The Determinants of Bid-Ask Spreads in the Foreign Exchange Futures Market: A Microstructure Analysis

DAVID K. DING*

This paper investigates and analyzes the intraday and daily determinants of bid-ask spreads (BASs) in the foreign exchange futures (FXF) market. It is found that the number of transactions and the volatility of FXF prices are the major determinants. The number of transactions is negatively related to the BAS, whereas volatility in general is positively related to it. The study also finds that there are economies of scale in trading FXF contracts. The intraday BAS follows a U-shaped pattern, and they tend to be higher on Mondays and Tuesdays than on other days of the week. Higher spreads at the beginning and end of a trading day are consistent with the presence of adverse selection and the avoidance of the possibility of carrying undesirable inventory overnight, respectively. Seasonal differences in BASs that are related to the delivery date of a contract are also found. © 1999 John Wiley & Sons, Inc. Jrl Fut Mark 19: 307–324, 1999

The author gratefully acknowledges the helpful comments of the editor and two anonymous referees.
*Correspondence author, Division of Banking and Finance, Nanyang Business School, Nanyang Technological University, Singapore 639798, Singapore.

■ *David K. Ding is Associate Professor and Head, Division of Banking and Finance, Nanyang Technological University, Singapore.*

The Journal of Futures Markets, Vol. 19, No. 3, 307–324 (1999)

CCC 0270-7314/99/030307-18

INTRODUCTION

This article examines the determinants of bid-ask spreads (BAS) in the foreign exchange futures (FXF) market using the bid-ask spread estimator advanced by Chu, Ding, and Pyun (CDP, 1996). Many previous studies concerning bid-ask spreads have focused their analyses on the determinants, components, and behavior of BASs in the equity markets (see, for example, George, Kaul, and Nimalendran, 1991; McInish and Wood, 1992; Glosten and Milgrom, 1985; Glosten, 1987; Glosten and Harris, 1988; Copeland and Galai, 1983; Haller and Stoll, 1989; and Stoll, 1989, among others). A few researchers have examined BASs in the financial futures market (for example, Wang, Michalski, Jordon, & Moriarty, 1994; Ma, Peterson, & Sears, 1992; and Laux & Senchack, 1992). These studies deal mainly with the estimation and intraday behavior of the BAS.

There are some studies that analyze the BASs in the foreign exchange spot market (Overturf, 1982; Boothe, 1988; Glassman, 1987; Fieleke, 1975; Allen, 1977; and Bossaerts & Hillion, 1991). But hardly any study has been done to examine the determinants of BASs in the FXF market. The most closely related research is that by Harvey and Huang (1991), who study the volatility in the FXF market. Essentially, they find that increases in price volatility coincide with announcements of macroeconomic news and recognize that the variance is affected by the BAS.

The bid-ask spread represents a major component of a trader's transaction cost. In an order-driven market, such as in the futures market of the Chicago Mercantile Exchange (CME), the spread can only be implied. There are no specific quotes by official market makers. It is therefore imperative, in such a market, for a serious trader to have an understanding of the various factors that can have a significant impact on the BAS. A trader in the FXF market would want to know what drives the spread: (i) what is the impact of trading activity and price volatility on the BAS; (ii) whether there are any macroeconomic variables that can explain the size of the spread; and (iii) whether there is a particular period within the trading day, week, or contract month that represents higher or lower spreads and, hence, higher or lower transaction costs. The effect of the various factors on BASs in the FXF market may not necessarily be the same as those that drive the spreads in the foreign exchange spot market. Thus it is important for traders in the FXF market to appreciate the underlying factors that can contribute to their transaction costs and the timing of their transactions.

TRADING ON THE CHICAGO MERCANTILE EXCHANGE AND OTHER INSTITUTIONAL DETAILS

The Chicago Mercantile Exchange (CME) trades futures contracts in six currencies, including the deutsche mark (DM) and Japanese yen (JY) contracts. The trading hours are from 7:20 AM to 2:00 PM daily. A standard delivery schedule of March, June, September, and December is followed. Trading on the floor is through a system of open outcry where bid and offer prices are made known verbally in a trading pit. The actual trading of futures contracts on the exchange floor is done by *floor traders* or *floor brokers*, who are members of the exchange. Floor traders are those who trade for their own account, whereas floor brokers trade on behalf of their brokerage firm or for their firm's customers. Both floor traders and brokers are granted equal access to the market. However, brokers are required to trade for their customers before trading for their own account.

In the trading process, orders to buy or sell futures are sent to a member firm's representative on the trading floor through the telephone or a computerized order-entry system. The orders are then time-stamped and taken to the trading pit by an appointed runner. The floor broker, who handles a firm's trades in a specific contract or delivery month, takes responsibility for executing the order. All bids and offers must be announced through open outcry. Trading in a particular contract can only take place in a designated trading pit and within the officially established trading times. When an order is executed, it is again time-stamped, together with its price and trade size. Confirmation of the transaction is then transmitted to the firm's originating office and the customer. At the same time, a *pit observer* records the price of the trade for immediate entry into the CME's computerized price-reporting system for immediate transmission of the information to market participants globally.

In FXF markets, there are no official market makers such as the dealer-specialists of organized stock markets. Scalpers provide liquidity by quoting bid and ask prices against which market orders can be executed. This is as close as it can get to certain equity markets (such as the NYSE), where specialists make the market by buying and selling from their own inventory—but fundamentally different from a screen-based computerized market (such as in Singapore and Malaysia), where no designated market makers exist and transactions occur only when buy and ask orders match. In the screen-based equity markets, all trades are effected through computer matching of buy and sell quotes by strict price and time priority, and all transactions occur at posted prices. This means that there can be no difference between posted and effective spreads.

On the NYSE, also, the opening procedure is different from that of the futures market. The NYSE procedure involves a price discovery process in which the market is called to determine the best price that will effect the greatest number of transactions. In contrast, transaction prices in the futures market are determined through an open outcry process of bid and ask quotes on the trading floor. This means that even a pseudo-market maker such as the scalper does not simultaneously reveal both bid and ask quotes even though he may stand ready to buy from or sell to the market. This is very different from the specialist system of the NYSE, wherein the market makers (specialists) provide immediacy to the market by standing ready to buy and sell through quoting their bid and ask prices simultaneously. Because of the way prices are quoted, there can be some fundamental differences in the way bid-ask spreads are determined in the futures and equity markets. The implicit BASs of the futures contracts are not directly observable, but can be estimated using the covariance of price changes. These will be discussed later in this article.

FXF contracts trade primarily on the International Monetary Market (IMM) of the Chicago Mercantile Exchange (CME) with deutsche mark (DM) and Japanese yen (JY) futures contracts being the most actively traded of all currency contracts. FXF contracts also trade on the London International Financial Futures Exchange (LIFFE) and the smaller Singapore International Monetary Exchange (SIMEX), the Philadelphia Board of Trade, and some South American exchanges. However, interest on the LIFFE tapered off and trading was suspended in 1990. The CME had a mutual offset arrangement with the Singapore International Monetary Exchange (SIMEX) during 1990 (it was in operation from 1984 to 1995), whereby traders on the CME can offset their positions on the SIMEX without incurring any additional transaction costs. Thus, conceivably, a trader on the CME can react to new information and offet his position on the SIMEX during Chicago's closing hours.

LITERATURE REVIEW AND HYPOTHESES

In the equity market, McInish and Wood (1992) show that intraday BASs depend negatively on the level of activity and market competition, and positively on the level of risk and information. In the foreign exchange market, Boothe (1988) finds that different measures of risk and transactions volume have an impact on BASs. Specifically, he provides evidence for a positive relationship between the level of uncertainty regarding future prices and BASs. The relationship between trading volume and BASs is found to be negative.

In the futures market, Ma, Peterson, and Sears (1992) examine various measures of BASs on different futures contracts and find that spread levels are significantly higher at the beginning and end of a trading session. They provide the explanation of higher levels of trading noise and information uncertainty during those periods. However, these phenomena can be caused by infrequent trading.

Wang, Michalski, Jordan, and Moriarty (1994) investigate the determinants of the bid-ask spread and price volatility of S&P 500 index futures that are traded on the Chicago Mercantile Exchange. They find that the major factors affecting BASs are the price risk, trade volume, and market competition. They also find a U-shaped pattern in BASs. However, they realize that this pattern is not significant after adjusting for the effects of price volatility, transaction volume, and market competition.

I utilize the findings in the equity and foreign exchange markets to investigate the forces driving BASs in the FXF market. Activity measures usually encompass two main components—the number of transactions and the trading volume per transaction. As trading activity increases, the market becomes more liquid. Scalpers in the FXF market provide liquidity by quoting bid and ask prices against which market orders can be executed. Garbade and Silber (1979) find that the actions of scalpers reduce the volatility of price movements. Hence, an increase in the number of transactions and trading volume can lead to scale economies, resulting in lower BASs. However, Easley and O'Hara (1987), Glosten (1989), and Kyle (1985) suggest that adverse selection should increase with order size.

Similarly, according to inventory models of the BAS, order processing costs also increase with trade size. Thus an increase in BASs due to both adverse selection and order processing costs should be due to an increase in the order size. But Haller and Stoll (1989) find an inverse relationship between BASs and trading volume in the German auction equity market. Copeland and Galai (1983) maintain that market activity is a negative function of BASs. Based on the results of previous studies, I do not expect to see any significant difference, if any, in the way trading activity affects the BAS among the equity, spot foreign exchange, and futures markets. The following hypothesis is therefore investigated.

Hypothesis 1: BASs in the FXF market are negatively related to trading activity.

McInish and Wood (1992) use a transformed ratio of the number of shares traded on regional exchanges to the number of shares traded on the New York Stock Exchange (NYSE) to establish an inverse relationship between BASs and the level of competition. In the FXF market, contracts trade primarily on the International Monetary Market (IMM) of the CME with deutsche mark (DM) and Japanese yen (JY) futures contracts being the most actively traded. Competition from other exchanges is slight and any effects from the competition should be minimal. Consequently, this study does not attempt to establish such a relationship in the FXF market.

The uncertainty regarding future exchange rates subjects dealers to the risk of holding onto a contract. There are a number of possible measures of risk in the FXF market, such as those investigated by Fieleke (1975) and Overturf (1982). Overturf finds a positive BAS relation to price volatility measured by its standard deviations, whereas Fieleke reports a positive relationship between the rate of change in the exchange rate and the cost of transacting in the foreign exchange market. Overturf further suggests that the uncertainty regarding the rate of change in exchange rates tends to widen the BAS. In the FXF market, BASs are not directly observable but can be estimated using the covariance of price changes. Wang et al. (1994) demonstrate that OLS estimates of the BAS equation are inconsistent if the standard deviation of transaction price changes is found in the regression. Thus, in order to avoid a misspecification of the BAS regression model [such as eq. (3)], a measure of volatility other than the standard deviation, which is related to the covariance, should be applied.

Garman and Klass (1980) provide a volatility measure that does not contain the standard deviation but rather takes into account the open, high, low, and closing prices of each time period. Their estimator has been found to be more efficient than the traditional close-to-close estimators. The specification of the Garman-Klass estimator is detailed later in this article. In line with prior expectations, the following hypothesis is anticipated to hold.

***Hypothesis* 2**: The volatility of FXF prices has a direct relationship with the BAS.

The presence of asymmetric information exposes a trader to the problem of adverse selection. The trader expects a loss, a priori, due to uninformed trading. Copeland and Galai (1983) show that, all else being equal, informational uncertainty is positively related to the BAS. They report that the BAS is a positive function of the price level and the return variance. If high price levels result from informed trading, then the relationship between price levels and BASs should be positive. In most empirical studies of BASs in the stock markets, a positive price–BAS relation has been found (for example, Demsetz, 1968; Benston & Hagerman, 1974; Stoll, 1976; and Copeland & Galai, 1983). These studies generally attribute their findings of large dealer spreads to the risk of adverse selection or uninformed trading. However, McInish and Wood (1992) find a negative BAS–price relationship. They ascribe their finding to the presence of economies of scale in trading. When prices are high, the dollar volume of transactions rises. This leads to a lowering of dealers' required BAS to cover their costs.

In FXF markets, however, there are no official market makers such as the dealer-specialists of organized stock markets. Therefore, the relationship between price levels and BASs, if any, may not be obvious. A positive BAS-price relationship supports an asymmetric information hypothesis, whereas a negative relationship lends support to the presence of scale economies in trading in the FXF market. Hence this study examines the information conveyed through price levels in the framework of the FXF market. The following null hypothesis is examined.

Hypothesis 3: There is no relationship between BASs in the FXF market and price levels.

This article further postulates that there are intraday, weekday, and seasonal patterns in the BAS, reflecting the changing underlying structure of the market. Admati and Pfleiderer (1988) suggest that trades will be concentrated during certain times of the day. In particular, discretionary liquidity traders are thought to concentrate their trades during the periods near the opening and closing of the market. McInish and Wood (1992) report a reversed J-shaped pattern in intraday BASs that is inversely related to trading activity. This means that BASs are higher at the beginning and end of a trading day than the rest of the day. In addition, they find that weekday patterns, though mostly significant, are weaker than intraday patterns. Weekday patterns are also found to be unstable over time. In the FXF market, traders are possibly faced with a greater degree of the adverse selection problem at the start of a trading day than the rest of the day. There is also an increase in the likelihood of carrying undesirable inventory overnight toward the end of the trading day. Hence spreads are expected to be higher at the beginning and end of a trading day.

Bossaerts and Hillion (1991) have developed an asymmetric information model of BASs in the foreign exchange market and they document evidence of asymmetric information for all days of the week. However, spreads on Fridays are found to be more pronounced. Information asymmetry is thought to be accompanied by an increase in the BAS. Because governments usually reveal their intention to intervene in the currency market during weekends when the foreign exchange markets are closed, BASs may be expected to increase on Fridays. This may be explained by the increased uncertainty from the possibility of having informed traders transact on the Friday before the government's announcement. McInish and Wood (1992) also present evidence of larger spreads on Fridays in the equity market. Moreover, because futures contracts can have different delivery dates, a seasonal pattern that reflects the various maturities is also expected and is investigated. This article represents one of the first to study the existence of a maturity pattern.

DATA AND METHODOLOGY

Data

The study uses the time-stamped transaction-by-transaction data of the deutsche mark (DM) and Japanese yen (JY) futures contracts that are traded on the International Monetary Market of the Chicago Mercantile Exchange (CME) for the year 1990. Time series of transaction prices and price changes for the March, June, September, and December delivery dates of each FXF are constructed. Close-to-open (that is, overnight, weekend, and holiday) price changes, from the market's closing time to the its next opening session, and trades after the market's official closing time are excluded from the data. In order to avoid a possible maturity effect and the necessity to adjust for a time-varying volatility in price changes (Laux & Senchack, 1994), observations are collected for each contract until two weeks prior to its delivery date. Data for the March contract begin 2 January; for the June contract, 8 March; for the September contract, 7 June; and for the December contract, 6 September. The series of data are then chronologically appended to each other to form a long time series of prices and price changes for 1990. The total number of price change observations for the DM futures over the four contract dates is 294,502; for the JY futures, it is 281,980.

Deutsche mark and Japanese yen futures prices are selected for this study for two main reasons: (i) They are the two most actively traded currency futures contracts on the CME that are chosen in order to avoid a possible bias caused by infrequent trading as pointed out by Ma et al. (1992); (ii) the BAS estimator used in this study follows that advanced by Chu, Ding, and Pyun (CDP, 1996) and it is judicious to use a similar data set as that employed by CDP in the development of their model. In the current analysis, as in CDP, the trading period from 7:20 AM to 2:00 PM within each trading day is divided into thirteen time intervals: The first interval has 40 minutes, whereas the remaining twelve intervals consist of 30 minutes each for a total of 400 minutes in each trading day.

The CDP Estimator for Bid-Ask Spreads

The CDP spread estimator shown in eq. (1) considers the intraday Markovian bid-ask bounce process, which leads to a desirable equilibrium condition of reaching a bid or an ask transaction type with equal chances. Based upon a second-order Markov process, the derived estimator is shown to be a more generalized estimator of BASs than in previous studies, such as those of Roll (1984) and Choi, Salandro, and Shastri (1988). It considers the conditional probability of a subsequent transaction's being the same type as that of the current transaction (δ), and the conditional probability of the next transaction's being the same as the current type but different from the previous type (α). CDP's results show that the average implied BAS is about \$10, which is less than the value of one tick size of \$12.50. The small BAS reveals the low trading cost and high operational efficiency in the FXF market.

Methodology

Various models have been advanced for the estimation of the BAS and its components (for example, Roll, 1984; Choi, Salandro, & Shastri, 1988; George, Kaul, & Nimalendran, 1991; Laux & Senchack, 1994; and Chu, Ding, & Pyun, 1996). Because BASs are not directly observable in the FXF market, they need to be estimated first. The model derived by Chu, Ding, and Pyun (1996) is used for this purpose. The CDP model builds on both the Roll (1984) and Choi, Salandro, and Shastri (1988) models and is intended to be an improvement over the two models. CDP have shown that these two previous models are a special case of their new model. As shown by Laux and Senchack (1992), Roll's estimator is more suited for futures prices, because it mainly measures order processing costs that form the bulk of the transaction costs in the futures market where adverse selection problems are less pronounced. It follows, therefore, that BAS estimators that are Roll-based are more applicable to the futures market rather than the equity market.

The approach of George, Kaul, and Nimalendran (1991) is largely applicable to equity prices where the components of the BAS are estimated separately. Laux and Senchack (1992) provide an alternative estimate for the BAS of currency futures in a heteroskedastic market in which more weight is assigned to observations in periods of light trading. The CDP model, however, assumes a second-order Markov process to derive a more general BAS estimator that is Roll-based but has less restrictive assumptions than Roll's estimator. It utilizes only the transaction price data to estimate BASs and is specified as:

$$s = \sqrt{\frac{-Cov(\Delta p_t, \Delta p_{t+1})}{(1 - \delta)(1 - \alpha)}} \tag{1}$$

where s is the implied BAS; Δp_t is the price change at time t; Cov refers to the covariance between two consecutive price changes; δ is the conditional probability that the next transaction type (bid or ask) is the same as the current transaction type; and α is the conditional probability that the next transaction type is the same as the current type but different from the previous type. Eq. (1) has been derived using a second-order Markov chain transition matrix model where α and δ are maximum likelihood estimates. If $\alpha = \delta$, eq. (1) reduces to the Choi, Salandro, and Shastri (1988) model. If $\alpha = \delta = 0.5$, it reduces to Roll's (1984) model. Thus, eq. (1) is a more generalized BAS estimator and both the Roll and Choi et al. estimators are special cases of the CDP model.

The implied BASs are first estimated for each time interval and trading day by the CDP method.[1] In order to ascertain the determinants of the BAS, the implied spread is regressed against variables that represent the level of activity, risk, information, and interest rate differential, together with three sets of dummy variables (D1, D2, D3) that serve to measure intraday, weekday, and seasonal effects, respectively. The intraday and weekday effects are readily understood. The seasonal effects are those that exhibit differences in spreads for the different delivery months in a year. It should be pointed out that spread values, rather than percentages spreads (as in McInish & Wood, 1992), are measured in this study for two reasons. First, the results where the spread value, rather than the relative spread, is used as the dependent variable would convince that the significance of the regression coefficients is not spurious. Sec-

[1]It should be noted that the CDP estimator is Roll (1984) based and utilizes the covariance of price changes in each time interval of a trading day. There are, however, some intervals where the covariance is positive, rendering it impossible to estimate a BAS for those intervals. If this occurs, then observations for the affected intervals will not be included in the analysis. The author recognizes that the exclusion of data in this manner is a fundamental weakness of all Roll-based spread estimators. But, in this study, no more than a third of the observations have been excluded in any time interval. In Roll's study, however, his sample included up to a 51% occurrence rate of positive covariances.

ond, unlike McInish and Wood's study, no averaging of the spreads is required. The regression for each contract is a time series one and there is no motivation to measure relative spreads.

Because data for the trading volume per transaction are not available, activity levels can only be measured by the number of transactions (NTRANS) in each time interval t and trading day d together with the trading volume per day. The variable NTRANS therefore serves as a proxy measure for intraday activity levels. Differential risk over the thirteen time intervals in each day are captured through the Garman-Klass (1980) volatility measure (GK) in each time interval. The GK estimator is specified as

$$GK = 0.511(a + b)^2 - 0.019[x(a - b) + 2ab] - 0.383x^2 \quad (2)$$

where x = ln(close/open); a = ln(high/open); and b = −ln(low/open). It is recognized that the GK estimator is susceptible to the effects of outliers. To check for the possible existence of outliers, the basic statistics in each time interval are examined for any inconsistencies and the transaction prices are visually inspected to identify any unusual prices. This procedure resulted in the elimination of one observation that was peculiarly large in the JY December contract on October 5, 1990.[2]

Information effects are evaluated by a price dummy variable (PRDUM) in each time interval.[3] The median transaction price is first identified from the entire time series. The average price within each interval is then computed and compared to the overall median price. If the average price is greater than the median price, then the variable PRDUM is assigned a value of one. Otherwise, a value of zero is assigned.

The empirical analysis is performed through the use of a regression model. The model, which is an interval analysis of transaction prices, is specified as

$$\begin{aligned} s_{t,d} = {} & \beta_0 + \beta_1 NTRANS_{t,d} + \beta_2 NGK_{t,d} + \beta_3 PRDUM_{t,d} \\ & + \sum_{i=4}^{15} \beta_i D1_{i,t,d} + \sum_{i=16}^{19} \beta_i D2_{i,t,d} + \sum_{i=20}^{22} \beta_i D3_{i,t,d} + e_{t,d} \quad (3) \end{aligned}$$

where $s_{t,d}$ is the interval BAS; NTRANS is the number of transactions in

[2]Caution was taken not to arbitrarily eliminate legitimate large price change observations, because, other than the one already eliminated, the next "big" price change has many occurrences and they cannot be prudently regarded as outliers.

[3]Although the price level, rather than a price dummy, may generally provide more information, the regression with the dummy shows a stronger relationship with the BAS, and only the results containing the dummy variable are reported here. Moreover, the intention is to find out if there is a BAS-price relationship, rather than the magnitude of such a relationship.

TABLE I

Intraday Implied Bid-Ask Spreads and Volatility (Amounts in US$ Per Contract)

		Bid-Ask Spread		*Std Dev of BAS*		*% of Neg. Cov.*	
Time Interval		*DM*[a]	*JY*[b]	*DM*	*JY*	*DM*	*JY*
1.	7:20–8:00	12.89	12.27	3.68	3.71	95	87
2.	8:00–8:30	11.14	11.88	3.91	4.31	92	81
3.	8:30–9:00	10.62	10.85	3.78	4.08	87	79
4.	9:00–9:30	10.35	10.26	3.91	4.00	82	72
5.	9:30–10:00	9.35	9.82	3.40	3.96	81	69
6.	10:00–10:30	9.19	9.85	3.52	4.03	79	72
7.	10:30–11:00	8.61	9.83	3.65	3.78	77	68
8.	11:00–11:30	9.31	9.85	3.65	4.82	83	74
9.	11:30–12:00	9.96	10.29	3.73	4.31	84	69
10.	12:00–12.30	9.78	10.84	3.82	4.66	77	72
11.	12:30–13:00	10.10	10.52	3.88	4.20	78	70
12.	13:00–13:30	10.77	10.23	3.82	4.18	83	76
13.	13:30–14:00	12.87	12.32	3.78	4.36	92	89

Notes: BASs for each time interval and trading day over the four delivery dates are computed for those intervals where a negative covariance in price changes exist. Positive covariances are ignored. BASs are then averaged across all days for each time interval to obtain the mean BAS and the standard deviation for that interval. The percentage of days with a negative covariance of price changes is reported in the last two columns. There are 294,502 price change observations for DM futures and 281,980 price change observations for JY futures.

[a]Deutsche mark futures contracts. Each contract trades for DM125,000.

[b]Japanese yen futures contracts. Each contract trades for ¥12.5 million.

the time interval; NGK is 10,000 times the value of GK; PRDUM is the price dummy described above; D1, D2, and D3 capture the intraday, weekday, and seasonal effects, respectively; and $e_{t,d}$ is a random error term.

EMPIRICAL RESULTS

Results are presented for the intraday analysis for each of the DM and JY contracts. A pooled data analysis of both contracts was also done but the results are not reported here. Overall, the findings from the pooled analysis support the individual analysis.

Utilizing the 294,502 price change observations of the DM contracts and the 281,980 price change observations of the JY contracts, the maximum likelihood estimates of α and δ are found to be 0.4447 and 0.4372, respectively, for the DM contract; and 0.4941 and 0.4748, respectively, for the JY contract. Substituting the values of these estimates into eq. (1) yields the average intraday BASs and their standard deviations reported in Table I. It should be pointed out that, whereas the values of α and δ

for the JY contracts are close to 0.5 [which could justify simply using the Roll (1984) model], the corresponding values for the DM contracts deviate sufficiently from 0.5 to support the use of the CDP model in estimating bid-ask spreads. Applying Roll's model would have over estimated the size of the spread. The estimated spreads shown in Table I are largely within one tick size of $12.50 except during the first and last time interval of DM trading. This is consistent with efficient estimators of the BAS.

Although it is observed that the BAS for both contracts is higher during the first 40 minutes and last 30 minutes of trading, the corresponding volatility, as measured by their daily standard deviation in each time interval, does not reveal any particular pattern. However, it is interesting to see that the BASs of the JY contracts are, in general, more volatile than those of the DM contracts. The last two columns of Table I report the percentage of negative covariances in each time interval. It is noted that the lowest value for the DM contract is 77%, whereas that for the JY contract is 68%. These figures provide a sense for the validity of using eq. (1) in estimating the implied BASs.

The regression model of eq. (3) is run to examine the determinants of intraday BASs in the FXF market. Results of this regression are presented in Table II. The strength of this regression is supported by the F-statistics of 58.44 for the DM contracts and 38.17 for the JY contracts. These values are statistically significant at the 0.01 level. The adjusted R-squares of 0.3296 for the DM and 0.2616 for the JY show that, respectively, 32.96% and 26.16% of the variation in intraday BASs are explained by the independent variables.

As expected, the level of trading activity, as measured by the variable NTRANS, is significantly negative at the 0.01 level for both the DM and JY contracts. The result confirms Hypothesis 1 that the number of transactions in an intraday time interval is negatively related to the size of the BASs in the interval. One inference from this result is that there are economies of scale in trading. The interval risk in FXF prices has been found to be directly related to the intraday BAS, confirming Hypothesis 2. This is supported by the strong coefficients of the Garman-Klass volatility measure (NGK) that are statistically significant at the 0.01 level. These results are consistent with findings from the existing microstructure literature that show a positive relationship between risk and the size of spreads.

The price dummy variable (PRDUM), on the other hand, is found to be negatively significant at the 0.01 level for both contracts. This finding dominates the presence of any asymmetric information trading. It is therefore consistent with the presence of trading economies in the FXF

TABLE II

Results for the Regression of Interval Bid-Ask Spreads per Contract Against Activity, Risk, and Information Variables

	Deutsche Mark		Japanese Yen	
Independent Variables	*Coefficients*	*t-statistics*	*Coefficients*	*t-statistics*
Intercept	11.6002	29.88[b]	11.6965	22.93[b]
NTRANS	−0.0446	−22.07[b]	−0.0475	−19.67[b]
NGK	15.8543	6.21	30.4039	9.51[b]
PRDUM	−0.853	−4.11[b]	−0.7435	−2.72[b]
Interval 1	7.3781	21.24[b]	6.2545	14.60[b]
Interval 2	3.2195	9.96[b]	2.9005	7.33[b]
Interval 3	2.2179	6.78[b]	1.6857	4.24[b]
Interval 4	1.9434	5.85[b]	1.0087	2.48[b]
Interval 5	1.0061	3.02[b]	0.3092	0.76
Interval 6	0.8143	2.43[a]	0.3570	0.88
Interval 8	0.4380	1.32	0.2077	0.52
Interval 9	1.0759	3.26[b]	0.5215	1.27
Interval 10	0.3515	1.04	0.7018	1.73
Interval 11	0.6546	1.94	0.4386	1.07
Interval 12	1.2178	3.65[b]	0.2675	0.67
Interval 13	4.6912	14.45[b]	3.8241	9.82[b]
Monday	1.1251	5.51[b]	0.9853	3.99[b]
Tuesday	0.4407	2.19[a]	0.5287	2.16[a]
Wednesday	0.2799	1.38	0.0479	0.20
Thursday	0.3947	1.90	0.3529	1.40
March	0.6131	2.13[a]	1.8801	6.91[b]
June	1.1975	4.79[b]	1.5719	4.38[b]
September	0.4991	2.56[b]	0.1052	0.31
N	2572		2309	
Adjusted R^2	0.3296		0.2616	
F-Statistic	58.44[b]		38.17[b]	

Notes: The trading period from 7:20 AM to 2:00 PM within each trading day is divided into thirteen time intervals: The first interval has 40 minutes and the remaining twelve intervals consist of 30 minutes each for a total of 400 minutes. BASs are first estimated for each time interval and trading day. They are then regressed against variables that represent the level activity, risk, information, and interest parity together with three sets of dummy variables (D1, D2, D3) that serve to measure intraday, weekday, and seasonal effects, respectively. Activity level is measured through the number of transactions (NTRANS) in each time interval. Differential risk across time intervals in each day is captured through the German-Klass (1980) volatility measure (GK) that takes into account the open, high, low, and closing prices. The variable NGK is 10,000 times GK. Information effects are evaluated by a price level dummy variable (PRDUM) for each time interval. The median transaction price is first identified from the entire time series. The average price within each interval is then computed and compared to the overall median price. If the average price is greater than the median price, then the variable PRDUM is assigned a value of one. Otherwise, a value of zero is assigned.
[a]Significant at the 0.05 level.
[b]Significant at the 0.01 level.

market and supports the results of McInish and Wood (1992) for the stock market. Copeland and Galai (1983) had argued that higher price levels in the stock market are associated with larger spreads because of a higher informational uncertainty due to the bidding up of prices by informed traders. But my finding of lower spread levels when prices increase supports the notion of the presence of economies of scale in trading futures contracts. Thus Hypothesis 3, which states that there is no relationship between BASs and prices, does not hold.

The existence of intraday patterns in BASs implies that the size of the BAS depends on the time interval in a trading day. The first five and last two intervals of trading for the DM contract contribute positively and significantly to BASs at the 0.01 level. These are evidenced by the statistically significant interval dummy variables at the 99% confidence level. These intervals encompass the time from 7:20 AM to 10:00 AM, and from 1:00 PM to 2:00 PM, respectively. For the JY contract, BASs are positively significant at the 0.01 level during the first four and the last intervals of trading. These occur during the trading times from 7:20 AM to 9:30 AM, and from 1:30 PM to 2:00 PM, respectively. The results demonstrate that, except in interval 9 for the DM contract, it may be less costly to trade during the interior time periods of a trading day.

Higher spreads at the beginning of a trading day may be due to certain traders having less information and their uncertainty about the behavior of the market. It can also be attributed to some traders having private or superior information that are not available to others. The higher BASs serve to compensate the unofficial market makers for assuming the risk of uninformed trading. The higher price risk at the end of the trading day and the resultant increase in spreads may be caused by the uncertainty related to an increase in the possibility of carrying undesirable inventory overnight. There are also weekday trading patterns in the FXF market. Both the DM and JY contracts portray significantly positive coefficients in the weekday dummy variables on Monday (at the 0.01 level) and on Tuesday (at the 0.05 level). This phenomenon reveals a weekday preference for trading that may be related to a varying cost of transaction.

The coefficients of the dummy variables for each contract delivery month are all positive. They are significant at the 0.01 level for the June and September DM contracts, and the March and June JY contracts. In addition, the March DM contract is significantly related to BASs at the 0.05 level. These results indicate that there are differences in BASs by delivery months, suggesting the presence of a seasonal effect in BASs. The findings reveal that it may be less costly, in terms of the BAS, to transact in the FXF market for nearby December DM and JY contracts, and more costly to execute trades in nearby June DM and March JY contracts. The lower BAS for December contracts is consistent with a higher trading activity which saw 85,299 price changes for the DM contracts and 102,553 price changes for the JY contracts. This contrasts with

70,538 and 48,228 observations for the March DM and JY contracts, respectively; 65,837 and 66,113 for the June contracts; and 72,828 and 65,086 for the September contracts.

SUMMARY AND CONCLUSIONS

This article has investigated and analyzed the intraday determinants of BASs in the FXF market. It has been found that the number of transactions and the volatility of FXF prices are major determinants of intraday BASs. The number of transactions is negatively related to BASs, whereas volatility in general is positively related. These variables proxy for activity level and risk and are consistent with findings from previous studies. This study also finds that there are economies of scale in trading FXF contracts.

Intraday and weekday patterns in BASs have been found. BASs exhibit a U-shape pattern during the trading day, whereas BASs are higher during Mondays and Tuesdays than during other days of the week. Higher spreads at the beginning and end of a trading day reflect the presence of adverse selection and the possibility of carrying undesirable inventory overnight, respectively. There are also seasonal differences in BASs that have been found in the analysis.

Although this paper has investigated and identified some key determinants of BASs in the FXF market, it recognizes the possibility that others may exist. The identification of such other determinants is best left to future research to examine the stability of the present determinants over time and contract type. In general, however, activity levels and risk are thought to be stable determinants and are found to support those of previous studies. Moreover, the patterns of BASs should also prove to be time and contract invariant.

BIBLIOGRAPHY

Admati, A., & Pfleiderer, P. (1988). A theory of intraday trading patterns: Volume and price variability. Review of Financial Studies, 1, 3–40.

Allen, W. (1977). A note on uncertainty, transactions cost and interest parity. Journal of Monetary Economics 3, 367–373.

Benston, G. J., & Hagerman, R. L. (1974). Determinants of bid-ask spreads in the over-the-counter market. Journal of Financial Economics, 1, 353–364.

Boothe, P. (1988). Exchange rate risk and the bid-ask spread: A seven country comparison. Economic Inquiry, 26, 485–492.

Bossaerts, P., & Hillion, P. (1991). Market microstructure effects of government intervention in the foreign exchange market. Review of Financial Studies, 4, 513–541.

Choi, J., Salandro, D., & Shastri, K. (1988). On the estimation of bid-ask spreads: Theory and evidence. Journal and Financial and Quantitative Analysis, 23, 219–230.

Chu, Q. C., Ding, D. K. & Pyun, C. S. (1996). Bid-ask bounce and spreads in the foreign exchange futures market. Review of Quantitative Finance and Accounting, 6, 19–37.

Copeland, T., & Galai, D. (1983). Information effects on the bid-ask spread. Journal of Finance, 38 (December), 1457–1469.

Demsetz, H. (1968). The cost of transacting. Quarterly Journal of Economics, 82, 33–53.

Easley, D. & O'Hara, M. (1987). Price, trade size, and information in securities markets. Journal of Financial Economics, 19, 69–90.

Fieleke, N. (1975). Exchange-rate flexibility and the efficiency of the foreign-exchange markets. Journal of Financial and Quantitative Analysis, 10, 409–428.

Garbade, K., & Silber, W. (1979). Structural organization of securities markets: Clearing frequency, dealer activity and liquidity risk. Journal of Finance, 34, 577–593.

Garman, M. B., & Klass, M. J. (1980). On the estimation of security price volatilities from historical data. Journal of Business, 53, 67–78.

George, T., Kaul, G., and Nimalendran, M. (1991). Estimation of the bid-ask spread and its components: A new approach. Review of Financial Studies, 4, 623–656.

Glassman, D. (1987). Exchange rate risk and transactions costs: Evidence from the bid-ask spread. Journal of International Money and Finance, 6, 479–490.

Glosten, L. (1987). Components of the bid-ask spread and the statistical properties of transaction prices. Journal of Finance, 42, 1293–1307.

Glosten, L. (1989). Insider trading, liquidity, and the role of the monopolist specialist. Journal of Business, 62, 211–235.

Glosten, L., & Harris, L. (1988). Estimating the components of the bid/ask spread. Journal of Financial Economics, 21, 123–142.

Glosten, L., & Milgrom, P. (1985). Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. Journal of Financial Economics, 14, 71–100.

Haller, A., & Stoll, H. (1989). Market structure and transaction costs: Implied spreads in the German stock market. Journal of Banking and Finance, 13, 697–708.

Harvey, C., & Huang, R. (1991). Volatility in the foreign currency futures market. Review of Financial Studies, 4, 543–569.

Kyle, A. (1985). Continuous auctions and insider trading. Econometrica, 53, 1315–1335.

Laux, P., & Senchack, A. (1992). Bid-ask spreads in financial futures. The Journal of Futures Markets, 12, 621–634.

Laux, P., & Senchack, A. (1994). Estimating the bid-ask spread in a heteroskedastic market: The case of foreign currency futures. Review of Quantitative Finance and Accounting, 4, 219–237.

Ma, C., Peterson, R., & Sears, S. (1992). Trading noise, adverse selection, and intraday bid-ask spreads in futures markets. The Journal of Futures Markets, 12, 519–538.

McInish, T., & Wood, R. (1992). An analysis of intraday patterns in bid/ask spreads for NYSE stocks. Journal of Finance, 47, 753–764.

Overturf, S. (1982). Risk, transactions charges, and the market for foreign exchange services. Economic Inquiry, 20, 291–302.

Roll, R. (1984). A simple implicit measure of the effective bid-ask spread in an efficient market. Journal of Finance, 39, 1127–1139.

Stoll, H. (1976). Dealer inventory behavior: An empirical investigation of NASDAQ stocks. Journal of Financial and Quantitative Analysis, 11, 350–380.

Stoll, H. (1989). Inferring the components of the bid-ask spread: Theory and empirical tests. Journal of Finance, 44, 115–134.

Wang, G., Michalski, R., Jordan, J., & Moriarty, E. (1994). An intraday analysis of bid-ask spreads and price volatility in the S&P 500 index futures market. The Journal of Futures Markets, 12, 621–634.