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Bid-Ask Spreads and Trading Activity in the S&P 100 Index Options Market

Thomas J. George and Francis A. Longstaff*

Abstract

This paper examines the cross-sectional distribution of bid-ask spreads in the S&P 100 index options market. Cross-sectional differences in bid-ask spreads are found to be directly related to differences in market-making costs and trading activity across options. We also examine the relation of an option's bid-ask spread and trading activity to the spread and trading activity in other options. Call option trading activity is inversely related to the call option bid-ask spread but positively related to the spread of the put option having the same strike price and maturity, and vice versa. These findings suggest that traders view call and put options as substitutes.

I. Introduction

On a typical trading day, more than 40 different S&P 100 index option contracts are actively traded at the Chicago Board Options Exchange (CBOE). These calls and puts differ only in terms of their strike prices and maturity dates. At a given point in time, there is a market-determined bid-ask spread for each of these options. This raises the question of how these bid-ask spreads compare across options. This issue is important because these transaction costs can affect a trader's choice of option contracts, which in turn affects the liquidity of trading in these options and the ultimate viability of individual option contracts.

Market making is highly competitive in S&P 100 index options, implying that bid-ask spreads should be equal to the expected marginal cost of supplying liquidity services. There are several possible patterns for the cross-sectional distribution of bid-ask spreads that are intuitively appealing because of their simple forms. One possibility is that market makers equalize bid-ask spreads across options. This is reasonable if order processing costs are the dominant cost of providing liquidity since the CBOE charges market makers the same fee for each option

*College of Business, Ohio State University, 1775 College Road, Columbus, Ohio 43210–1399, and Anderson Graduate School of Management, University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles, CA 90024, respectively. The authors are grateful for the helpful comments of Warren Bailey, Stephen Buser, K. C. Chan, Margaret Forster, Joel Hasbrouck, Larry Harris, Andrew Karolyi, Gautam Kaul, Anthony Sanders, Barry Schachter, Duane Seppi, Burney Simpson, Hans Stoll, S. Viswanathan, and an anonymous **JFQA** referee; and for the research assistance of Wai-Ming Fong. All errors are the authors' responsibility.

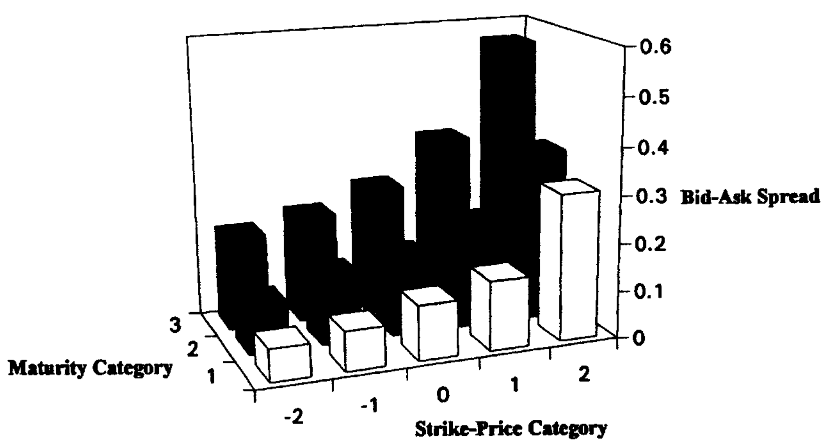
traded. Alternatively, inventory holding costs could be the dominant cost faced by market makers and these costs could be related to option prices. In this case, bid-ask spreads would be a constant percentage of option value. A third possibility is that expected marginal costs are equal across options, regardless of trading volume. This would lead market makers to equalize revenue across options by quoting high bid-ask spreads for low-volume options, and vice-versa.

In actuality, the cross-sectional distribution of bid-ask spreads is much more complex than implied by these simple patterns. Figures 1 and 2 show that bid-ask spreads for calls and puts are not equal across options—actual bid-ask spreads range from five cents to nearly one dollar. Percentage bid-ask spreads are also far from constant, ranging from less than 2 to more than 20 percent of the option's value. Furthermore, there is no simple relation between spreads and the average daily trading volume of these options.

FIGURE 1

Call Option Bid-Ask Spreads

Bid-Ask Spread is the S&P 100 index call option bid-ask spread in dollars per option graphed by maturity and strike-price categories. The data consist of 2456 observations during 1989, averaged within categories. Maturity Categories 1, 2, and 3 include all options with maturities up to 30 days, 31 to 60 days, and greater than 60 days, respectively. Strike-Price Categories −2, −1, 0, 1 and 2 include all options with strike prices 7.5 or more points less than the index, between 2.5 and 7.5 points less than the index, at the money, etc.



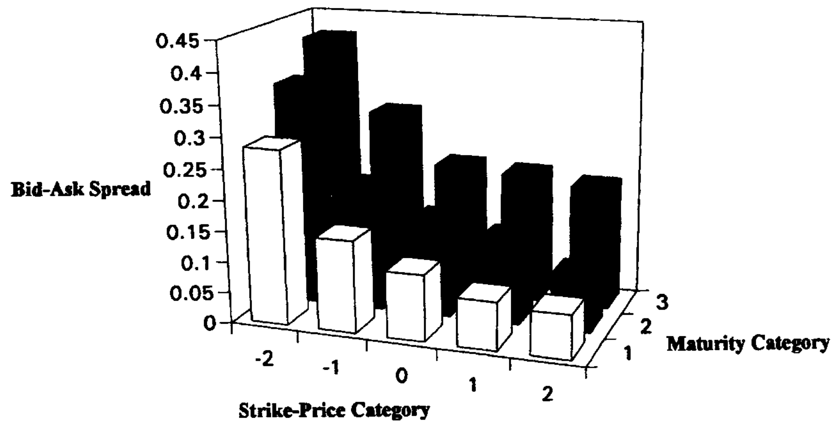
This paper examines the cross-sectional distribution of bid-ask spreads in the S&P 100 index options market. A key advantage of this cross-sectional approach is that the market structure and underlying sources of risk are held fixed across options. Because of this, differences in bid-ask spreads can be directly related to differences in the costs faced by market makers across options. In addition, a cross-sectional approach allows direct examination of the interrelation between bid-ask spreads and trading activity.

A number of important results emerge from this analysis. First, bid-ask spreads in this market are comparable to those in other markets with competitive market makers, but are larger than those in markets with specialists. Second, ap-

FIGURE 2

Put Option Bid-Ask Spreads

Bid-Ask Spread is the S&P 100 index put option bid-ask spread in dollars per option graphed by maturity and strike-price categories. The data consist of 2456 observations during 1989, averaged within categories. Maturity Categories 1, 2, and 3 include all options with maturities up to 30 days, 31 to 60 days, and greater than 60 days, respectively. Strike-Price Categories −2, −1, 0, 1, and 2 include all options with strike prices 7.5 or more points less than the index, between 2.5 and 7.5 points less than the index, at the money, etc.



proximately 70 percent of the cross-sectional variation in bid-ask spreads can be explained on the basis of a simple cost model motivated by a detailed examination of exchange rules and market structure. The results indicate that spreads incorporate premiums for the risk of holding uncovered positions in illiquid options. These inventory costs can be large in absolute terms—the cost to the market maker of holding an at-the-money option is approximately 50 cents per hour. Furthermore, more than 50 percent of the cross-sectional variation in trading activity is explained by variation in bid-ask spreads and features of the option contracts. The results also indicate bid-ask spreads have a significant impact on traders' behavior. Estimates indicate that a \$1/16 increase in the bid-ask spread increases the average time between option transactions by approximately 2.9 minutes. The economic significance of this is highlighted by the fact that the average time between transactions for all options in the sample is five minutes.

Also analyzed is how the bid-ask spread and trading activity of one option is related to the bid-ask spread and trading activity of another option. Results from these tests confirm the findings for individual options. The evidence also suggests that traders view closely related options—puts and calls having the same strike price and maturity—as substitutes. This is because trading activity in call options is significantly positively related to the bid-ask spreads of the related put options; and vice versa. The magnitude of the estimates implies that a \$1/16 increase in the bid-ask spread for a call (put) option decreases the average time between transactions in the corresponding put (call) option by about 1.7 (0.4) minutes. While both are statistically significant, the relative magnitudes suggest that put trading is more sensitive to call option spreads than call trading is to put option spreads. Also found is evidence of dependence in bid-ask spreads across options. Call option spreads are significantly positively related to the spreads of corresponding puts. Put option spreads are positively related to call options spreads, but this result is not statistically significant.

The paper is organized as follows. Section II discusses the structure of the S&P 100 index options market and the costs faced by market makers. Section III presents the empirical results and discusses their implications. Section IV summarizes and concludes the paper.

II. Market Structure and Market-Making Costs

The details of the structure of the S&P 100 index options market are described in this section. Because of the competitive nature of the market, equilibrium bid-ask spreads should reflect the expected costs of providing liquidity services to the market. The various types of costs faced by market makers are considered, and this analysis is used to identify a number of potential determinants of cross-sectional differences in bid-ask spreads.

A. Market Structure

S&P 100 index options are traded at the CBOE. Since their introduction in 1983, these options have experienced dramatic growth in popularity and are now one of the most actively traded option contracts in the world. All S&P 100 index options are traded at the same location on the trading floor. On a typical trading day, hundreds of market participants are physically present and actively trading on the floor of the exchange.

The trading system for S&P 100 index options is a continuous open-outcry auction among competitive traders similar to that of futures markets. This system is very different from the specialist system used for NYSE/AMEX stocks or AMEX options. In this system, there are essentially two types of traders—floor brokers and market makers. By CBOE rules, floor brokers are limited to bringing public orders to the floor of the exchange and executing them at the best possible prices. Public customers pay commissions to floor brokers for executing transactions. In contrast, market makers trade only for their own accounts.[1] To trade as a market maker for S&P 100 index options, a member must apply for and receive designation from the CBOE as a market maker in the *entire* class of S&P 100 index options. By CBOE rules, market makers have a responsibility to quote bid and ask prices—firm for 10 contracts—in a way that contributes to the maintenance of a fair and orderly market, provides price continuity, and encourages competition among market makers. By standing ready to trade with other traders at his current bid and ask prices, a market maker provides both liquidity and immediacy to the market.

Each market maker is required "to compete with other market makers to improve markets in *all* series of options classes at the station where a market

[1]Members of the CBOE who have market-maker designations can trade as floor brokers or as market makers. CBOE Rule 8.8, however, requires that each day these members must elect whether they will trade as floor brokers or as market makers.

maker is present" (CBOE Rule 8.7). Since each market maker is required to be competitive in each option, bid-ask quotes reflect the market-making costs of a common set of competitive market makers. These rules governing market makers are enforced. At six-month intervals, the CBOE takes a written survey of all the members trading these options, asking them to evaluate the performance of the other traders. Those found to be deficient in fulfilling their membership responsibilities are subject to sanctions. For market makers, these sanctions can include the revocation of their designation as market makers (CBOE Rule 8.60).

CBOE Rule 6.73 requires that each transaction be executed at the highest bid and lowest ask prices emerging from the group of market makers participating in the open-outcry process at the time the transaction arrives on the floor. Furthermore, public limit orders are included in the set of market-maker quotes for the purpose of determining the highest bid and lowest ask prices (CBOE Rule 6.45). These requirements, as well as the sheer number of market makers participating, induce vigorous competition.[2] Given this high degree of competition, bid-ask spreads should be equal to the market makers' marginal cost of executing transactions. In the next subsection, a number of potential costs faced by market makers is identified.

B. Market-Making Cost Structure

Market makers face two costs that are assessed on a per-trade basis. For every contract (100 options) traded, a CBOE fee of nine cents and an Options Clearing Corporation (OCC) fee of 10 cents is assessed to the firm that clears the trade. Thus, if the market maker is a clearing member of the OCC, the marginal cost of trading a contract is 19 cents. If a market maker is not a clearing member, however, the market maker must contract with a clearing member to clear his trades. Because clearing firms compete for market makers' transactions, the fees they charge approach 19 cents per contract for their best customers.[3] Thus, in either case, the direct marginal cost to a market maker for trading a contract is 19 cents. These clearing fees support the exchange and the clearing corporation, and impose an order-processing cost on market makers that is the same for all S&P 100 index options.

Despite the large volume of trading in these options, trading is not continuous. During 1989, the average time between trades for a typical S&P 100 index option was approximately five minutes. With continuous trading, market makers can maintain inventory positions that are riskless with respect to changes in the index. The lack of continuity, however, implies that market makers may bear some risk of price changes in their open option positions. For a given transaction, the market maker's expected inventory risk is related to the amount of time that the market maker expects to hold an open option position and the variance of the option's price changes. If bearing inventory risk is costly to market makers, then

[2] On a personal visit to the trading floor, an exchange official told the authors that, of the approximately 400 S&P 100 index option traders present, roughly 300 were market makers.

[3] Clearing firm fees charged to a market maker are often based on the annual revenue that the market maker provides to the clearing firm. One clearing firm the authors spoke with charges 19 cents for market makers whose year-to-date clearing commissions are above $80,000.

competitively-determined bid-ask spreads should reflect this cost. In the Black-Scholes framework, the variance of the option's price change is the product of the square of the option's delta and the volatility of the underlying asset. Since these options have the same underlying asset, the same volatility applies to all the options. Consequently, cross-sectional differences in squared deltas capture differences in the risk of holding uncovered inventory positions.[4]

Following Neal (1987), the empirical analysis allows bid-ask spreads to depend on option prices because CBOE tick-size rules induce a positive relation between bid-ask spreads and option prices. Options with prices of $3 or more have tick sizes of $1/8; whereas options with lower prices have tick sizes of $1/16 (CBOE Rule 6.42). Consequently, the quoted spreads of high-priced options are constrained to be at least $1/8. This means that narrow spreads that are feasible for low-priced options are infeasible for high-priced options. Other incremental costs incurred by market makers may be related to option prices. For example, if frictions in money markets imply that market makers' working capital is not perfectly liquid at zero cost, changing the value of net inventory is costly. These costs would be positively related to the price of the option traded because higher priced options imply a greater change in the value of inventory.[5]

The procedure for exercise notification is an institutional feature of the S&P 100 index options market that affects the costs of market making. When a holder of an option exercises, the index level used in determining the payoff is the level prevailing at the end of the day of the exercise. The writer of the option does not know that an exercise has been assigned until the next day.[6] By this time, however, the index value could have changed substantially. Therefore, index options impose nonsystematic price risk on market makers who write these options because covered positions are prohibitively costly to maintain (they require portfolios of 100 stocks). This implies that near-maturity options may have wider bid-ask spreads than other options because they are more likely to be exercised.[7] Other indirect costs faced by market makers include the opportunity cost of their time, any fixed costs associated with being a market maker, and the cost of the capital invested in a CBOE membership.[8] These are not marginal costs of executing transactions,

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[4]Transaction prices in the Grossman and Miller (1988) model are related to the market maker's inventory risk. Biais and Hillion (1990) show that inventory risk is a determinant of spreads in a model where market makers in options markets find it costly to fully hedge their positions. The effect of inventory costs on bid-ask spreads has also been considered by Stoll (1978), Amihud and Mendelson (1980), and Ho and Stoll (1981).

[5]Many clearing firms also require that market makers maintain a cash balance, which plays the role of a margin account. The amount of additional funds posted is negotiated between the market maker and the clearing member. Any funds posted with the clearing firm can be seized by the OCC if the clearing member defaults on its obligations.

[6]*Characteristics and Risks of Standardized Options*, Options Clearing Corporation (1987), p. 36.

[7]Harvey and Whaley (1991) show that S&P 100 index options are frequently exercised early. The majority of the early exercises occur during the 10 days prior to expiration. However, early exercise activity for options with more than 100 days to expiration can occur. Put options are exercised early more frequently than call options.

[8]The average cost during 1989 of a transferable CBOE membership was approximately $225,000. CBOE Rule 3.16, however, allows members to lease their memberships to qualified nonmembers. Furthermore, the lease term can be for as short a period of time as one day. Annual exchange dues are $2,000.

however, so competition among market makers should imply that determinants of these costs would not affect the cross-sectional distribution of bid-ask spreads.

There are several other institutional features of options markets that one might expect to impose costs on CBOE market makers. These include option position limits, exercise limits, margins, and the cost of exercising options. S&P 100 index options, however, do not have position limits. Exercise limits for S&P 100 index options are not binding for market makers since they can exceed the limits by notifying the CBOE of the impending exercise of their options. Furthermore, S&P 100 index option market makers are not required to post margin with the OCC. Finally, the cost of simultaneously exercising a block of options with the same strike price and maturity is $1, independent of the size of the block. For a given option, therefore, the direct cost associated with early exercise is likely to be small.

In summary, this analysis suggests that cross-sectional differences in S&P 100 index option bid-ask spreads should be related to five cost-related variables. These variables are the price of the option, its time until expiration, its squared delta, an indicator for whether the option price is at least $3, and the average time between trades. The average time between trades is a determinant of inventory risk. Glosten and Harris (1988) use this variable as an inverse measure of trading activity because its value depends on the demand for each option. Demand, in turn, depends on the features of the option contract—maturity and nearness to the money—because traders' hedging motives are determinants of their choices of option contracts. As Glosten and Harris point out, trading activity should also depend on the level of the bid-ask spread. This is because the bid-ask spread is the price traders must pay for order execution. If demand for order execution is price-elastic, trading activity should be inversely related to the bid-ask spread.

III. The Empirical Estimates

This section describes the data used in the study and compares the bid-ask spreads for S&P 100 index options with the spreads for other securities. The relation between bid-ask spreads and the variables identified in Section II is estimated, explicitly recognizing that bid-ask spreads and trading activity are simultaneously determined. Finally, a model is estimated in which bid-ask spreads and trading activity of pairs of related options are simultaneously determined to examine across-option relations between these variables.

A. Data

S&P 100 index options are cash settled and are listed on a monthly expiration date cycle. Options with expiration dates in the three nearby months represent the majority of trading volume. Exercise prices are set at five-point intervals to bracket the current value of the underlying S&P 100 index. Option premiums are expressed in terms of dollars and fractions per unit of the S&P 100 index. Each point represents $100. The minimum fraction is 1/16 for options trading below 3, and 1/8 for all other options.

The data for the study are obtained from the CBOE Market Data Retrieval tape, which contains all last-sale transactions and bid-ask quotes during 1989 for all S&P 100 index options. The bid-ask quotations are reported by CBOE employees who are physically located among the traders on the trading floor. All quotes are for a trade size of 10 contracts. Quotes may be recorded as frequently as 30 times a minute for actively-traded options.

The data used in the empirical analysis are drawn from the set of all bid-ask quotations using the following procedure. First, the average bid and ask prices are computed for each option for the 15-minute interval from 2:00 p.m. to 2:15 p.m. Central Standard Time for each trading day during 1989. This window is used in order to avoid intra-day effects and to avoid using data from time periods near the market opening at 8:30 a.m. and the market closing at 3:15 p.m. Options that do not have reported bid-ask quotations during this window are dropped from the sample for that day. In addition, options with fewer than 10 trades during a day are dropped from the sample for that day. Averaging over a 15-minute interval allows one to obtain reliable spread estimates for less-actively traded options without much loss of synchronicity in the data. Furthermore, since bid-ask quotes are captured by quote reporters stationed at different locations on the trading floor, averaging over a short period of time yields a more accurate measure of the market bid-ask spread for the option. Next, the price of each option during the window is computed using the midpoint of the average bid-ask quotes. Also included is the maturity of the option (measured in days). Then the average time in minutes between transactions is calculated for each option in the sample by dividing the total number of minutes during a trading day (405) by the number of transactions for that option that day. The average time between transactions provides an intuitive measure of (the inverse of) trading activity in the option and is also used by Glosten and Harris (1988) for this purpose. The delta is also computed for each option using the Black-Scholes formula. This process results in a sample of 2456 bid-ask quotes for both calls and puts.

Table 1 presents summary statistics for the data. The call and put bid-ask spreads are denoted by CBA and PBA; call and put prices by C and P; the time in minutes between option trades for calls and puts by CL and PL; the call and put deltas by CD and PD; and call and put trading volume by CV and PV. T denotes the number of days until expiration for the options. The statistics are broken down by maturity and strike-price categories. From Table 1, the average quoted spread is 18.5 cents for calls and 15.6 cents for puts. These averages are consistent with those reported by Phillips and Smith (1980)—16.1 cents for calls and 18.8 cents for puts. Using intra-day data, Vijh (1990) reports average quoted spreads of 23.7 cents for CBOE options.

B. Bid-Ask Spread Comparisons

These option bid-ask spreads can also be compared to those reported in the literature for stocks by using the put-call parity theorem. Specifically, the bid-ask spread for a synthetic share of stock (long a call, short a put with the same strike price and maturity date, and long discount bonds) can be compared to the bid-ask spread for an actual share of stock. In this study's sample, the average bid-ask

TABLE 1

Summary Statistics

Maturity Category	Strike-Price Category	*CBA*	*PBA*	*C*	*P*	*CL*	*PL*	*CD*	*PD*	*CV*	*PV*	*T*	*N*
$0 < T \leq 30$	$M \leq -7.5$	0.067	0.282	0.982	11.457	1.439	10.077	0.084	−0.916	10.8	2.3	17.34	192
	$-7.5 < M \leq -2.5$	0.082	0.148	1.971	6.450	0.529	1.967	0.237	−0.763	20.2	8.3	15.39	237
	$-2.5 < M \leq 2.5$	0.115	0.106	4.090	3.485	0.350	0.406	0.559	−0.441	26.2	22.7	14.84	254
	$2.5 < M \leq 7.5$	0.146	0.076	7.595	1.904	1.281	0.464	0.848	−0.152	13.5	20.6	15.02	245
	$7.5 < M$	0.309	0.069	14.743	0.939	11.547	1.961	0.973	−0.027	2.8	9.5	16.01	377
$30 < T \leq 60$	$M \leq -7.5$	0.103	0.359	2.993	12.648	3.320	18.521	0.213	−0.787	4.9	0.8	42.25	144
	$-7.5 < M \leq -2.5$	0.144	0.200	5.149	8.518	3.240	8.908	0.407	−0.593	4.6	2.0	43.83	209
	$-2.5 < M \leq 2.5$	0.167	0.157	7.769	6.174	4.746	3.030	0.589	−0.411	3.9	4.4	44.90	240
	$2.5 < M \leq 7.5$	0.221	0.136	10.759	4.254	11.060	2.050	0.757	−0.243	2.2	5.4	43.58	201
	$7.5 < M$	0.359	0.090	15.510	2.582	19.101	2.217	0.903	−0.097	1.3	5.6	40.41	167
$60 < T$	$M \leq -7.5$	0.198	0.416	4.805	12.846	18.041	25.716	0.305	−0.695	0.8	0.3	68.28	25
	$-7.5 < M \leq -2.5$	0.226	0.296	7.081	9.377	19.524	21.434	0.468	−0.532	0.5	0.4	69.20	51
	$-2.5 < M \leq 2.5$	0.272	0.215	9.622	7.372	21.161	12.320	0.604	−0.396	0.7	0.8	70.95	80
	$2.5 < M \leq 7.5$	0.365	0.209	12.534	5.824	24.440	8.292	0.729	−0.271	0.8	1.2	68.33	30
	$7.5 < M$	0.563	0.197	20.751	3.661	27.722	13.788	0.866	−0.134	0.9	0.7	74.25	4
	Overall	0.185	0.156	7.715	5.449	6.098	4.495	0.592	−0.408	8.7	8.4	30.64	2456

Summary statistics for S&P 100 index calls and puts by maturity and strike-price categories using daily observations during 1989.
The sample includes all observations for which contemporaneous data for a call and a put are available, where the call and put have the same maturity date and strike price.
T denotes the maturity of the options in days.
M is the difference between the S&P 100 index value and the strike price of the option.
CBA and *PBA* are the average call and put bid-ask spreads measured in dollars. *C* and *P* are the average call and put prices measured in dollars and computed using the midpoint of the bid-ask spread.
CL and *PL* are liquidity measures equal to the average time in minutes between call and put trades during the day.
CD and *PD* are the deltas for the call and put computed using the Black-Scholes formula.
CV and *PV* are the daily trading volume for the call and put.
N is the number of options in each category.
The variables *CBA*, *PBA*, *C*, *P*, and *M* are averages computed daily during the 2:00 p.m. to 2:15 p.m. period.

spread for the options-market component of a synthetic share is $18.5 + 15.6 = 34.1$ cents. The average bid-ask spread for 13-week Treasury bills during 1989 implies that the average bid-ask spread for the bond-market component of a synthetic share is approximately 2.9 cents. Together, this implies that the bid-ask spread associated with a synthetic share of stock is about 37.0 cents. This is somewhat larger than the average quoted spread for NYSE stocks reported by Phillips and Smith (1980) and Vijh (1990)—20.5 cents and 21.3 cents, respectively. In contrast, the average spread for a synthetic share is similar to the average quoted spread for NASDAQ shares reported by Stoll (1989). Across volume deciles, he finds average quoted spreads to be between 33 and 35 cents, except for the largest decile where the average spread is 28 cents. These comparisons suggest that differences in market structure (the NYSE is a specialist market while the CBOE and NASDAQ have competitive market makers) have important implications for the costs of transacting. In particular, quoted bid-ask spreads appear to be smaller under a specialist system. This is consistent with Ho and Macris (1985) who argue that competitive-market-maker systems have higher fixed costs than specialist systems, but provide greater market depth because competing market makers are better able to absorb shocks to inventories.[9] This is also consistent with the hypothesis that informational asymmetries faced by specialists are less because specialists observe the information in the order book.

[9] Vijh (1990) conducts an empirical test of the Ho and Macris (1985) hypothesis using CBOE equity options data and also finds evidence that bid-ask spreads are lower in the NYSE specialist market.

C. Regression Results—Two-Equation Systems

The first set of results provides estimates of the relation between bid-ask spreads and the variables identified in Section II, while allowing trading activity to depend on the bid-ask spread and contractual features of option contracts. Since bid-ask spreads depend on trading activity and trading activity depends on bid-ask spreads, the following simultaneous system of regression equations is estimated for call options,

$$(1) \qquad CBA_i = \alpha_0 + \alpha_1 CDUM_i + \alpha_2 C_i + \alpha_3 CL_i + \alpha_4 T_i + \alpha_5 CR_i + e_i,$$

$$(2) \qquad CL_i = \gamma_0 + \gamma_1 CBA_i + \gamma_2 T_i + \gamma_3 T_i^2 + \gamma_4 M_i^2 + v_i,$$

where CR_i is the squared delta of the call option and $CDUM_i$ is a dummy variable that takes the value of one if the call option price is at least \$3. For put options, the following equations are estimated

$$(3) \qquad PBA_i = \beta_0 + \beta_1 PDUM_i + \beta_2 P_i + \beta_3 PL_i, + \beta_4 T_i + \beta_5 PR_i + u_i,$$

$$(4) \qquad PL_i = \delta_0 + \delta_1 PBA_i + \delta_2 T_i + \delta_3 T_i^2 + \delta_4 M_i^2 + w_i$$

as a simultaneous system, where PR_i is the squared delta of the put option and $PDUM_i$ is a dummy variable that takes the value of one if the put option price is at least \$3. The coefficient estimates from (1) and (3) can be used to test whether these variables have explanatory power for bid-ask spreads. The specifications of (2) and (4) are symmetric with respect to calls and puts to enable comparison of the results across contracts. These equations allow trading activity to depend on the bid-ask spread for the option; therefore, one can test for simultaneous determination of bid-ask spreads and trading activity. Trading activity is allowed to depend on maturity since hedging demands for the option may be horizon specific; T^2 is included to allow for the possibility of a nonlinear dependence. M^2 is included since trading volume tends to be higher for at-the-money options. These systems are estimated using a standard two-stage least squares procedure. The results from estimating Equations (1) and (2) for call options are reported in Table 2, and results from estimating (3) and (4) for put options are reported in Table 3.

The R^2 coefficients for the call and put bid-ask spread regressions are 0.688 and 0.675, respectively. Thus, the regressions are successful in capturing the majority of the cross-sectional variation in bid-ask spreads. This explanatory power is particularly striking given the simplicity of the cost model employed for the bid-ask spread.[10] Similarly, more than 50 percent of the cross-sectional variation in trading activity is explained by the level of the spread and features of the option contract. The explanatory variables used, however, are not designed to

[10]Other studies report R^2 coefficients of similar magnitudes for cross-sectional regressions involving bid-ask spreads for stocks. For example, Stoll (1989) and George, Kaul, and Nimalendran (1991) report R^2 coefficients of up to 0.68 and 0.89, respectively, for cross-sectional regressions of autocovariance-based spread estimates on quoted spreads of NASDAQ stocks. The regressions in this paper do not include explicit estimates of the spread, however. The independent variables in these regressions are determinants of market-making costs.

TABLE 2

Call Option Regression

$CBA_i = \alpha_0 + \alpha_1 CDUM_i + \alpha_2 C_i + \alpha_3 CL_i + \alpha_4 T_i + \alpha_5 CR_i + e_i$

α_0	α_1	α_2	α_3	α_4	α_5	Adj. R^2
0.08362	0.06114	0.01679	0.00902	−0.00228	−0.15378	0.688
(16.80)	(8.63)	(15.49)	(14.01)	(−12.31)	(−12.52)	

$CL_i = \gamma_0 + \gamma_1 CBA_i + \gamma_2 T_i + \gamma_3 T_i^2 + \gamma_4 M_i^2 + v_i$

γ_0	γ_1	γ_2	γ_3	γ_4		Adj. R^2
−3.8542	46.592	−0.12412	0.00406	0.00866		0.618
(−10.50)	(30.49)	(−6.01)	(14.43)	(4.76)		

Two-stage least squares estimates of a two-equation system for call bid-ask spreads and call liquidity. The data consist of daily observations during 1989.
CBA denotes the call bid-ask spread measured in dollars.
CDUM is a dummy variable that equals one if the call price is greater than or equal to three dollars.
C is the call price measured in dollars.
CL is a measure of the liquidity of the option and equals the average time in minutes between transactions during the day for the call.
T is the maturity of the call in days.
CR is a measure of the relative risk of the call and equals the squared delta for the call computed from the Black-Scholes formula.
M^2 is the squared difference between the S&P 100 index value and the strike price of the call.
t-statistics are reported in parentheses.
2456 observations.

TABLE 3

Put Option Regression

$PBA_i = \beta_0 + \beta_1 PDUM_i + \beta_2 P_i + \beta_3 PL_i + \beta_4 T_i + \beta_5 PR_i + u_i$

β_0	β_1	β_2	β_3	β_4	β_5	Adj. R^2
0.05707	0.03258	0.01726	0.00839	−0.00120	−0.08662	0.675
(15.19)	(5.35)	(15.90)	(12.56)	(−7.13)	(−7.15)	

$PL_i = \delta_0 + \delta_1 PBA_i + \delta_2 T_i + \delta_3 T_i^2 + \delta_4 M_i^2 + w_i$

δ_0	δ_1	δ_2	δ_3	δ_4		Adj. R^2
−2.8932	46.460	−0.15151	0.00339	0.01347		0.517
(−8.42)	(34.06)	(−7.74)	(12.90)	(10.86)		

Two-stage least squares estimates of a two-equation system for put bid-ask spreads and put liquidity. The data consist of daily observations during 1989.
PBA denotes the put bid-ask spread measured in dollars.
PDUM is a dummy variable that equals one if the put price is greater than or equal to three dollars.
P is the put price measured in dollars.
PL is a measure of the liquidity of the option and equals the average time in minutes between transactions during the day for the put.
T is the maturity of the put in days.
PR is a measure of the relative risk of the put and equals the squared delta for the put computed from the Black-Scholes formula.
M^2 is the squared difference between the S&P 100 index value and the strike price of the put.
t-statistics are reported in parentheses.
2456 observations.

fully account for the effects of adverse selection and strategic behavior on bid-ask spreads and trading activity (see Glosten and Milgrom (1985) and Kyle (1985)). This may explain why these explanatory variables do not explain all of the cross-sectional variation in spreads and trading activity.

The estimates of α_1 and β_1 measure the effect that the constraint on tick-size has on the quoted spreads of high-priced options. The greater the proportion of the sample for which the constraint is binding, the closer the estimates of these parameters will be to $1/16. The estimates of α_1 and β_1 are both statistically significant. The estimate of α_1 is just slightly smaller than $1/16, and the estimate of β_1 is approximately $1/32. This indicates that the constraint has a significant impact on the spreads of both calls and puts, but its impact is greater on the bid-ask spreads of calls. In addition to the importance of tick-size constraints on spreads, the estimates of α_2 and β_2 suggest the presence of a price-related component of market-making costs. The magnitude of these costs represents 1.68 percent of the call value and 1.73 percent of the put value. Both estimates are positive and statistically significant.

From Table 2, the level of trading activity is also an important determinant of bid-ask spreads. The estimates of α_3 and β_3 are both highly statistically significant and imply that the cost of market making is higher for options that are less actively traded.[11] A possible explanation is that market makers find it more difficult to maintain a neutral inventory position in less actively traded options. For these options, market makers bear relatively more unsystematic risk, which is reflected in the bid-ask spread. The magnitude of these estimates indicates that the market maker's cost of holding an option is 54 cents per hour for calls and 50 cents per hour for puts. These results are consistent with the models of Grossman and Miller (1988) and Biais and Hillion (1991) and suggest that market makers are averse to the risk of potential price changes associated with holding nonneutral option positions. Admati and Pfleiderer (1988), Foster and Viswanathan (1990), and Subrahmanyam (1990) offer an alternative explanation for these findings. In a model with strategic informed traders and discretionary liquidity traders, they show that concentrated trading activity reduces the adverse selection costs borne by market makers. This, in turn, implies that bid-ask spreads are smaller for options with greater trading activity.

The results imply that, on average, near-maturity options have wider spreads than long-maturity options. The estimates of α_4 and β_4 are both negative and statistically significant. This is consistent with the hypothesis that market making is more risky for near-maturity options, and that market makers increase the bid-ask spread to be compensated for bearing risk. A potential source of this risk is the risk of early exercise. To examine this further, each equation system was reestimated, including a dummy variable in the spread equation to indicate whether the option is within 14 days of expiration. In each case, the coefficient on this variable is insignificant and the other results remain unchanged. Each equation system was also reestimated, including a dummy variable in the spread equation to indicate whether the option is within 14 days of expiration *and* its strike price is within $3.00 of the level of the S&P 100 index. In each case, the coefficient on this variable is insignificant and the other results remain unchanged. This indicates that the risk of early exercise is not isolated to near-maturity (or near-maturity near-the-money) options. Instead, these findings are consistent with Harvey and Whaley's (1991) evidence that both long- and short-maturity options are exercised

[11]This is consistent with Stoll and Whaley (1990) who find that implicit bid-ask spreads for NYSE stocks tend to be inversely related to dollar volume of trade, and Neal (1987) who estimates a single-equation model of bid-ask spreads of equity options.

early, and suggest that the risk of early exercise has a significant impact on the bid-ask spreads of options of all maturities.

The estimates of α_5 and β_5 are both negative and significant. This finding is inconsistent with the hypothesis that options with greater deltas impose greater inventory risk on market makers. In fact, spreads are greater for options that are less risky, holding constant the level of trading activity and the option's time to maturity. A possible explanation for this puzzling finding is that options with the smallest deltas are the options whose *returns* are the most sensitive to changes in the S&P 100 index.[12] To examine this possibility, each equation system was reestimated, replacing option deltas with elasticities. In each case, the coefficient on the elasticity variable is insignificant, and the other results remain qualitatively unchanged. Differences in elasticities are not the explanation for the finding that spreads are negatively related to option deltas.

The parameter estimates for the regressions for trading activity in Tables 3 and 4 support the hypothesis that trading costs and trading activity are simultaneously determined. The estimates of γ_1 and δ_1 are both negative and highly significant. This is consistent with the prediction that higher trading costs diminish discretionary trading. To gauge the economic significance of this relation, note that a 1/16 increase in the bid-ask spread increases the average time between trades by 2.91 minutes for calls and 2.90 minutes for puts. The other parameter estimates reflect the fact that trading volume is higher for near-maturity at-the-money options.

D. Regression Results—Four-Equation System

One implication of the results so far is that bid-ask spreads and trading activity are jointly determined. Specifically, bid-ask spreads are larger for options that trade less actively, and trading activity is inversely related to the level of the spread. There may be an additional dimension of dependence between spreads and trading activity of S&P 100 index options. Because all of these options are written on the same underlying risk, traders may view them as close substitutes. This implies, for example, that the trading activity in one option depends on its bid-ask spread and the bid-ask spreads of other options. In addition, when market makers quote spreads for one option, they might condition their quotes on information contained in the spreads of other options.

These effects are analyzed by focusing on pairs of puts and calls that have the same strike price and maturity. For each pair, the following simultaneous system of four regression equations is estimated,

$$(5)\quad CBA_i = \alpha_0 + \alpha_1 CDUM_i + \alpha_2 C_i + \alpha_3 CL_i + \alpha_4 T_i + \alpha_5 CR_i + \alpha_6 PBA_i + e_i,$$

$$(6)\quad PBA_i = \beta_0 + \beta_1 PDUM_i + \beta_2 P_i + \beta_3 PL_i + \beta_4 T_i + \beta_5 PR_i + \beta_6 CBA_i + u_i,$$

$$(7)\quad CL_i = \gamma_0 + \gamma_1 CBA_i + \gamma_2 T_i + \gamma_3 T_i^2 + \gamma_4 M_i^2 + \gamma_5 PBA_i + v_i,$$

$$(8)\quad PL_i = \delta_0 + \delta_1 PBA_i + \delta_2 T_i + \delta_3 T_i^2 + \delta_4 M_i^2 + \delta_5 CBA_i + w_i.$$

[12]For example, Cox and Rubinstein (1985) show that out-of-the-money options have the highest elasticity with respect to the index.

These equations differ from those whose results appear in Tables 2 and 3 in two important respects. First, the bid-ask spread equation for call options, (5), includes the put bid-ask spread as an explanatory variable; and the bid-ask spread equation for put options, (6), includes the call bid-ask spread as an explanatory variable. The significance of these variables indicates whether market makers set bid-ask spreads in a manner that reflects information in the bid-ask spreads of closely related options. Second, the trading activity equation for call options, (7), includes the put option bid-ask spread as an explanatory variable; and the trading activity equation for put options, (8), includes the call option bid-ask spread as an explanatory variable. The sign and magnitude of the coefficients on these variables indicates the sensitivity of trading activity to the bid-ask spread of closely related options (i.e., potential substitutes). The results from estimating this system are presented in Table 4.

TABLE 4

Call and Put Option Regression

$CBA_i = \alpha_0 + \alpha_1 CDUM_i + \alpha_2 C_i + \alpha_3 CL_i + \alpha_4 T_i + \alpha_5 CR_i + \alpha_6 PBA_i + e_i$

α_0	α_1	α_2	α_3	α_4	α_5	α_6	Adj. R^2
0.05855	0.05628	0.01869	0.00751	−0.00217	−0.13969	0.09461	0.705
(8.01)	(8.37)	(18.29)	(12.50)	(−12.26)	(−11.28)	(3.54)	

$PBA_i = \beta_0 + \beta_1 PDUM_i + \beta_2 P_i + \beta_3 PL_i + \beta_4 T_i + \beta_5 PR_i + \beta_6 CBA_i + u_i$

β_0	β_1	β_2	β_3	β_4	β_5	β_6	Adj. R^2
0.05137	0.03016	0.01789	0.00783	−0.00114	−0.08032	0.01764	0.686
(9.81)	(5.44)	(17.43)	(13.48)	(−7.44)	(−6.67)	(1.09)	

$CL_i = \gamma_0 + \gamma_1 CBA_i + \gamma_2 T_i + \gamma_3 T_i^2 + \gamma_4 M_i^2 + \gamma_5 PBA_i + v_i$

γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	Adj. R^2
−2.8357	40.692	−0.11330	0.00431	0.01439	−6.1423	0.626
(−5.08)	(14.46)	(−5.44)	(14.62)	(4.89)	(−2.32)	

$PL_i = \delta_0 + \delta_1 PBA_i + \delta_2 T_i + \delta_3 T_i^2 + \delta_4 M_i^2 + \delta_5 CBA_i + w_i$

δ_0	δ_1	δ_2	δ_3	δ_4	δ_5	Adj. R^2
1.1569	25.601	−0.11308	0.00442	0.03875	−27.030	0.529
(2.16)	(10.06)	(−5.64)	(15.59)	(13.70)	(−9.98)	

Two-stage least squares estimates of a four-equation system for call and put bid-ask spreads and liquidity measures.
The data consist of daily observations during 1989.
CBA and *PBA* denote the call and put bid-ask spreads measured in dollars.
CDUM and *PDUM* are dummy variables equalling one when the call and put prices are greater than or equal to three dollars.
C and *P* are the call and put prices measured in dollars.
CL and *PL* are measures of the liquidity of calls and puts and equal the average time in minutes between transactions during the day for the options.
T is the maturity of the options in days.
CR and *PR* are measures of the relative risk of the options and are equal to the squared delta for each option computed from the Black-Scholes formula.
M^2 is the squared difference between the S&P 100 index value and the strike price of the option.
t-statistics are reported in parentheses.
2456 observations.

The results in Table 4 confirm the findings of Tables 2 and 3 for the variables included in the earlier regressions. In particular, option bid-ask spreads are positively related to the option price and the average time between transactions, and negatively related to the option's time to maturity and its squared delta. Furthermore, trading activity in an option is negatively related to the option's bid-ask spread, and positively related to the option's nearness to the money. Thus, even after accounting for the effect that put spreads have on call spreads and call trading activity, and vice-versa, the determinants of spreads implied by this analysis of market-making costs remain significant. The R^2 coefficients for the bid-ask spread regressions are slightly larger than those obtained with the earlier estimates of the two-equation systems.

The estimate of γ_5 measures the sensitivity of trading activity in call options to the bid-ask spread of put options having the same strike price and maturity, and vice-versa for δ_5. Both of these estimates are negative and highly statistically significant. This finding suggests that traders regard these matching call and put options as substitutes because trading activity in call options is positively related to the level of the bid-ask spread for the matching put options, and vice-versa. The magnitudes of these effects differ across options. A \$1/16 decrease in the put option bid-ask spread increases the time between trades in the matching call option by 0.38 minutes, on average. By contrast, a \$1/16 decrease in the call option bid-ask spread increases the average time between trades in the matching put option by 1.69 minutes. Thus, put option trading activity is more than four times as sensitive to call option spreads as call trading is to put spreads. This suggests that call option trading is an acceptable substitute for a portion of put option trading; while put option trading appears not to be as acceptable a substitute for call option trading.

The estimate of α_6 is positive and statistically significant, but its economic significance is small. Holding the determinants of market-making costs constant, the put bid-ask spread would have to change by over \$5/8 to generate a \$1/16 change in the bid-ask spread of the matching call. This suggests that in quoting call option bid-ask spreads, market makers incorporate information in the bid-ask spreads of matching put options, but the economic impact this has on call option spreads is small. The estimate of β_6 is statistically insignificant, which indicates that call option spreads have no explanatory power for put option spreads beyond that provided by the market-making cost variables.

IV. Conclusion

This paper examines the cross-sectional distribution of bid-ask spreads and trading activity in the S&P 100 index options market. An important feature of the analysis is that the underlying risks and market structure are held fixed across options. This enables one to focus on the relation between bid-ask spreads and determinants of the costs of market making, and the relation between trading activity and bid-ask spreads.

The first set of tests regards the bid-ask spread and trading activity of each option as jointly determined variables. Determinants of market-making costs explain almost 70 percent of the cross-sectional variation in bid-ask spreads. Approximately 50 percent of the cross-sectional variation in trading activity is explained by bid-ask spreads and features of the option contracts—maturity and nearness to the money. The resulting coefficient estimates suggest that bid-ask spreads are positively related to the option's time to maturity and its price, and negatively related to its delta and the level of trading activity. The evidence also indicates that trading activity is negatively related to the level of the bid-ask spread. These findings suggest that institutional features of the S&P 100 index options market affect the costs imposed on market makers, and that market makers bear unsystematic risk associated with their inventory positions in option contracts. The results also indicate that spreads and trading activity are simultaneously determined, and that trading activity is inversely related to the level of the bid-ask spread. This is consistent with the hypothesis that some of the trading in options is discretionary, and that higher levels of trading activity are associated with lower costs to market makers as predicted by a number of asymmetric information models (Admati and Pfleiderer (1988), Foster and Viswanathan (1990), and Subrahmanyam (1990)).

The second set of tests examines the relation between spreads and trading activity *across* options. To do this, the bid-ask spreads and trading activity of puts and calls having the same strike price and maturity are modeled as simultaneously determined variables. The results from these tests confirm the findings of the first set of tests, and provide evidence that spreads and trading activity of different options are simultaneously determined. In addition, the evidence suggests that traders regard these puts and calls as substitutes. Trading activity in calls is positively related to the bid-ask spreads of put options, and trading activity in puts is positively related to call bid-ask spreads. Both of these relations are statistically significant. Furthermore, call option bid-ask spreads are significantly positively related to bid-ask spreads for put options. This suggests that, in addition to the costs of market making, market makers quote spreads in a manner that reflects information contained in the quoted spreads of other options.

References

Admati, A., and P. Pfleiderer. "A Theory of Intra-Day Patterns: Volume and Price Variability." *Review of Financial Studies*, 1 (1988), 3–40.

Amihud, Y., and H. Mendelson. "Dealership Markets: Market-Making with Inventory." *Journal of Financial Economics*, 8, (1980), 31–53.

Biais, B., and P. Hillion. "Option Prices, Insider Trading, and Interdealer Competition." Working Paper, INSEAD (1991).

Characteristics and Risks of Standardized Options, Options Clearing Corporation (1989).

Constitution and Rules: Chicago Board Options Exchange and Options Clearing Corporation (Jan. 1990).

Cox, J., and M. Rubinstein. *Options Markets*. Englewood Cliffs, NJ: Prentice-Hall (1985).

Demsetz, H. "The Cost of Transacting." *Quarterly Journal of Economics*, 82 (1968), 33–53.

Easley, D., and M. O'Hara. "Price, Trade Size, and Information in Securities Markets." *Journal of Financial Economics*, 19 (1987), 69–90.

Foster, F. D., and S. Viswanathan. "A Theory of the Intraday Variations in Volumes, Variances and Trading Costs in Securities Markets." *Review of Financial Studies*, 3 (1990), 593–624.

George, T.; G. Kaul; and M. Nimalendran. "Estimation of the Bid-Ask Spread and its Components: a New Approach." *Review of Financial Studies*, 4 (1991), 623–656.

Glosten, L., and L. Harris. "Estimating the Components of the Bid-Ask Spread." *Journal of Financial Economics*, 21 (1988), 123–142.

Glosten, L., and P. Milgrom. "Bid, Ask and Transactions Prices in a Specialist Market with Heterogeneously Informed Traders." *Journal of Financial Economics*, 14 (1985), 71–100.

Grossman, S., and M. Miller. "Liquidity and Market Structure." *Journal of Finance*, 43 (1988), 617–637.

Harvey, C., and R. Whaley. "Dividends and S&P 100 Index Option Valuation." Working Paper, Duke Univ. (1991).

Ho, T., and R. Macris. "Dealer Market Structure and Performance." In *Market Making and the Changing Structure of the Securities Industry*, Y. Amihud, S. Y. Ho, and R. A. Schwartz, eds. Lexington Books (1985).

Ho, T., and H. Stoll."Optimal Dealer Pricing under Transactions and Return Uncertainty." *Journal of Financial Economics*, 9 (1981), 47–73.

Kyle, A. "Continuous Auctions and Insider Trading." *Econometrica*, 53 (1985), 1315–1335.

Neal, R. "Potential Competition and Actual Competition in Equity Options." *Journal of Finance*, 42 (1987), 511–531.

Phillips, S., and C. Smith. "Trading Costs for Listed Options: the Implications for Market Efficiency." *Journal of Financial Economics*, 8 (1980), 179–201.

Roll, R. "A Simple Measure of the Effective Bid-Ask Spread in an Efficient Market." *Journal of Finance*, 39 (1984), 1127–1139.

Stoll, H. "The Supply of Dealer Services in Securities Markets." *Journal of Finance*, 33 (1978), 1133–1151.

____________. "Inferring the Components of the Bid-Ask Spread: Theory and Empirical Tests." *Journal of Finance*, 44 (1989), 115–134.

Stoll, H., and R. Whaley. "Stock Market Structure and Volatility." *Review of Financial Studies*, 3 (1990), 37–71.

Subrahmanyam, A. "A Theory of Trading in Stock Iindex Futures." *Review of Financial Studies*, 4 (1990), 17–51.

Tinic, S. "The Economics of Liquidity Services." *Quarterly Journal of Economics*, 86 (1972) 79–93.

Vijh, A. "Liquidity of the CBOE Equity Options." *Journal of Finance*, 45 (1990), 1157–1179.

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