Concentrated Trading in the Foreign Exchange Futures Markets: Discretionary Liquidity Trading or Market Closure?

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INTRODUCTION

Several foreign exchange futures contracts, including the mark, yen, and pound, have been traded on the Chicago Mercantile Exchange (CME) since the early 1970s. In the mid-1980s an alternative market [the Singapore International Monetary Exchange (SIMEX)] began trading virtually identical mark, yen, and pound contracts during the overnight hours when the Chicago markets are closed. This paper exploits this situation—the introduction of foreign exchange futures contracts in Singapore which have a mutual offset arrangement with the CME—to examine the

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impact of nontrading hours on domestic foreign exchange futures trading.[1]

Financial economists have documented several intraday patterns in trading volume, volatilities, returns, and bid–ask spreads in the equities markets.[2] This paper investigates intraday volume and volatility patterns in the foreign exchange futures markets in *Chicago* around the introduction of foreign exchange futures trading in *Singapore*. Brock and Kleidon (1992) argue that intraday trade clustering is due to the liquidity demand from traders rebalancing their portfolios before and after market closures. Their market closure model predicts significantly less concentrated trading in Chicago when nontrading hours are reduced by trading in Singapore. This paper provides a direct test of the market closure model by comparing trade clustering at the open and close of trading in Chicago before and after trading begins in Singapore.

The primary alternatives to Brock and Kleidon's (1992) market closure model are models based on the minimization of adverse selection costs (e.g., Admati and Pfleiderer, 1988). The adverse selection models have received more attention in the literature. For example, Foster and Viswanathan (1990) develop a model similar to Admati and Pfleiderer's (1988) and empirically test both models. This paper empirically investigates Brock and Kleidon's (1992) alternative to the adverse selection models.

This study utilizes computerized trade reconstruction (CTR) records maintained by the Commodity Futures Trading Commission (CFTC). CTR records are derived from audit trail data which include time-stamped price and *volume* data for every transaction throughout the day. These records also identify the parties to the trade. By comparison, the most widely available intraday futures market data, Time and Sales data, include only time-stamped price *changes* throughout the day. Thus, it is possible to calculate accurate measures of intraday volume, broken down by trader type (e.g., local, customer). This is not possible with the Time and Sales data.

[1]Foreign exchange futures have been traded on the International Monetary Market (IMM) of the CME since 16 May 1972. The contracts are currently traded from 7:20 AM to 2:00 PM Central Standard Time (CST). The SIMEX began offering foreign exchange futures in late 1984. These contracts are perfect substitutes for the CME contracts because of the mutual offset link established between the two exchanges. Trading hours in Singapore are from approximately 6:20 PM to 3:20 AM CST. Although SIMEX and the CME are separately owned and operated and maintain separate clearinghouses, the mutual offset link has effectively created a single trading floor on two continents.

[2]For example, Gerety and Mulherin (1992) (volume), McInish and Wood (1990) (volatility), Brock and Kleidon (1992) (bid–ask spreads), and Jain and Joh (1988) (returns), among many others, document U-shaped patterns in intraday data.

Despite fundamentally different market information and trading period characteristics, it is documented that patterns for volume in foreign exchange futures are similar to patterns reported for domestic equities markets. In particular, intraday volume is U-shaped, although volatility is not. In fact, volatility tends to decrease throughout the afternoon. To date, relatively little of the research on trading patterns has focused on futures markets.[3]

A second contribution of the paper is that it examines the impact that the introduction of a competing market has on the original futures market. Serendipitously, this amounts to a test of Brock and Kleidon's (1992) alternative to the adverse selection models of concentrated trading. The introduction of trading in Singapore has little effect on the Chicago mark or pound futures markets. A notable exception to this is the yen contract. Trading volume has declined and has become significantly less concentrated at the opening since yen futures trading was initiated in Singapore. This suggests that there may be an "institutional trading day" tied to the normal business hours of the country which issues the underlying currency. The competing Singapore market is open during hours that approximate the normal business hours of Japan, but not those of Germany or England. Therefore, it may be less costly for yen trading to shift to the "overnight" (relative to Chicago) market than it is for mark or pound trading to shift to Singapore.

Relatedly, because mark and pound spot market trading is dominated by European banks, spot market activity in these currencies falls off dramatically at the end of the business day in *Europe*. The end of the business day in Europe corresponds to late morning in Chicago.[4] In addition, volume and volatility decline from this time throughout the day (although volume, but not volatility, jumps up at the close). These observations are also consistent with the existence of an institutional trading day.

The sections of the paper describe the following, respectively: The market closure model and its empirical implications; the data studied, the market parameters to be estimated, and the methodology employed; several intraday patterns that exist in the foreign exchange futures markets and the results of the test of changing intraday patterns around the introduction of trading in Singapore; the possibility that there is an institutional trading day; and conclusions.

[3]A notable exception is Harvey and Huang (1991). They document inter- and intraday patterns in volatilities in the foreign exchange futures markets. Cornett, Schwarz, and Szakmary (1995) is another exception. However, neither of these papers reports results on volume.

[4]CST is seven hours behind Central European Time. Thus, 6:00 PM on the Continent is 11:00 AM in Chicago.

THE MARKET CLOSURE MODEL

The first model of concentrated trading in financial markets was developed by Admati and Pfleiderer (AP) (1988). The AP discretionary liquidity trading model relies on a subset of uninformed (liquidity) traders who strategically execute their trades to minimize their trading costs. AP show that trade clustering reduces trading costs in their model. An alternative explanation of trade clustering was developed by Brock and Kleidon (BK) (1992). Their model relies on portfolio rebalancing at trading halts due to the fact that the optimal portfolio is a function of the ability to trade. Note that the mechanism which generates concentrated trading in the AP and BK models is different, but not mutually exclusive. In this paper the focus is on the implications of alternative trading opportunities in the BK model.

BK's explanation of concentrated trading is based on the structure of the market. In particular, organized exchanges are not open 24 hours a day, 7 days a week. BK extended Merton's (1971) model of continuous trading in the presence of transactions costs to include periodic market closures. Because of the focus on periods when the market is closed, the BK extension leads naturally to the prediction that trading concentrates at the open and at the close.

In the BK model, traders continuously rebalance their portfolios as new information arrives. At the close traders will want to hold an optimal portfolio given that trading will not be possible again until the next opening. In general, this optimal portfolio will differ from the optimal portfolio held during the period when trading is possible. Therefore, there will be an increase in demand for liquidity at the close to accommodate portfolio rebalancing trades. Likewise, at the opening traders will want to shift into the optimal portfolio given the new information which has arrived during the market closure and to reflect the optimal portfolio to be held during the period when trading is possible. There will be an increase in demand for liquidity at the open to accommodate these portfolio rebalancing trades.

Following Garman (1976), the BK formulation of the bid–ask spread models the market maker as a monopolist who responds to increased liquidity demand by increasing the price of liquidity; i.e., widens the spread. Grossman and Miller (1988) argue that this result is robust to the generalization of competitive market makers. Unfortunately, prior to 1990, the CTR data were aggregated at half-hour intervals. This presents no problem for volume or robust volatility estimates (described below). However, spreads are more problematical when the prices being compared may represent trades as many as 30 minutes apart. Therefore, it is not appropriate to investigate this claim with this data set.

In addition to examining intraday volume data for patterns consistent with the market closure model, tests for changes in these intraday volume patterns when the length of the market closure is decreased are also conducted. Recall that in the market closure model trade concentration occurs *because* the market closes. If market closure becomes significantly less important, then trading should cluster less. Thus, the BK model predicts that the relative increases in trading volume associated with the market opening and closing periods will be smaller when alternative markets are available because liquidity demand for portfolio rebalancing will decline. Thus, the market closure model implies that the intraday patterns in *Chicago* should be less U-shaped after SIMEX trading begins. Note that BK do not model information arrival. This accounts for the lack of an explicit prediction about price volatility in the BK model.

DATA AND PARAMETERS TO BE ESTIMATED

CTR Data

The data consist of price and volume data for the deutsche mark, pound sterling, and yen contracts for the 64 trading days before and the 64 trading days after the introduction of the SIMEX mark (7 September 1984), pound (1 July 1986), and yen (7 November 1984) contracts. These data are derived from the CTR records maintained by the CFTC, collected from the trading cards of individual traders. Each time a trade is made, the traders on each side note the details of the trade on their cards. *Both* traders record the price, delivery month, quantity, time bracket (30 minutes before 1990, 15 minutes since), and whether the trade is for the trader's personal account or executed on behalf of a third party (i.e., for a customer or another broker). Each transaction is therefore recorded twice, once on each trader's card. At the end of the day's trading, traders submit the cards to the exchange clearinghouse for settlement and reconciliation.

The CFTC requires all contract markets to maintain a complete record of each trade and to submit these records to the Commission monthly. The trading cards submitted by the traders are the original source of these records. Recall that each trade is recorded twice, once by the buyer and once by the seller. Both sides of the trade identify the executing traders and the trade direction (whether the trade was a purchase or a sale). The record details the commodity and delivery month, the quantity, the price, and the date and time. Time is defined to the nearest minute by use of a computer algorithm. The manually recorded time bracket and price are used in conjunction with the Time and Sales data, and augmented by the trade sequence on each trader's card, to recover a CTR time.[5]

CTR data from the mid-1980s contain many errors. Most of these errors are not easily detected and corrected, e.g., a misplaced decimal point. The data are screened using a relatively conservative criterion that considers an observation to be an error if the recorded price "could not have occurred" using the highest and lowest trade prices recorded in the CFTC Permanent Record File for each contract on each day. These records are constructed from a different data source than the CTR data. All observations where the price is below the lowest or above the highest price for that day are eliminated.

Parameters to Be Estimated

Volume and price volatility are examined over 12 approximately equal time periods ("brackets") throughout the trading day. The opening bracket (A in Table I) is from 7:30 AM through 7:59 AM. Because the trading open switched to 7:20 AM after 15 October 1985, the opening bracket is ten minutes longer during the last six months of the sample period. Brackets B through L divide the time from 8:00 AM through 12:59 PM into ten equal 30-minute intervals. The closing bracket (M in Table I) is from 1:00 PM through the close of trading for each contract. Prior to October 1988 (hence, during the entire sample period), trading ended at different times for each currency: 1:20 PM (mark), 1:22 PM (yen), and 1:24 PM (pound). Thus, the closing bracket is the smallest. Volume is calculated by aggregating across all contracts for a given bracket. For example, the volume is summed for all the yen futures contracts during the opening bracket of the day without regard to the settlement date. The volatility measure is constructed using the most active contract of the day, which is usually the nearby contract.[6] The interquartile range of prices for a given bracket—a distributionally robust statistic—is used as the volatility measure to mitigate potential problems due to the possibility of using

[5]The CTR time is not entirely dependable, because some trades are unable to be placed unambiguously within the 30-minute bracket. Trades not accurately timed are artificially placed at the start of the 30-minute bracket. However, the integrity of the individual trade sequence (from the cards) for each trader is maintained.

[6]Total volume is used to mitigate seasonalities associated with the spillover from the nearby to the next maturity that occurs when the most active contract changes. There is no clear way to aggregate across maturities for the volatility measures, however. Since Manaster and Mann (1996) found that price discovery is essentially restricted to the most active contract in the foreign exchange futures pits, this contract is used to estimate the volatility measure.

TABLE I

Intraday Patterns in Volume and Volatility over the Entire Sample Period

Bracket (Time)		*Mean Percentage of Daily Volume*			*Mean Interquartile Price Range*		
		Mark	*Yen*	*Pound*	*Mark*	*Yen*	*Pound*
A:	Open–7:59	14.26	17.35	12.65	55.2	38.5	35.9
B:	8:00–8:29	9.03	9.73	9.86	44.4	36.1	36.1
C:	8:30–8:59	8.54	8.22	9.01	48.8	33.5	40.3
D:	9:00–9:29	9.33	8.96	8.34	60.2	34.6	46.6
E:	9:30–9:59	8.80	7.34	7.87	57.5	32.0	46.7
F:	10:00–10:29	8.15	6.66	8.19	58.4	29.8	46.0
G:	10:30–10:59	8.11	7.64	7.52	57.2	32.7	42.7
H:	11:00–11:29	7.24	6.04	6.58	52.9	33.4	43.1
J:	11:30–11:59	6.36	5.76	6.17	51.2	33.1	41.1
K:	12:00–12:29	6.56	5.56	5.01	50.6	34.0	35.6
L:	12:30–12:59	7.77	7.12	6.27	48.5	32.4	38.5
M:	1:00–Close	10.00	12.64	12.54	39.5	28.4	38.0

Notes: Volume is transformed to a percentage by dividing each bracket's volume by the total volume for the day. The table reports the mean percentage of daily volume for each bracket. Volatility, as measured by the interquartile range, is reported as the mean interquartile price range for each bracket, using the most active contract for each day. Patterns are reported for the entire sample (6/1/84–2/7/85 and 4/1/86–9/30/86). The opening was 7:30 am until 15 October 1985, when trading opened at 7:20 am. Bracket A, therefore, contains an extra ten minutes of trading for the latter six months of the sample. Trading closed at different times for each currency during this period. Closings were 1:20 pm (mark), 1:22 pm (yen), and 1:24 pm (pound). Closings were changed to 2:00 pm for all currencies in October 1988.

"bad" observations. Essentially, robust estimators are those that are minimally impacted by the presence of outliers, or bad observations (outlier resistant). See Huber (1977) for more detail.

CTR data classify trades by the identity of the trader for whom the broker is buying or selling. There are four trader classifications: CTI1 (floor broker personal account), CTI2 or CTI3 (trades for another member's account or for the trader's clearinghouse account), or CTI4 (customer account). Both the buyer and the counterparty to a trade are identified.

Methodology

The day is divided into three periods (opening, midday, and close). The opening period is simply the opening bracket. The closing period is the closing bracket for each contract. The midday consists of every bracket between the open and close. The volume data are normalized by the mean daily volume so that the proportion of trading during the opening is compared to the mean proportion of trading that occurs during a midday bracket, etc.

TABLE II

Serial Correlation in Volume and Volatility

Pit	Intercept	Overnight Closing to Opening Pre	Overnight Closing to Opening Post	Midday All Except Open/Close Pre	Midday All Except Open/Close Post	End-of-Day Closing 2 Brackets Pre	End-of-Day Closing 2 Brackets Post
			A. Total Volume				
Mark	977.6	0.59	0.90	0.29	0.38	0.49	0.64
	(50.0)	(0.11)	(0.12)	(0.03)	(0.03)	(0.08)	(0.06)
	Chi-square (1) test: $\beta_1 = \beta_2$			3.7[a]			
	Chi-square (3) test: pre = post			21.7[c]			
Yen	228.2	1.02	0.89	0.42	0.26	0.99	0.78
	(12.7)	(0.15)	(0.8)	(0.3)	(0.4)	(0.14)	(0.12)
	Chi-square (1) test: $\beta_1 = \beta_2$			0.6			
	Chi-square (3) test: pre = post			22.3[c]			
Pound	365.7	0.36	0.46	0.32	0.38	0.87	1.26
	(22.5)	(0.07)	(0.12)	(0.04)	(0.05)	(0.08)	(0.21)
	Chi-square (1) test: $\beta_1 = \beta_2$			0.6			
	Chi-square (3) test: pre = post			7.2[a]			
			B. Volatility: Interquartile Range (Most Active Contract)				
Mark	34.5	0.28	0.45	0.31	0.38	0.16	0.22
	(1.7)	(0.12)	(0.12)	(0.03)	(0.04)	(0.11)	(0.07)
	Chi-square (1) test: $\beta_1 = \beta_2$			1.2			
	Chi-square (3) test: pre = post			5.6[a]			
Yen	22.4	0.56	0.25	0.41	0.22	0.36	0.02
	(1.5)	(0.16)	(0.07)	(0.06)	(0.06)	(0.07)	(0.06)
	Chi-square (1) test: $\beta_1 = \beta_2$			3.45			
	Chi-square (3) test: pre = post			33.7[c]			
Pound	32.6	0.19	0.09	0.28	0.14	0.20	0.07
	(1.4)	(0.10)	(0.07)	(0.03)	(0.04)	(0.06)	(0.08)
	Chi-square (1) test: $\beta_1 = \beta_2$			0.68			
	Chi-square (3) test: pre = post			22.5[c]			

Notes: The table reports GMM estimates of the intercept and β coefficients of the following model:

$$\text{Volume}_t = \alpha + \sum_{i=1}^{6} \delta \beta_i \, \text{Volume}_{t-1}$$

$$\text{QRange}_t = \alpha + \sum_{i=1}^{6} \delta \beta_i \, \text{QRange}_{t-1}$$

where $\delta_i = 1$ if t is an (opening bracket, midday bracket, closing bracket) pre-SIMEX (for $i = 1, 3, 5$, respectively) and is 0 otherwise, and where $\delta_i = 1$ if t is an (opening bracket, midday bracket, closing bracket) post-Simex (for $i = 2, 4, 6$, respectively) and is 0 otherwise. Standard errors are in parentheses.

[a] p-Value < 10%.

[b] p-Value < 5% (not shown).

[c] p-Value < 1%.

TABLE III

CME Volume Patterns before and after Introduction of SIMEX Trading

Volume Ratios for		*Mean Volume Ratios (Bracket Volume Divided by Daily Volume) for All CME Contracts—All Delivery Months and All Trader Types*					
		CME Mark		*CME Yen*		*CME Pound*	
		Before	*After*	*Before*	*After*	*Before*	*After*
A. SIMEX Mark Contract (7 September 1984)							
Opening bracket	(Open–7:59)	0.133	0.143	0.170	0.179	0.151	0.136
Midday brackets	(8:00–12:59)	0.076	0.074	0.074	0.071	0.076	0.077
Closing bracket	(1:00–Close)	0.091	0.102	0.097	0.119	0.097	0.097
GMM chi-square (3) test		4.13		7.83[b]		1.70	
B. SIMEX Yen Contract (7 November 1984)							
Opening bracket	(Open–7:59)	0.147	0.127	0.182	0.156	0.147	0.132
Midday brackets	(8:00–12:59)	0.075	0.074	0.071	0.073	0.077	0.075
Closing bracket	(1:00–Close)	0.102	0.116	0.114	0.130	0.094	0.116
GMM chi-square (3) test		6.67[a]		9.31[b]		9.28[b]	
C. SIMEX Pound Contract (1 July 1986)							
Opening bracket	(Open–7:59)	0.126	0.135	0.134	0.131	0.116	0.119
Midday brackets	(8:00–12:59)	0.077	0.077	0.069	0.069	0.069	0.069
Closing bracket	(1:00–Close)	0.092	0.083	0.107	0.112	0.120	0.115
GMM chi-square (3) test		2.83		0.495		0.279	

Customer Volume Ratios for		*Mean Customer Volume Ratios (Bracket Volume Divided by Daily Volume) for All Deliver Months, but CTI4 Trade Types Only*					
		CME Mark		*CME Yen*		*CME Pound*	
		Before	*After*	*Before*	*After*	*Before*	*After*
D. Customer Volume (Own Contract Introduction Only)							
Opening bracket	(Open–7:59)	0.122	0.139	0.180	0.167	0.112	0.104
Midday brackets	(8:00–12:59)	0.075	0.733	0.070	0.070	0.067	0.069
Closing bracket	(1:00–Close)	0.109	0.115	0.131	0.149	0.145	0.141
GMM chi-square (3) test		2.23		2.39		0.49	

Notes: A–C report normalized (by daily volume) mean bracket volume by contract at each contract introduction date. D reports normalized mean bracket volume for customer trades only, for each contract at its own introduction.
[a] *p*-Value < 10%.
[b] *p*-Value < 5%.

The tests for serial correlation in Table II and for trading characteristic equality across the pre- and post-SIMEX periods in Tables III and IV are suggested by Harvey and Huang (1991). Consider first the model:

$$y_t = \alpha + \delta_1\beta_1 x_{1t} + \delta_2\beta_2 x_{2t} + \ldots + \delta_6\beta_6 x_{6t} + \varepsilon_t \qquad (1)$$

TABLE IV

CME Price Volatility Patterns before and after Introduction of SIMEX Trading

Interquartile Range Ratios for:		*Interquartile Price Range Ratios (Bracket Range Divided by the Mean Daily Bracket Range) for Most Active Contract and All Trader Types*					
		CME Mark		*CME Yen*		*CME Pound*	
		Before	*After*	*Before*	*After*	*Before*	*After*
A. SIMEX Mark Contract (7 September 1984)							
Opening bracket	(Open–7:59)	1.06	0.96	1.30	1.21	0.93	0.95
Midday brackets	(8:00–12:59)	1.03	1.02	0.98	0.99	1.02	1.01
Closing bracket	(1:00–Close)	0.68	0.78	0.76	0.88	0.91	0.95
GMM chi-square (3) test		2.77		1.95		0.24	
B. SIMEX Yen Contract (7 November 1984)							
Opening bracket	(Open–7:59)	0.93	0.84	1.30	1.06	0.99	0.84
Midday brackets	(8:00–12:59)	1.03	1.02	0.98	1.02	1.00	1.02
Closing bracket	(1:00–Close)	0.78	0.86	0.91	0.76	0.98	0.93
GMM chi-square (3) test		2.20		8.76[b]		3.36	
C. SIMEX Pound Contract (1 July 1986)							
Opening bracket	(Open–7:59)	0.98	0.99	1.07	1.10	0.80	0.99
Midday brackets	(8:00–12:59)	1.02	1.02	1.00	1.00	1.03	1.01
Closing bracket	(1:00–Close)	0.77	0.75	0.91	0.90	0.92	0.95
GMM chi-square (3) test		0.13		0.14		3.64	

Notes: The table reports normalized (by mean daily bracket interquartile range) interquartile range by contract at each contract introduction date.
[a] *p*-Value < 10% (not shown).
[b] *p*-Value < 5%.

where the indices 1–6 represent different times of the day during different time periods. For example, index 1 represents the opening bracket of trading during the pre-SIMEX era, index 2 represents the opening bracket of trading post-SIMEX, index 3 represents the midday pre-SIMEX, and so on. For the case of serial correlation (Table II), y_t represents the volume$_t$, the explanatory variables x_{it} represent volume$_{t-1}$, and δ_i are dummy variables representing the time of day and pre- or post-SIMEX period. Rewriting eq. (1) in vector notation, $y = X\beta + \varepsilon$. When the elements of the explanatory variable matrix X are treated as instrumental variables, then the moment conditions are simply the ordinary least squares (OLS) normal equations:

$$X'(y - X\beta) = 0 \tag{2}$$

Define the moment conditions as $g = X'(y - X\beta)$ (6×1). The generalized method of moments (GMM) solution procedure minimizes the quadratic form:

$$g'wg \tag{3}$$

where w is the weighting matrix (estimated simultaneously with the parameter vector) that provides for asymptotic normality of the estimates (see Andrews, 1991).

The test employed estimates eq. (1) with a first-pass GMM estimation and saves the weighting matrix, w_{ur} (where ur indicates unrestricted). Then the restriction is imposed that the parameters are equal (constant over the day and/or across time periods) and the parameters are reestimated using the saved weighting matrix from the first-pass estimation. Then an asymptotic $\chi^2_{(3)}$ statistic is calculated as

$$\chi^2_{(3)} = g_r'w_{ur}g_r - g_{ur}'w_{ur}g_{ur} \tag{4}$$

where r represents the restricted moment conditions.

For testing differences in volumes and variances in Tables III and IV, model (1) is estimated without an intercept and the explanatory variables are simply dummy (1,0) variables for time of day and time period. The first-pass estimation of the unrestricted model therefore provides the classical estimates for mean characteristics by time of day, and the first-pass unrestricted quadratic form, $g_{ur}'\ w_{ur}g_{ur}$, is exactly zero. The second-pass estimation imposes the restriction and uses the first-pass weighting matrix, yielding the test statistic (4).

TESTS OF THE IMPLICATIONS OF THE MARKET CLOSURE MODEL

Table V reports the summary statistics for the volume and volatility data. Average volume per bracket is greatest for the mark and lowest for the yen in both the pre- and post-SIMEX periods. Interestingly, volume actually declines for the yen contract post-SIMEX, although it increases for the mark and pound. The mark is the most volatile and the yen the least volatile contract in both subperiods.

Intraday Patterns in the Foreign Exchange Futures Market

The intraday volume and volatility data are plotted in Figure 1A,B. These plots are based on the data in Table I. Figure 1A plots the volume for the

TABLE V

Sample Distributions

Pit	Statistic	Volume: Entire Sample	Volume: Pre-SIMEX	Volume: Post-SIMEX	Interquartile Price Range: Entire Sample	Interquartile Price Range: Pre-SIMEX	Interquartile Price Range: Post-SIMEX
Mark	Mean	1556	1398	1806	55.4	48.4	55.5
	Minimum	45	65	127	0	12.5	12.5
	Lower quartile	862	805	1056	37.5	25	37.5
	Median	1353	1240	1594	50	37.5	50
	Upper quartile	2027	1790	2296	62.5	62.5	62.5
	Maximum	7498	5037	7498	450	212.5	412.5
	sd	974	816	1064	37.1	27.0	38.7
	Number of observations	3749	750	749	3749	750	749
Yen	Mean	705	501	333	50.9	37.0	29.1
	Minimum	6	13	6	0	0	0
	Lower quartile	250	181	130	25	25	12.5
	Median	494	347	242	37.5	25	25
	Upper quartile	939	620	430	62.5	37.5	37.5
	Maximum	5800	3028	2398	600	600	287.5
	sd	665	489	305	43.1	34.7	21.4
	Number of observations	3764	757	747	3764	757	747
Pound	Mean	494.2	569	663	38.8	46.3	35.5
	Minimum	6	28	20	0	0	0
	Lower quartile	206	250	258	25	25	25
	Median	369	434	468	37.5	37.5	25
	Upper quartile	621	734	846	50	62.5	50
	Maximum	6280	3753	6280	375	237.5	175
	sd	465	493	669	26.2	29.5	23.5
	Number of observations	3778	768	768	3778	768	768

Notes: Bracket contract volume is total volume (across all contracts) during the bracket. Bracket interquartile price range is the interquartile range in trade prices (for the most active contract of the day) during the bracket. Distributions reported for the entire sample period are for the periods 6/1/84–2/7/85 and 4/1/86–9/30/86 for each pit. Distributions reported for pre- and post-SIMEX introduction are specific to each pit, covering the 64 trading days before and after SIMEX introduction. The pre- and post-SIMEX periods are 6/7/84–9/6/84 and 9/7/84–12/6/84 (mark), 8/8/84–11/6/84 and 11/7/84–2/7/85 (yen), and 4/1/86–6/30/86 and 7/1/86–9/30/86 (pound).

mark, pound, and yen by the time period of the day. Figure 1B plots the interquartile range of prices for each contract during each time period of the day. The horizontal axis identifies the bracket.

Two regularities are apparent in the volume plot. First, consistent with the BK model, there is a significantly U-shaped pattern in the data. Second, the intraday volume patterns are consistent across the three contracts. Table I reports that 25–30% of daily volume is concentrated at the open and close of trading. Note that volume declines after late morning (bracket G or F). This suggests that the decline in spot market activity after normal London business hours impacts the derivatives markets as well.

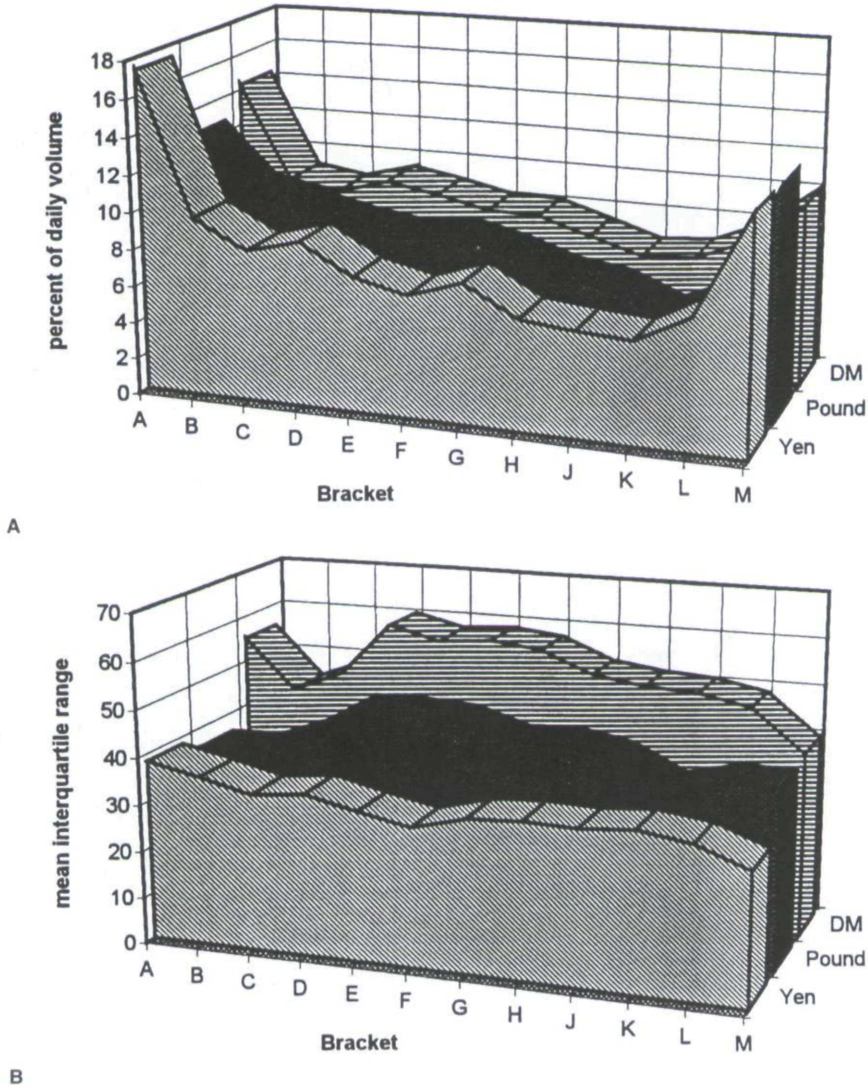


FIGURE 1

A: Intraday volume: Entire sample, all customer types. **B:** Intraday volatility: Mean interquartile price range.

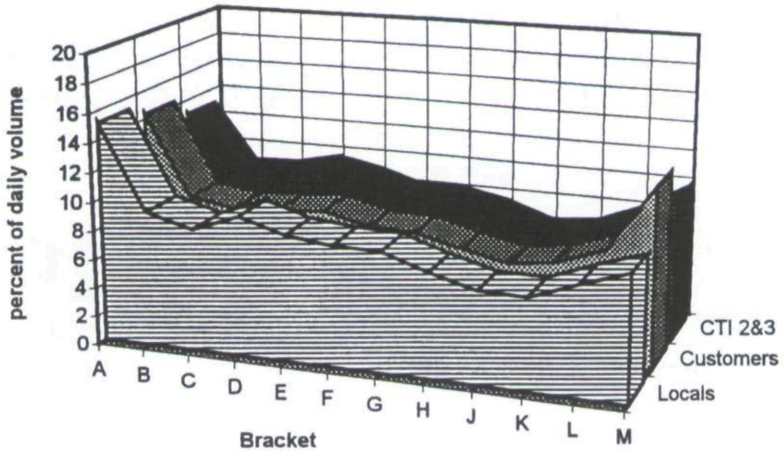
The interquartile range is not characterized by a U-shape. The mark drops off sharply after the open and rises through bracket D (as does the pound), then the volatility declines throughout the day, never returning to its earlier level again. Note that there is not a corresponding up-tick at the close for any of the three contracts, as there is with volume. There is relatively little variation in the interquartile range of the yen price. This difference from the two European currencies is interesting in light of Harvey and Huang's (1991) conjecture that it is the *home* country's business hours that govern volatility patterns. Of course, Asian business hours do not overlap Chicago trading hours, but European business hours do.

Figure 2A–C considers bracket-by-bracket volume by each trader type separately. It is readily apparent that the intraday patterns across trader types are very similar. This is true across all three contracts. Thus, trade clustering is equally prevalent among locals (floor brokers trading for their own account) and customers and is not driven by the trades of one particular class of traders. Note, however, that there is a relatively larger spike at the close for the customer trades. This is true across all three contracts and is consistent with anecdotal evidence which suggests that a large number of "market at close" orders are crossing (i.e., customer-to-customer volume is high) at the close.

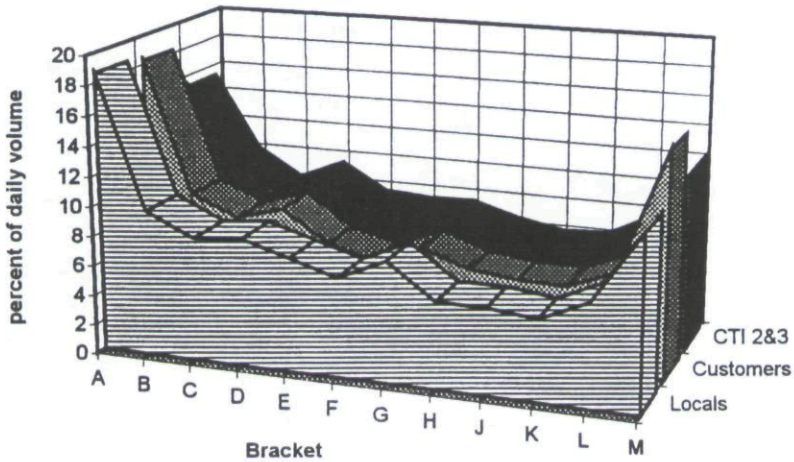
Introduction of Foreign Exchange Futures Trading on SIMEX

One implication of the market closure model of concentrated trading is that the introduction of trading on SIMEX should affect the intraday patterns observed in Chicago. Therefore, the null hypothesis that there is no difference in the intraday patterns for volume and volatility across the pre- and post-SIMEX periods is tested. The pre- and post-SIMEX periods are defined as the 64 trading days before and after trading is introduced in Singapore. As noted above, the foreign exchange contracts traded on SIMEX did not begin trading on the same day (the mark contract was introduced on 7 September 1984, the pound on 1 July 1986, and the yen on 7 November 1984). Thus, there are three introduction "events" for the three contracts. For each introduction there is one "listing" contract and two control contracts. Note that because the 7th in Singapore precedes the 7th in Chicago, the introduction date is the first date where there has been overnight trading (relative to Chicago).

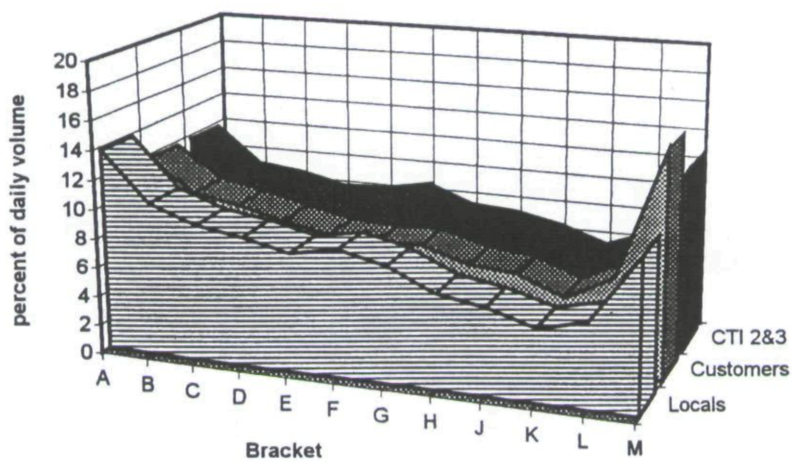
It is well known that financial market data are serially correlated (Bollerslev, Chau, and Kroner, 1992). Thus, there is quite likely some intraday structure present in the data. Before proceeding to the main tests, the data are examined for serial correlation and changes in serial correlation pre- and post-SIMEX. The results of these tests are presented in Table II. The test is whether volume (volatility) in one bracket is correlated with the volume (volatility) in the immediately preceding bracket. The standard errors and the estimated coefficient estimates for the volume and volatility time series clearly indicate that both volume and volatility are serially correlated.



A



B



C

FIGURE 2
A: Volume by customer type: Mark (CME). **B:** Yen (CME). **C:** Pound (CME).

As noted above, most financial data time series exhibit serial correlation. An interesting question is whether the correlation of the data has been affected by the introduction of SIMEX trading. Two tests are conducted. The first restricts all the pre- and post-SIMEX coefficients to be the same in one test. A second, more focused test restricts the close-to-open coefficient to be the same pre- and post-SIMEX, because it is the most likely to be affected by overnight trading. The chi-square test of the hypothesis that the serial correlation between yesterday's closing bracket and today's opening bracket is the same is rejected for the mark volume, but not for its volatility or for either the yen or pound series. However, the restriction that the serial correlation is the same throughout the day pre- and post-SIMEX is rejected for both data series across all three contracts. There is some change in the serial correlation after SIMEX trading begins, but it is not clear that a strong inference can be drawn from this. There is significant serial correlation before and after SIMEX trading is introduced. The relative magnitudes are similar even if they are statistically different. More importantly, the overnight serial correlation is not statistically different. Since this is the most likely to be directly affected by SIMEX trading, it is unwarranted to attribute too much importance to SIMEX for the change in serial correlation across the day.

Tables III and IV report the results of a test that intraday volume and volatility patterns are unchanged pre- and post-SIMEX. Overall, there is not much change in the intraday patterns around an introduction date. The yen contract introduction is the most interesting exception. All three contracts exhibit sharp decreases in the proportion of volume traded at the open. The yen is the only contract that is characterized by a significant change in its intraday volume and volatility patterns at its own introduction date. Note that the volatility of the yen contract is lower in the post-SIMEX period at the open and close and drops off even more sharply by the close than in the pre-SIMEX period. Thus, there appears to be no significant difference in intraday trading patterns pre- and post-SIMEX for the mark or pound. There is a change, however, for the yen. In particular, volatility is lower post-SIMEX, suggesting that the information content of the trading volume has been reduced.

IS THERE AN INSTITUTIONAL TRADING DAY?

Volume is significantly U-shaped, as predicted by BK. Nonetheless, the results of the previous section do not offer much support for the BK model. One interpretation of the results is that the relative costs of trading around the clock are higher than assumed in the BK model. If trading becomes more costly as the trading hours lengthen, traders may not trade around the clock even when it is possible. To trade around the clock requires more people, more information, and more monitoring (of markets and employees). In addition, the cost of acquiring information relevant to the value of a currency is likely to be greater the further removed trading hours are from the normal business hours of the currency issuing country. Thus, there may be a natural "institutional trading day" which is a function of these costs. The relatively small volume of trading in Singapore relative to Chicago is consistent with this possibility.[7]

The fact that all the movement post-SIMEX seems to be taking place in the yen contract, rather than in the European contracts, is consistent with this explanation. Yen volume declines and becomes less concentrated post-SIMEX. Volatility in this contract also declined post-SIMEX. Finally, volatility is relatively stable throughout the day for the yen contract. These observations suggest that relatively little information enters the yen contract in Chicago. Moreover, as trading volume migrates to Singapore post-SIMEX, Chicago trading becomes even less informative.

The spot market for foreign exchange consists of global and regional banks that trade via electronic screens. This market is often characterized as the closest thing to an around-the-clock market that exists—and it is. However, it is not uniformly deep. For example, Bollerslev and Domowitz (1993) report that for the most actively traded currency, the deutsche mark, the number of quotes on the Reuter's trading screens drops off sharply after 5:00 PM in London. Although the quoted bid–ask spread remains roughly constant, the reduced frequency of quotes suggests that the market is less deep after the London banks leave the market. Moreover, the depth of the market appears to decline monotonically after London closes until the Asian markets open. During this period there is another significant drop in depth when the New York banks close.

If portfolio rebalancing is the motivation for concentrated trading, then the dramatic decline in spot market activity while the futures market

[7]The following are the annual number of contracts traded in each currency market for the years 1984–1986 in Singapore and Chicago (source: McGraw-Hill World Futures and Options Directory 1991–1992).

	1984	1985	1986
SIMEX deutsche mark	41,128	170,346	213,762
CME deutsche mark	5,508,308	6,449,384	6,582,145
SIMEX pound	—	—	17,978
CME pound	1,444,492	2,799,024	2,701,330
SIMEX yen	2,104	31,537	111,339
CME yen	2,334,764	2,415,094	3,969,777

is still trading in Chicago has implications for the futures markets. When the spot market closes (or becomes significantly more costly), the optimal portfolio will change. This implies that trading patterns will change as spot market activity declines. Figures 1 and 2 show that volume declines after late morning (say 11:00 AM) in Chicago. This corresponds to 6:00 PM in London, the end of the trading day for the big banks engaged in spot market currency trading. Additionally, volatility declines after this time, suggesting that less information is entering the market after European business hours.[8] This pattern is not present in the yen volatility data. These observations suggest that the end of spot market trading in London is important and are consistent with the view that there is an institutional trading day related to the normal business hours of the issuing country.

CONCLUSIONS

This paper documents several empirical regularities in the foreign exchange futures markets.

1. Intraday volumes are U-shaped.
2. Intraday volatilities are not U-shaped. They peak in late morning in Chicago and decline throughout the rest of the trading day.
3. Volume and volatility for the European currency contracts are greater when European banks are active in the spot market than after normal London business hours.
4. Yen futures trading in Chicago is more greatly affected than either of the European currencies by the introduction of trading in Singapore.

This paper contributes to the market microstructure literature by testing the Brock and Kleidon (1992) model of concentrated trading. The foreign exchange futures markets are particularly well suited to this task due to the introduction of substitute contracts in overseas markets which effectively shorten the market closure period.

Changes are not found in trading patterns that are predicted by the market closure model when nontrading hours are significantly reduced. This may be due to the fact that trading "overnight" (relative to Chicago) is costly. In fact, the data are consistent with this "institutional trading day" explanation. Volume and volatility for the European contracts are

[8]Ederington and Lee (1995) show that news announcements that affect the market (e.g., unemployment, CPI, GNP, etc.) are made early in the trading day. Thus, the higher volatility during the early part of the trading day may simply reflect these announcements. However, Ferguson, Mann, and Schneck (1997) find that higher morning volatility is also a feature of days without announcements. The data necessary to examine this issue more precisely are not available to the authors.

higher when European banks are active in the spot market. Moreover, volatility for these contracts steadily declines as the European night falls. Finally, the Asian currency is more greatly influenced by the introduction of trading in Asia than the European currencies.

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