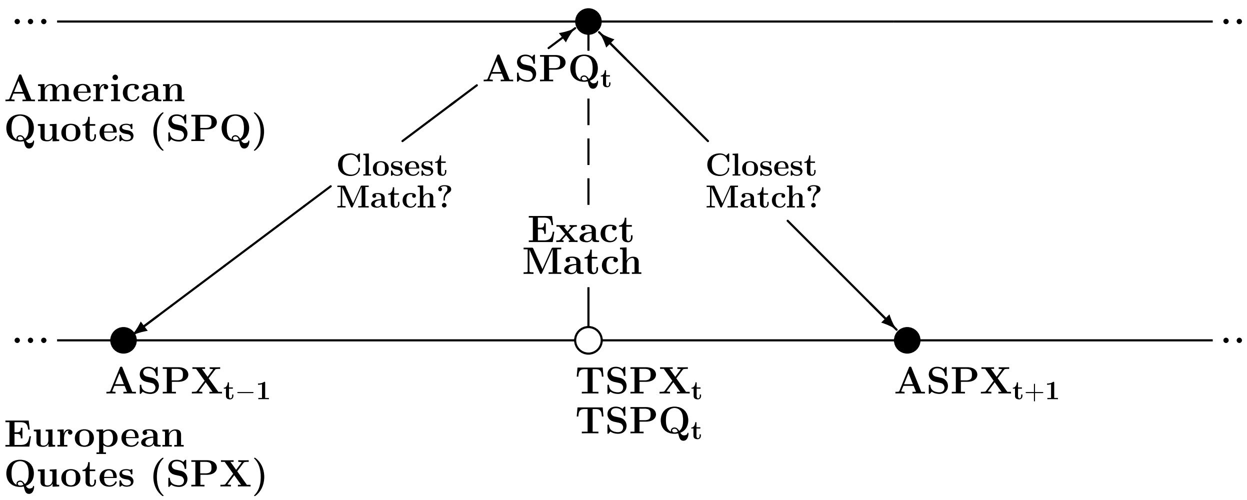
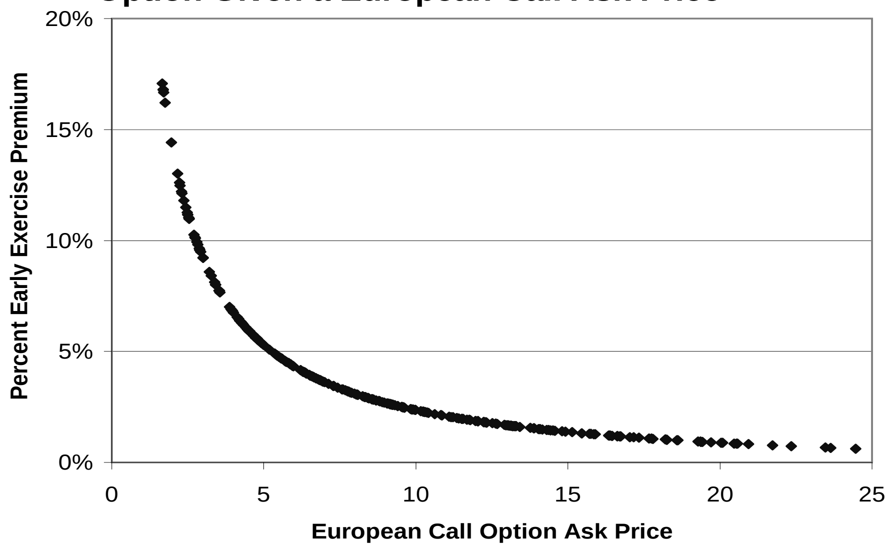


Figure 1. Matching the American and European Quotes. **For each actual American option quote observation, $ASPQ_t$, the closest, otherwise matching, European option quote observation, $ASPX_{t-1}$ or $ASPX_{t+1}$, is selected based on its timestamp. Suppose the matching European quote is $ASPX_{t+1}$. Using the Black-Scholes model, we generate a theoretical European option price at the exact time of the observed American quote, $TSPX_t$. The European implied standard deviations are from the matched time $ASPX_{t+1}$ and the cash index used is the implied S&P 500 index level implied by the S&P 500 futures price at time $ASPQ_t$. Using the Barone-Adesi-Whaley algorithm, we generate a theoretical American option price at the exact time of the observed America quite, $TSPQ_t$. Inputs for the Barone-Adesi-Whaley algorithm are the European Black-Scholes price described above, and other option inputs from the time of the observed American option quote ($ASPQ_t$).**

Figure 2. Estimated Percent Early Exercise Premium for an Otherwise Identical American Call Option Given a European Call Ask Price



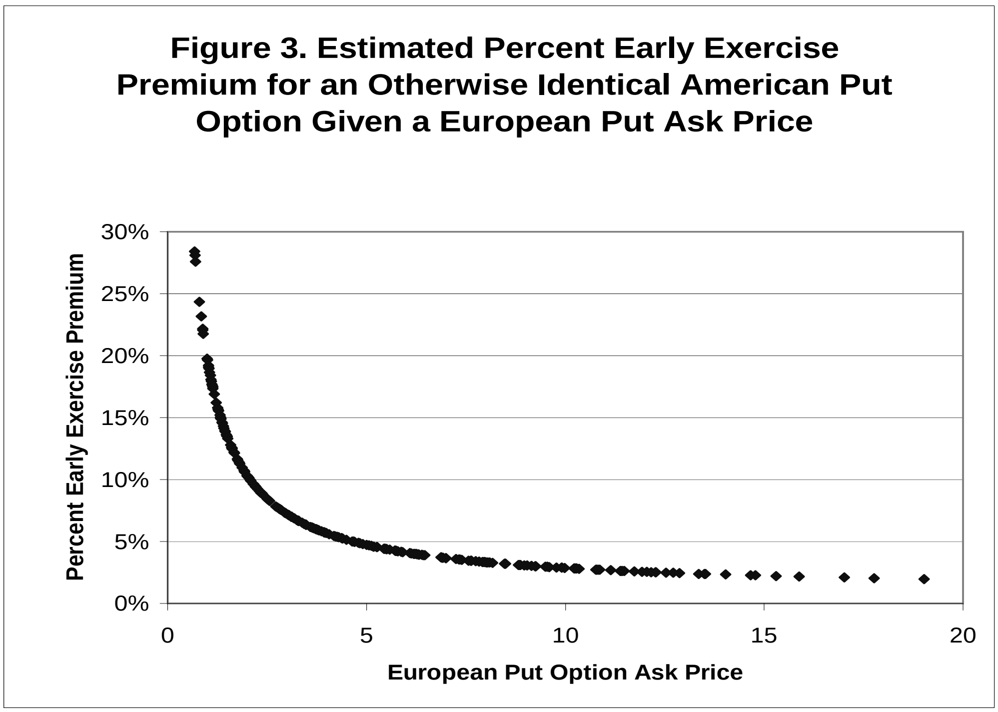


Figure 3. Estimated Percent Early Exercise Premium for an Otherwise Identical American Put Option Given a European Put Ask Price
30%
25%
20%
15%
10%
5%
0%
Percent Early Exercise Premium
0
5
10
15
20
European Put Option Ask Price

TABLE I

Mean Observed American and European Option Premiums; Mean Observed Bid-Ask Spreads, and; Mean and Median Observed Early Exercise Premiums. The observed sample consists of a matched-pair of American and European options using a set of intradaily American option quotes and their closest-in-time otherwise identical European option quote. The intradaily call and put option quotes are the American-style (SPQ) and European-style (SPX) options on the Standard and Poor's 500 Index that traded at the Chicago Board Options Exchange from April 2, 1986 through June 20, 1986. Panel A reports the mean observed option premiums and Panel B reports mean observed bid-ask spreads. In Panel B, the observed early exercise premiums are calculated by subtracting the European ask, bid, or bid-ask midpoint from the observed American ask, bid, or bid-ask midpoint, respectively. The sample consists of 414 call observations and 321 put observations.

		Calls	Puts
Panel A. Observed Option Premiums.			
American option price (bid-ask midpoint)	Mean	$10.26	$4.84
	Median	$9.3125	$3.75
	Maximum	$25.00	$18.50
	Minimum	$0.625	$0.125
European option price (bid-ask midpoint)	Mean	$10.17	$4.81
	Median	$9.25	$3.625
	Maximum	$24.9375	$18.625
	Minimum	$0.6875	$0.09375
Panel B. Observed Bid-Ask Spreads.			
American-style (SPQ) bid-ask spread,	Mean	$0.78	$0.66
	Median	$0.75	$0.50
European-style (SPX) bid-ask spread,	Mean	$0.39	$0.28
	Median	$0.375	$0.25
Panel C. Observed Early Exercise Premiums.			
American Ask minus European Ask:	mean	5.36%	10.86%
	median	2.33%	4.76%
American Bid minus European Bid:	mean	-0.80%	-6.86%
	median	-2.02%	-5.26%
Bid-Ask Midpoints:	mean	2.38%	2.76%
	median	0.00%	0.00%

TABLE II

Theoretically Contemporaneous Early Exercise Premiums with and without Wildcard Value. The observed sample consists of a matched pair of American and European options using a set of intradaily American option quotes and their closest-in-time otherwise identical European option quote. The intradaily call and put option quotes are the American-style (SPQ) and European-style (SPX) options on the Standard and Poor's 500 Index that traded at the Chicago Board Options Exchange from April 2, 1986 through June 20, 1986. Using the observed matched-pairs, we calculate two early exercise premiums at the time stamp of the American option. For the observed early exercise premium, we use the observed American option price and a European Black-Scholes option price calculated by using the implied standard deviation from the nearest observed European option price and other option inputs from the time of the observed American option. This observed premium includes the value of being able to exercise the option at closing NYSE prices during the wildcard period between the close of trading on the NYSE and CBOE. The mean and median of this observed early exercise premium are in Panel B. To check the adequacy of a theoretical early exercise premium that does not reflect wildcard value to describe the observed data, we use the Barone-Adesi-Whaley (1987) American option algorithm and the European Black-Scholes price described above, taking option pricing factors from the time of the observed American option. The mean and median of this theoretical early exercise premium are in Panel C. Panel A contains the mean values of the inputs used to calculate theoretical American option prices and Black-Scholes European option prices.

		Calls	Puts
Panel A. Mean of the Inputs Used to Calculate Theoretical Option Prices.			
Implied Standard Deviations (from Midpoints of Observed European Quotes):		16.93%	17.47%
Other Inputs (from the time of the American Quote):			
Dividend Adjusted S&P 500 Cash Index:		237.66	237.06
Strike Price:		233.65	233.96
Days to Expiration:		45.64	47.77
T-bill Rate, in Percent:		6.28	6.27
Panel B. Theoretically Contemporaneous Early Exercise Premiums With a Wildcard Value:			
Using observed American asks and Black-Scholes prices	mean	5.90%	8.43%
calculated using the ISDs from observed European asks	median	2.22%	5.20%
Using observed American bid-ask midpoints and Black-Scholes	mean	2.43%	0.88%
prices using the average ISD from observed European bid and ask	median	-0.10%	0.00%
Panel C. Theoretically Contemporaneous Early Exercise Premiums Without Wildcard Value:			
Barone-Adesi-Whaley price relative to Black-Scholes price	mean	0.05%	0.75%
calculated using ISDs from observed European asks	median	0.05%	0.72%
Barone-Adesi-Whaley price relative to Black-Scholes price	mean	0.05%	0.78%
calculated using average ISD from observed European bid and ask	median	0.05%	0.74%

TABLE III

An Empirical Pricing Relationship between American and European Option Prices that Reflects Wildcard Value. Within each panel, regression coefficients and implied Early Exercise Premiums are reported based on how many minutes separate the American and European quotes. The observed American price is regressed on either the observed noncontemporaneous European quote or the Black-Scholes European price that takes the implied standard deviation from the observed European quote and other option pricing factors from the time of the American quote. Standard errors are in parentheses.

$$\text{Price of an American Option} = \alpha + \beta(\text{Price of an Otherwise Identical European Option}) + \eta.$$

	Calls				Puts			
	N	$\hat{\alpha}$	$\hat{\beta}$	Pct. EEP	N	$\hat{\alpha}$	$\hat{\beta}$	Pct. EEP
Panel A. Observed American and European Bid-Ask Midpoints.								
Quotes < 1 Hour Apart	414	0.105 (.041)	0.998 (.003)	1.65	321	0.018 (.020)	1.004 (.003)	1.77
Quotes < 10 Minutes Apart	306	0.124 (.049)	0.999 (.004)	2.07	209	-0.006 (.026)	1.007 (.004)	0.38
10 Min. Apart ≤ Quotes < 1 Hour Apart	108	0.022 (.073)	0.999 (.006)	0.29	112	0.053 (.033)	1.000 (.006)	5.87
Panel B. Observed American Bid-Ask Midpoint and Black-Scholes at Bid-Ask Average ISD.								
Quotes < 1 Hour Apart	303	0.125 (.040)	0.992 (.004)	1.65	257	-0.008 (.023)	1.009 (.004)	0.49
Quotes < 10 Minutes Apart	224	0.141 (.048)	0.993 (.005)	2.11	170	-0.006 (.027)	1.006 (.004)	0.32
10 Min. Apart ≤ Quotes < 1 Hour Apart	79	0.044 (.068)	0.993 (.006)	0.09	87	-0.014 (.041)	1.015 (.007)	0.78

TABLE III, Cont.

	Calls				Puts			
	N	$\hat{\alpha}$	$\hat{\beta}$	Pct. EEP	N	$\hat{\alpha}$	$\hat{\beta}$	Pct. EEP
Panel C. Observed American and European Asks.								
Quotes < 1 Hour Apart	414	0.253 (.043)	1.003 (.004)	4.49	321	0.186 (.023)	1.009 (.004)	13.07
Quotes < 10 Minutes Apart	306	0.279 (.050)	1.004 (.004)	5.04	209	0.159 (.029)	1.013 (.004)	9.44
10 Min. Apart $\leq$ Quotes < 1 Hour Apart	108	0.139 (.080)	1.005 (.006)	2.71	112	0.226 (.038)	1.001 (.006)	21.09
Panel D. Observed American Ask and Black-Scholes at European Ask ISD.								
Quotes < 1 Hour Apart	303	0.294 (.043)	0.994 (.004)	5.04	257	0.186 (.026)	1.010 (.004)	9.05
Quotes < 10 Minutes Apart	224	0.319 (.051)	0.995 (.005)	5.72	170	0.170 (.031)	1.011 (.005)	7.97
10 Min. Apart $\leq$ Quotes < 1 Hour Apart	79	0.168 (.078)	0.997 (.007)	2.76	87	0.215 (.048)	1.009 (.008)	11.32

TABLE IV

Observed Early Exercise Premiums, by Days to Expiration and Moneyness. The early exercise premium reported is the observed SPQ (American) ask price minus the most closely observed in time SPX (European) ask price. Each cell contains the number of observations, the mean, and the median. The moneyness measure is defined as: $M = (S - Ke^{-rT})/S$.

Panel A. Call Options.

Moneyness (M):	Days to Expiration: $D \leq 31$	$32 \leq D \leq 56$	$56 < D$	All Days
$M \leq 0$	25	36	42	103
(out-of-the-money)	36.71	9.46	1.31	12.75
	10.00	6.46	0.00	5.26
$0 \leq M \leq 0.04$	46	41	68	155
(in-the-money)	7.35	3.09	1.59	3.69
	5.26	2.70	1.46	2.70
$0.04 < M$	60	44	52	156
(most in-the-money)	2.55	2.29	1.56	2.15
	2.30	1.94	0.80	1.68
All Moneyness, N:	131	121	162	414
Mean :	10.75	4.69	1.51	5.36
Median:	3.57	3.03	0.98	2.32

Panel B. Put Options.

Moneyness (M):	Days to Expiration: $D \leq 31$	$32 \leq D \leq 56$	$56 < D$	All Days
$M \leq 0$	16	30	41	87
(in-the-money)	5.03	2.60	2.91	3.20
	2.76	3.12	2.43	2.40
$0 \leq M \leq 0.04$	36	33	48	117
(out-of-the-money)	10.97	3.79	5.25	6.60
	8.39	4.17	4.68	4.76
$0.04 < M$	33	42	42	117
(most out-of-the-money)	38.08	16.70	11.40	20.82
	33.33	14.29	8.71	14.30
All Moneyness, N:	85	105	131	321
Mean :	20.38	8.61	6.49	10.86
Median:	11.11	4.44	4.17	4.76

TABLE V

Estimated OLS Coefficients from Regressing the Observed Early Exercise Premium on Two Implied Early Exercise Premiums and Other Option Pricing Factors. The dependent variable is the percentage difference between the observed American price and the contemporaneous Black-Scholes European price that is calculated using the Black-Scholes implied standard deviation from the nearest European quote. The first implied EEP does not reflect wildcard value and is the percentage difference between the Barone-Adesi-Whaley (BAW) theoretical American price and the contemporaneous Black-Scholes European price, as summarized in Table II; the other implied EEP reflects wildcard value and is the percentage EEP implied by the fitted values of the regressions in Table III. These two implied EEP are denoted BAW EEP and Wildcard EEP, respectively. The additional option-pricing factors included in the regression are the interest rate, moneyness, time to expiration and the Black-Scholes implied volatility. Standard errors are in parentheses.

Number of Observations	R-Bar Square	Barone-Adesi Whaley EEP	Wildcard EEP	Dividend Yield / Riskless Rate	Moneyness	Days to Expiration	Implied Volatility
Panel A. Entire Sample.							
i. Calls, Using Ask Prices.							
302	0.28	0.681	2.40	0.102	1.27	-0.232	0.650
		(0.570)	(0.275)	(0.121)	(0.486)	(0.484)	(1.25)
ii. Calls, Using Bid-Ask Midpoints.							
302	0.16	0.592	4.02	0.090	1.25	-0.166	0.620
		(0.563)	(0.629)	(0.122)	(0.488)	(0.525)	(1.38)
iii. Puts, Using Ask Prices.							
257	0.32	0.549	0.313	0.020	1.038	-0.063	-0.451
		(0.184)	(0.079)	(0.057)	(0.212)	(0.153)	(0.226)
iv. Puts, Using Bid-Ask Midpoints.							
257	0.06	0.583		0.000	0.171	0.124	-0.213
		(0.154)		(0.047)	(0.143)	(0.127)	(0.200)
Panel B. Sample Without Days to Expiration Less Than 31.							
i. Calls, Using Ask Prices.							
240	0.41	1.421	2.336	0.043	0.773	0.219	-0.829
		(0.390)	(0.255)	(0.111)	(0.268)	(0.434)	(1.149)
ii. Calls, Using Bid-Ask Midpoints.							
240	0.26	1.381	3.816	-0.072	0.713	0.003	-0.310
		(0.372)	(0.614)	(0.110)	(0.262)	(0.426)	(1.166)
iii. Puts, Using Ask Prices.							
210	0.54	0.702	1.216	-0.001	-0.167	0.074	-0.037
		(0.208)	(0.123)	(0.070)	(0.225)	(0.151)	(0.194)
iv. Puts, Using Bid-Ask Midpoints.							
210	0.07	0.518		-0.189	0.302	-0.122	-0.068
		(0.190)		(0.645)	(0.132)	(0.135)	(0.184)

TABLE VI

Mean Profitability of Apparent Arbitrage Opportunities when the Trade Occurs Either at the Midpoint of the Bid-Ask Spread or at the Relevant Bid and Ask Prices. In both comparisons, if the American price is less than the European price, we call this an 'apparent arbitrage.' We assume a transaction fee of $5 per contract and assume traders will conduct an arbitrage strategy only if the price differential exceeds this fee. We assume traders "leg-on" an arbitrage and receive two possible executions. In the first execution, we assume that the trader receives price improvement on both sides of the trade. That is, the trader buys the American option at the midpoint of the current, observed bid-ask spread and sells the European option at the midpoint of the next *observed* European quote. In the second execution, we assume the trader receives no price improvement. That is, the trader buys the American option at the ask price of the current, observed quote and sells the European option at the bid price of the next *observed* European quote. (Mean losses are in parentheses).

Apparent Arbitrages			Execution at Spread Midpoints			Execution at Relevant Bid/Ask		
				Winners			Winners	
Signal Used by Trader	N	Mean Profit	Mean Profit	N	Profit	Mean Profit	N	Profit
Panel A. Call Options								
1) Observed American Midpoint less than Prevailing European Midpoint	82	$28	$23	51	$50	($33)	20	$34
2) Observed American Ask less than Prevailing European Bid	7	61	117	7	117	55	6	73
Panel B. Put Options								
1) Observed American Midpoint less than Prevailing European Midpoint	30	$31	$15	19	$39	($37)	4	$34
2) Observed American Ask less than Prevailing European Bid	3	36	88	3	88	36	2	65