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**ESSAYS IN MICROSTRUCTURE OF FUTURES MARKETS**

by

AHMET KAMİL KARAGÖZOĞLU

A dissertation submitted to the Graduate Faculty in Business in partial fulfillment of the requirements for the degree of Doctor of Philosophy. The City University of New York

1999

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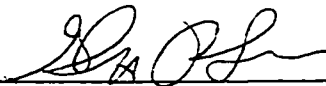
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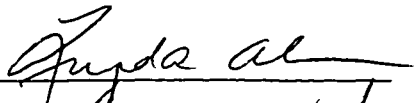
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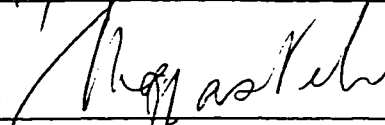
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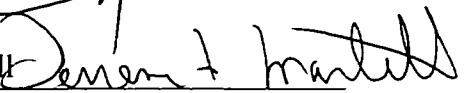
  
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**Abstract****ESSAYS IN MICROSTRUCTURE OF FUTURES MARKETS**

by

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Adviser: Professor Ashok Vora

The first essay investigates the potential success of an explicit futures contract when an implicit one, which can duplicate it, exists. It is hypothesized that the success of the explicit futures contract depends on its value-added being greater than that of its implicit counterpart given that sufficient hedging demand exists for it. Following a discussion of value-added analysis, hedging effectiveness of the Euro-rate Differential (DIFF), the Currency Cross-rate (CROSS) futures contracts, and their implicit counterparts are calculated and tests of relative hedging effectiveness of these contracts are performed.

The second essay examines the effects of both decreases and increases in futures contract size on the microstructure of a futures market. The Sydney Futures Exchange (SFE) modified the terms and conditions of two of its major contracts: Share Price Index (SPI) futures and 90-day Bank Accepted Bills (BAB) futures. The size of the SPI futures contract was decreased by a factor of four, and the minimum tick was raised. The BAB contract was doubled in size, with no changes made to minimum tick size. After controlling for market factors, the results indicate that the respecification of the SPI futures (decreased size) resulted in higher trading volume, while the respecification of the BAB futures (increased size) decreased trading volume. In these two cases, decreasing

the futures contract size was effective in terms of enhancing liquidity while increasing the contract size diminished liquidity.

Third essay develops a transaction cost model of the microstructure of futures markets and supports it with empirical evidence. The research examines the factors affecting the bid-ask spread, trading volume, and open interest patterns in contracts with different times to expiration on the same underlying asset. The model divides futures market participants into three groups: hedgers, speculators, and market makers. Provision of liquidity and its effect on the choice of futures contracts is the central theme in investigating the interactions among these three groups of market participants. The model's predictions explain the observed differences in the number of deferred contracts trading in the various futures markets, and support conclusions concerning hedgers' optimal choice of portfolios of contracts with different expirations in order to hedge underlying maturities that are not covered by existing contract maturities.

Dedicated to the memory of

my uncle  
Mustafa Namık Arslanerer

and

my grandmother  
Nesibe Karagözoğlu

who I lost during my studies abroad

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## **Essay I**

### **Hedging Effectiveness of Explicit versus Implicit Contracts**

## **I. Introduction**

Over the years, success and failure of futures contracts have attracted the interest of both academicians and practitioners. Success of a new contract has substantial implications for the prosperity of the exchange that introduces it, for the potential participants in its market and for the economy as a whole. Although some may consider the task of successful futures contract development more of an art form than science, many articles in the field have dealt with the issues concerning the success and failure of new contracts. This essay contributes to the success and failure literature by investigating the potential success of an explicit futures contract when an implicit one, which can duplicate it, exists. In this study, the new futures contract that is (or will be) introduced by an exchange is interpreted to be the explicit contract. An implicit contract is the one that can be created synthetically using existing highly liquid exchange-traded futures contracts to substitute for the explicit one.

If a futures contract does not exist for a given underlying asset, market participants can cross hedge their spot market positions using the futures market of a related underlying asset. If the new futures contract is purely innovative, i.e., no similar contract trades in any exchange, then intended participants of the new futures markets are likely to use existing exchange-traded futures contract to cross hedge their cash positions. Although no single exchange-traded contract may exist to provide a perfect hedge for the asset underlying the new (explicit) futures contract, the necessary contract for such a hedge may implicitly exist in the market. In this case, such an implicit contract can be created synthetically using any combination of existing exchange-traded futures contracts. In the absence of explicit futures contracts, market participants can create the implicit

contracts and hedge their spot holdings of the underlying. The extent to which market participants create and use the implicit contracts depends on the characteristics of the market, the objectives as well as the expertise of the participants.

Success of a futures contract is largely determined by its value-added. If a new contract provides higher value-added than its existing counterpart, then it is more likely to be the contract of choice in the market. The analysis of the value-added is dependent on the nature of the counterpart contract. In complete markets, any financial contract can be duplicated using a combination of other contracts. Therefore, if the markets are complete it is possible to construct implicit counterparts to duplicate the potential explicit ones. In the case that the markets are not complete, implicit counterparts may still exist for some new explicit futures contracts. In the absence of an implicit one, the existing counterpart can be an explicit one that is a related contract to the potential new futures contract.

In the context of futures markets, a necessary but not sufficient condition for the success of a new contract is the existence of sufficient hedging demand for such a contract. If there is sufficient hedging demand for the contract and its value-added exceeds that of its counterpart, then the new contract is likely to succeed. The new contract's value-added can appear as reduction in transaction costs compared to those of the counterpart and/or as reduction in risks associated with the counterpart. Transaction costs in futures markets are composed of bid-ask spreads, commissions/fees, and market cost of executing a large order. Risks associated with the counterpart contracts can be viewed as credit and basis risks.

This essay investigates the cases when counterparts are implicit contracts that can be constructed synthetically using existing exchange-traded futures contracts. In such

cases, when the components of the implicit counterpart are highly liquid exchange-traded futures contracts, the bid-ask spread of the new explicit contract may be more than the sum of the bid-ask spreads of the implicit components due to market liquidity. Clearly the commissions and fees are reduced when an explicit futures contract is used instead of an implicit one which is a combination at least two other contracts. Market cost of executing a large order depends on the depth of the market. As in the case of bid-ask spreads, when the implicit contract is composed of highly liquid exchange-traded futures contracts, market impact cost may be higher for the new explicit contract than for the implicit one. Since the first and the third, as listed above, are the largest components of the transaction costs in the futures markets, it is possible that the new explicit contract's value-added, in terms of reducing costs, can be less than that of the implicit one. However, if the new contract's value-added in terms of reducing risks is more than that of the implicit one, then it is likely to be preferred over its implicit counterpart.

If the new explicit contract is an exchange-traded one while its implicit counterpart is composed of one or more over-the-counter contracts, part of the new contract's value-added is the elimination of credit risk associated with the implicit counterpart. In this study, however, since explicit and implicit contracts are both exchange-traded ones, credit risk is not considered in the value-added analysis. In terms of the risk reduction, the second component of the value-added focuses on basis risk. Although explicit contracts may not eliminate the basis risk, they may provide superior price discovery and higher hedging effectiveness than that could be achieved by implicit ones. Such an increased hedging effectiveness can be considered as the value-added provided by the newly introduced explicit contract. When the new explicit contract provides considerably higher

hedging effectiveness than the implicit one, even though its transaction costs may be more than those of the implicit contract, the explicit contract's over-all value-added may exceed that of the synthetically created implicit counterpart. Working with a case study, this essay utilizes the ex-post hedging effectiveness measures to investigate an explicit futures contract's potential for success when exchange-traded futures contracts can synthetically duplicate it.

As a case study, this essay identifies the Euro-rate Differential (DIFF) and Currency Cross-rate (CROSS) futures contracts (both types were introduced by CME and then failed) as explicit contracts for which an implicit futures contract could synthetically be constructed at the time of their introduction. Hedging effectiveness of the implicit and explicit DIFF and CROSS contracts are calculated and tests of relative hedging effectiveness of these contracts are performed. The potential value-added provided by each explicit futures contract is discussed as well.

The next section reviews the previous and related research. The following ones describe the DIFF and CROSS futures and contain the construction of implicit contracts. The discussions of the hedging effectiveness methodology, the data, and the empirical results respectively follow. The last section contains the conclusions and indications for further research.

## **II. Previous Research**

Some of the previous research on the success and failure of futures contracts can be classified into four groups: i) studies that trace the development process of a successful futures contract (e.g. Sandor 1973, Sandor and Sosin 1983); ii) analyses of hedging

effectiveness of futures contracts (e.g. Ederington 1979, Dale 1981, Hill and Schneeweis 1982a and b); iii) models of successful futures contract development (e.g. Silber 1981, Carlton 1984, Black 1986, Duffie and Jackson 1990); iv) case studies that investigate the failure of a particular futures contract (e.g. Johnston and McConnell 1989, Nothaft, Lekkas, and Wang 1995, Thompson, Garcia, and Wildman 1996).

Sandor (1973) provides a case study of the development of the, then successful, plywood futures contract. Sandor asserts that price variability of the commodity, homogeneity, break down of forward contracting, existence of a viable cash market, and proper contract specifications to be the prerequisites for a successful futures contract. Sandor and Sossin (1983) document the development of the first interest rate futures contract, i.e. Chicago Board of Trade's (CBOT) initial GNMA contract. Following the requirements noted in Sandor (1973), Sandor and Sossin argue that the liquidity of these contracts and their use by commercial and speculative interests indicated the success of this new futures market. Although both studies are merely descriptive in nature, they can be considered pioneers in the literature on the success and failure of futures contracts.

Hedging effectiveness studies contribute to the literature on this topic by providing a measure of success, as well as a method to compare different contracts. Ederington (1979) evaluates the effectiveness of GNMA and Treasury bill futures contracts as hedge instruments. Dale (1981) analyzes the hedging effectiveness of currency futures markets. Dale concludes that the currency futures were as effective as agricultural commodity futures as hedging instruments. Hill and Schneeweis (1982a and b) also analyze the hedging effectiveness of foreign currency futures markets. Hill and Schneeweis use a more statistically accurate method in measuring the hedging effectiveness than Dale did. All of

these studies apply the portfolio theory of hedging to drive the minimum risk hedge ratios and corresponding hedging effectiveness measures (details of which are discussed in subsequent sections).

Silber (1981) focuses on innovations in futures markets and analyzed the role of competition, costs and benefits of new contract design, and the role of regulation in the success of futures contracts. Silber indicates that success of futures contracts is sensitive to minor changes in their specifications. Carlton (1984) documents the growth of futures markets and discussed the reasons for their success. These studies can be regarded as the descriptive models of successful futures contract development. Black (1986) provides an extensive review of the literature on success and failure of futures contracts. Johnston and McConnell (1989) study the failure of CBOT's GNMA CDR futures contract. Johnston and McConnell conclude that a design flaw appeared to be the cause, and documented that the Treasury bond futures provided better hedging effectiveness than the GNMA contract. Nothhaft, Lekkas, and Wang (1995) investigate the reasons for the failure of CBOT's mortgage-backed futures (MBF) contract. They analyze the hedging effectiveness of the MBF contract relative to the effectiveness of possible cross hedges. They conclude that the Treasury bond futures achieved nearly the same effectiveness as the MBF contract did, and the lack of liquidity in MBF market made the contract more expensive to trade than the Treasury bond contract.

Anderson and Danthine (1981) assert that "cross hedges are in order whenever the cash/futures correlation is a constant different from zero." Therefore, it is possible to state that cross hedging has a positive value-added in terms of risk reduction when cash/futures correlation is different from zero. If the new futures contract is purely innovative, i.e., no

similar contract trades in any exchange, then intended participants of the new futures markets are likely to use related existing exchange-traded futures contract to cross hedge their cash positions only if there is sufficient hedging need. Duffie and Jackson (1990) state that purely “innovative” futures contracts will result in maximized trading volume at the exchange where they are introduced. However, success of a purely innovative futures contract also depends on its value-added.

Building on the previous descriptive studies Black (1986) identifies relative residual risk of cross hedging versus own hedging; liquidity cost of own hedging; cash price volatility; and cash market size to be the determinants of a futures contract’s success and/or failure. Black defines an “own hedge” to take a position in futures contract in which the underlying asset is identical to the spot holdings. The residual risk of a hedge is the risk remaining in a hedged position compared with a theoretically perfect hedge in which all risk is eliminated. Black (1986, p. 22) hypothesizes that “if the risk of price change in a commodity can be reduced sufficiently by cross hedging in an existing, liquid contract, then hedgers have little incentive to use a new futures contract”. In the context of this essay, it is possible to hypothesize that the explicit futures contract’s value-added need to be substantial enough to induce hedgers to switch to it when they utilize its implicit counterpart for their hedging needs. In the case that an implicit contract is used in cross hedging, the residual risk may be less than the case when an own hedge is used. This is possible when the liquidity of new futures market is very low compared to the liquidity of futures used to create the implicit contract. Therefore, comparison of relative hedging effectiveness may be an appropriate method to measure value-added by the explicit contract over its implicit counterpart.

### III. Explicit Contracts

#### III.a. CME Three-month Euro-rate Differential Futures

A given Euro-Rate Differential Futures contract (DIFF) locks in the rate spread between three-month deposit rate on Eurodollars and three-month rate on corresponding Eurocurrency time deposits.<sup>1</sup> For example, Dollar-Mark DIFF locks in the difference between the three-month Eurodollar deposit rate and three-month Euromark deposit rate; i.e.  $\mathfrak{R}_{T,T-90}^f(\text{E\$-EDM}) = 100 - F_{t,T}(\text{E\$-EDM})$ , where  $F_{t,T}(\text{E\$-EDM})$  is the Dollar-Mark DIFF futures price and  $\mathfrak{R}_{T,T-90}^f(\text{E\$-EDM})$  is the spread implied by Dollar-Mark DIFF futures price. Taking a position in a DIFF contract is equivalent to taking a spread position between the three-month Eurodollar time deposit futures contract and a three-month Eurocurrency time deposit futures contract, only if such a Eurocurrency contract trades in any exchange. For example from a borrowers point of view, taking a short position in one DIFF contract is equivalent to taking a short position in one Eurodollar contract and taking a long position in one Euromark contract. Table I describes the salient features of the DIFF contracts.

CME introduced the DIFF's in July 1989. Total number of contracts traded during 1989 were 12,598; 9,618; and 9,390; for Dollar-Mark, Dollar-Pound, and Dollar-Yen DIFF futures, respectively. In 1990, these numbers were 1,478; 1,064; and 3,727, respectively. All contracts ceased trading in 1990, except Dollar-Pound DIFF which ceased trading in early 1992. At the time of the introduction of DIFF's, there were no

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<sup>1</sup> Chicago Mercantile Exchange (1989. p. 2).

futures contracts trading on Eurocurrency time deposits in any of the exchanges around the world. However, positions created by DIFF contracts (explicit futures contracts) could be duplicated synthetically using the existing foreign currency and Eurodollar contracts (implicit futures contracts). For example, a long position in a synthetic Euromark futures together with a short position in Eurodollar futures could duplicate the position created by Dollar-Mark DIFF futures contract.

Euro-rate Differential futures contracts were portrayed by CME to be a “natural hedging vehicle for international banking organizations and multinationals with sizable cross-currency money market activity”.<sup>2</sup> Marshall and Bansal (1993, p. 308) indicate that DIFF’s could be used to: (1) lock in or unlock interest rate differentials when funding in one currency and investing in another, (2) hedge exposures associated with non-dollar interest rate sensitivities, (3) manage the residual risks associated with running a swap book, and (4) manage the risks associated with changing interest rate differentials for a currency dealer. Given the intended users of DIFF’s, it is quite difficult to estimate the size of the cash market for these contracts. However, it is possible to conclude that the target market of the DIFF’s consists of sophisticated participants with sizable positions in variety of contracts. Therefore, it is likely that, in the absence of explicit Euro-rate Differential futures contracts, they could create and use synthetic contracts to hedge their spot positions. Chicago Mercantile Exchange indicated that sufficient cash price volatility existed for DIFF’s to attract hedgers and speculators to the new futures market.<sup>3</sup> Table II provides the descriptive statistics of spreads between the three-month Eurocurrency Time

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<sup>2</sup> Chicago Mercantile Exchange (1989, p. 9).

<sup>3</sup> Chicago Mercantile Exchange (1989, p. 3).

Deposit Rates that underlie the three DIFF contracts. Figure I depicts the volatility of these spreads graphically. The extent to which the cash price volatility was sufficient can be subject to criticism and needs to be further investigated. However, if it is assumed that the differentials between Eurocurrency and Eurodollar time deposits possessed high volatility, then this is further indication that the intended users of DIFF's could already be creating and using synthetic differential contracts for hedging and speculation purposes. However, if the cash price volatility did not warrant sufficient need for hedging, then implicit contracts would not have been utilized, which may further indicate that there was no hedging need for the explicit DIFF contracts in the market. If the intended users of DIFF's were using synthetic contracts, in order for the explicit DIFF contracts to succeed they had to render sufficient value-added to induce these intended users to switch to explicit ones. Up to date, there seems to be no anecdotal evidence neither supporting nor refuting the above discussion regarding the use of synthetic DIFF's as hedging tools.

In a CME Strategy Paper, Kawaller (1990, p. 8) discusses the potential arbitrage and quasi-arbitrage possibilities between the explicit DIFF and forward markets. The possibility of arbitrage between the new futures market and other existing financial contracts provides further price discovery and increased volume in the new futures market. In order for arbitrageurs to enter into the market potential profits need to outweigh the costs. CME's Strategy Paper indicates that the outcome of such arbitrage positions is uncertain. However, an investigation of potential arbitrage strategies with foreign exchange and Eurodollar futures markets would have revealed that explicit DIFF's could synthetically be duplicated using such exchange-traded futures contracts.

### *III.b. CME Currency Cross-rate Futures*

A given Currency Cross-rate Futures contract (CROSS) locks in the cross exchange rate between two foreign currencies. For example, Deutsche mark/Japanese yen (Mark/Yen) CROSS locks in the cross currency exchange rate between Deutsche mark and Japanese yen. Taking position in a CROSS contract is equivalent to taking positions in two separate US dollar denominated foreign currency futures contracts, the currency cross-rate futures price reflects the ratio of the futures prices of two relevant currencies. Table III describes the salient features of the CROSS's.

CME introduced the CROSS's in 1991. Total number of contracts traded during 1991 was 3,605; 8,561, and 1,409 respectively for Pound/Mark, Mark/Yen and Mark/Swiss Franc Cross futures. All contracts ceased trading in 1992. However, a revised version of Mark/Yen CROSS was introduced in 1992 with 10,005 contracts traded in that year. The new Mark/Yen CROSS contract trading ended in 1993. At the time of the introduction of CROSS's, no other exchange around the world had currency cross-rate futures contracts trading. However, positions created by CROSS's (explicit futures contracts) could be duplicated synthetically using the existing US dollar denominated foreign currency futures contracts (implicit futures contracts).

Currency Cross-rate futures contracts were designed to "expand the range of tools available in the foreign exchange market place to traders and hedgers who would endeavor to formulate opinions about the relative values of major international currencies".<sup>4</sup> Given the nature of CROSS's, importers and exporters based in countries other than US, were among the most likely intended users of these contracts. However, trading hours for

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<sup>4</sup> Chicago Mercantile Exchange (1991, p. 11).

CROSS contracts did not exactly match the business hours of respective countries for the importers and exporters to utilize them. Furthermore, since CROSS contracts were settled in US dollars, they could not be easily incorporated into portfolios of foreign importers and exporters. In light of these arguments, it is inferred that CROSS's were also most likely to be used by international banking organizations and multinationals with sizable cross-currency money market activity. Arguments similar to those given for DIFF's suggests that if the intended users of CROSS's had been using synthetic contracts, in order for the explicit CROSS contracts to succeed they needed to render sufficient value-added to induce these intended users to switch to explicit ones. In a CME Strategy Paper on CROSS contracts, Kawaller (1991, p. 3) discusses potential near-arbitrage trades that can be accomplished with increased transaction costs. It is clear that potential participation of arbitrageurs may help increase the value-added created by the introduction of a new contract. However, such participation can not guarantee the success of the new contract if there is lack of sufficient hedging demand for it

#### **IV. Implicit Contracts**

##### *IV.a. Synthetic Euro-rate Differential Futures Contracts*

Siegel and Siegel (1990, pp. 377-378) show that it is possible to create synthetic foreign currency denominated interest rate futures by using foreign currency and Eurodollar futures contracts. Following their arguments, steps 1 through 3 create a long position in synthetic foreign currency denominated interest rate futures contract (for Eurocurrency A). The addition of Step 4 creates the short position in the synthetic Euro-

rate Differential futures contract (for the rate differential between Eurodollars and Eurocurrency A). To create a short position in synthetic DIFF contract, at t:

- a) Short currency A futures (expiring at T) to lock in the exchange rate  $F_{t,T}(\$/A)$ ,
- b) Long  $N_{ES, T}$  Eurodollar futures (expiring at T) to lock in the lending rate (between T and T+90) implied by the futures price  $F_{t,T}(\text{ES})$ ,
- c) Long currency A futures (expiring at T+90) to lock in the exchange rate  $F_{t,T-90}(\$/A)$ ,
- d) Short one Eurodollar futures contract (expiring at T).

The spread implied by synthetic Euro-rate differential futures (expiring at T) is given by:<sup>5</sup>

$${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{ES-EC}_A) = \dot{r}'_{T,T-90}(\$) - {}_s \dot{r}'_{T,T-90}(\text{EC}_A), \quad (1)$$

where  $\dot{r}'_{T,T-90}(\$)$  is the three month deposit rate implied by Eurodollar futures at t, and

${}_s \dot{r}'_{T,T-90}(\text{EC}_A)$  is the three month deposit rate implied by synthetic Eurocurrency futures at

t. Then, at t, the Synthetic Euro-rate Differential futures price, i.e.,  ${}_s F_{t,T}(\text{ES-}_s\text{EC}_A)$  can be

derived as:

$${}_s F_{t,T}(\text{ES-}_s\text{EC}_A) = F_{t,T}(\text{ES}) \left( 1 - \frac{F_{t,T}(\$/A)}{F_{t,T-90}(\$/A)} \right) + 500 \frac{F_{t,T}(\$/A)}{F_{t,T-90}(\$/A)} - 400. \quad (2)$$

Derivation of equation (2) is included in the Appendix. The implied spread,

$${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{ES-EC}_A),$$

$${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{ES-EC}_A) = 100 - {}_s F_{t,T}(\text{ES-}_s\text{EC}_A), \quad (3)$$

corresponds to either an effective borrowing rate (percent per annum) if the Eurodollar

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<sup>5</sup> Where the use of (.) above the rate denotes that it is implied by the futures price and the use of pre-subscript S denotes that the synthetic nature of the variable.

rate is greater than the Eurocurrency rate or an effective lending rate if the Eurocurrency rate is greater than the Eurodollar rate. The net Eurodollar position depends on the coefficient of  $F_{t,T}(\text{E}\$)$ , i.e.  $(1 - F_{t,T}(\$ / A) / F_{t,T-90}(\$ / A))$ . If  $F_{t,T}(\$ / A)$  is less (greater) than  $F_{t,T-90}(\$ / A)$  then this corresponds to a net long (short) position in Eurodollar contracts, which is consistent with the theory on exchange rates and interest rates. If the interest rates for currency A denominated securities are expected to rise relative to interest rates for US dollar denominated securities then the demand for currency A increases which, in turn, is reflected in currency A, futures prices ( $F_{t,T-90}(\$ / A)$  is greater than  $F_{t,T}(\$ / A)$ ). If one expects the interest rates for currency A denominated securities to rise relative to interest rates for US dollar denominated securities, he/she would take a short position in the synthetic Euro-rate Differential futures contract to take advantage of the narrowing of the spread between Eurodollar rates and Eurocurrency rates (in the case of the Eurodollar rate being greater than the Eurocurrency rate).

#### *II.b. Synthetic Cross-rate Futures Contracts*

Siegel and Siegel (1990, pp. 372-373) also show that it is possible to create synthetic currency cross-rate futures by using US dollar denominated foreign currency futures contracts. To create a long position in synthetic CROSS contract, at t:

- a) Long  $N_{A,T}$  currency A futures (expiring at T) to lock in the exchange rate  $F_{t,T}(\$ / A)$ .
- b) Short  $N_{B,T}$  currency B futures (expiring at T) to lock in the exchange rate  $F_{t,T}(\$ / B)$ .

Then, at t, the currency cross-rate futures price, i.e.,  ${}_s F_{t,T}(A/B)$ , can be derived as,

$${}_s F_{t,T}(A/B) = \frac{F_{t,T}(\$ / A)}{F_{t,T}(\$ / B)} \quad (4)$$

Equation (4) represents the exchange rate (at T) which is locked in by the synthetic cross-rate futures. Derivation of equation (4) is presented in the Appendix.

Both types of implicit contracts are created synthetically using existing highly liquid futures contracts. Therefore, pricing of implicit and explicit contract would be affected by margin requirements. Combined margin requirements of the components of implicit contracts may be higher than margin requirement of the explicit contract. However, the additional margin requirement due to using implicit contracts instead of the explicit ones would be insignificant since intended users would already have sizable positions in each of the futures contracts making up the necessary synthetic contract.

## V. Hedging Effectiveness Methodology

In this essay, first the effectiveness of individual implicit and explicit contracts in reducing the price risk of spot positions is analyzed. Then the relative hedging effectiveness of these contracts are determined.

Following Ederington (1979), hedging effectiveness of each contract are estimated using the coefficient of determination,  $R^2$ , between the change in the cash price and the change in the futures price, i.e.

$$HE \equiv R^2 = \frac{\sigma_{cf}^2}{\sigma_c^2 \sigma_f^2}, \text{ of the regression } \Delta \tilde{P}_c = \beta_0 + \beta_1 \Delta \tilde{P}_f + \tilde{e}, \quad (5a, b)$$

where  $\sigma_{cf}$  is the covariance between cash (spot) and futures price changes;  $\sigma_c^2$  and  $\sigma_f^2$  are the variances of cash price changes and futures price changes, respectively. Hill and

Schneeweis (1982) assert that this measure of hedging effectiveness can be interpreted as the proportional reduction in the variance of spot (cash) price changes when the appropriate futures contract is used to construct the hedge portfolio with minimum risk. In this context, higher values of  $R^2$  imply greater degree of hedging effectiveness. However, a simple comparison of  $R^2$ 's cannot be a statistical test of relative hedging effectiveness of the explicit contracts over the implicit ones. This essay utilizes the method suggested by Nothaft, Lekkas, and Wang (1995) to statistically test the hedging effectiveness of own hedge versus cross hedge.<sup>6</sup> In the context of this essay own hedge corresponds to using the explicit futures contracts, i.e., either DIFF's or CROSS's accordingly, as a hedging instrument. Cross hedging can be achieved by maintaining a position in implicit futures, i.e., in synthetically created contracts. Regression equations for own and cross hedging, respectively, are given by:

$$\Delta \tilde{P}_c = \beta_{0e} + \beta_{1e} \Delta \tilde{P}_{fe} + \varepsilon_{e,t}, \quad \Delta \tilde{P}_c = \beta_{0i} + \beta_{1i} \Delta \tilde{P}_{fi} + \varepsilon_{i,t}, \quad (6a, b)$$

where subscripts  $e$  and  $i$  denote the usage of explicit and implicit futures contracts as the hedging instrument. Since equations (6a) and (6b) have the same dependent variable, i.e., the cash price changes,  $\varepsilon_{e,t}$  and  $\varepsilon_{i,t}$  are not independent. Nothaft, Lekkas, and Wang used an indirect test on the equality of the residual variances. The null hypothesis that the variances of residuals from equations (6a) and (6b) are equal implies that explicit and implicit futures contracts achieve the same hedging effectiveness. To proceed with the testing of the null hypothesis, i.e.,

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<sup>6</sup> The Nothaft, Lekkas, and Wang method help determine the statistical significance of the observed difference in the  $R^2$ 's of the two regressions.

$$H_0 : \text{var}(\varepsilon_{e,t}) = \text{var}(\varepsilon_{i,t}), \quad (7)$$

the following transformation is necessary:<sup>7</sup>

$$z_{1,t} = \varepsilon_{e,t} + \varepsilon_{i,t} \quad \text{and} \quad z_{2,t} = \varepsilon_{e,t} - \varepsilon_{i,t}. \quad (8a, b)$$

As a result of this transformation, covariance between the new variables establishes the relationship between residual variances in (7), i.e.,

$$\text{cov}(z_{1,t}, z_{2,t}) = \text{var}(\varepsilon_{e,t}) - \text{var}(\varepsilon_{i,t}). \quad (9)$$

Then, the test of  $\text{cov}(z_{1,t}, z_{2,t})$  being equal to zero is equivalent to the testing of the original null hypothesis that the variances of the residuals are equal. However, the test of  $\text{cov}(z_{1,t}, z_{2,t})$  being equal to zero is equivalent to the testing the significance of  $\beta_1$  in the following regression:

$$z_{1,t} = \beta_0 + \beta_1 z_{2,t} + u_t. \quad (10)$$

Since  $\beta_1 = \text{cov}(z_{1,t}, z_{2,t}) / \text{var}(z_{2,t})$ , testing (using the t-test) whether or not  $\beta_1$  is significantly different from zero is sufficient to test the null hypothesis given in (7). If  $\beta_1$  is not significantly different from zero, then the two futures contracts under examination are equal in hedging effectiveness. Therefore, if  $\beta_1$  is not significantly different from zero, then explicit and implicit futures contracts achieve the same hedging effectiveness. If  $\beta_1$  is significantly different from zero and it is positive, i.e.,  $\text{var}(\varepsilon_{e,t}) > \text{var}(\varepsilon_{i,t})$ , then the implicit futures contract proves to be a better hedging instrument than the explicit futures

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<sup>7</sup>For further discussion of this test refer to Nothhaft, Lekkas and Wang (1995).

contract. In the case when  $\beta_1$  is negative, the explicit contract is a better hedge than the implicit one. If  $\beta_1$  is significant and positive, then the implicit contract provides higher risk reduction than the explicit contract.<sup>8</sup> The next section discusses the results of the analysis of hedging effectiveness and the test of relative hedging effectiveness of DIFF and CROSS contracts versus the corresponding synthetic ones.

Before proceeding to the next section, it is necessary to note that the hedging effectiveness measures and tests described above possess “a time dimension.” More specifically, the above procedures do not take into account the effect of basis risk on the minimum-variance hedge ratios. The minimum-variance hedge ratio can be defined as the ratio of the quantity of futures position to the quantity of cash position that minimizes the risk of the hedged portfolio. Castelino (1992, p. 188) indicates that the “the minimum-variance hedge ratio is low for hedges lifted far from contract expiration and monotonically increases as the hedge-lifting date approaches contract expiration.” Castelino also discusses the relationship of “time dimension” to basis risk and the need to adjust the procedures described above to obtain more accurate hedge ratios and hedging effectiveness measures. Since this essay uses the same measure of hedging effectiveness for both implicit and explicit contracts, the test derived from that measure ( $R^2$ ) is sufficient to compare the effectiveness of DIFF and CROSS contracts to those of corresponding synthetic ones.<sup>9</sup>

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<sup>8</sup> Since, in a simple regression, there is a one-to-one correspondence between the variance of the error terms and the  $R^2$  of the regression, the results of the Nothhaft, Lekkas, and Wang method would be consistent with observed  $R^2$ 's as long as the variances of error terms are statistically significantly different.

<sup>9</sup> Another reason for not including the “time dimension” is that both the explicit and implicit contracts would have the same hedge lifting date.

## **VI. Data and Empirical Results**

The daily settlement prices for the Euro-rate Differential and Currency Cross-rate futures are provided by the Chicago Mercantile Exchange's data retention division. The daily settlement prices of the foreign currency and Eurodollar futures contracts, as well as the spot foreign exchange rates and Eurodollar time deposit rates are from the Futures Industry Institute. Spot Eurocurrency time deposits rates are obtained from DRI, Inc.

The data set for the DIFF contracts extend from July 6, 1989 to December 17, 1990, covering the entire duration of their trading. Since the available data set for the initial CROSS contracts does not contain a sufficient number of usable prices, the analysis is carried out only for the revised Deutsche mark/Japanese yen CROSS futures, using the prices between January 1, 1992 and December 17, 1992. The necessary prices for the construction of synthetic DIFF and CROSS contracts are also compiled to match the above dates.

Futures price level data sets (for both DIFF's and CROSS's) are constructed by using the settlement price of the contract with the closest expiration for each date that the explicit contracts traded. Cash price level data sets for DIFF's are constructed by taking the difference between the two corresponding spot Eurocurrency deposit rates. Cash price level set for the Deutsche mark/ Japanese yen (Mark/Yen) CROSS consists of the ratio of the corresponding spot foreign exchange rates. Futures prices for synthetic DIFF's are calculated using equation (2). Futures prices for synthetic Deutsche mark/Japanese yen currency cross-rate are calculated using equation (4). By using the prices of the futures contract with the closest expiration, the effect of basis risk on the hedging effectiveness measure is minimized. Prior futures markets research indicates that the nearby contracts

attain higher liquidity than those with distant expirations do. The dates for which one or more futures or cash price was missing are eliminated from the data sets. The futures and cash price change data sets are the first differences of corresponding price level data sets. Any missing futures or cash price from the original levels data sets were preserved as missing during the construction of price change sets and the changes for which any missing value was recorded were eliminated from the price change data sets.

Hedging effectiveness estimates, the coefficient of determination,  $R^2$ , and the standard error (S.E.R) of the price change regressions, for Dollar-Mark, Dollar-Pound, Dollar-Yen DIFF, Mark/Yen CROSS contracts and for corresponding synthetic contracts are presented in Table IV.

As shown in Table IV,  $R^2$ 's of regressions with synthetic (SYNT) futures price changes are consistently higher than those of the explicit (DIFF and CROSS) futures price changes. The use of Dollar-Mark DIFF (explicit) contract as the hedging instrument results in 11.68% reduction in the variance of spot price changes. However, if the synthetic (implicit) futures contract is used to hedge the rate differential between the Eurodollar and the Euromark time deposits, then a 14.51% reduction is obtained. The figures for Dollar-Pound and Dollar-Yen DIFF's are 7.21% and 2.23%, respectively. The use of synthetic contracts instead of the Dollar-Pound and Dollar-Yen DIFF's increases the proportion of reduction in the variance of spot price changes to 10.60% and 8.42%, respectively. The use of Mark/Yen CROSS (explicit) contract as the hedging instrument results in 68.24% reduction in the variance of spot price changes. However, if the synthetic (implicit) currency cross-rate futures contract is used instead of the Mark/Yen CROSS, then 74.51% reduction is obtained.

The regressions where the independent variables are  $\Delta DIFF$ ,  $\Delta CROSS$ , and  $\Delta SYNT$  show the relationship between the explicit futures price changes and synthetically created implicit futures price changes<sup>10</sup>. Furthermore, in the regressions where the independent variable is  $\Delta CASH$ , the higher standard error of regression (S.E.R.) indicates that the variance of the dependent variable is higher than that of the  $\Delta CASH$ . Table IV shows that, except in the case of Dollar-Pound DIFF, the S.E.R.'s are higher in the lower diagonal regressions than those in the upper diagonal regressions.

Table V presents the results of the test of relative hedging effectiveness for each pair of explicit and implicit contracts. As stated earlier, the test of the significance of  $\beta_1$  is sufficient to test the equality of the variances of residuals from the regressions with explicit and implicit futures. Table V shows that the estimate of  $\beta_1$  (0.5616), in testing the relative hedging effectiveness of Dollar-Mark DIFF versus the synthetic differential contract, is significant at 5% level. This significant and positive coefficient implies that the synthetic (implicit) contract was a better hedging instrument than the Dollar-Mark DIFF (explicit) contract at the time of its trading. In comparing the Dollar-Yen DIFF and the Mark/Yen CROSS to the corresponding synthetic contracts, the estimates of  $\beta_1$  (1.2672 and 0.2360, respectively) are also found to be significant at the 5% level. The estimate of  $\beta_1$  (0.7022), in testing the relative hedging effectiveness of Dollar-Pound DIFF versus the synthetic contract, is significant at the 10% level. These results show, ex post, that the synthetic contracts achieve higher hedging effectiveness than the DIFF and CROSS contracts. The fact that, ex-post, the hedging effectiveness of implicit contracts are found

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<sup>10</sup> This is because, in a simple regression,  $R^2$  is the square root of the correlation coefficient between the dependent and independent variables.

to be higher than those of the DIFF and CROSS contracts indicates that the value-added provided by the explicit contracts was not sufficient to induce their intended users to use them instead of their implicit counterparts.

## **VII. Conclusions**

This essay, utilizing a case study approach, investigates the potential success of an explicit futures contract when an implicit one, which can duplicate it, exists. The essay specifically focuses on the cases in which an explicit contract is interpreted to be the new futures contract, while an implicit contract is defined to be one which can be created synthetically using existing highly liquid exchange-traded futures contracts. It is hypothesized that the success of the explicit futures contract depends on its value-added being greater than that of its implicit counterpart given that sufficient hedging demand exists for it. The new contract's value-added can appear as reduction in transaction costs compared to those of the counterpart and/or as reduction in risks associated with the counterpart. Transaction costs in futures markets are composed of bid-ask spreads, commissions/fees, and market cost of executing a large order. Risks associated with the counterpart contracts can be viewed as credit and basis risks. As discussed in the essay, an explicit contract's value-added, in terms of reducing transaction costs, can be less than that of its implicit counterpart due to market liquidity. In such a case, an explicit contract should provide higher value-added, in terms of reducing risks, than the implicit one in order for it to succeed. However, if the implicit contract provides equal or higher hedging effectiveness than the explicit contract, it is possible to assert that the explicit contract fails

to provide sufficient value-added to warrant its intended users to switch to it when they utilize its implicit counterpart for their hedging and speculative needs.

The CME's failed Euro-rate Differential Futures (DIFF's) and Currency Cross-rate Futures (CROSS's) are identified as explicit contracts which, at the time of their introduction, could be replicated by corresponding implicit ones. The hedging effectiveness of the explicit and implicit differential and cross contracts are estimated. The results of the statistical test of relative hedging effectiveness of the explicit versus the implicit contracts support the above hypothesis. The hedging effectiveness of the synthetically created Euro-rate differential and currency cross-rate contracts is found to be higher than those of the corresponding DIFF and CROSS contracts. This suggests that the intended users of the new futures contracts would utilize the synthetic contracts instead of the DIFF's and CROSS's. The fact that the hedging effectiveness of the DIFF and CROSS contracts were less than the corresponding synthetic ones may indicate that the introduction of the explicit DIFF and CROSS contracts could not create sufficient value-added. Ex post, this indication may further explain the lack of success of either the DIFF or CROSS contracts. These findings have important implications for the introduction of a new futures contract, namely that if a combination of exchange-traded futures contracts can implicitly duplicate an intended new contract, a thorough analysis of contract's potential value-added should be conducted.

Further research on this topic is both necessary and useful. An ex ante value-added analysis can be developed to aid successful futures contract development efforts. A possible ex-ante value-added analysis focusing on risk reduction, i.e. hedging effectiveness, could include a simulation methodology which forecasts the hedging

effectiveness of the implicit contracts and examine the potential of the explicit contract attaining equal or higher hedging effectiveness levels. Ex ante value-added test results should be compared with the ex post conclusions using explicit and implicit contracts from both the US and foreign futures markets.

## Appendix

The derivations of synthetic Euro-rate Differential and synthetic Currency Cross-rate Futures Contracts are presented in this appendix. Preceding each derivation, the necessary notation is also provided.

### Notation for Synthetic Euro-rate Differential Futures Contracts:

All rates are quoted in percentages per annum and compounded quarterly.

$F_{t,T}(\$/A)$  : Currency A futures (expiring at T) price at t,

$F_{t,T}(\text{E}\$)$  : Eurodollar futures price at t,

$F_{t,T}(\text{E}\$-\text{E}C_A)$  : Euro-rate differential futures (expiring at T) price at t.

${}_s F_{t,T}(\text{E}\$-{}_s\text{E}C_A)$  : Synthetic Euro-rate differential futures price at t,

$r'_{t,T-90}(\text{\$})$  : Three month spot Eurodollar deposit rate at t,

$r'_{t,T-90}(\text{E}C_A)$  : Three month spot Eurocurrency deposit rate at t,

$\dot{r}'_{T,T-90}(\text{\$})$  : Three month deposit rate implied by Eurodollar futures (expiring at T) at t.

$\dot{r}'_{T,T-90}(\text{E}C_A)$  : Three month deposit rate implied by Eurocurrency futures at t,

${}_s \dot{r}'_{T,T-90}(\text{E}C_A)$  : Three month deposit rate implied by synthetic Eurocurrency futures at t.

$\mathfrak{R}'_{T,T-90}(\text{E}\$-\text{E}C_A)$  : Spread implied by Euro-rate differential futures (expiring at T) at t,

${}_s \mathfrak{R}'_{T,T-90}(\text{E}\$-\text{E}C_A)$  : Spread implied by synthetic Euro-rate differential futures at t.

$Q_T^A$  : Amount of currency A at T,

$N_{A,T}$  : Number of A futures (expiring at T) to short/long,

Following the futures contract specifications:

$$r'_{T,T-90}(\$) = 100 - F_{t,T}(\text{E\$}), \text{ at } \forall t < T \text{ and } F_{T,T}(\text{E\$}) = 100 - r'_{T,T-90}(\$), \text{ at } T; \quad (\text{A.1})$$

$$\mathfrak{R}'_{T,T-90}(\text{E\$-EC}_A) = 100 - F_{t,T}(\text{E\$-EC}_A), \text{ at } \forall t < T \text{ and} \quad (\text{A.2})$$

$$F_{T,T}(\text{E\$-EC}_A) = 100 - [r'_{T,T-90}(\$) - r'_{T,T-90}(\text{EC}_A)] \text{ at } T. \quad (\text{A.3})$$

Using foreign currency and Eurodollar futures contracts steps 1 through 3 create a long position in synthetic foreign currency denominated interest rate futures contract. The addition of Step 4 creates the short position in the synthetic Euro-rate Differential futures contract (for the rate differential between Eurodollars and Eurocurrency A).

**Step 1:** At  $t$ , short currency A futures (expiring at  $T$ ) to lock in the exchange rate

$F_{t,T}(\$ / A)$  at  $T$ . Amount of US dollar funds to hold at  $T$  is:

$$Q_T^S = Q_T^A F_{t,T}(\$ / A). \quad (\text{A.4})$$

Number of currency A contracts (expiring at  $T$ ) to short is:

$$N_{A,T} = \frac{Q_T^A}{\text{currency A futures contract size}}. \quad (\text{A.5})$$

This ensures the purchase of  $Q_T^S$  dollars at  $T$  by paying  $Q_T^A$  of currency A.

**Step 2:** At  $t$ , long Eurodollar futures (expiring at  $T$ ) to lock in the lending rate (between  $T$  and  $T+90$ ) implied by the futures price  $F_{t,T}(\text{E\$})$ . US dollar holdings at  $T+90$  is:

$$Q_{T-90}^S = Q_T^S \left( 1 + \frac{r'_{T,T-90}(\$)}{4 \times 100} \right). \quad (\text{A.6})$$

Using (A.1) and (A.6),

$$Q_{T-90}^S = Q_T^S \left( 1 + \frac{100 - F_{t,T}(\text{E\$})}{4 \times 100} \right) = Q_T^S (500 - F_{t,T}(\text{E\$})) / 400. \quad (\text{A.7})$$

Number of Eurodollar contracts (expiring at  $T$ ) to long is;

$$N_{ES, T} = \frac{Q_T^S}{\$1,000,000} \quad (A.8)$$

This ensures investing  $Q_T^S$  (at a rate  $r'_{T, T-90}(\$)$  p.a.) at T and receiving  $Q_{T-90}^S$  at T+90.

**Step 3:** At t, long currency A futures (expiring at T+90) to lock in the exchange rate

$F_{t, T-90}(\$/A)$  at T. Amount of currency A funds to acquire at T is:

$$Q_{T-90}^A = \frac{Q_{T-90}^S}{F_{t, T-90}(\$/A)} \quad (A.9)$$

Using (A.7) and (A.9),

$$Q_{T-90}^A = \frac{Q_T^S (500 - F_{t, T}(\text{E}\$)) 400}{F_{t, T-90}(\$/A)} = \frac{Q_T^S (500 - F_{t, T}(\text{E}\$))}{400 F_{t, T-90}(\$/A)} \quad (A.10)$$

Using (A.4) and (A.10),

$$Q_{T-90}^A = \frac{Q_T^A F_{t, T}(\$/A) (500 - F_{t, T}(\text{E}\$))}{400 F_{t, T-90}(\$/A)} \quad (A.11)$$

Number of currency A contracts (expiring at T+90) to short is:

$$N_{A, T-90} = \frac{Q_{T-90}^A}{\text{currency A futures contract size}} \quad (A.12)$$

This ensures the purchase of  $Q_{T-90}^A$  currency A at T+90 by paying  $Q_{T-90}^S$  US dollars.

Then, at t, the three month deposit rate implied by synthetic Eurocurrency futures

(expiring at T) is given by: 
$$s'_{T, T-90}(\text{EC}_A) = 400 \left( \frac{Q_{T-90}^A}{Q_T^A} - 1 \right) \quad (A.13)$$

Using (A.4), (A.11) and (A.13),

$$s'_{T, T-90}(\text{EC}_A) = 400 \left[ \left( \frac{Q_T^A F_{t, T}(\$/A) (500 - F_{t, T}(\text{E}\$))}{400 F_{t, T-90}(\$/A)} \right) / Q_T^A - 1 \right], \text{ and} \quad (A.14)$$

$${}_s \dot{r}'_{T,T-90}(\text{EC}_A) = 400 \left[ \left( \frac{F_{l,T}(\$ / A)(500 - F_{l,T}(\text{E\$}))}{400F_{l,T-90}(\$ / A)} \right) - 1 \right].$$

As a result, at  $t$ , three month deposit rate implied by synthetic Eurocurrency futures (expiring at  $T$ ),  ${}_s \dot{r}'_{T,T-90}(\text{EC}_A)$ , can be derived as:

$${}_s \dot{r}'_{T,T-90}(\text{EC}_A) = \left( \frac{F_{l,T}(\$ / A)}{F_{l,T-90}(\$ / A)} [500 - F_{l,T}(\text{E\$})] \right) - 400. \quad (\text{A.15})$$

**Step 4:** At  $t$ , short one Eurodollar futures contract (expiring at  $T$ ). The spread implied by synthetic Euro-rate differential futures (expiring at  $T$ ) is given by ,

$${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{E\$-EC}_A) = \dot{r}'_{T,T-90}(\$) - {}_s \dot{r}'_{T,T-90}(\text{EC}_A). \quad (\text{A.16})$$

Using (A.1), (A.15) and (A.16),

$${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{E\$-EC}_A) = 100 - F_{l,T}(\text{E\$}) - \left[ \left( \frac{F_{l,T}(\$ / A)}{F_{l,T-90}(\$ / A)} [500 - F_{l,T}(\text{E\$})] \right) - 400 \right] \quad (\text{A.17})$$

$${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{E\$-EC}_A) = [500 - F_{l,T}(\text{E\$})] \left[ 1 - \frac{F_{l,T}(\$ / A)}{F_{l,T-90}(\$ / A)} \right]. \quad (\text{A.18})$$

This implied spread,  ${}_s \dot{\mathcal{R}}'_{T,T-90}(\text{E\$-EC}_A)$ , corresponds to the Synthetic Euro-rate Differential futures (expiring at  $T$ ) price  ${}_s F_{l,T}(\text{E\$-sEC}_A)$  and it is given by:

$${}_s F_{l,T}(\text{E\$-sEC}_A) = 100 - {}_s \dot{\mathcal{R}}'_{T,T-90}(\text{E\$-EC}_A). \quad (\text{A.19})$$

Using (A.3),

$${}_s F_{l,T}(\text{E\$-sEC}_A) = 100 - \dot{r}'_{T,T-90}(\$) + {}_s \dot{r}'_{T,T-90}(\text{EC}_A), \text{ and} \quad (\text{A.20})$$

$${}_s F_{l,T}(\text{E\$-sEC}_A) = F_{l,T}(\text{E\$}) + {}_s \dot{r}'_{T,T-90}(\text{EC}_A).$$

Using (A.15) and (A.19),

$${}_s F_{t,T}(\text{E\$-sEC}_A) = F_{t,T}(\text{E\$}) + \left( \frac{F_{t,T}(\$ / A)}{F_{t,T-90}(\$ / A)} [500 - F_{t,T}(\text{E\$})] \right) - 400 \quad (\text{A.21})$$

Then, at t, the Synthetic Euro-rate Differential futures (expiring at T) price,

${}_s F_{t,T}(\text{E\$-sEC}_A)$  can be derived as:

$${}_s F_{t,T}(\text{E\$-sEC}_A) = F_{t,T}(\text{E\$}) \left( 1 - \frac{F_{t,T}(\$ / A)}{F_{t,T-90}(\$ / A)} \right) + 500 \frac{F_{t,T}(\$ / A)}{F_{t,T-90}(\$ / A)} - 400. \quad (\text{A.22})$$

### Notation for Synthetic Cross-Rate Futures Contracts:

$P_t (\$/A)$  : Spot exchange rate for currency A at t (\$'s per unit of currency A),

$P_t (B/A)$  : Spot cross exchange rate between currency A and currency B at t (units of currency B per unit of currency A),

$F_{t,T} (\$/A)$  : Currency A futures (expiring at T) price at t (\$'s per unit of currency A),

$F_{t,T} (A/B)$  : Cross-rate futures (between currencies A and B) price at t,

${}_s F_{t,T} (A/B)$  : Synthetic cross-rate futures (between currencies A and B) price at t,

Both cross-rate and synthetic futures prices are in units of currency A per unit of currency B.

$Q_T^A$  : Amount of currency A at T,

$N_{A,T}$  : Number of A futures (expiring at T) to short/long.

By definition:

$$P_t (B / A) = \frac{P_t (\$ / A)}{P_t (\$ / B)}. \quad (\text{A.23})$$

Following the futures contract specifications:

$$F_{t,T}(A/B) = \frac{F_{t,T}(\$ / A)}{F_{t,T}(\$ / B)}. \quad (\text{A.24})$$

Using U.S. dollar denominated foreign currency futures contracts, following steps 1 and 2 create a long position in synthetic currency cross-rate futures contract.

**Step 1:** At  $t$ , long currency A futures (expiring at  $T$ ) to lock in the exchange rate  $F_{t,T}(\$ / A)$  at  $T$ .

Amount of US dollars to pay at  $T$  is:

$$Q_T^S = Q_T^A F_{t,T}(\$ / A). \quad (\text{A.25})$$

Number of currency A contracts (expiring at  $T$ ) to long is:

$$N_{A,T} = \frac{Q_T^A}{\text{currency A futures contract size}}. \quad (\text{A.26})$$

This ensures the purchase of  $Q_T^A$  of currency A by paying  $Q_T^S$  dollars at  $T$ .

**Step 2:** At  $t$ , short currency B futures (expiring at  $T$ ) to lock in the exchange rate  $F_{t,T}(\$ / B)$  at  $T$ .

Amount of currency B to pay at  $T$  is:

$$Q_T^B = Q_T^S \frac{1}{F_{t,T}(\$ / B)}. \quad (\text{A.27})$$

Number of currency B contracts (expiring at  $T$ ) to short is:

$$N_{B,T} = \frac{Q_T^B}{\text{currency B futures contract size}}. \quad (\text{A.28})$$

This ensures the purchase of  $Q_T^S$  dollars by paying  $Q_T^B$  of currency B at  $T$ .

Using (A.25),

$$Q_T^B = Q_T^A \frac{F_{t,T}(\$ / A)}{F_{t,T}(\$ / B)}. \quad (\text{A.29})$$

Then, as the result of steps 1 and 2,

$${}_S F_{t,T}(A / B) = \frac{F_{t,T}(\$ / A)}{F_{t,T}(\$ / B)}, \quad (\text{A.30})$$

which is in accordance with the currency cross-rate futures defined in (A.24). Thus, a long position in currency A futures contract combined with a short position in currency B futures contract ensures the purchase of  $Q_T^A$  of currency A by paying  $Q_T^B$  of currency B at T. The exchange rate,  ${}_S F_{t,T}(A/B)$ , locked in by the synthetic cross-rate futures is the price

of the synthetic contract i.e.,  $\frac{F_{t,T}(\$ / A)}{F_{t,T}(\$ / B)}$ .

**Table I**  
**CME Three-month Euro-Rate Differential Futures Contracts Salient Features**

	<u>Dollar-Mark</u>	<u>Dollar-Yen</u>	<u>Dollar-Sterling</u>
Nominal Contract Size	\$1,000,000	\$1,000,000	\$1,000,000
Contract Months	March, June, September, December, spot		
Price Quotations	100-(E\$%-EM%)	100-(E\$%-EY%)	100-(E\$%-ES%)
	(%'s are annualized interest rates)		
Min Price Change	0.01=\$25	0.01=\$25	0.01=\$25
Trading Hours	7:20am-2:00pm CST, last day of trading close 9:30am (3:30pm London)		
Final Settlement	Cash settlement		
Settlement Prices	Final settlement price calculated based on the London Interbank Offer Rates for 3-month Eurodollar and Eurocurrency Time Deposits.		

Source: Chicago Mercantile Exchange (1989).

**Table II**  
**Descriptive Statistics of Euro-Currency Rate Spreads**  
 October 21, 1986 - October 20, 1992

	Eurodollar-Euromark ES%-EM%	Eurodollar-Eurosterling ES%-ES%	Eurodollar-Euroyen ES%-EY%
<b>Mean</b>	0.1586	-4.6481	1.4976
<b>Variance</b>	11.5096	3.5929	4.6166
<b>Min</b>	-6.5625	-8.8125	-1.9375
<b>Max</b>	4.5000	0.0000	5.7500
<b>Median</b>	0.5000	-5.0625	1.6875

**Table III**  
**CME Currency Cross-rate Futures Contracts Salient Features**

	<u>Pound/Mark</u>	<u>Mark/Yen</u>	<u>Mark/Swiss Franc</u>
Nominal Contract Size	\$50.000xBP/DM	\$125.000xDM/JY	\$125.000xDM/SF
Contract Months	March. June. September. December		
Price Quotations	US.\$ per BP price ÷ US.\$ per DM price	US.\$ per DM price ÷ (US.\$ per JY price x100)	US.\$ per DM price ÷ US.\$ per SF price
Min Price Change	0.0005=\$25	0.0002=\$25	0.0002=\$25
Daily Price Limit	0.0500	0.0150	0.0150
Trading Hours	7:20am-2:00pm CST		
Last Day of Trading	Second Friday preceding the third Wednesday of the contract month		
Final Settlement	Cash settlement		
Settlement Prices	Final settlement price based on the appropriate ratio of IMM currency futures settlement prices on the last day of trading.		

Source: Chicago Mercantile Exchange (1991).

**Table IV**  
**Estimates of Hedging Effectiveness of Explicit and Implicit Futures Contracts**

<b>Dollar-Mark</b> Euro-rate <i>DIFF</i> erential Futures and <i>SYNT</i> hetic Differential Futures Contracts				<b>Dollar-Pound</b> Euro-rate <i>DIFF</i> erential Futures and <i>SYNT</i> hetic Differential Futures Contracts			
$\Delta \tilde{P}_c = \beta_0 + \beta_1 \Delta \tilde{P}_f + \tilde{\varepsilon}$				$\Delta \tilde{P}_c = \beta_0 + \beta_1 \Delta \tilde{P}_f + \tilde{\varepsilon}$			
R <sup>2</sup> (S.E.R)	Independent Variable			R <sup>2</sup> (S.E.R)	Independent Variable		
Dependent Variable	$\Delta$ CASH	$\Delta$ <i>DIFF</i>	$\Delta$ <i>SYNT</i>	Dependent Variable	$\Delta$ CASH	$\Delta$ <i>DIFF</i>	$\Delta$ <i>SYNT</i>
$\Delta$ CASH		0.1168 (0.0664)	0.1451 (0.0653)	$\Delta$ CASH		0.0721 (0.1102)	0.1060 (0.1047)
$\Delta$ <i>DIFF</i>	0.1168 (0.0713)		0.4431 (0.0559)	$\Delta$ <i>DIFF</i>	0.0721 (0.1101)		0.5206 (0.0780)
$\Delta$ <i>SYNT</i>	0.1451 (0.0922)	0.4431 (0.0705)		$\Delta$ <i>SYNT</i>	0.1060 (0.1251)	0.5206 (0.0918)	

<b>Dollar-Yen</b> Euro-rate <i>DIFF</i> erential Futures and <i>SYNT</i> hetic Differential Futures Contracts				<b>Deutsche mark/Japanese yen</b> Euro-rate <i>CROSS</i> -rate Futures and <i>SYNT</i> hetic Cross-rate Futures Contracts			
$\Delta \tilde{P}_c = \beta_0 + \beta_1 \Delta \tilde{P}_f + \tilde{\varepsilon}$				$\Delta \tilde{P}_c = \beta_0 + \beta_1 \Delta \tilde{P}_f + \tilde{\varepsilon}$			
R <sup>2</sup> (S.E.R)	Independent Variable			R <sup>2</sup> (S.E.R)	Independent Variable		
Dependent Variable	$\Delta$ CASH	$\Delta$ <i>DIFF</i>	$\Delta$ <i>SYNT</i>	Dependent Variable	$\Delta$ CASH	$\Delta$ <i>CROSS</i> <i>S</i>	$\Delta$ <i>SYNT</i>
$\Delta$ CASH		0.0223 (0.0751)	0.0842 (0.0747)	$\Delta$ CASH		0.6824 (0.0029)	0.7451 (0.0026)
$\Delta$ <i>DIFF</i>	0.0223 (0.0754)		0.4742 (0.0550)	$\Delta$ <i>CROSS</i>	0.6824 (0.0030)		0.9019 (0.0017)
$\Delta$ <i>SYNT</i>	0.0842 (0.0887)	0.4742 (0.0651)		$\Delta$ <i>SYNT</i>	0.7451 (0.0027)	0.9019 (0.0017)	

R<sup>2</sup> : coefficient of determination, S.E.R : standard error of regression

**Table V**  
**Tests of Relative Hedging Effectiveness of**  
**Explicit versus Implicit Contracts**

Explicit vs Implicit	$\beta_1^\dagger$	t-statistics	Number of observations
Dollar-Mark DIFF vs Synthetic Dollar-Mark	0.5616	1.963 <sup>**</sup>	328
Dollar-Pound DIFF vs Synthetic Dollar-Pound	0.7022	1.648 <sup>*</sup>	328
Dollar-Yen DIFF vs Synthetic Dollar-Yen	1.2672	2.177 <sup>**</sup>	337
Mark/Yen CROSS vs Synthetic Mark/Yen	0.2360	3.638 <sup>**</sup>	252

<sup>†</sup> Positive coefficient implies that variance of residuals when the synthetic (implicit) contract is used is less than the case when the explicit contract is used as the hedging instrument, i.e. implicit contracts is a better hedge than the explicit one.

<sup>\*\*</sup>, <sup>\*</sup> Indicates statistical significance at 0.05 and 0.10 level, respectively.

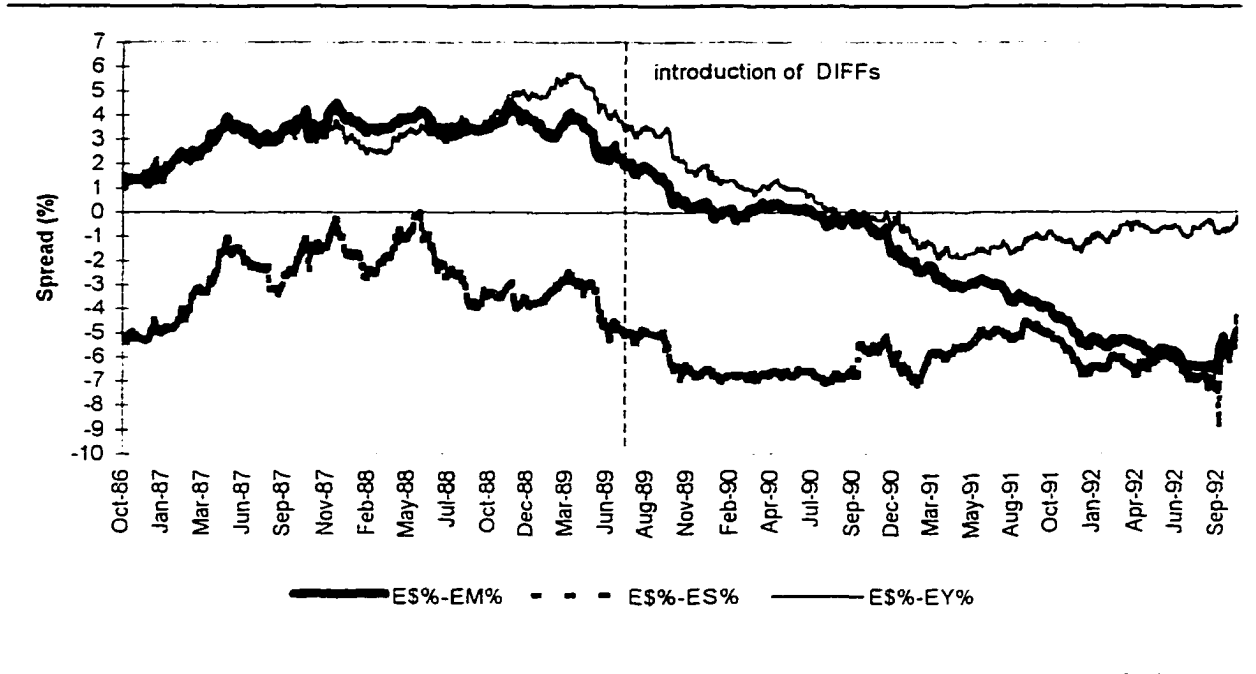
$\beta_1$  : slope coefficient from the regression  $z_{1,t} = \beta_0 + \beta_1 z_{2,t} + u_t$ , where  $z_{1,t} = \varepsilon_{e,t} + \varepsilon_{i,t}$ , and

$z_{2,t} = \varepsilon_{e,t} - \varepsilon_{i,t}$ ;  $\varepsilon_{e,t}$  and  $\varepsilon_{i,t}$  are residuals of regressions when hedging instrument is the

explicit and the implicit contracts, i.e.  $\Delta \tilde{P}_c = \beta_{0e} + \beta_{1e} \Delta \tilde{P}_{je} + \varepsilon_e$ ,

$\Delta \tilde{P}_c = \beta_{0i} + \beta_{1i} \Delta \tilde{P}_{ji} + \varepsilon_i$ , respectively.

**Figure I**  
**Spread between Three Month Eurocurrency Time Deposit Rates**  
**October 21, 1986 - October 20, 1992**



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## **Essay II**

### **Impact of Contract Size Change on Microstructure of a Futures Market**

## **I. Introduction**

Contract size is an essential element in design of a successful futures contract. Sandor (1973), Silber (1981), and Black (1986) note the importance of appropriate contract and tick size for the viability of a futures market. There is limited empirical research on this topic, with the exception of Brown, Laux, and Schachter (1991), who investigate the optimal futures tick size, and Huang and Stoll (1998), who examine the need to split the S&P 500 futures contract.

On November 1, 1997 the CME split the S&P 500 futures by reducing the multiplier by half. Both before and after the split, there was considerable debate about the effects of such a split on liquidity and transaction costs (see Hunter 1998).

A comparable event on the Sydney Futures Exchange (SFE) is the reduction in size of its All Ordinaries Share Price Index (SPI) futures contract traded and the increase in size of its 90-day Bank Accepted Bill (BAB) futures contract. Respecification of the SPI and BAB contracts presents a unique opportunity to investigate the effects of decreases and increases in futures contract size on the same exchange. After controlling for market factors, the results indicate that the decrease in the size of the SPI futures contract resulted in higher trading volume, while the decrease in the size of the BAB futures contract resulted in lower trading volume. For both the SPI and BAB contracts, the impact of contract respecification on bid-ask spreads is ambiguous.

Modifications made to the contract terms of the SPI futures included not only a reduction of the multiplier, effectively reducing the value of the contract, but also an increase in the size (not the dollar value) of the minimum allowed price fluctuation (tick). In the case of the BAB futures, the face value of the underlying deliverable bank bills was increased but the minimum tick size was not changed.

Implemented independently, a decrease in contract size and an increase in the minimum tick may have offsetting effects on liquidity and transaction costs. This essay uses market microstructure theory to develop and test the implications of these contract respecifications. The institutional details of SFE and the particular contracts are explained and the effectiveness of the modifications to the contract terms is discussed.

## II. Review of Microstructure Theory

Microstructure theory has principally focused on adverse selection and inventory control to explain the role of equity market-making as related to liquidity and transaction costs.<sup>1</sup> Manaster and Mann (1996), using detailed futures audit trail transaction data, present evidence that neither the adverse selection nor the inventory control models accurately describe market maker behavior in futures markets. Tse (1999) indicates that none of the three models developed for equity markets (adverse selection, inventory control, and specialist market power) can reasonably describe the bid-ask spread behavior in futures markets. Grossman and Miller (1988) argue that risks borne by any single scalper are reduced through the diversifying effects of many market makers in the competitive open outcry futures markets. These research articles can be taken as evidence against the suitability of adverse selection and inventory control models for futures markets.

There are no designated market makers in the futures markets. Silber (1984).

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<sup>1</sup> Examples of research on adverse selection are Glosten and Milgrom (1985), Kyle (1985), and Admati and Pfleiderer (1989); research on inventory control models includes Demsetz (1968), Amihud and Mendelson (1980), Ho and Stoll (1983).

Brorsen (1989), and Kuserk and Locke (1993) argue that, since scalpers voluntarily provide liquidity, the returns they earn are based on their quoted bid-ask spread and on the frequency with which their bids are hit and their offers lifted. Silber (1984) and Manaster and Mann (1996) indicate that the income scalpers earn is derived more from the frequency of trading and the ability to predict intraday price moves than from their market power in setting bid-ask spreads. Consequently, any exogenous factors that increase trading frequency will increase the income scalpers earn and, given scalpers income elasticity, will likely result in narrower quoted spreads.

Wang, Michalski, Moriarty, and Jordan (1990); Wang, Michalski, Jordan, and Moriarty (1994); Wang, Yau, and Baptiste (1997); and Tse (1999) find that bid-ask spreads in futures markets decrease with increasing trading volume.<sup>2</sup> Therefore, if a change in the contract size increases trading volume, the bid-ask spread would be expected to decrease (with a decrease in trading volume expected to cause a wider spread).

In the case of the SPI contract, the SFE anticipated an increase in trading volume (in size-adjusted terms) figuring that a smaller size would make the contract accessible to investors with smaller portfolios. This anticipation was based on indications that 50 percent of trades were for one contract, suggesting that the large contract size was binding for some traders (see Figure 1). Huang and Stoll (1998) report similar frequency distribution of transaction size for S&P 500 futures<sup>3</sup>.

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<sup>2</sup> This observation is also supported by the predictions of competitive dealer models of Ho and Stoll (1980), Ho and Marcis (1985), and Laux (1995).

<sup>3</sup> Huang and Stoll (1998) report that 50 percent of all S&P 500 futures trades were for one contract. They site this observation as a potential motive to split the contract and suggest that 50 percent of the trades were individuals who otherwise would be willing to trade in smaller lots.

Anecdotal evidence suggests that U.S. commodity trading advisors viewed pre-split trading volume for the SPI, which was below 3,000 to 5,000 contracts per day, as a deterrent to participation. A nominal increase in trading volume as a consequence of the split was expected to promote offshore trading of the SPI contract, thus resulting in a size-adjusted increase.

In equity markets, stock splits have been used to increase liquidity. Baker and Gallagher (1980) find that the managerial objective for stock splits is to make the stock more appealing to a broader investor group by reducing its price, thus increasing its liquidity. Lamoureux and Poon (1987) find that the number of shareholders, number of trades, and trading volume all increase following a split. These results, however, do not indicate a size-adjusted increase in trading volume. Although stock splits and reductions in index futures size appear to be similar in nature, in the latter the minimum trading unit is being reduced (the multiplier) rather than the price of the underlying.

A study by Amihud, Mendelson, and Uno (1999) investigates the reduction in minimum trading units on the Tokyo Stock Exchange, which appears to be a more comparable case to futures splits. They find that reducing the stock's minimum trading unit increases both the firm's investor base and its stock liquidity through greater trading volume. Their findings would imply for the SFE contracts an increase in trading volume for the SPI and a decrease for the BAB.

Huang and Stoll (1998) suggest that reducing the size of a futures contract would allow individuals to make small adjustments to their portfolios and further increase trading activity. Thus, for the SPI futures, microstructure literature supports the anticipation of a size-adjusted increase in trading volume following a split. All else being

equal, the doubling of its size would predict a decrease in trading volume for the BAB contract. However, if the modifications made to minimum tick have opposing liquidity effects, they counteract the impact of changes in contract size on liquidity.

In futures markets, dollar values of the minimum tick and bid-ask spreads are determined by their size as well as the contract's multiplier. If the minimum tick and bid-ask spreads remain unchanged, a decrease in the contract size by reducing the multiplier decreases their dollar value. All else being equal, an increase in contract size increases the dollar value of both minimum ticks and spreads.

Demsetz (1968), Silber (1984), and Harris (1994) suggest that market makers' willingness to provide liquidity increases with their income. Therefore, the dollar values of minimum tick and bid-ask spreads, as well as their levels, need to be considered when investigating the effects of contract size change on liquidity. Findings of Harris (1997) further support an examination of the value of minimum tick and bid-ask spreads relative to the value of the underlying futures contract, i.e., proportional spreads.

In equity markets, much of the debate on tick size centers on whether the decrease in the fixed costs of transacting (the spread) associated with a smaller tick also results in a less liquid market through a reduction in the returns to providing liquidity. Harris (1991) argues that minimum price variation determines the minimum quotable bid-ask spread. Sandor and Sosin (1983) indicate that minimum tick size is also the minimum return to scalpers. Harris (1997) suggests that if the minimum tick is greater than the spread dealers would otherwise quote, i.e., the minimum tick is binding, they may choose to increase their quoted depth. Kyle's (1985) model implies that depth increases with trading volume.

In the case of the SPI futures, the multiplier of the contract was reduced by a factor of four while the minimum tick was increased by a factor of ten. Thus, the dollar value of the minimum tick increased by a factor of 2.5. The minimum tick size remained unchanged when the BAB futures doubled in size, resulting in the increased dollar value of a tick. All else being equal, an increase in the level of the minimum tick would be expected to both widen the quoted bid-ask spread level and increase the depth. If the pre-split minimum tick were not binding, however an increase in the value of the minimum tick is not expected to increase the dollar and percentage values of spreads.

Reductions in the quoted cost of liquidity services could impact the profitability of liquidity providers. Harris (1994) estimates that market maker profits will remain largely unchanged if the percentage minimum tick size increases. If the increase in market maker volume is greater than the decrease in spreads, then, for both SPI and BAB futures, the total profit of liquidity providers is not expected to change. Given the competitive open outcry trading mechanism of the futures pits, returns to providing liquidity for the scalpers as a group are expected to remain the same.

The focus of this study is to determine the extent to which trading volume, bid-ask spreads, depth, and provision of liquidity changed subsequent to the contract respecification. Recognizing that any observed change in these variables may not necessarily be attributable to the changes in contract specifications, market factors that may impact these variables need to be controlled.

Wang, Yau, and Baptiste (1997) model the relationship among trading volume, bid-ask spreads, price level, and volatility. They find that volume and spreads are jointly determined. Their results indicate that trading volume is positively related to intraday

volatility and negatively related to bid-ask spread, while spreads are positively related to intraday volatility and price level. Chordia, Roll, and Subrahmanyam (1999) indicate that liquidity is affected by market factors such as volatility and price levels.

This essay uses price levels and volatility, as well as the spot market trading activity, to control for factors that may potentially explain the observed changes in microstructure characteristics of SPI and BAB futures both before and after the contract respecifications.

### **III. SFE Contract Specifications**

According to the 1998 Futures Industry Association (FIA) rankings, the Sydney Futures Exchange is the largest futures exchange in the Asia Pacific region, with an annual turnover of 28.4 million contracts. The Sydney Futures Exchange introduced the Share Price Index futures on February 16, 1983. The SPI contract is based on the Australian Stock Exchange's (ASX) All Ordinaries Index (AOI), which is the benchmark indicator of the Australian stock market.

SPI futures and options are regarded as the primary equity derivative products in Australia. Major international and Australian banks, fund managers and other large investment institutions use them. The other active participants in the SPI market include SFE locals, and Australian as well as offshore private investors. The SPI contract is approved by the Commodity Futures Trading Commission for trading by U.S. investors.

The AOI is calculated using capitalization-weighted market prices of approximately 330 of the largest companies listed on the ASX. The aggregate market value of these shares totals over 95% of the value of the 1,188 domestic stocks listed.

Companies must meet a minimum market capitalization and an adequate turnover in order for a firm to be included in the AOI.

On October 11, 1993, the size of the SPI futures contract was reduced from A\$100 times the All Ordinaries Index level to A\$ 25 times the index level. At the same time, the minimum price change (minimum tick) was increased from 0.1 to 1.0 index point. The changes made to the specifications of the SPI futures are detailed in Table I.

The SFE waived the exchange fees until trading reached an average daily volume of 10,000 contracts. This volume of trade was first attained in early November 1993, and the fees were reinstated in March 1994. Following the reduction in the size of the SPI futures, the initial margin on the contract was reduced accordingly to A\$ 1,500 from its pre-split level of A\$ 6,000.

The 90-day Bank Accepted Bill (BAB) futures and options contracts are Australia's leading short-term interest rate derivative instruments. The 90-day Bank Bill contract, the first interest rate futures contract to be listed outside the United States, was introduced on October 17, 1979. The BAB futures contract is one of the world's most actively traded short-term interest rate derivatives.

Bank Accepted Bills (bank bills) are negotiable short-term securities with typical maturities between 30-180 days. A bank bill essentially represents a promise to pay the full face value of the bill at maturity; its credit risk is based on the debt rating of the bank that has accepted or guaranteed its payment. The bank bill market is the largest short-term interest rate market in Australia and is viewed as the benchmark indicator of Australian short-term interest rates. Bank bills are quoted on a yield percent per year

basis, and are priced according to a yield formula that discounts the face value to earn the appropriate interest cost.

The SFE doubled the size of the 90-day BAB futures contract to A\$ 1 million on May 1, 1995. Meanwhile, the minimum tick remained at 0.01%. Table II provides the contract specifications of the BAB futures. There were no changes made to the exchange fees on the BAB contract.

The 90-day BAB respecification was also designed to increase commercial participation in the SFE's market. The view of the financial institutions actively trading the contract was the initial size of A\$ 500,000 was unnecessarily small. They supported increasing the contract to A\$ 1 million, with a corresponding increase in the tick value and a reduction in direct transaction costs (i.e., exchange fees and commissions). The desired result was greater offshore participation due to a contract size more in line with international standards. Of course, Australian institutional users also supported the increase in the contract size as it reduced their direct trading costs.

The pricing conventions used for SFE's interest rate products differ from those used in European and U.S. exchanges. In Europe and the United States, interest rate securities are traded in the cash market on the basis of their capital price; in Australia, the convention is to price such instruments on the basis of their yield to maturity. The BAB contract, like other interest rate contracts at the SFE, is traded on the basis of yield to maturity with the futures price quoted as 100 minus the yield expressed in percent per year.

One advantage of pricing interest rate contracts in this fashion is that their yield to maturity is transparent and easily compared to yields on cash market instruments. As a

direct result of this pricing convention, the tick value on BAB contract does not remain constant but changes according to movements in the underlying interest rate. That is, the tick value decreases as interest rates rise, and increases as interest rates fall.

The values of physical bank bills are calculated according to a yield to maturity formula that discounts the face value to establish the appropriate interest cost over term of the instrument. The price of a bank bill is given by:

$$P = (365 \cdot \text{Face Value}) / (365 + \{(Yield / 100) \cdot \text{Days to Maturity}\}) \quad (1)$$

where the yield is the yield to maturity. The Australian convention is to use a 365-rather than a 360-day year. After May 1, 1995, for SFE 90-day Bank Bill Futures, where the contract value is A\$ 1 million and the term to maturity is 90 days, the bank bill futures contract value is given by:

$$P = 365,000,000 / (365 + \{(Yield/100) \cdot 90\}) \quad (2)$$

where the yield is the futures price deducted from 100.

In order to determine the dollar value of a BAB futures tick, at a given futures price (yield), the contract value in equation (2) is calculated once with that yield (i.e., 100-futures price) and once with the yield increased by 0.01%. The difference between the two contract values is the dollar value of a tick at the given yield level.

#### **IV. Data and Variables**

The data set for this study is provided by the SFE. The daily data include the open, high, low, and settlement prices, as well as the number of deals and trading volume.

The exchange also supplied information on the daily trading volume by locals and floor members.<sup>4</sup>

The intraday data consist of the time-stamped price and volume of each transaction. Intraday bid-ask quotes were generated from the Interexchange Technical Committee (ITC) data by calculating a new spread every time a new bid or ask arrived that changed the best bid or ask quote. The data on spot market activity provided by SFE include the volume of cash bank bills traded on a weekly basis as well as the spot share traded on the ASX.

The data extend from September 18, 1992, through October 27, 1994, for SPI futures, and from April 6, 1994, through May 20, 1996, for BAB futures. The period of coverage is approximately one year before and one year after the dates of changes in contract specifications. The variables are constructed using the data on the active nearby futures contract. The active nearby series is formed using the contract with the closest maturity, rolling over to the upcoming contract month ten trading days prior to the expiration of the nearby.

Between May 5, 1994, and September 30, 1994, the SFE experimented with lunchtime trading (12:30 pm to 2:00 pm) for the SPI futures contract. This experiment did not generate significant additional trading volume and was dropped. The observations for lunchtime trading are removed from the data set to eliminate potential biases.

In the case of BAB futures, approximately fifteen weeks of quote data (out of 102) are missing. The effective bid-ask spreads for these weeks are estimated from the

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<sup>4</sup> Local trading volume does not include off-floor local trading. Locals' off-floor trades would not likely be liquidity-providing trades, since they would not know the best bid and offer when their orders reach the floor. Floor members are authorized to execute customer orders on the floor of the exchange. They also can trade for their own accounts, so their trading volume includes liquidity-providing (market making) trades.

intraday transaction prices using the Smith and Whaley (1994) method of moments estimator. Smith and Whaley assume that consecutive price changes include two components, the true price change,  $\epsilon_i$ , and the bid-ask spread,  $s$  and estimate both the spread and the variance of price changes using the equations:

$$E(|\Delta P_i^0|) = \sqrt{\frac{2}{\pi}} \sigma e^{-s^2/2\sigma^2} - s \left[ 1 - 2N\left(\frac{s}{\sigma}\right) \right] \quad (3)$$

$$E(|\Delta P_i^0|^2) = \sigma^2 + s^2 \quad (4)$$

where  $N(\cdot)$  is the cumulative unit normal distribution function. In order to estimate the effective spread and the variance of true price changes,  $E(|\Delta P_i^0|)$  and  $E(|\Delta P_i^0|^2)$  are replaced by the mean absolute price change and the mean squared price change from the observed futures price change distribution.<sup>5</sup>

As a result of the reduction in the size of SPI contract, all else being equal, the number of contracts traded would increase by four. For BAB, doubling the contract size, all else being equal, would reduce the number of contracts traded by half. Thus, volume variables after the contract respecification are size-adjusted by dividing values by four in the case of the SPI futures and multiplying them by two, for the BAB.

Changes in the liquidity and transaction cost variables are demonstrated by both daily and weekly sampling of available data. Using daily observations, trading volume, daily number of deals, lotting factor, local trading volume, floor member trading volume, and the ratio of local to total pit trading volume are investigated.

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<sup>5</sup> Locke and Venkatesh (1997) criticize bid-ask spread estimation techniques that are based on transaction price changes. The robustness of the effective spreads is verified by comparing the estimates to the quoted spreads for the eighteen weeks surrounding the change of the BAB contract size. There are no great differences.

Lotting factor is the ratio of total trading volume to the daily number of deals. It is the daily average number of contracts traded per transaction<sup>6</sup>. An increase (decrease) in the size-adjusted lotting factor would indicate that the contract size was large (small) compared to what market participants demanded.

Local trading volume provides a measure of aggregate immediacy provided by market makers, while floor member volume represents the immediacy demanded by outsiders. If the anticipated increase (decrease) in trading volume is proportional to the decrease (increase) in dollar spreads earned, no change in local participation is expected. The ratio of the local to total pit trading volume represents market maker participation relative to overall trading activity.

In the weekly data set, trading volume (TV) shows the aggregate number of futures contracts traded, while the spot trading volume is the total number of shares traded. Relative trading volume (RTV), the number of futures contracts divided by the number of equity shares, is included in the analysis, together with relative value of trading volume, to control for trading activity in the underlying spot market.

Demsetz (1968) suggests that the appropriate measure of transaction costs is the aggregate dollar flow from customers to market makers. Working from an earlier discussion of market microstructure, the total revenue of the locals is used to measure the returns to providing liquidity. Locals revenue is defined as the product of the value of quoted bid ask spread (VQS) and the locals trading volume.<sup>7</sup>

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<sup>6</sup> The data from SFE do not distinguish between market and limit orders.

<sup>7</sup> This definition implicitly assumes that scalpers earn the dollar value of the quoted bid-ask spread. Kuserk and Locke (1993) show that this may not be necessarily true for each scalper. However, since the quoted bid-ask spread figures used in this essay are the weekly averages and local trading volume is the weekly total, locals revenue can be used as a proxy for the returns to providing liquidity.

The value of the quoted bid-ask spread is the product of the value of the minimum price fluctuation and QSL, where QSL is the quoted bid-ask spread in multiples of the minimum tick. The percentage value of the quoted bid-ask spread (PVQS), which is the ratio of value of quoted spread to value of the contract, is also investigated in order to control for spread fluctuations caused by changes in the value of the underlying futures contract.

The average volume per trade is the average of the actual number of contracts traded in each transaction and represents an estimate of market depth.<sup>8</sup> Using weekly data, the average volume of trade before and after the contract and tick size changes is also examined. The average time between trades is the weekly average of the time (measured in seconds) between each transaction, which represents the frequency of trading activity. If changes in contract specifications have favorable effects on liquidity, there should be an increase in the depth and frequency of trading.

## V. Empirical Results

Formal comparison of the variables under investigation is carried out by testing for the equality of the means of each variable before and after the change in contract specifications. The null hypothesis that the mean of the variable remained the same one year before and after the change is tested under the assumption of unequal variances. In order to capture the effects of different observations periods on the variables, equality of means tests are repeated for one- through six-month subperiods, and a nine-month

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<sup>8</sup> Unlike equity market data, the SFE data used in this study do not provide the depth associated with quoted bids and asks. Therefore, average trade size can be viewed as an estimate of market depth. If limit order transactions are also included in the data, the average size could overstate the depth supplied by locals.

subperiod before and after the change. The results of subperiod analysis are presented and discussed in the appendix. To verify the robustness of the observed changes the Wilcoxon equality of medians tests are repeated for each variable under investigation.<sup>9</sup>

Table III reports the results, for both the SPI and the BAB contracts, of the equality of means test using daily data for one year before and one year after the change in contract specification. For the SPI contract, trading volume adjusted for contract respecification significantly increased; that is, trading volume increased by more than four times. The daily number of deals significantly increased. The size-adjusted lotting factor significantly decreased, suggesting that the pre-split contract was too large for some users. Local trading volume did not change, while floor member volume did significantly increase. The ratio of local to total pit traded volume decreased.

The increase in floor member volume may be the result of increased participation by investors with smaller portfolios and by U.S. fund managers. Recall that one of the stated reasons for reducing the contract size was to reach volume levels more consistent with the needs of money managers. Such trades would be executed through floor members.

An examination of the impact of increasing the size of the BAB contract produces similar results in the opposite direction. The size-adjusted trading volume declined, as did the daily number of deals. There is no prior reason to expect a change in the size-adjusted lotting factor, and no significant change is found. Consistent with the significant decline in trading volume, local and floor member trading volume also declined significantly in

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<sup>9</sup> The hypothesis tested is that the medians of two samples (before and after) are from populations using the Wilcoxon rank-sum test, which is also known as the Mann-Whitney two-sample statistic (Wilcoxon, 1945; Mann and Whitney, 1947).

size-adjusted terms. The ratio of local to total pit traded volume did not change significantly.

Table IV reports the same comparisons, using the Wilcoxon equality of medians test. The results in Table IV are consistent with the results in Table III in all cases.

Tables V and VI report the results of the equality of means and medians tests, respectively, before and after the contract size change for both SPI and BAB contracts using weekly data. As can be seen in Panel A in both tables, and consistent with the results from daily analysis, the size-adjusted trading volume significantly increased after the SPI contract was split. A significant decrease in average time between trades indicates more frequent trading. Average volume per trade increased significantly, suggesting an increase in depth.

The level (size) of the quoted bid-ask spread increased significantly. This is consistent with the increase in value of the minimum tick. Both the dollar value and the percentage value of the bid-ask spread decreased. The significant decrease in the value of the spread is consistent with the reduction in the multiplier of the contract.

Panel B of Tables V and VI reports the results for the BAB contract. While trading volume declined after the contract was doubled, the decline was not significant. The time between trades significantly increased, and the average volume per trade significantly decreased. While the level of the bid-ask spread and the percentage value of the quoted spread did not change when measured in means, they significantly decreased in medians. After the size of the BAB contract was increased, the value of the bid-ask spread significantly increased.

For the SPI contract, locals revenues, measured by the product of local trading volume and the value of the quoted bid-ask spread, did not significantly change following the contract respecifications. This result suggests that the increase in local trading volume was proportional to the decrease in the value of the bid-ask spread. For the BAB contract, locals revenues decreased when measured in means but did not significantly change in medians.

For the SPI contract, the results of the equality of means tests, before and after contract respecification are that trading activity increased, while the value of the bid-ask spread decreased. There is some indication that the increase in volume was due to more floor member participation. This is consistent with the SFE's interest in raising nominal trading volume to attract non-Australian fund managers as well as investors with smaller portfolios. For the BAB contract, increasing the contract size significantly decreased trading volume, while value of the quoted bid-ask spread increased.

Markets are dynamic environments. The possibility remains that the observed changes in volume and spreads were caused by variables other than change in contract size. This study uses price levels and volatility to control for factors that might potentially explain the observed changes in microstructure characteristics of SPI and BAB futures both before and after the contract respecifications.

Following Edwards (1988), the intraday futures price volatility is measured by the Parkinson (1980) estimator:

$$IV = \frac{[\text{Ln}(H) - \text{Ln}(L)]^2}{4 \text{Ln}(2)} \quad (5)$$

where H and L represent the highest and the lowest futures price of the day.<sup>10</sup>

Sets of relationships are modeled to control for market factors. Dummy variables are used in the econometric models to test for the effects of contract size change on the modeled relationships. The dummy variable used to control for the before and after periods, D, is given by:

$$D = \begin{cases} 0, & \text{before the change in specifications} \\ 1, & \text{after the change in specifications} \end{cases} \quad (6)$$

The hypothesis that the mean of the dependent variable is different following the change is tested by the significance of the coefficient of the intercept dummy ( $\alpha_1$ ). If the estimated coefficients of the intercept dummies are significant, then it is possible to confirm the observed changes in the variables under investigation while controlling for market factors. The standard errors of the estimated parameters are computed using a Newey-West (1987) heteroskedasticity- and autocorrelation-consistent (HAC) covariance matrix. Two regression equations are estimated for both the SPI and BAB contracts.

The relationship between the trading volume and the intraday volatility and price level is modeled as follows:

$$\text{Ln}(TV) = \alpha_0 + \alpha_1 D + \alpha_2 IV + \alpha_3 \text{Ln}(FP) \quad (7)$$

where TV is futures trading volume, IV is intraday volatility estimated using equation (5), and FP is futures price.

As can be seen from Regression 1 in Table VII for the SPI, the estimated coefficient of the intercept dummy is positive and significant, indicating that the SPI contract's trading volume increased after the contract value was reduced. As expected,

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<sup>10</sup> The results are robust when the analysis is repeated with a similar measure of intraday volatility, i.e.,  $IV = \text{Ln}(H - L)$ .

trading volume is found to be positively related to intraday volatility and the price level. The  $R^2$  of the regression is 0.83, indicating a relatively good fit of the econometric model. After incorporating the market factors that could affect trading volume into the analysis, the results suggest that the splitting of the SPI contract increased trading volume.

Equation (8) seeks to confirm the results in Table V regarding the impact of contract respecification on the percentage quoted spreads:

$$\text{Ln(PVQS)} = \alpha_0 + \alpha_1 D + \alpha_2 IV + \alpha_3 \text{Ln(TV)} \quad (8)$$

The equation parameterizes the percentage value of the quoted spread as a function of intraday volatility and trading volume. As reported by Regression 2 in Table VII, for the SPI contract both variables that attempt to control for market factors have the expected sign, and their estimated coefficients are statistically significant. The percentage value of the spread increases as volatility increases and decreases with trading volume. The estimated coefficient on the intercept dummy is insignificant. This result indicates that intraday volatility and trading volume could account for the observed changes in the percentage value of quoted spread.

Regression 3 in Table VIII for the BAB explains the variation in trading volume using intraday volatility and the futures price level. The estimated coefficient on the intercept dummy is negative and significant. This indicates that, after accounting for market factors, BAB trading volume decreased following the doubling of contract size. The estimated coefficients of intraday volatility and price level are positive and statistically significant.

Regression 4 in Table VIII repeats the analysis of the effect of market factors on the percentage value of the quoted spread for the BAB. The estimation output suggests

that the econometric specification presented in equation (8) falls short of explaining the variation in the percentage value of the quoted spread. As Tables V and VI report, the results regarding the percentage value of the quoted spread are ambiguous for the BAB contract.

The econometric results support the findings presented in Tables III and VI after accounting for the effects of market factors. When there is a significant change in the means before and after the contract respecification, the estimation results are significant. When the change in means is inconclusive or inconsistent, the regression results generally are insignificant.

## **VI. Summary and Conclusions**

The respecification of the Share Price Index (SPI) futures and the 90-day Bank Accepted Bills (BAB) futures traded on the Sydney Futures Exchange offer an opportunity to investigate the effects of change in contract size on liquidity and transaction costs in futures markets. Market microstructure theory implies particular changes in liquidity and transaction costs subsequent to respecification. Changes in trading volume, number of deals, average transaction size, average time between transactions, quoted bid-ask spreads are compared one year before and one year after the respecification. Local and floor member trading volume as well as locals revenues are also investigated.

The results make a contribution to the literature by documenting and comparing the effects of both an increase and a decrease in futures contract size. There are effects also of interactions between the changes made to the contract size and the minimum tick.

The results for the univariate tests indicate that, for the SPI contract, a decrease in contract size along with an increase in minimum tick had a favorable liquidity effect. There are increases in volume of trade, trading frequency, and average transaction size is observed. It is also observed that the returns to providing liquidity did not change; i.e., there is an increased volume of business for liquidity providers at a decreased profit per lot. Consistent with the exchange's anticipation, an increase in floor member volume is observed, indicating a potential increase in the participation of offshore fund managers as well as investors with smaller portfolios.

The impact of contract respecification on trading volume in SPI futures is reaffirmed after controlling for market factors. Regression results confirm that after considering the impact of the futures price level and intraday volatility, the decrease in the contract size increased trading volume. An examination of the effect of contract respecification on spreads shows no consistent impact. Regression results suggest that the change in the spread is accounted for by the documented increase in trading volume.

When the BAB contract was doubled in size, no changes were made to its minimum tick size. Following this contract respecification, the volume of trade, trading frequency, and average transaction size decreased after accounting for volatility and the price level. A decrease in returns to the liquidity providers is observed. Contrary to exchange objectives, commercial participation appears to decrease following the increase in the BAB contract size. Results regarding the impact of contract size change on bid-ask spreads are ambiguous.

The results suggest that reducing a futures contract size is effective in terms of enhancing liquidity, while increasing contract size results in a slight reduction in liquidity.

## **Appendix**

To investigate the effects of changes in contract size, equality of means tests are conducted on key variables before and after the change dates. The test for equality of means can be carried out under two assumptions: equal and unequal variances. Changing the contract size may affect the variances of the variables under investigation. Means tests are therefore carried out assuming unequal variances.

Equality of means tests are run over several subperiods. Subperiod analysis is used in order to capture the effects of the change in contract size for different time intervals around the change date. For this study subperiods are chosen to be 22-, 44-, 66-, 88-, 110-, 132-, 198-, and 264-day windows around the change date. These days are chosen, assuming on average 22 trading days per month, to correspond to 1- through 6-, 9-, and 12-month periods.

### **Trading Volume**

It can be seen from Table A.I that the SPI contract's volume (in size-adjusted terms) increased following the reduction in its size. Over the 22-day period surrounding the change date, volume appears to be decreasing, but it is found to consistently increase over all other subperiods. This finding appears to support the expectation of the SFE that a smaller contract size would enable more outside investors with less capital to participate in the futures market.

In the case of the BAB futures, the increased contract size results generally in a decrease in the trading volume. The results indicate that average size-adjusted trading volume before and after the change date appears to be equal during the 22, 44, 66, and 88

days surrounding the change date. In the longer term around the change date, it appears that the BAB contract's trading volume decreased.

Figure A.I displays the size-adjusted trading volume for the SPI contract. An initial view of the graph suggests that the observed increase in volume might be attributable to a positive time trend, i.e., growth in market activity. During the two years surrounding its respecification the SPI futures' trading volume increased. This trend explains 6.64% of the variation in the volume, with a trend coefficient of 1.62 (with t-statistic = 6.11), which is statistically significant at the 0.05 level.

Figure A.II shows that the BAB futures' size-adjusted trading volume slightly decreased over the two-year window around its respecification. This trend explains 1.25% of the variation in trading volume, with a trend coefficient of  $-23.12$  (t-statistic =  $-2.03$ , significant at the 0.05 level). A positive time trend is also observed in the spot equity market trading volume, while a negative trend is observed in cash bank bill trading activity. In order to eliminate the effects of time trend, the ratio of spot market trading volume to futures trading volume is also investigated.

For the SPI futures, the weekly relative trading volume (spot/futures) does not exhibit a statistically significant time trend (the coefficient of time trend is  $1.67 \times 10^{-05}$ , with t-statistic 0.85 and  $R^2$  of trend regression 0.009). This result suggests that both spot and futures market trading expanded approximately at the same rate during the time period under investigation. In the case of the BAB futures, there is again no statistically significant time trend in weekly relative trading volume; i.e., the coefficient of time trend is 0.9068, with t-statistic 1.39 and  $R^2$  of trend regression 0.018634. It is possible to

conclude that use of the futures market to hedge the spot market trading activity is free of a potential time trend.

Table A.II presents the results of the equality of means tests for the relative trading volume. The results for the SPI contract indicate that the relative futures-spot market activity remained the same during all the subperiods surrounding the respecification. Similar results are obtained for the BAB contract except for the 51-week subperiod, when there is a statistically significant increase in relative trading volume.

### **Daily Number of Deals**

The results for the daily number of deals (presented in Table A.III) indicate an increase in the number of deals transacted each trading day following the reduction in size of the SPI futures. The result for BAB futures is a decrease in daily deals following the increase in the size of the contract. The results are consistent for each subperiod except the 22-day period in the case of the BAB futures. The observed changes in the number of daily deals suggest that SPI (BAB) futures market participants traded more (less) frequently after the contract respecifications.

### **Lotting Factor**

Table A.IV reports the results of equality of means tests for the size-adjusted lotting factor. Panel A indicates that the size-adjusted lotting factor decreased following the quartering of the size of the SPI futures contract. This decrease suggests that, in adjusted terms, fewer lots are traded per transaction following the reduction of the contract size. These observed changes are consistent through all subperiods.

In the case of the BAB futures, Panel B indicates no statistically significant change in the average size-adjusted lotting factor for the 264-day and 132-day subperiods. In the remainder of the subperiods, the average size-adjusted lotting factor increases following the doubling in size of the BAB contract. This increase suggests that, in adjusted terms, more lots are traded per transaction in the short run; at the same time, the average lot size remained unchanged for the longer observation periods.

### **Participation of Locals and Floor Members**

Table A.V indicates that the local trading volume (in size-adjusted terms) increased initially following the contract respecification, although for the 264-day period surrounding the reduction of the SPI contract's size no statistically significant change in the local trading volume is observed. The effect of doubling the BAB futures contract's size resulted in a decrease in locals trading volume (in size-adjusted terms) for the longer subperiods. Table A.VI, Panel A, indicates that following the reduction of the SPI futures contract's size outsiders traded more futures contracts (in size-adjusted terms). This, again, can be attributable to smaller size, permitting investors with less capital to use the futures contract. In the case of the BAB futures (Panel B), the increase in the size of the futures contract resulted in a decrease in the size-adjusted trading volume attributable to outsiders. Participation of locals (measured by local trading volume divided by total pit trading volume) initially increased following the reduction in the SPI contract's size, and declined over the longer horizon as indicated in Panel A of Table A.VII. In the case of the BAB futures, there is no significant difference in locals participation within a year surrounding the increase in the contract size.

**Table I**  
**Changes to Contract Specifications**  
**Share Price Index (SPI) Futures Contract**  
**Sydney Futures Exchange**

	<u>Before October 11, 1993</u>	<u>After October 11, 1993</u>
<b>Contract Unit</b>	A\$ 100 x All Ordinaries Index Value	A\$ 25 x All Ordinaries Index Value
<b>Price Quotes</b>	in index points, to one decimal	in index points, to full point
<b>Minimum Price Fluctuation (Tick)</b>	0.1 index point	1 index point <sup>*</sup>
<b>Value of Minimum Tick</b>	A\$ 10	A\$ 25
<b>Settlement Day</b>	Second business day following the last trading day	
<b>Settlement</b>	Cash settled to the closing quotation for the AOI on the last day of trading calculated to one decimal place, as adjusted and provided by the ASX	
<b>Contract Months</b>	Mar, Jun, Sep, Dec, up to six quarter months	
<b>Termination of Trading</b>	4:15 p.m. on the last business day of the contract month	
<b>Trading Hours</b>	Floor trading: 9:50 a.m. - 12:30 p.m. and 2:00 p.m. - 4:15 p.m. SYCOM <sup>**</sup> trading: 4:40 p.m. - 7:00 a.m.	
<b>Exchange Fees</b>	A\$ 1.00 per side, A\$ 2.00 a round-trip	
<b>Commissions</b>	Commission rates are negotiable between SFE members and clients	
<b>Initial Margin</b>	A\$ 6,000	A\$ 1,500 <sup>†</sup>

\* On the final trading day a provision exists for the minimum fluctuation to be in 0.1 index points = A\$2.50

\*\* After-hours electronic trading takes place in the Sydney Computerized Market (SYCOM)

† As of November 16, 1998 initial margin is A\$ 3,000

Source: SFE

**Table II**  
**Changes to Contract Specifications**  
**90-Day Bank Accepted Bills (BAB) Futures Contract**  
**Sydney Futures Exchange**

	Before May 1, 1995	After May 1, 1995
<b>Contract Unit</b>	A\$ 500,000 face value of 90-Day Bank Accepted Bills	A\$ 1,000,000 face value of 90-Day Bank Accepted Bills
<b>Price Quotes</b>	in 100 minus percentage yield to maturity, to two decimals	
<b>Minimum Price Fluctuation (Tick)</b>	0.01%	0.01%
<b>Value of Minimum Tick</b>	A\$ 12.03*	A\$ 24.06*
<b>Settlement Day</b>	The second Friday of the delivery month	
<b>Settlement</b>	Delivery of ten bank accepted bills (or bank negotiable certificates) each with face value A\$ 100,000 or two each with face value A\$ 500,000 or one with face value A\$ 1,000,000 maturing 85-95 days from settlement day	
<b>Contract Months</b>	Mar, Jun, Sep, Dec, up to twenty quartermonths	
<b>Termination of Trading</b>	12:00 p.m. on the business day immediately prior to settlement day	
<b>Trading Hours</b>	Floor trading: 9:50 a.m. - 12:30 p.m. and 2:00 p.m. - 4:15 p.m. SYCOM** trading: 4:40 p.m. - 7:00 a.m.	
<b>Exchange Fees</b>	A\$ 1.00 per side, A\$ 2.00 a round-trip	
<b>Commissions</b>	Commission rates are negotiable between SFE members and clients	
<b>Initial Margin</b>	A\$ 500	A\$ 1,000

\* At a yield of 5% (due to yield to maturity-based pricing convention, value of one basis point varies by yield)

\*\* After-hours electronic trading takes place in the Sydney Computerized Market (SYCOM).

Source: SFE

**Table III**  
**Descriptive Statistics: Daily Data**  
**One Year Before and After the**  
**Change in Contract Specifications**  
**Results of Equality of Means Tests<sup>†</sup>**

<b>Variable</b>	<b>Panel A: SPI Futures</b>				<b>Panel B: BAB Futures</b>			
	<b>Before: Sep. 18, 1992 - Oct. 8, 1993</b>		<b>After: Oct. 11, 1993 - Oct. 27, 1994</b>		<b>Before: Apr. 6, 1994 - Apr. 28, 1995</b>		<b>After: May 1, 1995 - May 20, 1996</b>	
	<b>Average</b>	<b>Direction of</b>	<b>t-statistic</b>		<b>Average</b>	<b>Direction of</b>	<b>t-statistic</b>	
	<b>Before</b>	<b>After</b>	<b>Change</b>		<b>Before</b>	<b>After</b>	<b>Change</b>	
<b>Trading Volume (Size-Adjusted)</b>	1,715	2,191	increased	6.25*	35,800	32,346	decreased	2.13*
<b>Daily Number of Deals</b>	1,366	2,713	increased	29.09*	2.502	2.147	decreased	4.22*
<b>Lotting Factor (Size-Adjusted)</b>	2.45	1.56	decreased	14.64*	27.79	28.60	inconclusive	1.89
<b>Local Trading Volume (Size-Adjusted)</b>	610	570	inconclusive	1.56	6.502	5,770	decreased	1.99*
<b>Floor Member Trading Volume (Size-Adjusted)</b>	1,102	1,621	increased	8.88*	29,298	26,577	decreased	2.11*
<b>Ratio of Local to Total Pit Trading Volume</b>	35.6%	26.0%	decreased	5.41*	17.3%	16.8%	inconclusive	1.13

<sup>†</sup> The averages of each variable over 264 trading days before and after the change are compared.

\* Indicates statistical significance at the 0.05 level.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis.

Inconclusive indicates that null hypothesis could not be rejected.

**Table IV**  
**Descriptive Statistics: Daily Data**  
**One Year Before and After the**  
**Change in Contract Specifications**  
**Results of Wilcoxon Equality of Medians Tests<sup>†</sup>**

Variable	Panel A: SPI Futures				Panel B: BAB Futures			
	Before: Sep. 18, 1992 - Oct. 8, 1993		After: Oct. 11, 1993 - Oct. 27, 1994		Before: Apr. 6, 1994 - Apr. 28, 1995		After: May 1, 1995 - May 20, 1996	
	Average Before	Average After	Direction of Change	z-statistic	Average Before	Average After	Direction of Change	z-statistic
Trading Volume (Size-Adjusted)	1,459	2,083	increased	6.81*	31,029	27,245	decreased	2.90*
Daily Number of Deals	1,341	2,714	increased	18.53*	2,319	1,957	decreased	4.52*
Lotting Factor (Size-Adjusted)	2.20	1.50	decreased	15.13*	27.15	28.45	inconclusive	1.91
Local Trading Volume (Size-Adjusted)	532	513	inconclusive	1.71	5,396	4,631	decreased	2.63*
Floor Member Trading Volume (Size-Adjusted)	914	1,512	increased	9.52*	25,453	22,298	decreased	2.90*
Ratio of Local to Total Pit Trading Volume	36.3%	24.2%	decreased	6.01*	17.3%	16.3%	inconclusive	1.44

<sup>†</sup> The medians of each variable over 264 trading days before and after the change are compared.

\* Indicates statistical significance at the 0.05 level.

Null hypothesis is that medians remain the same before and after the change. Significant z-statistics indicate rejection of the null hypothesis.

Inconclusive indicates that null hypothesis could not be rejected.

**Table V**  
**Descriptive Statistics: Weekly Data**  
**51 Weeks Before and After the**  
**Change in Contract Specifications**  
**Results of Equality of Means Tests**

<u>Variables</u>	<u>Panel A: SPI Futures</u>				<u>Panel B: BAB Futures</u>			
	<u>Before: Sep. 18, 1992 - Oct. 8, 1993</u>		<u>After: Oct. 11, 1993 - Oct. 27, 1994</u>		<u>Before: Apr. 6, 1994 - Apr. 28, 1995</u>		<u>After: May 1, 1995 - May 20, 1996</u>	
	<u>Average</u> <u>Before</u>	<u>Average</u> <u>After</u>	<u>Direction of</u> <u>Change</u>	<u>t-statistic</u>	<u>Average</u> <u>Before</u>	<u>Average</u> <u>After</u>	<u>Direction of</u> <u>Change</u>	<u>t-statistic</u>
Trading Volume (Size-Adjusted)	8,446	11,193	increased	3.70*	188,251	180,147	inconclusive	0.69
Average Time Between Trades	39.52 sec	27.56 sec	decreased	5.89*	18.57 sec	21.13 sec	increased	2.63*
Average Volume per Trade	2.94	8.07	increased	13.48*	40.85	25.66	decreased	16.34*
Quoted Bid-Ask Spread (Level)**	1.3017	1.3638	increased	3.38*	1.3097	1.2571	inconclusive	1.41
Value of Quoted Bid-Ask Spread	A\$ 130.17	A\$ 34.09	decreased	62.58*	A\$ 15.48	A\$ 29.87	increased	19.83*
Percentage Value of Quoted Spread	0.0787%	0.0651%	decreased	7.06*	0.0032%	0.0030%	inconclusive	1.36
Locals Revenue	A\$ 399,928	A\$ 399,943	inconclusive	0.00	A\$ 496,159	A\$ 421,034	decreased	2.18*
Relative Trading Volume (Spot/Futures)	0.99%	1.08%	inconclusive	1.29	4.41%	5.25%	increased	2.15*

\* Indicates statistical significance at the 0.05 level

\*\* Quoted Bid-Ask Spread measured in index points for SPI and in basis points for BAB

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive indicates that null hypothesis could not be rejected.

**Table VI**  
**Descriptive Statistics: Weekly Data**  
**51 Weeks Before and After the**  
**Change in Contract Specifications**  
**Results of Wilcoxon Equality of Medians Tests**

<u>Variables</u>	<b>Panel A: SPI Futures</b>				<b>Panel B: BAB Futures</b>			
	Before: Sep. 18, 1992 - Oct. 8, 1993		After: Oct. 11, 1993 - Oct. 27, 1994		Before: Apr. 6, 1994 - Apr. 28, 1995		After: May 1, 1995 - May 20, 1996	
	<u>Average</u> <u>Before</u>	<u>Average</u> <u>After</u>	<u>Direction of</u> <u>Change</u>	<u>z-statistic</u>	<u>Average</u> <u>Before</u>	<u>Average</u> <u>After</u>	<u>Direction of</u> <u>Change</u>	<u>z-statistic</u>
Trading Volume (Size-Adjusted)	7,465	10,638	increased	3.50*	188,344	178,780	inconclusive	0.92
Average Time Between Trades	37.76 sec	23.85 sec	decreased	5.62*	18.13 sec	19.92 sec	increased	2.39*
Average Volume per Trade	2.79	7.72	increased	8.70*	41.44	25.46	decreased	8.53*
Quoted Bid-Ask Spread (Level)**	1.3116	1.3461	increased	2.96*	1.2690	1.2056	decreased	2.16*
Value of Quoted Bid-Ask Spread	A\$ 131.16	A\$ 33.65	decreased	8.70*	A\$ 15.15	A\$ 28.65	increased	8.70*
Percentage Value of Quoted Spread	0.0782%	0.0564%	decreased	5.73*	0.0031%	0.0029%	decreased	2.11*
Locals Revenue	A\$ 378,904	A\$ 362,913	inconclusive	0.37	A\$ 498,248	A\$ 424,385	inconclusive	1.86
Relative Trading Volume (Spot/Futures)	0.90%	0.97%	inconclusive	1.72	4.15%	4.63%	increased	2.43*

\* Indicates statistical significance at the 0.05 level

\*\* Quoted Bid-Ask Spread measured in index points for SPI and in basis points for BAB

Null hypothesis is that medians remain the same before and after the change. Significant z-statistics indicate rejection of the null hypothesis. inconclusive indicates that null hypothesis could not be rejected.

**Table VII**  
**SPI Futures**  
**Trading Volume and Bid-Ask Spread**  
**Controlling for Market Factors**  
 October 8, 1993 through October 27, 1994

<b>Equation 7</b>		$Ln(TV) = \alpha_0 + \alpha_1 D + \alpha_2 IV + \alpha_3 Ln(FP)$					
<u>Regression 1</u>		$\alpha_0$	$\alpha_1$	$\alpha_2$	$\alpha_3$	$R^2$	<u>No. obs.</u>
<i>Daily Data</i>	Coefficient	-6.084	1.089	0.228	2.123	0.83	528
	t-Statistic	(-2.63)*	(10.55)*	(9.41)*	(6.85)*		
<b>Equation 8</b>		$Ln(PVQS) = \alpha_0 + \alpha_1 D + \alpha_2 IV + \alpha_3 Ln(TV)$					
<u>Regression 2</u>		$\alpha_0$	$\alpha_1$	$\alpha_2$	$\alpha_3$	$R^2$	<u>No. obs.</u>
<i>Weekly Data</i>	Coefficient	-5.479	0.042	0.037	-0.145	0.44	102
	t-Statistic	(-9.97)*	(0.45)	(2.60)*	(-2.89)*		

\* Indicates statistical significance at the 0.05 level.

Standard errors of the coefficients are computed using Newey-West (1987) heteroskedasticity- and autocorrelation-consistent (HAC) covariance matrix

**Table VIII**  
**BAB Futures**  
**Trading Volume and Bid Ask Spread**  
**Controlling for Market Factors**  
 April 28, 1995 through May 20, 1996

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<b>Equation 7</b>	$Ln(TV) = \alpha_0 + \alpha_1 D + \alpha_2 IV + \alpha_3 Ln(FP)$						
<b>Regression 3</b>		$\alpha_0$	$\alpha_1$	$\alpha_2$	$\alpha_3$	$R^2$	<u>No. obs.</u>
<i>Daily Data</i>	Coefficient	-16.11	-0.493	0.451	6.098	0.59	528
	t-Statistic	(-1.37)	(-8.01)*	(13.05)*	(2.35)*		
<hr/>							
<b>Equation 8</b>	$Ln(PVQS) = \alpha_0 + \alpha_1 D + \alpha_2 IV + \alpha_3 Ln(TV)$						
<b>Regression 4</b>		$\alpha_0$	$\alpha_1$	$\alpha_2$	$\alpha_3$	$R^2$	<u>No. obs.</u>
<i>Weekly Data</i>	Coefficient	-10.82	-0.009	0.002	0.040	0.04	102
	t-Statistic	(-18.48)*	(-0.16)	(0.23)	(0.85)		

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\* Indicates statistical significance at the 0.05 level.

Standard errors of the coefficients are computed using Newey-West (1987) heteroskedasticity- and autocorrelation-consistent (HAC) covariance matrix.

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**Table A.I**  
**Equality of Means Tests**  
**Trading Volume (Size-Adjusted)**

<b>Panel A: SPI Futures</b>					<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993					Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994					After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	<b>Number</b>	<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	
<b>Before</b>	<b>After</b>	<b>Change</b>		<b>of</b>	<b>Before</b>	<b>After</b>	<b>Change</b>		
				<b>Days</b>					
1,715	2,191	increased	6.25*	264	35,800	32,346	decreased	2.13*	
1,801	2,357	increased	6.22*	198	35,315	30,720	decreased	2.45*	
1,868	2,560	increased	6.32*	132	38,078	32,398	decreased	2.37*	
1,941	2,491	increased	4.74*	110	38,800	32,707	decreased	2.27*	
2,051	2,468	increased	3.08*	88	36,278	33,753	inconclusive	0.88	
2,054	2,476	increased	2.67*	66	37,604	35,068	inconclusive	0.76	
2,265	2,333	inconclusive	0.36	44	36,414	35,251	inconclusive	0.31	
2,640	1,998	decreased	2.74*	22	32,018	35,799	inconclusive	0.73	

\* Indicates statistical significance at the 0.05 level.

The averages of each variable over 264 trading days before and after the change are compared.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive Indicates that null hypothesis could not be rejected.

**Table A.II**  
**Equality of Means Tests**  
**Relative Trading Volume (Spot / Futures)**

<b>Panel A: SPI Futures</b>				<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993				Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994				After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>		<b>Number of Weeks</b>	<b>Average</b>		<b>Direction of</b>	
<b>Before</b>	<b>After</b>	<b>Change</b>	<b>t-statistic</b>		<b>Before</b>	<b>After</b>	<b>Change</b>	<b>t-statistic</b>
0.99%	1.08%	inconclusive	1.29*	51	4.41%	5.25%	increased	2.15*
1.06%	1.15%	inconclusive	0.99	39	3.73%	3.94%	inconclusive	1.53
0.98%	1.17%	inconclusive	1.63	26	3.60%	3.65%	inconclusive	0.72
1.08%	1.08%	inconclusive	0.02	19	3.84%	3.80%	inconclusive	0.64
1.11%	1.25%	inconclusive	0.74	12	3.78%	3.61%	inconclusive	1.21

\* Indicates statistical significance at the 0.05 level.

The averages of each variable over 51 weeks before and after the change are compared.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive Indicates that null hypothesis could not be rejected.

**Table A.III**  
**Equality of Means Tests**  
**Daily Number of Deals**

<b>Panel A: SPI Futures</b>				<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993				Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994				After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	<b>Number of Days</b>	<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>
<b>Before</b>	<b>After</b>	<b>Change</b>	<b>Before</b>		<b>After</b>	<b>Change</b>		
1,366	2,713	increased	29.09*	264	2,502	2,147	decreased	4.22*
1,392	2,818	increased	26.63*	198	2,555	2,091	decreased	4.65*
1,410	2,888	increased	23.28*	132	2,772	2,247	decreased	4.15*
1,417	2,816	increased	20.16*	110	2,867	2,267	decreased	4.28*
1,426	2,752	increased	16.73*	88	2,828	2,321	decreased	3.28*
1,456	2,596	increased	13.03*	66	2,948	2,364	decreased	3.29*
1,519	2,666	increased	10.18*	44	2,969	2,355	decreased	2.98*
1,665	2,379	increased	5.55*	22	2,741	2,354	inconclusive	1.34

\* Indicates statistical significance at the 0.05 level.

The averages of each variable over 264 trading days before and after the change are compared. Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive Indicates that null hypothesis could not be rejected.

**Table A.IV**  
**Equality of Means Tests**  
**Lotting Factor (Size-Adjusted)**

<b>Panel A: SPI Futures</b>					<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993					Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994					After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	<b>Number</b>	<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	
<b>Before</b>	<b>After</b>	<b>Change</b>		<b>of</b>	<b>Before</b>	<b>After</b>	<b>Change</b>		
				<b>Days</b>					
2.45	1.56	decreased	14.64*	264	27.79	28.60	inconclusive	1.89	
2.53	1.63	decreased	12.18*	198	26.81	27.84	increased	2.21*	
2.56	1.76	decreased	9.03*	132	26.57	27.31	inconclusive	1.29	
2.65	1.76	decreased	8.91*	110	25.96	27.33	increased	2.23*	
2.79	1.79	decreased	8.45*	88	24.78	27.50	increased	4.29*	
2.75	1.90	decreased	6.07*	66	24.68	28.20	increased	4.92*	
2.94	1.70	decreased	7.91*	44	23.74	28.63	increased	5.80*	
3.22	1.65	decreased	5.89*	22	22.51	29.06	increased	5.26*	

\* Indicates statistical significance at the 0.05 level.

The averages of each variable over 264 trading days before and after the change are compared.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive indicates that null hypothesis could not be rejected.

**Table A.V**  
**Equality of Means Tests**  
**Local Trading Volume (Size-Adjusted)**

<b>Panel A: SPI Futures</b>					<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993					Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994					After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>		<b>Number</b>	<b>Average</b>		<b>Direction of</b>		<b>t-statistic</b>
<b>Before</b>	<b>After</b>	<b>Change</b>	<b>t-statistic</b>		<b>Before</b>	<b>After</b>	<b>Change</b>	<b>t-statistic</b>	
610	570	inconclusive	1.56	264	6,502	5,770	decreased	1.99*	
624	645	inconclusive	0.71	198	6,466	5,360	decreased	2.61*	
596	759	increased	4.34*	132	7,119	5,832	decreased	2.33*	
612	774	increased	3.96*	110	7,182	6,157	inconclusive	1.65	
650	819	increased	3.54*	88	6,786	6,495	inconclusive	0.43	
647	863	increased	4.01*	66	7,420	6,840	inconclusive	0.74	
714	884	increased	2.42*	44	7,171	7,070	inconclusive	0.12	
832	769	inconclusive	0.68	22	6,493	7,330	inconclusive	0.62	

\* Indicates statistical significance at the 0.05 level.

The averages of each variable over 264 trading days before and after the change are compared.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive Indicates that null hypothesis could not be rejected.

**Table A.VI**  
**Equality of Means Tests**  
**Floor Member Trading Volume (Size-Adjusted)**

<b>Panel A: SPI Futures</b>					<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993					Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994					After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	<b>Number</b>	<b>Average</b>		<b>Direction of</b>	<b>t-statistic</b>	
<b>Before</b>	<b>After</b>	<b>Change</b>		<b>Days</b>	<b>Before</b>	<b>After</b>	<b>Change</b>		
1,102	1,621	increased	8.88*	264	29,298	26,577	decreased	2.11*	
1,177	1,712	increased	7.77*	198	28,848	25,360	decreased	2.35*	
1,272	1,800	increased	6.31*	132	30,959	26,566	decreased	2.31*	
1,329	1,718	increased	4.36*	110	31,617	26,550	decreased	2.40*	
1,401	1,649	increased	2.42*	88	29,491	27,258	inconclusive	0.99	
1,407	1,612	inconclusive	1.70	66	30,183	28,227	inconclusive	0.74	
1,551	1,450	inconclusive	0.77	44	29,243	28,182	inconclusive	0.36	
1,809	1,229	decreased	3.47*	22	25,525	28,470	inconclusive	0.75	

\* Indicates statistical significance at the 0.05 level.

The averages of each variable over 264 trading days before and after the change are compared.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive Indicates that null hypothesis could not be rejected.

**Table A.VII**  
**Equality of Means Tests**  
**Ratio of Local to Total Pit Trading Volume**

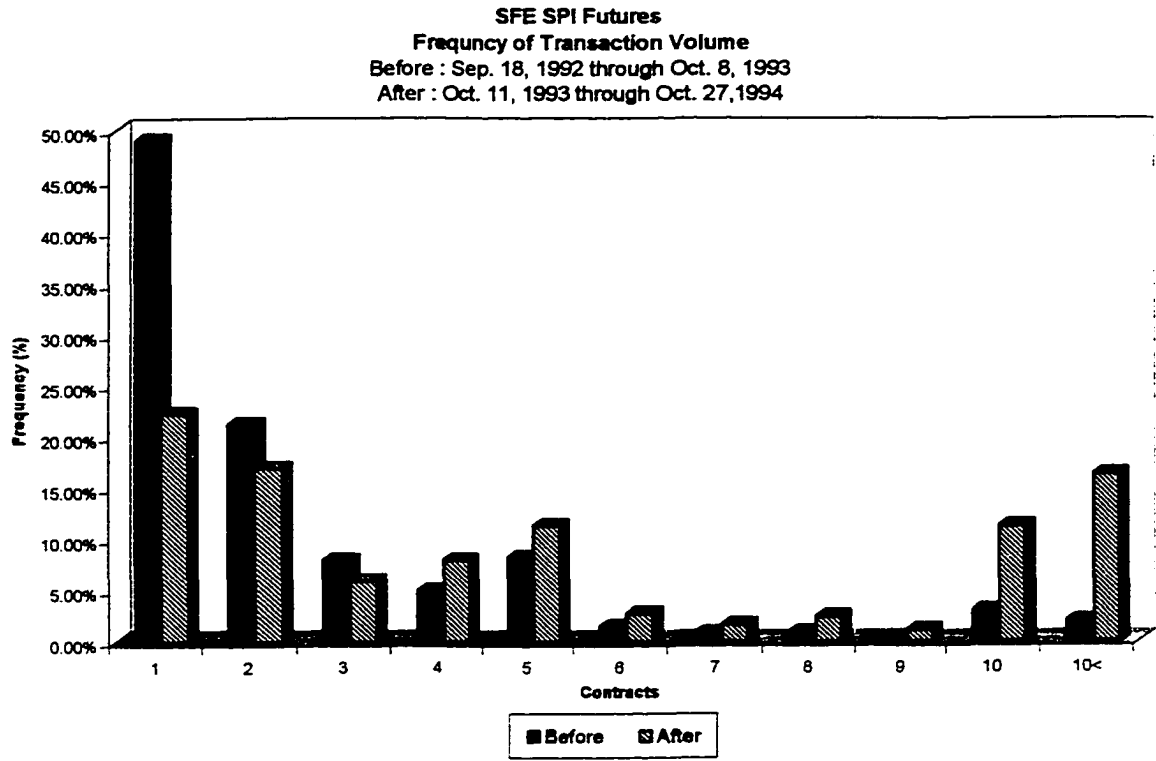
<b>Panel A: SPI Futures</b>					<b>Panel B: BAB Futures</b>				
Before: Sep. 18, 1992 - Oct. 8, 1993					Before: Apr. 6, 1994 - Apr. 28, 1995				
After: Oct. 11, 1993 - Oct. 27, 1994					After: May 1, 1995 - May 20, 1996				
<b>Average</b>		<b>Direction of</b>		<b>Number of Days</b>	<b>Average</b>		<b>Direction of</b>		<b>t-statistic</b>
<b>Before</b>	<b>After</b>	<b>Change</b>	<b>t-statistic</b>		<b>Before</b>	<b>After</b>	<b>Change</b>		
35.6%	26.0%	decreased	5.41*	264	17.3%	16.8%	inconclusive	1.13	
35.8%	27.5%	decreased	9.07*	198	17.4%	16.2%	decreased	2.34*	
32.1%	30.4%	inconclusive	1.78	132	17.7%	16.9%	inconclusive	1.06	
31.9%	31.8%	inconclusive	0.10	110	17.4%	17.7%	inconclusive	0.45	
32.0%	33.9%	inconclusive	1.66	88	17.5%	18.1%	inconclusive	0.75	
32.0%	35.8%	increased	2.86*	66	18.9%	18.9%	inconclusive	0.03	
31.5%	38.1%	increased	4.99*	44	19.2%	19.6%	inconclusive	0.35	
31.4%	38.8%	increased	3.57*	22	19.3%	19.3%	inconclusive	0.03	

\* Indicates statistical significance at the 0.05 level.

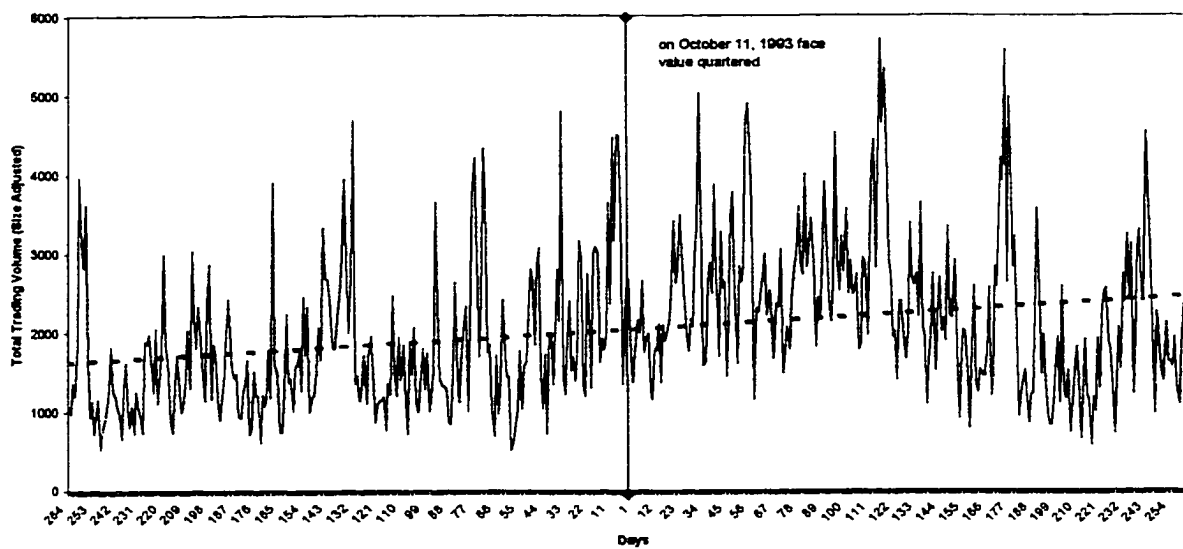
The averages of each variable over 264 trading days before and after the change are compared.

Null hypothesis is that means remain the same before and after the change. Significant t-statistics indicate rejection of the null hypothesis. Inconclusive Indicates that null hypothesis could not be rejected.

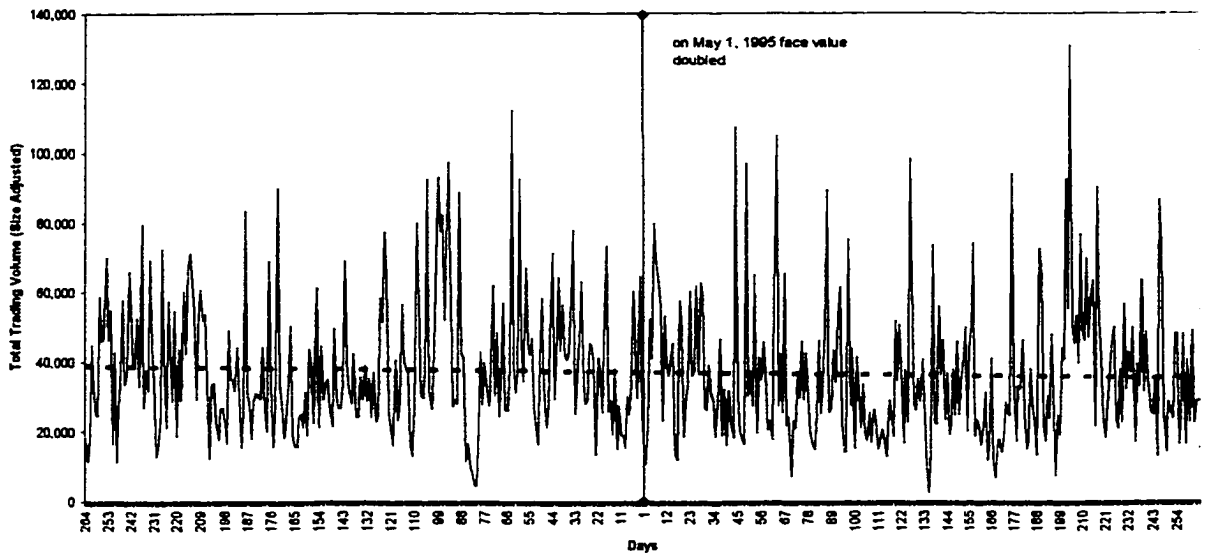
**Figure I**



**Figure A.I**  
**SPI Futures**  
**Trading Volume (Size-Adjusted)**



**Figure A.II**  
**BAB Futures**  
**Trading Volume (Size-Adjusted)**



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## **Essay III**

### **Microstructure Model of Futures Markets: Theory and Evidence**

## I. Introduction

In recent years, microstructure literature has extensively covered the equity markets. However, literature on futures markets microstructure is limited. Although, there has been considerable research done on the estimation of bid-ask spreads in futures market, no formal model of the microstructure of futures markets has been presented, except Hong (1997) who develops an asymmetric information model without the presence of market makers. This essay develops a transaction cost model of the microstructure of futures markets and provides supportive empirical evidence. By doing so it contributes to the literature by explicitly modeling and investigating the impact of market microstructure on the optimal hedging behavior.

Most futures markets exhibit fewer deferred contract months traded and even these are with relatively low open interest. Others like Eurodollar futures display many distant contract months with high open interest (liquidity). The essay investigates the microstructure issues that influence such observed differences among various futures markets. The results of this essay would be useful for the futures exchanges to develop contract that exhibit high liquidity in distant delivery months. Lack of liquid distant delivery contracts influences the optimal hedging behavior as well as limit the range of speculative strategies.

In principle, the contract providing the best hedge in terms of risk reduction is the one whose maturity is the closest to the spot commitment. However, if the longest futures maturity is before the spot commitment date, the hedge needs to be rolled-over to an upcoming expiration month. Duffie (1989) argues that since the liquidity often decreases considerably with the distant maturities, the cost of using distant contract may be large

enough to make hedging in the nearby contract more attractive, and lead to periodic rolling of the hedge into successive nearby ones. Lack of liquidity in the distant maturity months makes the execution of trades in those contracts expensive. Duffie refers to such costs as the market impact portion of transaction costs. In a less liquid market, a market sell order might be executed at a price low enough to induce a trader to hold the position until an offsetting order arrives. As it will be discussed later in the essay, market makers are the types of traders who bridge the gap between the market orders. However, when and if the “market makers” are reluctant to bridge such a gap, speculators might be willing to make the market for hedgers in the distant deferred contracts at a higher cost. Duffie suggests that with somewhat more liquidity in the nearby contracts, the higher market impact costs facing the hedge-motivated trades in the later-to-deliver contracts will cause some of these trades to be replaced with trades in contracts sooner-to-deliver. Duffie concludes, without empirical support, that there may be grounds for hedging always with the nearby contract and rollover the hedge as the delivery date on the nearby approaches. Microstructure model of this essay addresses the issues pointed out by Duffie (1989) and the empirical results suggest that the optimal hedging strategy may not necessarily be to always use the nearby contract and subsequent rollover.

The model divides the futures market participants into three groups: hedgers, speculators, and market makers. Earlier work has focused on specific market participants but not on all three explicitly within the same model. For example, Grossman and Miller (1988) model the role of the market makers in equity markets while labeling nonmarket makers as “outside customers”. Hong (1997) characterizes the futures market participants as informed and uninformed. In Hong’s model private information generates an adverse

selection effect and this effect is used to explain the volume and open interest patterns in futures markets. Silber (1984) provides an empirical analysis of market maker behavior in futures markets. Smidt (1986) indicates the need to identify all three groups of participants and discusses the role of each but stops short of developing a formal model. Numerous empirical articles focused, independently, on both hedging and speculating in the futures markets. This essay captures the behavior and interaction between these three distinct groups of futures market participants.

In the model, hedgers are the market participants who have natural positions in the asset underlying the futures contract and who utilize such a contract to reduce the risk associated with those positions. Speculators are the participants who do not have positions in the underlying asset. Speculators trade the contract in an attempt to make a profit by assuming the risk transferred from the hedgers. Market makers are the traders on the floor of the exchange who quote bid and offers against which market orders can be executed. As a direct result of the futures market design, there is continuous trading activity in any trading day during which buyers and sellers with price-compatible trading interests might arrive at the market at different moments. Stigler (1961) was the first to emphasize that inventory specialists, i.e. market makers, would emerge in response to the profit opportunities created by the temporally fragmented order flow associated with a continuous auction. The market makers use their inventory to bridge the gap between the stochastically arriving buy and sell orders. Futures exchanges are membership organizations that do not require any member to make the market. Silber (1984) indicates that since the market makers voluntarily provide liquidity to incoming market orders, the return on their time and effort should be based on their quoted bid-asked spread and on

the frequency with which their bids are hit and their offers are lifted. Provision of liquidity and its effect on the utilization of futures contracts is the central theme in investigating the interactions between the three groups of market participants.

This essay, besides providing a transaction cost model of futures microstructure, examines the factors affecting the bid-ask spread, trading volume, and open interest in contracts with different time to expiration for the same underlying asset. The model's predictions speak to the observed differences in the number of deferred contracts trading in various futures markets. The model leads to conclusions concerning the hedgers' optimal choice of portfolio of contracts with different times to expiration in order to hedge underlying maturities that are not covered with the existing contract maturities. This essay also provides the empirical evidence supporting the predictions of the model regarding the bid-ask spread, volume, and open interest patterns. Both the theoretical model and the empirical work focuses on the financial futures markets.

## **II. Related Literature**

This essay utilizes the literature on the equity and futures market microstructure, as well as the previous research on the volume-volatility relationship in futures markets.

### *II.a. Market Microstructure*

Silber (1984) examines the activities of scalpers, who are referred as the market makers on the futures exchange floor, to identify the role of market making and characteristics of their decision making process. He indicates that much of the literature on market microstructure assumes that the market makers' returns come from the

liquidity that they provide to the market. In this respect, he examines the relationship between market maker's trading activity (i.e. frequency and volume of transactions) and returns (i.e. bid-ask spread). His empirical work utilizes the data on the trading activity of a representative scalper on the NYFE trading floor. His findings include the following: The representative scalper's trades are held on average for less than two minutes indicating the very short time horizon of the scalper's decision making process. Scalpers' profits decrease and variance of those profits increase longer he holds his positions open. The profit per contract traded reaches a maximum in the 1-3 minute holding period. He indicates that "if the scalper's returns were solely compensation for bearing risk between the stochastically arriving buy and sell orders, we should observe larger returns earned on positions that are held longer" (Silber 1984, p. 950). Silber also finds that the scalper's average profit per contract traded is significantly less than the tick i.e. minimum possible price change. He shows that scalper has profitable trades when his markets are acted upon. Silber's findings support the optimization problem developed for the market makers in this essay.

Kuserk and Locke (1993) examine the scalper behavior in various futures markets and conclude that scalpers do little speculating or brokering and earn significant income from their trading strategy of frequent buying and selling smaller quantities within a trading day.

Hong (1997) provides an equilibrium model of competitive futures market in which investors trade to both hedge and speculate on private information. He indicates that private information regarding the future payoffs to holding spot positions generates an adverse selection cost to trading and this cost varies across the life of a given contract

as well as across contracts with different time to maturity at a given time. Hong's model implies that the return volatility and open interest of a futures contract initially rise with time and then fall as it expires. The model's first testable implication is that the expiration of nearby futures contract produces an information effect that interacts with Samuelson's effect to produce an inverted U-shaped time to maturity pattern in the return volatility of the contract (Hong 1997, p. 32). He indicates that quadratic specification may be more appropriate in testing the relationship between the time to maturity and return volatility of futures. The second testable implication of Hong's model is that markets with more mean-reverting convenience yields shocks tend to have a more dispersed open interest distribution for both allocational and informational reasons. The prediction of his research is that the open interest takes on an inverted U-shaped time to maturity pattern due to the ability of investors to adjust their spot trades and due to the changes in the level of adverse selection cost across the life of the contract. This essay, unlike Hong (1997), focuses on the symmetric information case while increasing the number of futures contracts with different times to maturity from two to three. Such a modification combined with the explicit modeling of three market participants better captures the characteristics of the microstructure of futures markets.

Wang, Yau, and Baptiste (1997) examine the relationships between trading volume and transactions costs. They estimate the elasticity of trading volume with respect to the bid-ask spread using a simultaneous equation system. They show that the trading volume and bid-ask spreads are jointly determined. Their empirical results indicate that there is a positive relationship between volume and intraday price volatility, and an inverse relationship between the volume and spreads. Wang et al. model the trading

volume as a function of changes in the reservation price of speculators, change in the expected physical position of hedgers, bid-ask spreads, and lagged open interest. They model the bid-ask spread as a function of price risk, trading volume, number of market makers in the pit, and average price of futures. They stop short of providing a formal theoretical model that explicitly presents the decision making of each market participants. Their empirical model and findings support the model developed in this essay.

### *II.b. Volume-volatility Relationship*

Studies that investigate the relationship between trading volume and price variability focus on the causality and/or lead-lag relationships. Rutledge (1979) investigates the relationship between trading volume and price variability for commodity futures contracts. He uses the causality tests developed by Sims (1972), and examines four-month trading periods for 136 different futures contracts for 13 commodities. His work provides modest evidence for the changes in price variability leading trading volume.

Cornell (1981) also examines the relationship between volume and price variability in futures markets by utilizing a standard regression model and argues that increases in uncertainty and differing beliefs about information would lead to increased volume of futures trading. His arguments suggest that trading volume and variance of prices are positively related. Pooling cross-sectional and time-series data he regresses the change in the standard deviation of the log price relative as a function of the change in average contemporaneous, leading and lagging trading volume. He finds the relationship

between the variables to be almost entirely contemporaneous, positive, and usually significant. However, he does not use the tests for Granger causality in his study.

Tauchen and Pitts (1983) examine the relationship between daily price change variability and trading volume on speculative markets and argue that the two are positively related. They utilize a series of assumptions that helped them to derive joint probability distributions to test their arguments. Their tests confirm the positive relationship between daily price change variability and trading volume on speculative markets.

Garcia, Leuthold, and Zapata (1986) attempt to identify lead-lag relationships between trading volume and futures price variability in a sample of 120 four-month trading periods involving corn, wheat, soybeans, soybean oil and soybean meal futures contracts during 1979 and the early 1980s. They find lead-lag relationships in about 15% of their usable data sets, and that the relationship is almost equally divided between the two price variability measures that they used. Their results are evenly split between the two possibilities, i.e. price variability leading the trading volume changes and vice versa. They claim that their empirical evidence suggest the absence of pronounced and recurrent lead-lag relationships between volume and futures price variability. Unlike Rutledge, they use Granger causality tests in their empirical work.

The works of Rutledge (1979) and Garcia et al. (1986) support the framework of the model developed in this essay. Rutledge argue that changes in daily trading volume are largely a measure of variations in speculation since hedgers' transactions comprise only a small proportion of daily trading volume. He also cites some historical data to back his arguments. Garcia et al. assert that the intuitive knowledge about the futures markets

offers support for such a claim. That is, most hedging positions are held for several days if not weeks. They also mention that many scalpers trade in and out of the market very rapidly looking for small price changes, and that these traders seldom hold positions overnight. They claim that many contracts turn over daily while total number of contracts in existence remains relatively constant in futures markets. Their conclusion is that “since most hedging orders are held for more than a day while many speculative trades are day orders, there does not appear to be strong evidence to refute the claim that changes in daily trading volume are primarily a reflection of speculative activity” (Garcia, Leuthold, and Zapata 1986, pp. 2-3). In light of these arguments, this essay’s intention to focus on the open interest to investigate hedging behavior with respect to different expiration month contracts appears to be appropriate.

Anderson (1985) empirically investigates the determinants of the volatility of futures prices and finds that in a variety of markets the distribution of futures prices is not constant and it changes over time in a systematic manner. The patterns observed by him are particularly strong for annually harvested storable goods, i.e. agricultural futures markets. Taking in to account these findings it is more appropriate to use futures markets that do not possess obvious seasonality patterns for the analyses of this essay. Therefore, data on the foreign currency futures are used in the empirical analysis.

Martell and Wolf (1987) use open interest in a model of the determinants of trading volume in metal futures markets. They find the estimates of the coefficients of open interest to be positive and significant. They utilize daily high and low futures prices contained in the daily futures data set to estimate the intraday volatility. Edwards (1988) examines the

relationship between futures trading and cash market volatility. He also employs intraday high and low futures prices to form an alternative measure of volatility.

### **III. Description of the Futures Market**

The microstructure of futures markets is rather different from those of the equity markets. There are no designated market makers in the futures pit. Trading takes place through an open outcry system on the floor of the exchange. Traders verbally announce their quotes in a collective manner and such quotes cease to exist as soon as they are uttered, if they are not repeated later on. There are a large number of traders present at once in the pit. Such large number and the rapidity of verbal announcements make it difficult to gather the explicit bid and ask quotes. Willingness of one trader, irrespective of his/her type, to buy or sell would generate bid or ask quotes and provide liquidity in the market. In order to investigate the interaction between the three different futures market participants, the role of representative market makers needs to be specified.

Individuals who are physically present on floor of the futures exchange are called floor traders and are classified under several titles. Floor brokers call in and represent the orders of the hedgers and speculators outside the exchange. Floor brokers may also trade for their own accounts. Other floor traders can be categorized as day traders, i.e. short-term speculators, who prefer to trade for their own account rather than executing orders through a floor broker. Scalpers are a specialized group of floor traders who stand ready to buy and sell by quoting bids and offers. In the context of this essay traders are classified as hedgers and speculators who may or may not be present on the floor of the exchange. The distinction between these two type of traders comes from the fact that

hedgers have positions in the underlying asset while speculators do not. Scalpers make up the third group of traders, i.e. market makers. The model focuses on the transaction costs and the structure of the market rather than potential information asymmetry among hedgers and speculators. Optimal decisions of the three groups of traders are modeled to be interacting through the behavior of the market makers.

In this essay no distinction is made between different types of orders, e.g. limit orders versus market orders. However, a review of liquidity and the role of scalpers from the point of view of order types enhance the modeling of the behavior market makers in this essay. Scalpers' bids and offers at specific prices provide liquidity to incoming orders to buy and sell at the prevailing market quotes. All limits orders provide liquidity and all market orders consume liquidity. Therefore, scalpers are self-styled market makers who provide liquidity in competition with limit orders represented by floor brokers, as well as with the bids and offers of other floor traders who are primarily speculating on future price movements.

### *III.a. Market Makers*

Market makers' objective is to turn their inventory over quickly at a profit, i.e. want to sell at their offer what they have bought at their bid or buy back at their bid what they have already sold at their offer. Unlike the risk-taking speculator, a scalper holds an inventory position only as long as necessary to accommodate market orders and turn a profit. Thus, a scalper's inventory should not deviate from zero for any considerable time (Silber 1984, p. 941). Market makers can have zero-profit trades, i.e. "scratch" trades. These trades are executed immediately upon accommodating a public order that scalper

does not think he/she can turn over at a profit at reasonable short period of time.

Therefore, scalpers' objective is to turn over their inventory quickly at a profit while accommodating public orders. Scalpers' decision making is also influenced by their expectations of the direction of price movements. Silber (1984) indicates that scalpers continuously evaluate the probabilities of their offers being lifted and their bids hit. If scalpers observe many floor brokers simultaneously hitting bids with new incoming market orders, they may conclude that it will be difficult for them to sell at their offer the inventory if they were bidding. When scalpers' evaluation of the market suggests a high probability of an imminent change in bids and offers, they will probably make only one-sided market. If scalpers have non zero inventory positions when they perceive a near change in the market quotes, they will try to close out their trades without a profit or loss by hitting or lifting other bids and offers. Therefore, "scratch" trades are direct result of scalpers' continuous reevaluation of market conditions. These discussions indicate the importance of the order flow generated by the "outsiders" on the market makers decision making. Scalpers find it optimal to hold a position for a very short time period. Working (1967) indicates that "scalpers who devote their attention to the smallest dips and bulges make a great number of purchases and sales each day, tend to hold the resulting speculative positions for only brief intervals of time, and almost invariably end the day with zero speculative position" (Working 1967, p.208). Silber (1984) provides empirical evidence supporting the above discussions.

In the model, market makers maximize their daily trading profit while maintaining zero open interest in any contract over-night. Therefore, they are only concerned with each trading day's profit. Market makers' profits increase with the

increasing frequency of trading during the day, i.e. arrival of market orders, and also with the higher spreads, i.e. the difference in the price they pay and receive for each round trip trade. However, market makers can not increase their daily trading profit without a bound. Excess spreads between the quoted bids and offers result in their inventory to build up and eventually lead to unprofitable trades. High spreads also discourage the frequent execution of market orders. Therefore, in the model neither market makers nor other floor traders take others' behavior given.

### *III.b. Hedgers*

Hedgers are defined to be the individuals or institutions that have natural positions in the asset underlying the futures contract. Hedgers use the futures contracts to hedge their net future spot obligations. They learn sequentially and in a random order certain information about the quantity and maturity of their net futures obligations, i.e. hedgers' net future spot obligation changes everyday through their spot market transactions. For simplicity, it is assumed that those dates coincide with the expiration of different deferred futures contracts. If a futures contract with time to expiration matching the maturity of the spot obligation trades in the market, the firm takes a position in that contract by executing a market order with one of the market makers. If the firm can not establish a position in such a contract (i.e. a long deferred contract), it chooses a portfolio of positions in the available nearby and short deferred contracts. This portfolio is chosen to minimize both the price risk associated with the underlying foreign currency and the trading (transaction) costs over the life of its hedge, i.e. until the maturity of underlying obligation. Total trading cost is a function of the availability of contracts for trading,

spreads charged by market makers, the number of times to rebalance the portfolio of contracts, time to maturity of the underlying obligation and the volatility of the prices.

The uncertainty in the information received can be in two folds. The exact maturity of the underlying obligation can be uncertain. The amount associated with such obligation may also pose uncertainty. In the most general case, the information that the firm receives can have uncertainty in terms of both timing and quantity. Either case of uncertainty results in rebalancing of the portfolio of futures contracts over the life of the hedge. Each trading day, hedgers' spot market activities change the timing of the net future spot obligation and/or the amount of that obligation. Hedgers evaluate such changes in the light of the market conditions, i.e. existence of the appropriate contracts, spreads, and again choose a portfolio of futures contracts. Such rebalancing generates different levels of frequency of transactions and trading volume for contracts with different times to expiration.

The frequency with which hedgers receive information regarding their future obligation or the frequency of changes in the net future spot positions decreases with increasing time to maturity. Such information contains more uncertainty as it relates to a more distant future date. The buy and sell orders on each futures contract do not arrive at the market makers at the same frequency as the information that hedgers receive. Orders are filtered through the hedgers' decision making process and disseminated over the existing contracts.

The number of hedgers in the market is large enough such that no single hedger can possess superior information about the future trajectory of prices by extrapolating from his/her quantity position to the overall market supply and demand conditions.

Hedgers sequentially and in random order receive information only regarding their own demand quantities. Therefore, trading based on the asymmetric information is ruled out in this model.

### *III.c. Speculators*

Speculators generate market orders in an attempt to profit through trading over different horizons. In the model, speculators are willing to hold positions in futures contracts with different time to expiration for a period of time, i.e. over-night to several days, weeks, etc. They attempt to forecast the price movements in the market, which in turn are determined by the demand and supply for the contracts. Speculators' forecasting ability decreases with the time to maturity. They choose a portfolio of futures contracts to maximize their trading profit while minimizing the cost of trading. The cost of trading that a speculator faces is a function of spreads charged by market makers, and depth. The trading profit is a function of price volatility and frequency of transaction demand of hedgers.

In the model, each participant's decision is made in light of others' behavior. The market makers are modeled to be in the center of the decision chain, while the hedging demand for contracts with different times to expiration is modeled to be the driving force.

## **IV. The Microstructure Model**

There are three types of traders, hedgers, speculators, and scalpers, and three contracts traded in the market, the nearby, first deferred, and second deferred ( $i = 1, 2, 3$ ).

Each contract is equally distant from others in time, second deferred contract (i.e.  $i=3$ ) being the one with the longest time to expiration. Earlier models (e.g. Hong 1997) of futures trading allowed only two contracts to be traded, nearby and a distant. In the actual markets, the number of contracts available for trading varies from time to time as well as from market to market. In equity index futures a maximum of four, in currencies six, in Eurodollar futures 40 distinct delivery months trade. In order to investigate the hedgers' portfolio of contracts with different expirations, two distinct deferred (near and distant) contracts are allowed to trade besides the nearby. Such a structure captures the flow of open interest and trading volume from the expiring nearby contract to the remaining deferred ones.

In the model,

$BA_{i,t}$  is the average one half of the round trip bid-ask spread on contract  $i$  at  $t$ .

$N_{i,t}$  is the number of transactions (trades) on contract  $i$  during the trading day  $t$ , with  $N_{i,t}^b$  and  $N_{i,t}^s$  denoting the number of transactions on contract  $i$  during day  $t$  initiated by hedging and speculative demand, respectively,

$TS_{i,t}$  is the average size of futures transaction, i.e. number of contracts  $i$  traded during the trading day  $t$ , with  $\Delta s_{i,t}^b$  and  $\Delta s_{i,t}^s$  denoting the size of hedger's and speculator's transactions, respectively, on contract  $i$  during day  $t$ .

The daily optimization problem faced by an individual market maker is given by:

$$\max \sum_{i=1}^3 (BA_{i,t} \cdot N_{i,t} \cdot TS_{i,t}) \quad (1)$$

$$\text{s.t.} \quad \sum_{k=1}^{N_{i,t}} (TS_{i,t,k} \cdot D_{i,t,k}) = 0 \quad \forall i = 1, 2, 3, \quad (2)$$

$$\text{where } D_{i,t,k} = \begin{cases} +1, & \text{if market maker buys (long)} \\ -1, & \text{if market maker sells (short)} \end{cases}$$

$$TS_{i,t} + \Delta s_{i,t}^h + \Delta s_{i,t}^s = 0, \quad i = 1, 2, 3. \quad (3)$$

Market makers' decision is given by  $\{BA_{i,t}, TS_{i,t}; \forall i\}$  that solves the above maximization problem. Market makers may choose not to trade against an incoming market order in a contract if they do not believe that they will be able to lay off that position by the end of the trading day, hopefully at a profit. This can be achieved by either quoting an unacceptably low bid or high offer, or by not quoting at all. The quoted spread is a function of expected number of transactions, future price volatility, and the volatility of the changes in the hedging and speculative positions, i.e.

$$BA_{i,t} = f\left\{E(N_{i,t}), \text{VAR}(\Delta FP_{i,t}), \text{VAR}(\Delta s_{i,t}^h), \text{VAR}(\Delta s_{i,t}^s)\right\} \quad \forall i, t. \quad (4)$$

Earlier empirical research documents that this volatility is a function of the time to expiration of the futures contract.

The hedgers maximize their utility of wealth over the life of the hedge. The underlying maturity of spot or future spot commitments determine the duration for which the hedge is necessary. Hedgers have a mean-variance utility function of the form

$$U(W_t) = E(W_t) - a \cdot \text{VAR}(W_t) \quad (5)$$

where  $a$  is the coefficient of risk aversion and wealth at time  $t$  is given by

$$W_t = E_t + C_t \quad (6)$$

where  $E$  is the endowment value of spot holdings,  $C$  is the cash. Investors' wealth can be rewritten as

$$W_t = SP_t \cdot Q_t + C_t, \quad (7)$$

where  $SP_t$  is the spot price and  $Q_t$  is the quantity of the spot or future spot commitment at  $t$  that has maturity  $T$ .

The optimization problem faced by a hedger is given by:

$$\max_{\Delta s_{i,t}^h} \sum_{t=1}^T U(W_t) = \sum_{t=1}^T \{E(SP_t \cdot Q_t + C_t) - a \cdot \text{VAR}(SP_t \cdot Q_t + C_t)\}, \quad (8)$$

$$\text{s.t. } C_{t-1} + SP_t \cdot (Q_t - Q_{t-1}) + \sum_{i=1}^3 \left[ (s_{i,t}^h \cdot \Delta FP_{i,t}) - \left( \Delta s_{i,t}^h \cdot BA_{i,t} \right) - \left( \Delta s_{i,t}^h \cdot IM \right) \right] = C_t \quad (9)$$

$$\Delta S_t^h = \sum_{i=1}^3 \Delta s_{i,t}^h, \text{ and } \Delta Q_t = Q_t - Q_{t-1} = \Delta S_t^h \quad (10a, b)$$

where  $\Delta FP_{i,t}$  is the change in the price of contract  $i$  from the previous trading day,  $BA_{i,t}$  is the average one half round trip bid-ask spread on contract  $i$  during trading day  $t$ ,  $s_{i,t}$  is the hedger's position in contracts  $i$  at the end of trading day  $t$ , measured by number of contracts. In equations (8) through (10) the superscript  $h$  refers to hedger's futures position.  $S_t$  is the sum of positions in distinct maturity contracts at trading day  $t$ .  $\Delta S_t$  is the total change in futures positions from the previous trading day and it should be equal to the change in the spot or future spot commitment during the same day.  $IM$  is the initial margin per contract required to establish new positions. In the model the initial margin does not vary across contracts months or through time during the life of the hedge. Hedgers' decision is given by  $\{\Delta s_{i,t}\}$  which maximizes the expected utility over the hedging duration subject to the availability of contracts for hedging.

The second term in equation (9) represents the increase or decrease in spot commitment during a trading day. This change can be due to additional purchase or liquidation of the underlying asset due to the normal business activities. It may also be as a result of increase or decrease in future spot commitments. Given the change in spot

commitment size, hedger chooses an optimal change in the futures positions in different contract months,  $\Delta s_{i,t}$ .

The summation term is the changes in cash as a result of futures trading activity at  $t$ . First term in the summation represents the marked-to-market of each futures position at the end of day  $t$ . The second term is the bid-ask spread on the futures trading activity at  $t$ . Hedger pays the spread whether his trade at  $t$  establishes additional position or reduces the existing position in that contract month. The last term represents the initial margin that must be posted if the trade increases the existing position or the recovery of the margin previously posted if the trade decreases the existing position. For simplicity, it is assumed that return on margin is zero.

Speculators' optimization is similar to the one given in equations (5) and (6), with the exception that they do not hold positions in the underlying asset. Speculator's optimization problem is given by:

$$\max_{\Delta s_{i,t}, \tau} \sum_{t=1}^{\bar{t}} U(W_t) = \sum_{t=1}^{\bar{t}} \{E(C_t) - a \cdot \text{VAR}(C_t)\} \quad (11)$$

$$\text{s.t. } C_{t-1} + \sum_{i=1}^3 \left[ (s_{i,t}^s \cdot \Delta FP_{i,t}) - (\Delta s_{i,t}^s \cdot BA_{i,t}) - (\Delta s_{i,t}^s \cdot IM) \right] = C_t \quad (12)$$

Since the speculators do not spot positions duration of their speculative position in futures ( $\tau$ ) is also a decision variable. Speculators choose the optimal set of  $\{\Delta s_{i,t}\}$  to maximize their utility from trading profit through  $\tau$ .

The choice of  $\Delta s_{i,t}$  is a result of hedgers' filtering, which is constrained by whether the contract trades in the market. For example, if hedgers can not take positions in contract  $i=3$  since it is not yet traded in the market, they can disseminate the amount of contracts needed over to the existing contracts  $i=1$  and  $i=2$ . When time to maturity

(expiration) is sufficiently nearer and information arrival is sufficiently high, it is possible that the first trade on contract  $i=3$  takes place in the market. This trade need not be facilitated by a market maker. Hedgers who are on the opposite side of the trade may make the market for each other. On the other hand if the “spread” paid by the hedger is sufficiently large, then a speculator may take the other side of the trade by making the market for the hedger. Since speculator’s forecast error increases with time to expiration, speculator accepts the other side of the trade only when the “spread” compensates the potential loss due to forecast error. Following the initial trade, while the frequency of information is low and “spread” is high there will be few trades taking place over the consecutive trading days on contract  $i=3$ . In this case, the “spread” paid by the hedger is not acceptable to the market makers since their probability of laying off the position before the end of that trading day is very low. Therefore, since in this model market makers are never willing to hold overnight position they will not make the market for contract  $i=3$ . However, there will exist a time when market makers also participate in the trading of contract  $i=3$  as time to expiration sufficiently nears.

## **V. The Data**

The data sets for this essay are obtained from Futures Industry Institute. Daily and intraday (tick) data on the Chicago Mercantile Exchange’s foreign currency contracts (i.e. British Pound, Canadian Dollar, Deutsche Mark, Japanese Yen, and Swiss Franc) are used for empirical tests. The daily data contains the opening, high, low, and closing futures prices on all available expiration month contracts, as well as the spot price of each currency. Daily trading volume and open interest for each contract month are also

included in the data. The intraday (tick) data consists of transaction-by-transaction prices for each contract month during each trading day. Empirical tests are run over the period January 3, 1994 through March 16, 1998, in the case of intraday analysis through December 31, 1997. Each of the variables in the daily data set is constructed for the nearby and for each of the deferred month contracts. On a given day, the nearby is the futures contract that is the closest to its expiration. Rolling-over is handled on the day following the expiration of the nearby (i.e. first contract).

Table I presents the distinct maturities traded, i.e. number of different expiration month contracts, for each of the underlying currency. For the period of this essay, the maximum number of distinct maturities traded of British Pound futures was four, while maximum five distinct maturities traded for Deutsche Mark and Swiss Franc futures. Maximum six distinct maturities traded for Canadian Dollar and Japanese Yen futures, indicating that the possibility of hedging a maximum of 18-month distant commitments.

In the case of Deutsche Mark futures contracts, Figure I through III illustrate the characteristics of open interest over time. Open interest in a given maturity contract is relatively constant during the majority of trading days following its inception. It reaches its highest level after the contract becomes nearby (i.e. nearest to expiration) as hedgers and speculators increase their positions in the contract. After its highest level, open interest decreases as investors liquidate their position as their hedging horizon ends or as they rollover to the following maturity months. Figure III depicts the critical open interest values and days throughout the life of a contract. The highest open interest attained and its timing, measured by the days-to-expiration (DTE), the ratio of delivered contracts to

the highest open interest, and days-to-expiration when the cross-over between the open interest in nearby and the first deferred occurs.

For example, Deutsche Mark futures contract expiring in March 1996 attains its highest open interest on February 1, 1996, 32 trading days prior to its expiration. In this essay, trading days from the day of highest open interest to the expiration day of nearby contract are referred to as the period of expiring open interest. Table II presents the summary statistics for the days-to-expiration when nearby contract attains highest open interest level. For all contracts expired during the period of investigation, the highest open interest level is attained when the contract is nearest to expiration. For example, the Canadian Dollar futures reach their highest open interest levels, on average, 34 trading days prior to their expiration. However, in the extreme cases the highest open interest levels are attained as low as 12, and as high as 63 trading days prior to expiration. The timing, measured by DTE, of the highest open interest is a function of hedging demand for the contract. As investors need to hedge more distant commitments, open interest is expected to build up far from the expiration of the contract.

In order to investigate the distribution of the open interest as the nearby contract expires, this essay focuses on the periods of expiring open interest, i.e. the trading days from the day of highest open interest to the expiration day. Table III presents the number of distinct maturities traded during the periods of expiring open interest. For example, for Japanese Yen futures out of 1,062 trading days between January 3, 1994 and March 16, 1998, 526 days are classified as periods of expiring open interest. During these 526 trading days at least three distinct maturities are traded, while four, five, and six distinct contracts are available for trade during 499, 301, and 34 trading days, respectively.

## VI. Empirical Results

### *VI.a Distribution of Expiring Open Interest*

In order to provide evidence supporting the predictions of the theoretical model the following question is answered empirically: As the nearby contract expires, how does the open interest in that contract get distributed among liquidation and rollover to the next nearby as well as to the distant deferred contracts? The distribution of expiring open interest is a direct result of hedger's optimal portfolio choice. As noted by the model, hedgers need to choose a portfolio of futures contracts with different expirations, when a contract with the time to expiration matching the maturity of their underlying obligation does not trade. If it is observed empirically that no part of expiring open interest gets distributed to the deferred contracts, then the hedgers' optimal choice would be to hedge any underlying maturity using the nearby futures contract and rollover to the next one as the nearby expires. On the other hand, empirical results indicate that some of the open interest in the expiring nearby contract gets distributed to the deferred ones. This result supports the hypothesis that there is an optimal mix of deferred contracts to hedge a given underlying maturity.

Lets denote the open interest in contract  $i$ ,  $i=1$  being the nearby and  $i=6$  being the most distant maturity, by  $O_{i,t}$ , where  $i = 1, \dots, 6$ . The change in open interest in contract  $i$ , from the previous trading day, at date  $t$  is given by:

$$\Delta O_{i,t} = O_{i,t} - O_{i,t-1}. \quad (6)$$

For each contract maturity,  $\Delta O_{i,t}$  is the net of positions entered into and liquidated of that maturity during trading day  $t$ . The expiring open interest is defined to be  $\Delta O_{1,t}$ , the open interest in the nearby (the first contract) during the trading days from the day of highest

open interest to the expiration day. By construction,  $\Delta O_{1,t}$  is negative, thus indicating expiring open interest. However, for all currencies, during the periods of expiring open interest there are few days in which an increase in open interest is observed for the nearby contract.

The following model is estimated to determine the distribution of the expiring open interest among delivery versus other existing contracts:

$$\sum_{i=2}^6 \Delta O_{i,t} = \alpha_0 + \alpha_1 \Delta O_{1,t} + \varepsilon_t, \quad (7)$$

where right hand side is the sum of changes in the open interest in all maturities except the nearby. This model is estimated over the days between the expiration date and the day in which the nearby contract attains its highest open interest. Table III presents the summary statistics for the days-to-expiration during the estimation period. Since by this construction  $\Delta O_{1,t}$  is negative, it is expected that  $-1 < \alpha_1 < 0$ .  $\alpha_1 = -1$  indicates that all the open interest in the expiring contract is rolled-over to the other deferred contracts with no liquidation. The results suggest that a significant portion of the expiring open interest does not rollover suggesting the liquidation of positions to get out of the market. For example for the Deutsche Mark futures, as nearby open interest decreases by thousand contracts total deferred month open interest increases by 282.1 contracts.  $\alpha_0$  is expected to be positive indicating the increase in the open interest in the deferred contracts that is not a direct result of rollover from the expiring nearby. Table IV, illustrates that the empirical results confirm with the expectations on  $\alpha_0$  and  $\alpha_1$ .

In order to show the distribution of expiring open interest over to the deferred contracts the following set of models are estimated:

$$\Delta O_{i,t} = \alpha_{0,i} + \alpha_{1,i} \Delta O_{1,t} + \varepsilon_t, \quad i = 2, \dots, 6. \quad (13)$$

In equation (8),  $\alpha_{0,i}$ 's are expected to be positive indicating the increase in the open interest in the deferred contracts as a result of new hedging and speculative demand entering into the markets. It is expected that  $-1 < \alpha_{1,i} < 0$ , i.e. as the nearby open interest decreases deferred month open interest increases. The magnitude of the estimates of slope coefficients is expected to have the following relationship:

$$|\alpha_{1,2}| > |\alpha_{1,3}| > |\alpha_{1,4}| > |\alpha_{1,5}| > |\alpha_{1,6}|.$$

As the nearby open interest decreases increase in the deferred open interest decreases by maturity. Theoretical model of the essay suggests that the smaller portion of the open interest in the nearby contract, as it expires, would be rolled-over to the distant contracts. This is due to the decrease in liquidity by maturity as well as the less frequent arrival of information pertaining to the distant maturities.

Table V provides the estimated coefficients of the regression models in equation (8). The results indicate that the decrease in the nearby open interest can explain the increase in the open interest of first, second, and third deferred contracts. The only exception being the British Pound futures for which the estimated coefficient for the third deferred contract ( $i=4$ ), which is the longest maturity, is insignificant. Decrease in the nearby open interest can not explain the increase in the open interest of the most distant maturity contract, suggesting that positions in the nearby, as it expires, are not rolled-over to the most deferred contract. For the Canadian Dollar and Japanese Yen futures, there is some evidence that the expiring nearby open interest is rolled-over to one-year deferred contracts ( $i=5$ ) (see Table V). These results suggest that the optimal hedging strategy may not necessarily be to use the nearby contract and rollover the next as it expires.

Granger causality tests are used to provide evidence supporting the findings presented in Table VI. The Granger (1969) approach to the question of whether variable  $x$  causes variable  $y$  is to see how much of the current  $y$  can be explained by past values of  $y$  and then to see whether adding lagged values of  $x$  can improve the explanation. Then,  $y$  is said to be Granger-caused by  $x$  if  $x$  helps in the prediction of  $y$ , or equivalently if the coefficients on the lagged  $x$ 's are statistically significant. It is important to note that the statement “ $x$  Granger causes  $y$ ” does not imply that  $y$  is the effect or the result of  $x$ . Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term. The following bivariate regressions are estimated to confirm the results presented in Table V:

$$\Delta O_{i,t} = \alpha_{0,i} + \alpha_{1,i} \Delta O_{i,t-1} + \beta_{1,i} \Delta O_{1,t-1} + \varepsilon_t, \quad i = 2, \dots, 6, \quad (14.a)$$

$$\Delta O_{1,t} = \alpha_{0,i} + \alpha_{1,i} \Delta O_{1,t-1} + \beta_{1,i} \Delta O_{i,t-1} + \gamma_t, \quad i = 2, \dots, 6. \quad (14.b)$$

The hypothesis that  $\Delta O_{1,t}$  does not Granger cause  $\Delta O_{i,t}$  is tested for all deferred contracts and the results are presented in Table VI. The decrease in nearby open interest is found to Granger cause the increase in the open interest in the first deferred maturities, except for the British Pound. Consistent with the results presented in Table V, in the case of the Canadian Dollar and Japanese Yen futures, decrease in the nearby open interest is found to Granger cause the increase in the open interest of fourth deferred contract ( $i=5$ ). For all currencies, the increase in first deferred open interest is found to Granger cause the decrease in nearby open interest suggesting that investors close their nearby position in order to take positions in the first deferred contract. However, since it is not found that the increase in the distant deferred open interest Granger cause the decrease in nearby

open interest, it is possible to conclude that the main reason to close nearby positions is not to rollover to the distant deferred contracts.

In order to confirm the reliability of regression and causality tests, the daily change in open interest values are further investigated. Table VII indicates that percentage of trading days when open interest remains unchanged increases with the maturity. As an example, in almost 60 percent of the trading days open interest in the second deferred contract ( $i=3$ ) does not change from the previous day. However, for Canadian Dollar futures this percentage is only about eight percent. This observation suggests that the modeled relationships are based on large discrete changes in the deferred open interest levels. Thus, it is necessary to confirm that the decrease in nearby open interest significantly differs during the days when the change in deferred open interest is zero and when it is not. Results presented in Tables VIII.a through VIII.c indicate that the nearby open interest decreases less when there is no change in the deferred open interest. This finding supports earlier results that the nearby positions are closed and rolled-over to the first deferred as well as to the second and third deferred contracts in the case of the Canadian Dollar and the Japanese Yen futures.

Anecdotal evidence help explain the pattern of open interest observed in the Canadian Dollar and Japanese Yen futures. In Canada the short-term interest rate market is not as liquid as that of its U.S. counterpart. Therefore, investors are known to create synthetic Canadian short-term interest rate instruments via Canadian Dollar currency futures. As a result, the demand for distant deferred currency contracts is relatively higher than, for example, British Pound and Deutsche Mark futures. The large trade deficit

between U.S. and Japan, as well as the longer duration of the trade payments can explain the relatively higher demand for the distant deferred Japanese Yen futures contracts.

These results suggest that the optimal hedging strategy is a portfolio of deferred contracts with weights on distant maturities decreasing with the variance of quantity of the commitment to be hedged. In markets where the quantity to be hedged is highly volatile due to frequent spot and anticipatory trading, the model predicts that open interest concentrates on the nearby contract. While markets with longer maturity and higher frequency of spot commitments exhibit greater open interest in distant deferred contracts.

#### *17.b Bid-Ask Spreads and Trading Volume*

An empirical question of interest pertaining to the optimal behavior of market makers is that whether the relationship between bid-ask spreads and trading volume differs across contract maturities. In the theoretical model market makers choose a bid-ask spread to maximize their daily trading profit while maintaining zero-open interest in any contract over-night. Market makers may choose not to trade a given maturity contract if they believe it won't be possible to lay off that position within the same trading day. Thus, this essay postulates that the bid-ask spreads and trading volume are jointly determined. This is also indicated in the literature (e.g. Wang, Yau, Baptiste 1997). In this essay, the relationship between the trading volume and bid-ask spread is tested for all available maturity contracts. It is shown that the relationship is stronger for the nearby contract and weaker for the deferred ones. This confirms with the theoretical model that

market makers choose to trade the nearby contract and that it is more likely for hedgers and speculators to make the market for each other for the deferred ones.

#### *VI.b.i Bid-Ask Spread Estimation*

In order to test the relationship between the bid-ask spreads and trading volume, spreads are estimated using the intra-day transaction prices from CME. This section utilizes a spread estimate based on the average price reversals. The details of the alternative bid-ask spread estimation techniques are described in Appendix AI.b. Using Deutsche Mark futures contract as an example, Figure IV displays the estimates of bid-ask spreads over time for both the nearby and the first deferred contracts. Table IX presents the descriptive statistics on the daily bid-ask spread estimates on nearby and first deferred for all currency futures contracts. For all currencies, the estimates of nearby bid-ask spreads are near one tick except for the British pound futures for which the estimated spread is around one and a half of a tick. Bid-ask spreads are much wider for the deferred contract for which the frequency of trading is much smaller. Table IX documents that, for all currencies, the bid-ask spread on the deferred contract is considerably more volatile than that on the nearby one. For Deutsche Mark futures, the mean daily bid-ask spreads for the nearby and deferred contracts are estimated to be 1.1627 and 4.3808 ticks, respectively. To estimate the Deutsche Mark spread 986,295 and 137,593 price changes are used for the nearby and deferred contracts, respectively. As suggested by the theoretical model, if speculators are making the market for hedgers in the deferred contracts, volatility of the spreads are expected to increase with the forecast error of

speculators. This point can further be investigated using exchange rate forecasting methods.

Estimates of the bid-ask spreads are used together with the daily futures data in estimating the volume-spread relationship across contracts with different maturities. As indicated by the theoretical model, it is expected that the market makers' choice of contracts to trade impacts the volume-spread relationship.

#### *VI.b.ii Determination of Bid-ask Spreads and Trading Volume*

Wang, Yau, Baptiste (1997) use the two-stage least-square (2SLS) procedure in estimating the formal relationship between the trading volume and bid-ask spreads. This essay utilizes their model as a starting point in investigating the market maker's optimal decisions in terms making the market for different maturity contracts. It is expected that the relationship between the bid-ask spreads and trading volume show diversity across contracts with different maturities.

Following Wang et al. (1997), the empirical model describing the joint determination of bid-ask spreads and trading volume is given by:

$$\ln(TV_{i,t}) = \beta_{0,i} + \beta_{1,i} \ln(BA_{i,t}) + \beta_{2,i} \ln(O_{i,t-1}) + \beta_{3,i} \ln(IV_{i,t}) + \beta_{4,i} \ln(RTB_t) + \varepsilon_{t,i} \quad (15.i)$$

$$\ln(BA_{i,t}) = \alpha_{0,i} + \alpha_{1,i} \ln(TV_{i,t}) + \alpha_{2,i} \ln(BA_{i,t-1}) + \alpha_{3,i} \ln(IV_{i,t}) + \alpha_{4,i} \ln(FP_{i,t}) + \xi_{t,i} \quad (15.ii)$$

where  $i=1,2$  indicate the nearby and deferred contracts, respectively. The extremely low volume of transactions prevents the estimation of bid-ask spreads on the distant deferred contracts, i.e.  $i>2$ . As a result, the model in equations (15.i) and (15.ii) is only estimated for the nearby and the first deferred contracts. In the model,  $TV_{i,t}$  is the daily trading volume,  $BA_{i,t}$  is the estimate of daily bid-ask spread,  $O_{i,t}$  is the level of open interest,  $IV_{i,t}$

is the intraday volatility of futures prices as described in Appendix A.I.a., and  $RTB_{ti}$  is the three month T-Bill rate.

The Hausman (1978) specification test is used to confirm that the bid-ask spreads and trading volume are jointly determined. Results of specification tests support the model developed in (15.i) and (15.ii). Another indication of the Hausman specification test is that the OLS estimates of coefficients in trading volume and bid-ask spread equations are inaccurate. Therefore, the choice of 2SLS estimation, as employed by Wang et al. (1997), is more appropriate. Instrumental variables used in 2SLS procedures are the cash price volatility and the days-to-expiration of the futures contract. The time-varying volatilities of cash prices are estimated using GARCH(1,1) as described in Appendix A.I.a.

Tables X through XIV present the estimated coefficients of the volume-spread relationship for each currency futures. As expected, the bid-ask spread and trading volume are negatively related while both increases with intraday futures price volatility. The estimated coefficients indicate that trading volume increases with the level of the open interest. Bid-ask spread estimates are also found to increase as the futures price increases. Estimation results are robust across different currency futures.

For the nearby Deutsche Mark futures, the model explains approximately the 72 percent of the variation in trading volume and the 68 percent of the variation in bid-ask spread. For the first deferred contract, while the 69 percent of the variation in volume is explained, only 22 percent of the variation in the bid-ask spread is explained. Similar results are obtained for the British Pound and Swiss Franc futures. This may suggest that in the nearby contract the strength of volume-spread relationship is attributable to market

makers' participation. However, lower R-squared of the bid-ask spread equation (15.ii) combined with higher daily bid-ask spread estimates may indicate that willingness of hedgers and/or speculators to make the market for the other hedgers at higher "spreads". In the case of Canadian Dollar and Japanese Yen futures, the model explains approximately 59 and 58 percent of the variation in the bid-ask spreads, respectively. This finding suggests that market makers' participation in the trading of deferred contract is relatively higher for Canadian Dollar and Japanese Yen futures. In the earlier part of this essay, it was found that relatively larger portion of the expiring open interest gets distributed to the first deferred contract, supporting the bid-ask spread results that the first deferred contract is relatively more liquid for Canadian Dollar and Japanese Yen futures. These findings support the assertions of the theoretical model regarding the activity in the deferred contracts.

A question of interest regarding the participation of market makers in the trading of the deferred contracts is that the optimal time, i.e. days-to-expiration or days-from-inception, for the market makers to participate in the trading of the distant deferred contracts. This optimal time is expected to be a function of the frequency of hedging and speculative trading, price volatility, and the number of contracts that already trade in the market. High intraday futures price volatility would indicate that the market makers are likely to quote higher spreads and/or reduce their quote frequency only if the frequency of trading is high enough to attract them to the deferred contracts.

Figure IV displays the estimated daily bid-ask spreads for the nearby and first deferred contracts. As it can be seen from the figure, the deferred bid-ask spread is extremely wider immediately following the expiration of the prior nearby contract and

becomes narrower as the current nearby nears its expiration. The nearby bid-ask spread is relatively steady but increases dramatically close to the expiration of the contract. Level of the estimated deferred bid-ask spread falls below that of the nearby as the nearby contract nears its expiration. This crossover is visible in Figure IV as well. Further investigation indicates that for all currency futures, except the British Pound, the crossover takes place six trading days before the expiration of all the nearby contracts expired between January 3, 1994 and December 31, 1997 (i.e. total 64 contracts). In the case of British Pound futures, crossover generally occurs six trading days before the expiration, however, within the six-day windows prior to expiration nearby bid-ask spread does not consistently lie below that of the deferred contract. The Chicago Mercantile Exchange officials indicate that on the trading floor the physical space allocated for the trading of nearby and deferred contract is switched 10 days prior to the expiration days. Thus, it appears that the participation of market makers in the trading of the deferred contracts is largely dependent on the institutional factors.

## **VII. Conclusions and Further Research**

The empirical results of the change in open interest regressions support the assertions of theoretical model. If a hedger can not establish a position in a long deferred contract, he or she chooses a portfolio of positions in the available nearby and short deferred contracts. In such a case, the results indicate that the choice is not always to use the nearby contract and rollover to the next one until the underlying maturity is reached. The optimal portfolio choice is a function of the liquidity costs that present a trade-off between the nearby and deferred contracts.

The empirical results suggest that, in the nearby contract, the strength of volume-spread relationship is attributable to market maker's participation. However, lower R-square of the bid-ask spread equation combined with the higher daily bid-ask spread estimates indicates that willingness of hedgers and/or speculators to make the market for other hedgers at higher "spreads".

Further empirical research can be directed towards predicting the probability of observing the first trade in the distant deferred contract on a given day. It is expected that the time-to-expiration, more specifically, number of days to expiration as well as the number of days since the first trading day can be significant factors in this prediction. Additionally simulation analysis can be used to determine the transaction-cost minimizing portfolio of contracts with different maturities for a given maturity of the underlying obligation. Bid-ask spreads, liquidity, and market maker participation in contracts with different times to expiration, the expected frequency of transactions and price volatility are expected to be key variables in determining the optimal mix of contracts.

## Appendix

### A.I. Estimation Techniques

The following section describes the estimation techniques used in the empirical part of the essay.

#### *A.I.a Estimation of Price Volatility*

Volatility of spot price and basis is central to the models depicting the optimization problem of both hedgers and speculators. There are several measures of volatility that can be used: historical volatility, implied volatility, and other estimates of volatility using time series techniques. As noted by Najand and Yung (1991), GARCH(1,1) is found to be a proper model of many financial time series.<sup>1</sup> GARCH provides a superior volatility estimate compared to those of historical and implied volatility approaches. Therefore, this essay uses GARCH(1,1) to provide an estimate of the conditional volatility of underlying spot price and the basis. The following section describes briefly the generalized autoregressive conditional heteroskedasticity model.

GARCH(1,1) specifies that the variance depends upon only the past values of the dependent variable and that this relation has the three simple terms given in (A.1). The residuals are defined by a conventional mean equation such as (A.2).

$$\sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (\text{A.1})$$

$$y_t = x_t \pi + \varepsilon_t \quad (\text{A.2})$$

The variance today depends upon three factors: a constant, yesterday's forecast variance (the GARCH term), and yesterday's news about volatility which is taken to be the squared residual from yesterday (the ARCH term). The (1,1) in GARCH(1,1) refers to

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<sup>1</sup> Also see Bollerslev (1987), Lamoureux and Lastrapes (1990), and Baillie and Bollerslev (1989)

one GARCH term and one ARCH term. This specification makes sense in financial settings where an agent or trader infers today's variance by forming a weighted average of a long term average or constant variance, the forecast from yesterday, and what was learned yesterday. If the asset return was large in either the upward or the downward direction, then the trader will increase the estimate of the variance for the next day. This specification of the variance equation incorporates the familiar phenomenon of volatility clustering which is evident in financial returns data. Large returns are more likely to be followed by large returns of either sign than by small returns. If equation (A.1) is lagged by one period and substituted for the lagged variance on the right hand side, then an expression with two lagged squared returns and a two period lagged variance is obtained. By successively substituting for the lagged conditional variance, an illuminating expression is found:

$$\sigma_t^2 = \frac{\omega}{(1-\beta)} + \alpha \sum_{i=1}^{\infty} \beta^{i-1} \varepsilon_{t-i}^2, \quad (\text{A.3})$$

An ordinary sample variance would give each of the past squares an equal weight rather than declining weights. Thus the GARCH variance is like a sample variance but it emphasizes the most recent observations. Since  $\sigma^2$  is the forecast variance one day ahead based on past information, it is called the conditional variance. The GARCH model is estimated by maximum likelihood, assuming that the errors are conditionally normally distributed. Because the variance appears in a non-linear way in the likelihood function, the likelihood function must be estimated using iterative algorithms. This essay uses the Marquardt algorithm.

In this essay, the intraday futures price volatility is estimated for each deferred month contract using two different approaches. First one is a simple measure utilized by Edwards (1988). It is derived from intraday highest ( $H_t$ ) and lowest ( $L_t$ ) futures prices:

$$IV_{n,t}^r = \frac{[\ln(H_{n,t}) - \ln(L_{n,t})]^2}{4 \ln 2}, \quad (\text{A.4})$$

where subscript  $t$  denotes each trading day and  $n=1,2,3,4,5$ , and 6 with 1 indicating the first closest expiration contract among all existing different expiration month contracts on a given underlying currency. Martell and Wolf (1987) used a similar measure,

$\ln(H_t - L_t)$ , utilizing daily high and low futures prices. Edwards (1988) indicated that the estimator given in equation (A.4), under certain restrictive assumptions-that the log-prices follow Brownian motion with zero drift-, when used in addition to closing futures prices is a substantially more efficient estimator than an estimator based on close-to-close futures prices (Edwards 1988, pp. 427-428).

#### *A.I.b Estimation of Bid-Ask Spreads*

Estimation of bid-ask spreads in futures markets is a rather difficult task since exchanges do not keep a record of sequence of transactions with quotes, prices and quantities. Prior literature contains three estimation techniques utilizing the time and sales data. The intraday data set contains the time and price of transaction if the price is different from the previous price. In the cases bid (ask) is greater (less) than the previous price then bid and ask quotes are identified. If the transaction takes place at the previous price that transaction can not be identified in the data.

Roll (1984) proved that under certain assumptions the effective bid-ask spread can be defined as:

$$s_t = 2\sqrt{-\text{cov}(\Delta P_t^0, \Delta P_{t-1}^0)}, \quad (\text{A.5})$$

where  $\Delta P_t^0$  and  $\Delta P_{t-1}^0$  are defined to be the observed stock price changes at times  $t$  and  $t-1$ , respectively. One of the restrictive assumptions of Roll's model is that next observed price can equally likely go up by  $s$ , down by  $s$ , or remain the same. Since time and sales data does not differentiate the cases when the trade occurs at the previously recorded price, Followill and Helm (1990) proposed a revised version of Roll's serial covariance estimator:

$$s_t' = \sqrt{-\text{cov}(\Delta P_t^0, \Delta P_{t-1}^0)}. \quad (\text{A.6})$$

However, as Followill and Rodriguez (1991) showed, estimates of the serial covariance obtained using the time and sales data of the futures markets often are positive and bid-ask spread can not be inferred from either equation (A.5) or (A.6).

Thompson and Waller (1988) propose an estimate of the bid-ask spread based on the mean absolute price changes, i.e.

$$s_{it} \equiv |\overline{\Delta P^0}| = \frac{1}{T} \sum_{t=1}^T |\Delta P_t^0|. \quad (\text{A.7})$$

Wang et al. (1990) and Wang et al. (1997) also utilize the mean absolute price change estimate of the realized bid-ask spread. In the procedure to compute the spread estimate, Wang et al. (1997) exclude the subset of the price changes that exhibit price continuity i.e., a positive change followed by another positive change (Wang, Yau, and Baptiste 1997, p. 761). In this respect equation (A.7) is estimated only using price changes that are price reversals. This procedure is also employed by the CFTC in computing the estimates of the realized bid-ask spreads in futures markets.

Smith and Whaley (1994) proposed a method of moments estimate of the effective bid-ask spread. They indicate that the crucial assumption that underlie equation (A.7) is that expected true futures price change and the variance of the true price change are both zero, which in reality is unrealistic as far as the variance is concerned (Whaley and Smith 1994, p. 441). Smith and Whaley (1994) assume that consecutive prices changes include two components, i.e.,  $\varepsilon_t$ , true price change and  $s_{it}$ , bid-ask spread, and the true price change is distributed normally with mean zero and variance  $\sigma^2$ . They show that the first two moments of the distribution of absolute price changes are given by:

$$E(|\Delta P^0|) = \sqrt{\frac{2}{\pi}} \sigma e^{-\frac{s_{it}^2}{2\sigma^2}} - s_{it} \left[ 1 - 2N\left(\frac{s_{it}}{\sigma}\right) \right], \text{ and} \quad (\text{A.8})$$

$$E(|\Delta P^0|^2) = \sigma^2 + s_{it}^2, \quad (\text{A.9})$$

where  $N(\cdot)$  is the cumulative unit normal distribution function.

In this essay, the spread estimate,  $s_t$ , based on the average price reversals is used to determine the daily mean bid-ask spread estimates on contracts with different maturities.

**Table I**  
**Distinct Maturities Traded**  
**CME Currency Futures Contracts**  
 January 3, 1994 through March 16, 1998  
 (1,062 Trading Days)

<u>Currency</u>	<u>Distinct Maturities Traded*</u>					
	<u>1 or more</u>	<u>2 or more</u>	<u>3 or more</u>	<u>4 or more</u>	<u>5 or more</u>	<u>6</u>
British Pound	1,062	1,062	1,062	530	0	0
Canadian Dollar	1,062	1,062	1,062	1062	1,062	526
Deutsche Mark	1,062	1,062	1,062	924	227	0
Japanese Yen	1,062	1,062	1,062	931	472	62
Swiss Franc	1,062	1,062	1,062	807	47	0

\* Trading days during which number of contracts, with different expiration months, have nonzero open interest.

**Table II**  
**Distinct Maturities Traded**  
**Periods of Expiring Open Interest\***  
 January 3, 1994 through March 16, 1998  
 CME Currency Futures Contracts

<u>Currency</u>	<u>Distinct Maturities Traded**</u>					
	<u>1 or more</u>	<u>2 or more</u>	<u>3 or more</u>	<u>4 or more</u>	<u>5 or more</u>	<u>6</u>
British Pound	512	512	512	305	0	0
Canadian Dollar	594	594	594	594	594	398
Deutsche Mark	451	451	451	441	113	0
Japanese Yen	526	526	526	499	301	34
Swiss Franc	469	469	469	437	40	0

\* Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity

\*\* Trading days during which number of contracts, with different expiration months, have nonzero open interest.

**Table III**  
**Days-to-expiration at the**  
**Start of Periods of Expiring Open Interest\***  
 January 3, 1994 through March 16, 1998

	<u>Number of</u> <u>Expiring Contracts</u>	<u>Days-to-expiration**</u>		
		<u>Average</u>	<u>Min</u>	<u>Max</u>
<b>British Pound</b>				
Nearby	17	29.1	10	53
First deferred		89.3	73	121
<b>Canadian Dollar</b>				
Nearby	17	34.1	12	63
First deferred		94.2	64	121
<b>Deutsche Mark</b>				
Nearby	17	25.5	11	41
First deferred		85.7	79	104
<b>Japanese Yen</b>				
Nearby	17	29.9	9	47
First deferred		90.1	73	110
<b>Swiss Franc</b>				
Nearby	17	26.6	10	57
First deferred		86.8	78	121

\* Number of trading days from the day of highest open interest to the expiration day.

\*\* For the first deferred, min and max correspond to the days-to-expiration of those of the nearby.

**Table IV**  
**CME Currency Futures Contracts**  
**Change in Open Interest**  
**Liquidation versus Rollover**  
**Periods of Expiring Open Interest\***  
**January 3, 1994 through March 16, 1998**

$$\sum_{i=2}^6 \Delta O_{i,t} = \alpha_0 + \alpha_1 \Delta O_{1,t} + \varepsilon_t$$

where  $\Delta O_{i,t} = O_{i,t} - O_{i,t-1}$ , and  $O_{i,t}$  is the open interest in  $i$ th contract at day  $t$

	$\alpha_0$	$\alpha_1$	N	R <sup>2</sup>
<b>British Pound</b>	483.0 (9.99)*	-0.2821 (-12.79)*, (-32.54)*	512	0.135
<b>Canadian Dollar</b>	489.6 (10.95)*	-0.3591 (-16.41)*, (-29.28)*	594	0.216
<b>Deutsche Mark</b>	823.9 (11.87)*	-0.3127 (-16.56)*, (-36.41)*	451	0.208
<b>Japanese Yen</b>	681.6 (10.22)*	-0.5456 (-26.03)*, (-21.68)*	526	0.394
<b>Swiss Franc</b>	436.2 (9.47)*	-0.4693 (-19.04)*, (-21.53)*	469	0.258

\* Indicates statistical significance at the 0.05 level.

+ Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity

For  $\alpha_1$ , first number in parenthesis is the t-statistics for testing the null hypothesis that  $\alpha_1=0$ , and second number in parenthesis is the t-statistics for testing the null hypothesis that  $\alpha_1=1$

$\alpha_1=1$  indicates that expiring open interest is rolled-over to other deferred contract.

Table V

CME Currency Futures Contracts  
 Distribution of Expiring Open Interest among Deferred Contracts  
 Periods of Expiring Open Interest\*  
 January 3, 1994 through March 16, 1998

$$\Delta O_{i,t} = \alpha_{0,i} + \alpha_{1,i} \Delta O_{i,t-1} + \varepsilon_t, \quad i = 2, \dots, 6$$

where  $\Delta O_{i,t} = O_{i,t} - O_{i,t-1}$ , and  $O_{i,t}$  is the open interest in  $i$ th contract at day  $t$

<u>British Pound</u>										
	$\alpha_{0,2}$	$\alpha_{1,2}$	$\alpha_{0,3}$	$\alpha_{1,3}$	$\alpha_{0,4}$	$\alpha_{1,4}$	$\alpha_{0,5}$	$\alpha_{1,5}$	$\alpha_{0,6}$	$\alpha_{1,6}$
Coefficient	476.0	-0.2807	5.905	-0.0013	2.163	-0.0002				
t-statistic	(9.86)*	(-12.73)*	(3.16)*	(-2.47)*	(1.51)	(-0.31)				
N		512		512		305				
R <sup>2</sup>		0.134		0.121		0.018				
<u>Canadian Dollar</u>										
	$\alpha_{0,2}$	$\alpha_{1,2}$	$\alpha_{0,3}$	$\alpha_{1,3}$	$\alpha_{0,4}$	$\alpha_{1,4}$	$\alpha_{0,5}$	$\alpha_{1,5}$	$\alpha_{0,6}$	$\alpha_{1,6}$
Coefficient	446.9	-0.3601	26.109	-0.0009	11.780	-0.0007	4.061	-0.0008	1.446	0.0000
t-statistic	(10.30)*	(-16.95)*	(3.33)*	(-2.24)*	(3.46)*	(-2.17)*	(4.33)*	(-1.98)*	(5.91)*	(-0.03)
N		594		594		594		594		398
R <sup>2</sup>		0.205		0.156		0.131		0.073		0.017
<u>Deutsche Mark</u>										
	$\alpha_{0,2}$	$\alpha_{1,2}$	$\alpha_{0,3}$	$\alpha_{1,3}$	$\alpha_{0,4}$	$\alpha_{1,4}$	$\alpha_{0,5}$	$\alpha_{1,5}$	$\alpha_{0,6}$	$\alpha_{1,6}$
Coefficient	788.9	-0.3097	28.908	-0.0011	6.503	-0.0019	0.024	-0.0001		
t-statistic	(11.41)*	(-16.48)*	(6.58)*	(-2.93)*	(2.13)*	(-2.36)*	(0.63)	(-1.55)		
N		451		451		441		113		
R <sup>2</sup>		0.207		0.182		0.159		0.011		
<u>Japanese Yen</u>										
	$\alpha_{0,2}$	$\alpha_{1,2}$	$\alpha_{0,3}$	$\alpha_{1,3}$	$\alpha_{0,4}$	$\alpha_{1,4}$	$\alpha_{0,5}$	$\alpha_{1,5}$	$\alpha_{0,6}$	$\alpha_{1,6}$
Coefficient	653.6	-0.5388	22.987	-0.0045	3.394	-0.0020	3.741	-0.0008	1.496	0.0000
t-statistic	(9.89)*	(-25.94)*	(7.22)*	(-4.55)*	(2.29)*	(-4.22)*	(1.40)	(-1.94)**	(3.98)*	(0.09)
N		526		526		499		301		34
R <sup>2</sup>		0.392		0.294		0.192		0.113		0.013
<u>Swiss Franc</u>										
	$\alpha_{0,2}$	$\alpha_{1,2}$	$\alpha_{0,3}$	$\alpha_{1,3}$	$\alpha_{0,4}$	$\alpha_{1,4}$	$\alpha_{0,5}$	$\alpha_{1,5}$	$\alpha_{0,6}$	$\alpha_{1,6}$
Coefficient	421.8	-0.4665	11.596	-0.0022	3.609	-0.0005	0.047	0.0000		
t-statistic	(9.22)*	(-19.06)*	(6.35)*	(-2.29)*	(2.57)*	(-2.42)*	(0.68)	(-0.05)		
N		469		469		437		40		
R <sup>2</sup>		0.258		0.15		0.122		0.001		

\*, \*\* Indicates statistical significance at 0.05 and 0.1 levels.

+ Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity

**Table VI**  
**Granger Causality Tests**  
**Distribution of Expiring Open Interest among Deferred Contracts**  
**Periods of Expiring Open Interest\***  
 January 3, 1994 through March 16, 1998

	<u>British Pound</u>	<u>Canadian Dollar</u>	<u>Deutsche Mark</u>	<u>Japanese Yen</u>	<u>Swiss Franc</u>
<u>Null Hypothesis</u>	<u>F-statistics</u>	<u>F-statistics</u>	<u>F-statistics</u>	<u>F-statistics</u>	<u>F-statistics</u>
$\Delta O_1$ does not Granger cause $\Delta O_2$	3.755**	9.803*	2.851*	3.327*	3.406**
$\Delta O_2$ does not Granger cause $\Delta O_1$	35.059*	96.115*	27.849*	62.099*	41.546*
$\Delta O_1$ does not Granger cause $\Delta O_3$	4.907*	4.037*	12.029*	3.871*	4.124*
$\Delta O_3$ does not Granger cause $\Delta O_1$	0.003	3.373**	3.115	1.757	0.728
$\Delta O_1$ does not Granger cause $\Delta O_4$	0.001	2.445**	4.159*	9.105*	5.359*
$\Delta O_4$ does not Granger cause $\Delta O_1$	0.044	0.043	0.343	1.321	0.202
$\Delta O_1$ does not Granger cause $\Delta O_5$	(N/A)	6.213*	1.404	4.535*	0.828
$\Delta O_5$ does not Granger cause $\Delta O_1$		0.007	0.209	0.055	0.042
$\Delta O_1$ does not Granger cause $\Delta O_6$	(N/A)	3.209**	(N/A)	2.991**	(N/A)
$\Delta O_6$ does not Granger cause $\Delta O_1$		0.515		1.056	

+ Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity.

F-statistics are the Wald statistics for the joint hypothesis that the coefficients of lagged values of both dependent and independent variables are zero in Granger causality tests.

**Table VII**

**Percent of trading days when open interest does not change  
during the Periods of Expiring Open Interest\***

January 3, 1994 through March 16, 1998

where  $\Delta O_{i,t} = O_{i,t} - O_{i,t-1}$ , and  $O_{i,t}$  is the open interest in  $i$ th contract at day  $t$

<b>Currency</b>	$\Delta O_1$	$\Delta O_2$	$\Delta O_3$	$\Delta O_4$	$\Delta O_5$	$\Delta O_6$
British Pound	0.00%	2.54%	59.38%	92.26%	N/A	N/A
Canadian Dollar	0.00%	0.00%	8.08%	31.65%	51.52%	73.87%
Deutsche Mark	0.00%	0.44%	17.96%	73.70%	84.96%	N/A
Japanese Yen	0.00%	0.00%	17.49%	61.72%	69.10%	47.06%
Swiss Franc	0.00%	0.85%	27.51%	77.80%	97.50%	N/A

\* Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity.

Table VIII.a

Average Change in Open Interest Nearby versus Deferred Contracts Periods of Expiring Open Interest* January 3, 1994 through March 16, 1998						
Panel A British Pound				Panel B Canadian Dollar		
	<b>Obs</b>	$\Delta O_1$	$\Delta O_2$		<b>Obs</b>	$\Delta O_1$ $\Delta O_3$
$\Delta O_2 \neq 0$	13	-321.2	0.0	$\Delta O_3 \neq 0$	48	-517.3    0.0
$\Delta O_2 = 0$	499	-901.5	1037.6	$\Delta O_3 = 0$	546	-1087.6    20.1
		(0.95)	(10.11)*			(1.95)    (3.29)*
		$\Delta O_1$	$\Delta O_3$			$\Delta O_1$ $\Delta O_4$
$\Delta O_3 \neq 0$	304	-617.6	0.0	$\Delta O_4 \neq 0$	188	-737.3    0.0
$\Delta O_3 = 0$	208	-1280.1	21.3	$\Delta O_4 = 0$	406	-1182.4    15.6
		(3.43)	(2.72)*			(2.60)*    (4.10)*
		$\Delta O_1$	$\Delta O_4$			$\Delta O_1$ $\Delta O_5$
$\Delta O_4 \neq 0$	274	-1129.7	0.0	$\Delta O_5 \neq 0$	306	-1054.0    0.0
$\Delta O_4 = 0$	23	-1937.7	48.0	$\Delta O_5 = 0$	288	-1028.2    11.4
		(1.89)	(1.58)			(0.16)    (3.57)*
		$\Delta O_1$	$\Delta O_5$			$\Delta O_1$ $\Delta O_6$
$\Delta O_5 \neq 0$	N/A	(N/A)	(N/A)	$\Delta O_6 \neq 0$	294	-1241.0    0.0
$\Delta O_5 = 0$	N/A	(N/A)	(N/A)	$\Delta O_6 = 0$	104	-1449.9    5.9
		(N/A)	(N/A)			(0.88)    (6.99)*

\* Indicates statistical significance at 0.05 level.

Numbers in parenthesis are the t-statistics for testing the equality of the average change in open interest for the days when change in open interest in deferred contract is zero and when it is not.

+ Period of expiring open interest denotes trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity.

Table VIII.b

Average Change in Open Interest Nearby versus Deferred Contracts Periods of Expiring Open Interest*			
January 3, 1994 through March 16, 1998			
Panel C Deutsche Mark		Panel D Japanese Yen	
	Obs	$\Delta O_1$	$\Delta O_2$
$\Delta O_2 \neq 0$	2	-1944.5	0.0
$\Delta O_2 = 0$	449	-2043.4	2033.0
		(0.04)	(12.32)*
	Obs	$\Delta O_1$	$\Delta O_3$
$\Delta O_3 \neq 0$	81	-573.6	0.0
$\Delta O_3 = 0$	370	-2364.7	50.2
		(3.73)*	(5.65)*
	Obs	$\Delta O_1$	$\Delta O_4$
$\Delta O_4 \neq 0$	325	-1726.5	0.0
$\Delta O_4 = 0$	116	-3048.2	44.7
		(3.08)*	(1.98)*
	Obs	$\Delta O_1$	$\Delta O_5$
$\Delta O_5 \neq 0$	96	-2997.5	0.0
$\Delta O_5 = 0$	17	-4831.4	3.2
		(1.58)	(0.72)
	Obs	$\Delta O_1$	$\Delta O_3$
$\Delta O_3 \neq 0$	92	-1101.5	0.0
$\Delta O_3 = 0$	434	-1803.8	47.5
		(1.81)	(7.26)*
	Obs	$\Delta O_1$	$\Delta O_4$
$\Delta O_4 \neq 0$	308	-1354.6	0.0
$\Delta O_4 = 0$	191	-2435.7	18.5
		(3.54)*	(2.73)*
	Obs	$\Delta O_1$	$\Delta O_5$
$\Delta O_5 \neq 0$	208	-1822.0	0.0
$\Delta O_5 = 0$	93	-2289.7	19.7
		(1.11)	(1.60)
	Obs	$\Delta O_1$	$\Delta O_6$
$\Delta O_6 \neq 0$	16	-2971.4	0.0
$\Delta O_6 = 0$	18	-2189.9	3.3
		(0.63)	(6.01)*

\* Indicates statistical significance at 0.05 level.

Numbers in parenthesis are the t-statistics for testing the equality of the average change in open interest for the days when change in open interest in deferred contract is zero and when it is not.

+ Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity.

**Table VIII.c**  
**Average Change in Open Interest**  
**Nearby versus Deferred Contracts**  
**Periods of Expiring Open Interest\***  
 January 3, 1994 through March 16, 1998

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**Panel E**  
**Swiss Franc**

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	<b>Obs</b>	$\Delta O_1$	$\Delta O_2$
$\Delta O_2 \neq 0$	4	-221.3	0.0
$\Delta O_2 = 0$	465	-1038.6	1160.7
		(1.26)	(10.42)*
		$\Delta O_1$	$\Delta O_3$
$\Delta O_3 \neq 0$	129	-458.6	0.0
$\Delta O_3 = 0$	340	-1243.9	23.3
		(3.85)*	(5.77)*
		$\Delta O_1$	$\Delta O_4$
$\Delta O_4 \neq 0$	340	-923.0	0.0
$\Delta O_4 = 0$	97	-1496.8	24.9
		(2.59)*	(1.39)
		$\Delta O_1$	$\Delta O_5$
$\Delta O_5 \neq 0$	39	-2538.9	0.0
$\Delta O_5 = 0$	1	-2681.0	2.0
		(0.05)	(N/A)

\* Indicates statistical significance at 0.05 level.

Numbers in parenthesis are the t-statistics for testing the equality of the average change in open interest for the days when change in open interest in deferred contract is zero and when it is not.

+ Periods of expiring open interest denotes the trading days from the day of highest open interest to the expiration day of the nearby contract, where the nearby is the contract with the closest maturity.

**Table IX**

**CME Currency Futures**  
**Descriptive Statistics on Daily Bid-Ask Spread Estimates\***  
 January 3, 1994 through December 31, 1997

	<u>British Pound</u>		<u>Canadian Dollar</u>		<u>Deutsche Mark</u>		<u>Japanese Yen</u>		<u>Swiss Franc</u>	
	<b>BA<sub>1</sub></b>	<b>BA<sub>2</sub></b>	<b>BA<sub>1</sub></b>	<b>BA<sub>2</sub></b>	<b>BA<sub>1</sub></b>	<b>BA<sub>2</sub></b>	<b>BA<sub>1</sub></b>	<b>BA<sub>2</sub></b>	<b>BA<sub>1</sub></b>	<b>BA<sub>2</sub></b>
Mean	1.5313	4.2827	1.2925	2.7337	1.1627	4.3808	1.4191	5.0665	1.4712	6.2843
Median	1.3000	3.1500	1.2171	2.4000	1.0477	3.7057	1.2392	4.5812	1.2543	5.8002
Std. Dev.	1.2060	3.6776	0.3809	1.4073	0.3987	2.9363	0.5735	2.8082	0.7120	3.4134
Minimum	1.0000	1.2000	1.0155	1.0638	1.0098	1.0724	1.0169	1.0760	1.0687	1.0943
Maximum	4.7500	9.4000	8.7999	11.5001	6.4673	12.8750	6.9160	15.4450	9.3878	16.8001

BA<sub>1</sub>, BA<sub>2</sub> are the daily bid-ask spread estimates for nearby and first deferred contract, respectively.

\* Bid-ask spread estimates are in multiples of minimum tick. The minimum tick is 0.0001 for Canadian Dollar, Deutsche Mark, and Swiss Franc futures. The minimum tick is 0.0002 and 0.000001 for British Pound and Japanese Yen futures, respectively.

**Table X**  
**CME British Pound Futures**  
**Relationship between Bid-Ask Spreads and Trading Volume**  
**Distinct Maturities Traded**

January 3, 1994 through December 31, 1997

$$\ln(TV_{i,t}) = \beta_{0,i} + \beta_{1,i} \ln(BA_{i,t}) + \beta_{2,i} \ln(O_{i,t-1}) + \beta_{3,i} \ln(IV_{i,t}) + \beta_{4,i} \ln(RTB_t) + \varepsilon_{t,i}$$

$$\ln(BA_{i,t}) = \alpha_{0,i} + \alpha_{1,i} \ln(TV_{i,t}) + \alpha_{2,i} \ln(BA_{i,t-1}) + \alpha_{3,i} \ln(IV_{i,t}) + \alpha_{4,i} \ln(FP_{i,t}) + \zeta_{t,i}$$

**Nearby Futures Contract ( i=1 )**

**Trading Volume Equation**

	$\ln(TV_{1,t})$	constant	$\ln(BA_{1,t})$	$\ln(O_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(RTB_t)$
Coefficient		6.656	-0.703	0.392	0.988	-0.758
t-stat.		(10.68)*	(-13.44)*	(7.06)*	(20.49)*	(-8.03)*
R-sq.		0.6326				

**Bid-Ask Spread Equation**

	$\ln(BA_{1,t})$	constant	$\ln(TV_{1,t})$	$\ln(BA_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(FP_{1,t})$
Coefficient		1.305	-0.097	0.643	0.233	0.241
t-stat.		(7.53)*	(-7.41)*	(27.71)*	(9.75)*	(12.04)*
R-sq.		0.5843				

**First Deferred Contract ( i=2 )**

**Trading Volume Equation**

	$\ln(TV_{2,t})$	constant	$\ln(BA_{2,t})$	$\ln(O_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(RTB_t)$
Coefficient		3.091	-0.222	1.147	0.146	-0.134
t-stat.		(5.05)*	(-2.85)*	(33.74)*	(8.15)*	(-4.39)*
R-sq.		0.6059				

**Bid-Ask Spread Equation**

	$\ln(BA_{2,t})$	constant	$\ln(TV_{2,t})$	$\ln(BA_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(FP_{2,t})$
Coefficient		2.154	-0.075	0.103	0.682	0.493
t-stat.		(7.48)*	(-8.53)*	(3.44)*	(9.31)*	(3.06)*
R-sq.		0.1383				

\* Indicates statistical significance at 0.05 level.

**Table XI**  
**CME Canadian Dollar Futures**  
**Relationship between Bid-Ask Spreads and Trading Volume**  
**Distinct Maturities Traded**

January 3, 1994 through December 31, 1997

$$\ln(TV_{i,t}) = \beta_{0,i} + \beta_{1,i} \ln(BA_{i,t}) + \beta_{2,i} \ln(O_{i,t-1}) + \beta_{3,i} \ln(IV_{i,t}) + \beta_{4,i} \ln(RTB_t) + \varepsilon_{t,i}$$

$$\ln(BA_{i,t}) = \alpha_{0,i} + \alpha_{1,i} \ln(TV_{i,t}) + \alpha_{2,i} \ln(BA_{i,t-1}) + \alpha_{3,i} \ln(IV_{i,t}) + \alpha_{4,i} \ln(FP_{i,t}) + \xi_{t,i}$$

**Nearby Futures Contract ( i=1 )**

**Trading Volume Equation**

$\ln(TV_{1,t})$	constant	$\ln(BA_{1,t})$	$\ln(O_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(RTB_t)$
Coefficient	4.951	-0.809	0.364	0.119	-0.076
t-stat.	(8.42)*	(-6.71)*	(6.75)*	(11.33)*	(-3.63)*
R-sq.	0.7326				

**Bid-Ask Spread Equation**

$\ln(BA_{1,t})$	constant	$\ln(TV_{1,t})$	$\ln(BA_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(FP_{1,t})$
Coefficient	0.421	-0.054	0.509	0.125	0.480
t-stat.	(4.04)*	(-7.36)*	(19.31)*	(4.68)*	(2.79)*
R-sq.	0.6655				

**First Deferred Contract ( i=2 )**

**Trading Volume Equation**

$\ln(TV_{2,t})$	constant	$\ln(BA_{2,t})$	$\ln(O_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(RTB_t)$
Coefficient	0.775	-1.745	0.864	0.543	-0.665
t-stat.	(2.03)*	(-20.42)*	(20.73)*	(13.19)*	(-3.53)*
R-sq.	0.7069				

**Bid-Ask Spread Equation**

$\ln(BA_{2,t})$	constant	$\ln(TV_{2,t})$	$\ln(BA_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(FP_{2,t})$
Coefficient	1.652	-0.153	0.243	0.135	0.582
t-stat.	(8.98)*	(-21.66)*	(9.04)*	(10.48)*	(3.75)*
R-sq.	0.5865				

\* Indicates statistical significance at 0.05 level.

**Table XII**  
**CME Deutsche Mark Futures**  
**Relationship between Bid-Ask Spreads and Trading Volume**  
**Distinct Maturities Traded**

January 3, 1994 through December 31, 1997

$$\ln(TV_{i,t}) = \beta_{0,i} + \beta_{1,i} \ln(BA_{i,t}) + \beta_{2,i} \ln(O_{i,t-1}) + \beta_{3,i} \ln(IV_{i,t}) + \beta_{4,i} \ln(RTB_t) + \varepsilon_{t,i}$$

$$\ln(BA_{i,t}) = \alpha_{0,i} + \alpha_{1,i} \ln(TV_{i,t}) + \alpha_{2,i} \ln(BA_{i,t-1}) + \alpha_{3,i} \ln(IV_{i,t}) + \alpha_{4,i} \ln(FP_{i,t}) + \xi_{t,i}$$

**Nearby Futures Contract ( i=1 )**

**Trading Volume Equation**

	$\ln(TV_{1,t})$	constant	$\ln(BA_{1,t})$	$\ln(O_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(RTB_t)$
Coefficient		5.010	-1.093	0.538	0.530	-0.623
t-stat.		(7.06)*	(-15.44)*	(9.97)*	(20.79)*	(-6.31)*
R-sq.		0.7242				

**Bid-Ask Spread Equation**

	$\ln(BA_{1,t})$	constant	$\ln(TV_{1,t})$	$\ln(BA_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(FP_{1,t})$
Coefficient		0.663	-0.065	0.667	0.107	0.015
t-stat.		(8.30)*	(-8.35)*	(31.69)*	(13.67)*	(3.09)*
R-sq.		0.6820				

**First Deferred Contract ( i=2 )**

**Trading Volume Equation**

	$\ln(TV_{2,t})$	constant	$\ln(BA_{2,t})$	$\ln(O_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(RTB_t)$
Coefficient		0.710	-1.317	0.978	0.103	-0.097
t-stat.		(2.47)*	(-16.72)*	(18.49)*	(12.54)*	(-4.29)*
R-sq.		0.6914				

**Bid-Ask Spread Equation**

	$\ln(BA_{2,t})$	constant	$\ln(TV_{2,t})$	$\ln(BA_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(FP_{2,t})$
Coefficient		2.125	-0.169	0.315	0.232	0.640
t-stat.		(19.34)*	(-20.63)*	(12.05)*	(7.98)*	(4.07)*
R-sq.		0.2187				

\* Indicates statistical significance at 0.05 level.

**Table XIII**  
**CME Japanese Yen Futures**  
**Relationship between Bid-Ask Spreads and Trading Volume**  
**Distinct Maturities Traded**

January 3, 1994 through December 31, 1997

$$\ln(TV_{i,t}) = \beta_{0,i} + \beta_{1,i} \ln(BA_{i,t}) + \beta_{2,i} \ln(O_{i,t-1}) + \beta_{3,i} \ln(IV_{i,t}) + \beta_{4,i} \ln(RTB_t) + \varepsilon_{t,i}$$

$$\ln(BA_{i,t}) = \alpha_{0,i} + \alpha_{1,i} \ln(TV_{i,t}) + \alpha_{2,i} \ln(BA_{i,t-1}) + \alpha_{3,i} \ln(IV_{i,t}) + \alpha_{4,i} \ln(FP_{i,t}) + \xi_{t,i}$$

**Nearby Futures Contract ( i=1 )**

**Trading Volume Equation**

$\ln(TV_{1,t})$	constant	$\ln(BA_{1,t})$	$\ln(O_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(RTB_t)$
Coefficient	6.011	-0.464	0.417	0.323	-0.508
t-stat.	(9.08)*	(-6.82)*	(7.12)*	(15.62)*	(-5.65)*
R-sq.	0.7267				

**Bid-Ask Spread Equation**

$\ln(BA_{1,t})$	constant	$\ln(TV_{1,t})$	$\ln(BA_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(FP_{1,t})$
Coefficient	0.500	-0.045	0.664	0.099	0.073
t-stat.	(4.17)*	(-3.71)*	(28.55)*	(12.57)*	(2.13)*
R-sq.	0.6164				

**First Deferred Contract ( i=2 )**

**Trading Volume Equation**

$\ln(TV_{2,t})$	constant	$\ln(BA_{2,t})$	$\ln(O_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(RTB_t)$
Coefficient	0.329	-1.117	0.899	0.583	-0.124
t-stat.	(5.31)*	(-14.09)*	(19.72)*	(9.79)*	(-5.67)*
R-sq.	0.6626				

**Bid-Ask Spread Equation**

$\ln(BA_{2,t})$	constant	$\ln(TV_{2,t})$	$\ln(BA_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(FP_{2,t})$
Coefficient	2.085	-0.174	0.309	0.176	0.803
t-stat.	(22.57)*	(-18.55)*	(10.91)*	(8.07)*	(5.96)*
R-sq.	0.5765				

\* Indicates statistical significance at 0.05 level.

**Table XIV**  
**CME Swiss Franc Futures**  
**Relationship between Bid-Ask Spreads and Trading Volume**  
**Distinct Maturities Traded**

January 3, 1994 through December 31, 1997

$$\ln(TV_{i,t}) = \beta_{0,i} + \beta_{1,i} \ln(BA_{i,t}) + \beta_{2,i} \ln(O_{i,t-1}) + \beta_{3,i} \ln(IV_{i,t}) + \beta_{4,i} \ln(RTB_t) + \varepsilon_{t,i}$$

$$\ln(BA_{i,t}) = \alpha_{0,i} + \alpha_{1,i} \ln(TV_{i,t}) + \alpha_{2,i} \ln(BA_{i,t-1}) + \alpha_{3,i} \ln(IV_{i,t}) + \alpha_{4,i} \ln(FP_{i,t}) + \xi_{t,i}$$

**Nearby Futures Contract ( i=1 )**

**Trading Volume Equation**

	$\ln(TV_{1,t})$	constant	$\ln(BA_{1,t})$	$\ln(O_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(RTB_t)$
Coefficient		7.363	-0.979	0.303	0.395	-0.555
t-stat.		(11.60)*	(-17.39)*	(5.37)*	(20.32)*	(-6.67)*
R-sq.		0.6820				

**Bid-Ask Spread Equation**

	$\ln(BA_{1,t})$	constant	$\ln(TV_{1,t})$	$\ln(BA_{1,t-1})$	$\ln(IV_{1,t})$	$\ln(FP_{1,t})$
Coefficient		1.135	-0.111	0.646	0.108	0.058
t-stat.		(10.02)*	(-9.65)*	(29.11)*	(13.16)*	(3.01)*
R-sq.		0.6850				

**First Deferred Contract ( i=2 )**

**Trading Volume Equation**

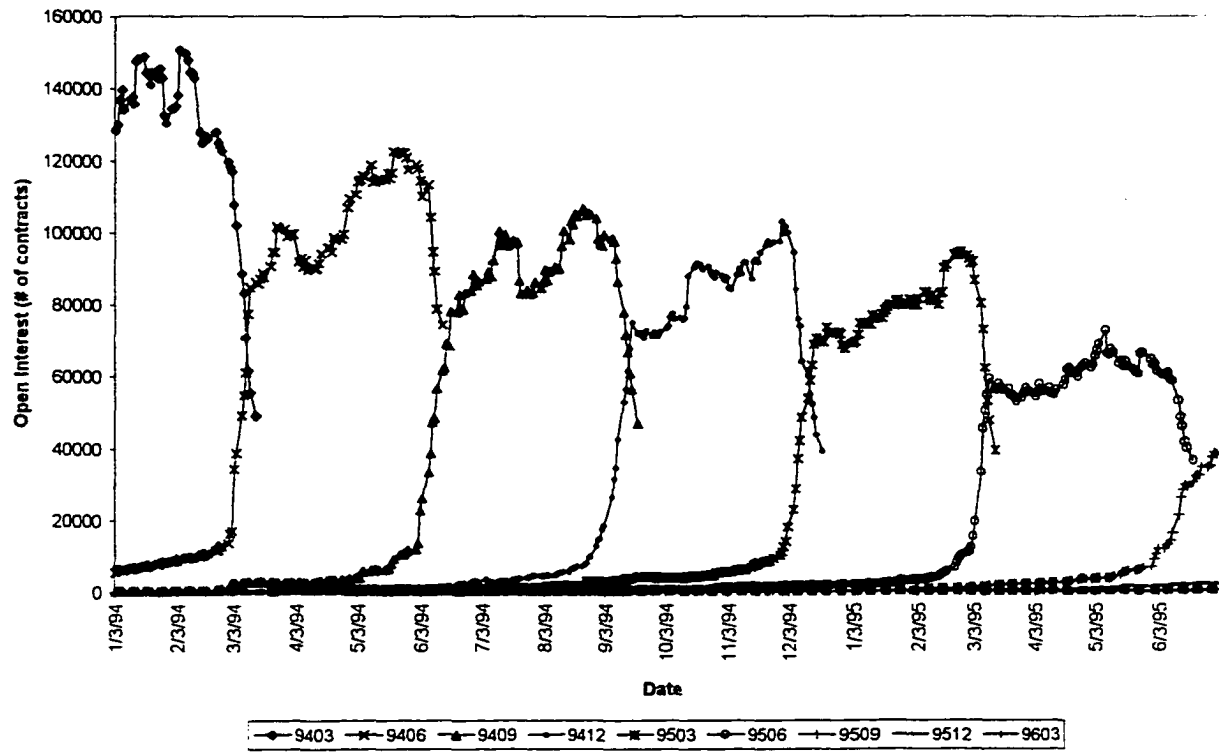
	$\ln(TV_{2,t})$	constant	$\ln(BA_{2,t})$	$\ln(O_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(RTB_t)$
Coefficient		2.677	-1.378	0.818	0.781	-0.902
t-stat.		(5.76)*	(-18.37)*	(17.22)*	(12.32)*	(-3.99)*
R-sq.		0.6113				

**Bid-Ask Spread Equation**

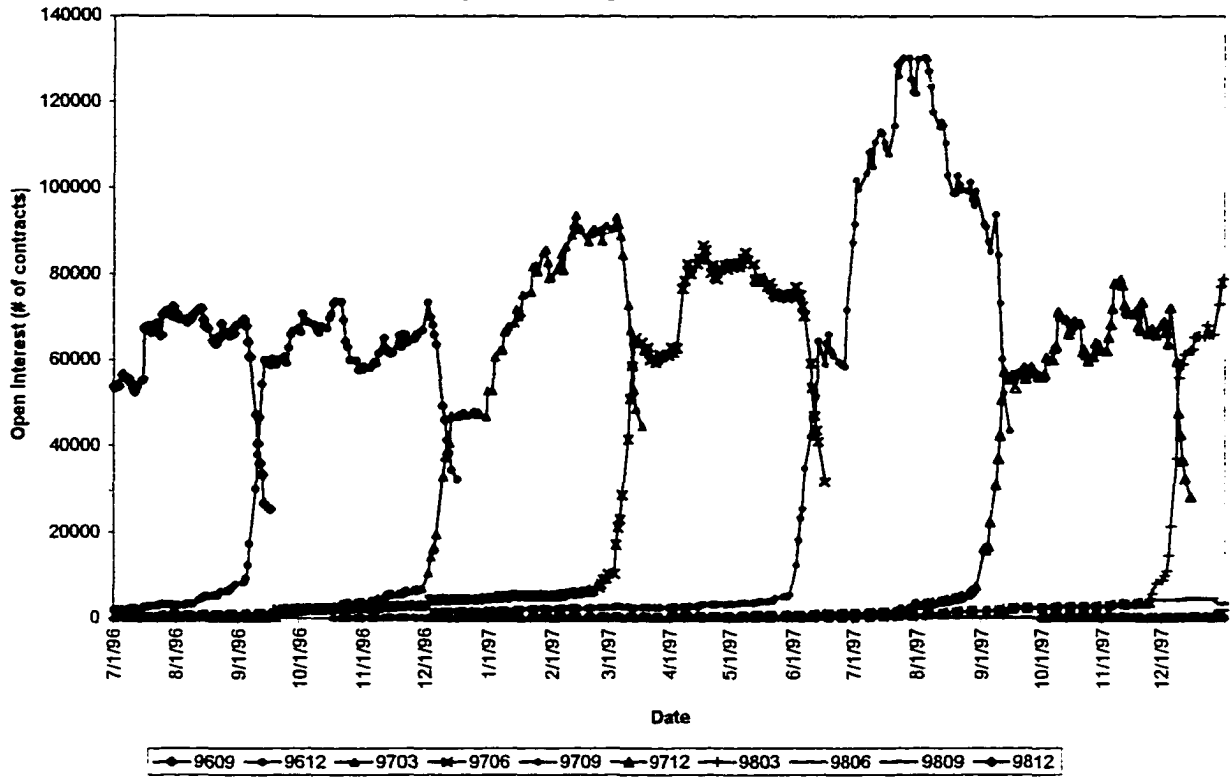
	$\ln(BA_{2,t})$	constant	$\ln(TV_{2,t})$	$\ln(BA_{2,t-1})$	$\ln(IV_{2,t})$	$\ln(FP_{2,t})$
Coefficient		2.307	-0.194	0.289	0.203	0.456
t-stat.		(25.75)*	(-23.41)*	(11.54)*	(8.63)*	(3.34)*
R-sq.		0.2479				

\* Indicates statistical significance at 0.05 level.

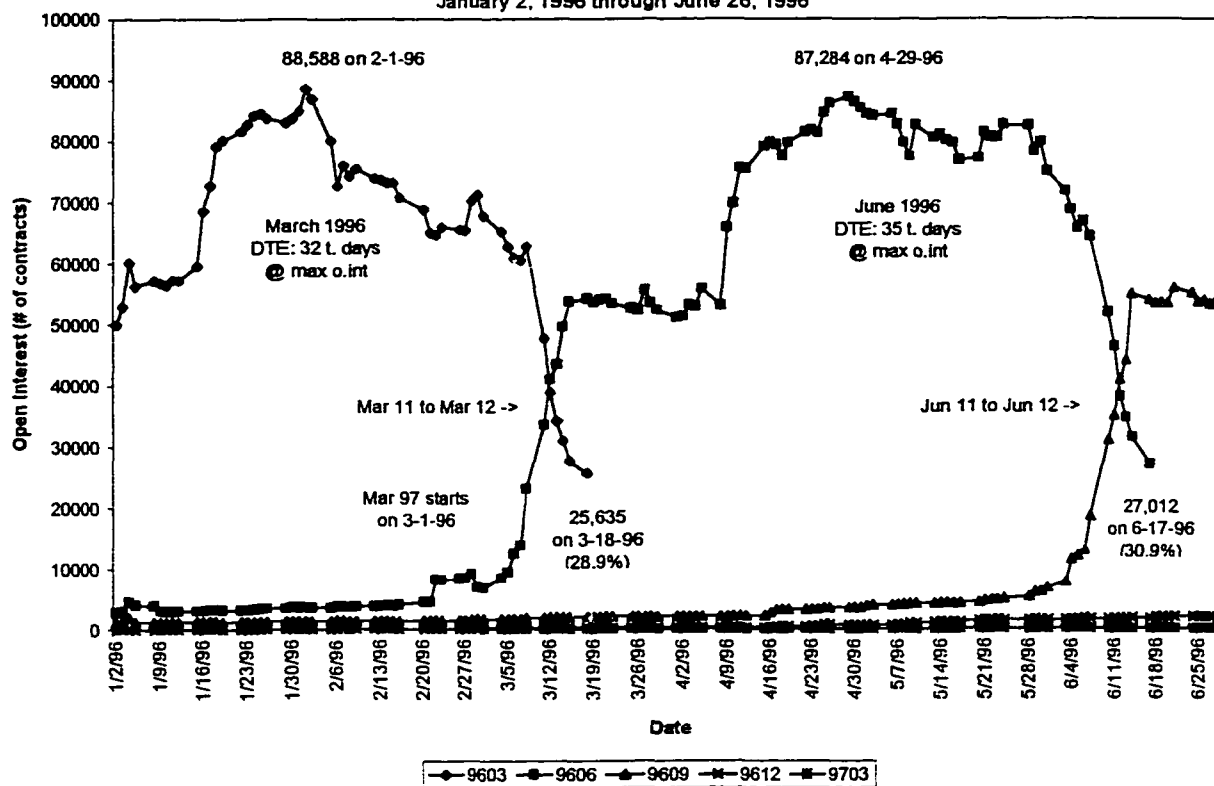
Figure I  
 CME Deutsche Mark Futures  
 Open Interest in Distinct Maturities Traded  
 January 3, 1994 through June 30, 1995



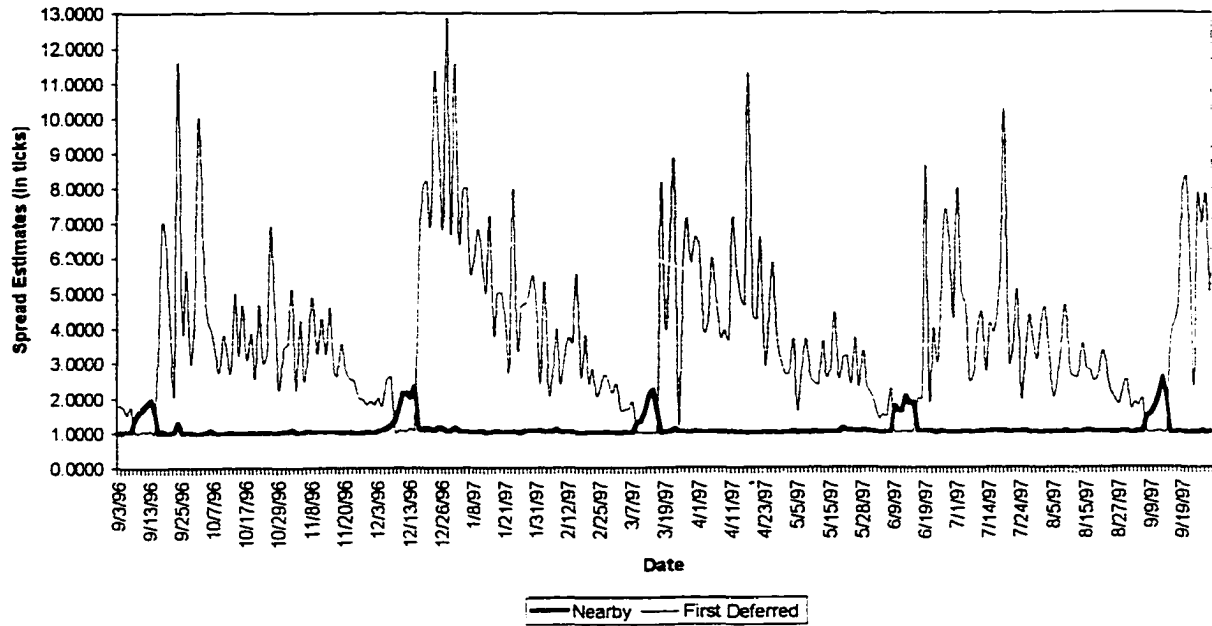
**Figure II**  
**CME Deutsche Mark Futures**  
**Open Interest in Distinct Maturities Traded**  
**July 1, 1996 through December 31, 1997**



**Figure III**  
**CME Deutsche Mark Futures**  
**Open Interest in Distinct Maturities Traded**  
 January 2, 1996 through June 28, 1996



**Figure IV**  
**CME Deutsche Mark Futures**  
**Daily Bid-Ask Spread Estimates**  
**Nearby versus First Deferred Contracts**  
**September 3, 1996 through September 30, 1997**



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