# International Linkages in Euromark Futures Markets: Information Transmission and Market Integration

YIUMAN TSE

## INTRODUCTION

Introduced in April 1989, the three-month Eurodeutschmark (Euromark) interest rate futures contract traded on the London International Financial Futures and Options Exchange (LIFFE) is now the most actively traded of all European short-term interest rate futures contracts.[1] Major international corporations, particularly banks, rely heavily on the Euromark market for short-term funds and international transactions. Euromark futures provide these corporations with efficient means of hedging interest rate risk associated with Euromark deposits.

The strong demand for Euromark futures is spurred also by several other reasons. First, exchange-traded interest rate contracts are exempt from capital weighing for counterparty credit risk under the 1988 Basle Capital Agreement.[2] Thus, positions may be established in the LIFFE

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[1]The LIFFE Euromark futures contract has the third highest trading volume of short-term interest rate futures worldwide, next to the trading volume of Eurodollar futures at CME (Chicago) and Euroyen futures at TIFFE (Tokyo).

[2]The Basle Capital Agreement is an agreement by the country committee members to adopt a common definition of capital and to impose risk-related capital adequacy requirements covering both on- and off-balance sheet risks.

■ *Yiuman Tse is an Assistant Professor in the School of Management at Binghamton University, (SUNY) NY.*

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Euromark contract to minimize the constraints on banks' credit limits or balance sheet exposure. Second, continuing financial uncertainties in the world's major economies have made exchange and interest rates unstable. Third, Euromark futures provide investors with strategies on the short, medium, and long ends of the deutschmark yield curve when combined with the Bobl (medium-term German government bond) and Bund (long-term German government bond) futures contracts.

In response to the increasing demand for interest risk management during the Asia-Pacific hours, Singapore International Monetary Exchange Limited (SIMEX) launched the Euromark futures contracts in September 1990. Investors with Eurodollar futures positions in the LIFFE thus have the opportunity to place overnight orders to initiate positions, take profits, or stop losses, taking advantage of interest rate price movements during the Asia-Pacific hours. The SIMEX Euromark futures contract is traded under a final settlement arrangement with the LIFFE, whereby the final settlement price for the Euromark futures at SIMEX is the same as that of LIFFE. This price is based on the British Bankers' Association Interest Settlement Rate (BBAISR) for three-month Euromark deposits at 11:00 AM on the last trading day.[3] Furthermore, the LIFFE Euromark and SIMEX Euromark futures markets are almost identical in many aspects, including the same (i) contract size: one million deutschmarks; (ii) contract months: March, June, September, and December; (iii) trading mechanism: open outcry auctions with a large number of brokers and dealers; and (iv) minimum price fluctuation: one basis point or DM 25, etc. However, the trading volume of the SIMEX Euromark futures is still less than 1% of that of the LIFFE Euromark futures, although the trading volume of the SIMEX Euromark futures contract has been increasing moderately since its introduction.[4]

This paper studies the international transmission of information and market integration in the Euromark futures traded on the LIFFE and SIMEX from January 1991 to June 1996. A better understanding of the transmission mechanism (more specifically, which market is more informationally efficient) may provide investors with more efficient strategies for hedging or speculating in interest rate risk associated with Euromark deposits. Using the Johansen (1988, 1991) maximum likelihood tests, this study finds that the futures prices of the two Euromark markets are

[3]Note that this final settlement arrangement between the LIFFE and SIMEX is different from the mutual offset system between CME and SIMEX. The mutual offset system, which is more flexible to investors, means contracts traded at CME (SIMEX) may be transferred to or liquidated at SIMEX (CME).

[4]The trading volumes of the LIFFE and SIMEX Euromark futures in 1995 are 25.7 and 0.23 million contracts, respectively.

cointegrated with one common stochastic trend. To explore this common trend in the cointegration system, the King et al. (1991) model of variance decomposition and impulse response functions is employed. Results suggest that the two Euromark futures markets are closely informationally linked and the information transmission between the markets is rapid (within three hours).

Numerous papers [among many others, Eun and Shim (1989), Jeon and von Furstenberg (1990), Hamao, Masulis, and Ng (1990), Bae and Karolyi (1995), and Koutmos and Booth (1996)] have examined information transmission between international stock markets, particularly between the U.S., U.K., and Japanese stock markets. On balance, these papers report that the U.S. market was more efficient than the others for the pre-October 1987 crash period, in that information flowed from the United States to other markets but not vice versa. For the post-crash period, however, a bidirectional flow of information between the Japanese and U.S. markets is observed. In any case, few papers have investigated information transmission between nearly identical futures contracts traded on different international markets. Some examples are Bacha and Fremault Vila (1994) (Nikkei stock index futures traded on the Singapore, Osaka, and Chicago exchanges), Dhillon, Lasser, and Watanabe (1997) (gold futures traded on Tokyo and New York), Shyy and Lee (1995) (Bund futures traded on London and Frankfurt), and Tse, Lee, and Booth (1996) (Singapore, London, and Chicago Eurodollar futures).

The cointegration and variance decomposition approach used in the current study is similar to that of Tse, Lee, and Booth (TLB) (1996). Using nonsynchronous closing prices of three international Eurodollar futures markets, TLB cannot determine which market is more informationally efficient, although they also report rapid information transmission between markets. They conclude that "each trading market is informationally efficient, on a daily basis" (TLB, 1996, p. 461). In other words, the London and Singapore Eurodollar futures markets are equally efficient on a daily basis. The current study, however, uses synchronous data at 11:10 AM London time and shows that the London Euromark futures market is more efficient than the Singapore market, a finding different from TLB's. Thus, the current paper provides a better understanding of information transmission by using synchronous data.[5] The nonsynchronous trading problem is discussed in later sections.

Rapid information transmission between markets (as documented by the current study and some papers cited previously) does not imply that

[5]Nevertheless, the underlying economic stories of TLB and the current paper are different.

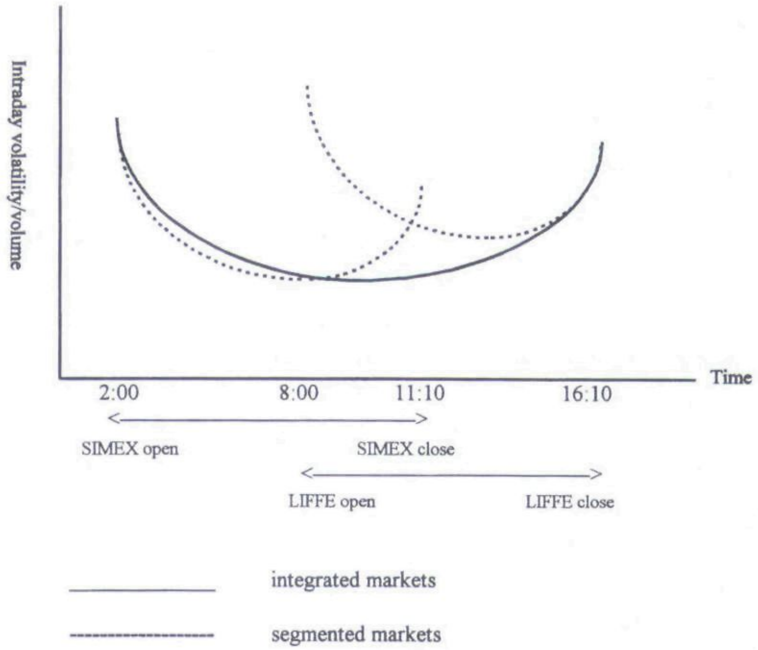


**FIGURE 1**
Intraday volatility and trading volume: Integrated vs. segmented markets.

the markets are informationally integrated. Market integration in an information sense is "defined as prices in both markets reflecting the same fundamental information" (Werner and Kleidon, 1996, p. 620). None of the above-mentioned papers has studied this relatively new issue. The U-shaped patterns in intraday volatility and volume (with very high values at the opening) of the LIFFE Euromark futures suggest that they are segmented in the sense that London traders trade on the LIFFE only. Put another way, traders do not consider trading on the SIMEX an alternative to trading on the LIFFE. The overall results indicate that traders take a much less global view on trading than one might think given the relative ease by which information is transmitted between markets.

## DATA AND DESCRIPTIVE STATISTICS

Daily opening and closing futures prices of the LIFFE Euromark and SIMEX Euromark nearest contract, until the first day of the delivery months, for the period of January 1991–June 1996 are obtained from Commodity Systems, Inc. (CSI). Transactions data of the LIFFE Euromark futures from July 1993 (the first month that these data are available) to June 1996 are provided by the LIFFE. In London time, the SIMEX

**TABLE I**

Summary Statistics of Log Futures Changes (Close-to-Close)
January 1991–June 1996

| | $\Delta LEM$ | | $\Delta SEM$ | |
|---|---|---|---|---|
| Mean (e-4) | 0.467 | (0.032)* | 0.460 | (0.037) |
| Median (e-4) | 0.000 | | 0.000 | |
| Variance (e-8) | 0.643 | | 0.613 | |
| Skewness | 6.327 | (<0.001) | 5.946 | (<0.001) |
| Excess kurtosis | 74.94 | (<0.001) | 74.94 | (<0.001) |
| Ljung-box $Q(10)$-stat, $\chi^2(12)$ | 15.52 | (0.214) | 11.89 | (0.455) |
| Correlation coefficient | | | 0.737 | |
| Bartletts homogeneity of variance test, $\chi^2(1)$ | | | | |
| $H_0$: $\sigma^2_{\Delta LEM} = \sigma^2_{\Delta SEM}$ | | | 0.756 | (0.385) |

*Asymptotic $p$-values are in parentheses.

trades from 2:00 to 11:10, the LIFFE is open from 8:00 to 16:10 (see Fig. 1). Thus, on a real-time basis, the LIFFE opens and closes later than the SIMEX with about three overlapping trading hours between the Singapore close and London open. The sample size of the study is 1418 after 73 trading days are deleted because trading day data are unavailable due to different national holidays. Moreover, logarithm of the futures price is used in the paper.[6] Hereafter, for simplicity, LEM and SEM are used to represent the LIFFE and SIMEX Euromark futures, respectively.

The descriptive statistics of close-to-close futures price changes are summarized in Table I. As expected, both futures price changes give similar mean, variance, positive skewness, and leptokurtosis, and the correlation coefficient between markets is high: 0.74. The result of statistically equal variance implies that the two markets incorporate information at the same speed on a daily basis, assuming that variances are directly related to information flow (Ross, 1989).

## UNIT ROOTS, COINTEGRATION, AND COMMON STOCHASTIC TREND

The augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979, 1981) and Phillips-Perron (Phillips, 1987; Phillips and Perron, 1988) unit root tests reported in Table IIA show that the closing prices of LEM and SEM follow an $I(1)$ or nonstationary process. However, the Monte Carlo study

[6]Results reported are qualitatively the same if the futures price of these 73 trading days is assumed to stay the same as the previous trading day and/or the implied interest rate, i.e., 100 − index future price, is used.

**TABLE II**

Unit Root and Cointegration Tests

*A. ADF, Phillips-Perron, and Weighted Symmetric (WS) Estimator Unit Root Tests*[a]

| | *LEM* | *SEM* | *Critical Values at the 5% Level*[a] |
|---|---|---|---|
| ADF (no drift, no trend) | −0.431 | −0.480 | −1.95 |
| ADF (with drift, no trend) | −0.425 | − 0.473 | −2.86 |
| ADF (with drift, with trend) | −2.285 | −2.327 | −3.41 |
| Phillips-Perron (no drift, no trend) | −0.356 | −0.312 | −1.95 |
| Phillips-Perron (with drift, no trend) | −0.360 | −0.330 | −2.86 |
| Phillips-Perron (with drift, with trend) | −2.472 | −2.502 | −3.41 |
| WS estimator (no trend) | −0.064 | −0.039 | −2.50 |
| WS estimator (with trend) | −2.909 | −2.921 | −3.19 |

*B. Johansen Cointegration Tests*[b]

| | *Trace* | *Critical Values at the 1% Level*[b] | $\lambda_{max}$ | *Critical Values at the 1% Level*[b] |
|---|---|---|---|---|
| Cointegrating rank, $r = 1$ | 0.219 | 11.65 | 0.219 | 11.65 |
| $r = 0$ | 321.6[d] | 23.52 | 321.3[d] | 19.19 |

*C. Hypothesis Testing of Cointegrating Vector, $(1\ \beta)'$*[c]

| | |
|---|---|
| $\beta$ | −1.000 |
| $p$-value of $H_0$: $\beta = 1$[b] | (0.445) |

[a]The ADF test statistics and WS estimators are computed with five lags. Five non-zero autocovariances in the Newey-West (1987) correction are used also for the Phillips-Perron tests. Results are qualitatively the same for ten lags. The critical values of the ADF and Phillips-Perron tests are reported in Fuller (1976, p. 373), and those of the WS estimator are available in Pantula, Gonzalez-Farias, and Fuller (1994).

[b]The lag order, $k = 3$, in the VECM is chosen by the SIC. Results are qualitatively the same for $k = 1$–10. The critical values are obtained from Osterwald-Lenum (1992).

[c]Following Johansen (1991), the hypothesis that $H_0$: $\beta = -1$ against $H_a$: $\beta \neq -1$ is tested by the test statistic, $\Phi_H$:

$$\Phi_H = (T - nk) \sum_{i=1}^{r} \ln[(1 - \lambda_i^*)/(1 - \lambda_i)]$$

where $\lambda_i^*$ and $\lambda_i$ are the eigenvalues associated with the $H_0$ and $H_a$ specifications and $T$ is the sample size. In this bivariate system, $n = 2$, $r = 1$, and $Q_H$ is distributed asymptotically as $\chi^2(1)$.

of Pantula, Gonzalez-Farias, and Fuller (PGF) (1994) demonstrates that the ADF test has low power against the stationary alternative. PGF recommend using the more powerful weighted symmetric (WS) estimator.[7] The WS estimator is introduced by Dickey, Hasza, and Fuller (1984) and modified by PGF. (See Appendix A for an analytical summary of the estimator.) The last two rows of Table IIA indicate that the conclusions of

[7]PGF also suggest using the unconditional maximum likelihood (ML) estimator. As reported by PGF, the WS and ML estimators yield similar powers and the former is easier to compute. Thus, only the WS estimator is used in the current study.

the WS estimator approach are the same as the ADF and Phillips-Perron tests, i.e., the null that the series has a unit root is not rejected.

Since LEM and SEM are closely informationally linked, they should move together in the long run, although they may drift apart in the short run. Cointegration, which describes this stationary relationship, is used to investigate the international information transmission of Euromark futures markets. Let $Y_t \equiv (y_{1t}\, y_{2t})' \equiv (\mathrm{LEM}_t\ \mathrm{SEM}_t)'$. If $\mathrm{LEM}_t$ and $\mathrm{SEM}_t$ are cointegrated, $Y_t$ can be represented by a vector error-correction model (VECM):

$$\Delta Y_t = \mu + A_k Y_{t-1} + \sum_{i=1}^{k-1} A_i \Delta Y_{t-i} + e_t \tag{1}$$

where $\mu$ is a $2 \times 1$ vector of drift, $A$'s are $2 \times 2$ matrices of parameters, and $e_t$ is a $2 \times 1$ white noise vector. Johansen (1988, 1991) developed the maximum likelihood test statistics, *trace* and $\lambda_{\max}$, for a cointegrated system. [The Johansen tests are reasonably robust to various non-normal innovations as reported by Gonzalo (1994), Cheung and Lai (1993), and Lee and Tse (1996).] The lag order $k$, which is set equal to three (or two lags of $\Delta Y_t$), in the VECM eq. (1) is chosen by the SIC, and the residuals are not autocorrelated.[8] Results are qualitatively the same for $k = 1$–$10$. Both the *trace* and $\lambda_{\max}$ statistics reported in Table IIB indicate that the two closing futures prices are cointegrated with one cointegration vector, $r = 1$, i.e., one common stochastic trend in this bivariate system, at any conventional significance level.

Following Johansen (1991) with finite-sample adjustment, the null hypothesis that $H_0$: the cointegrating vector, $(1\ \beta)' = (1\ -1)'$, against $H_a$: $\beta \neq -1$ is tested by the test statistic, $\Phi_H$:

$$\Phi_H = (T - nk) \sum_{i=1}^{r} \ln[(1 - \lambda_i^*)/(1 - \lambda_i)] \tag{2}$$

where $\lambda_i^*$ and $\lambda_i$ are the eigenvalues associated with the $H_0$ and $H_a$ specifications, $T$ is the sample size, and $n$ is the number of variables. Table IIC shows that $H_0$ is not rejected, and, therefore, the cointegrating vector is restricted to be the futures price differential. Rewrite eq. (1) as

$$\Delta Y_t = \mu + \alpha z_{t-1} + \sum_{i=1}^{k-1} A_i \Delta Y_{t-i} + e_t \tag{1'}$$

where $z_{t-1} = \mathrm{LEM}_{t-1} - \mathrm{SEM}_{t-1}$ is the error-correction term.

[8] $\mathrm{SIC} = \ln|\Omega| + q\ln(T)/T$, where $\Omega$ denotes the Johansen maximum likelihood of the residual covariance matrix and $q$ is the number of freely estimated parameters of the VECM.

## Variance Decomposition and Impulse Response Functions

In this paper, the King et al. (KPSW) (1991) model of variance decomposition and impulse response analysis is employed to explore the common stochastic trend in the cointegrating system. The model describes how movement in one market can be explained by the shock to the common trend and how rapidly the movements in the common trend are transmitted to different markets.

The intuition of the KPSW model can be illustrated by the following common-trend representation:

$$Y_t = \mu t + \begin{pmatrix} 1 \\ 1 \end{pmatrix} \omega_t + Y_t^* \tag{3}$$

where $\omega_t$ is the scalar common stochastic trend and $Y_t^* \equiv (y_{1t}^* \, y_{2t}^*)'$ is a 2 $\times$ 1 vector of transitory component (Stock and Watson, 1988). The common trend is assumed to be driven by information and provides permanent movement for the series. The transitory component is induced by market imperfections, e.g., transaction costs. Accordingly, the more efficient the market is, the more the movement of the market will be explained by the common trend. More specifically, the KPSW model decomposes the variance of individual series, $y_{it}$, $i = 1$ and 2, into the variances of common trend, $\omega_t$, and transitory component, $y_{it}^*$. If the variance of $y_{it}$ is predominately derived from that of $\omega_t$ (say 99%) and minimally from $y_{it}^*$ (1%), the movement of $y_{it}$ behaves as that of the common trend and, therefore, $y_{it}$ is considered informationally efficient.

The first step of the KPSW model is to convert the estimated VECM eq. (1′) to a vector moving average (VMA) model:

$$\Delta Y_i = \mu + \sum_{i=0}^{\infty} C_i e_{t-i} = \mu + C(B) e_t \tag{4}$$

where $C$'s are 2 $\times$ 2 parameter matrices of parameters and $C(B)$ is a 2 $\times$ 2 matrix polynomial in the lag operator, $B$. The VECM results are not discussed in detail but are available in Appendix B. Since there is only one common stochastic trend, $C(1)$ is of rank 1 (see Engle and Granger, 1987; Stock and Watson, 1988) and, accordingly, there exists a 1 $\times$ 2 vector, $G$, such that

$$C(1) = \begin{pmatrix} 1 \\ 1 \end{pmatrix} G \tag{5}$$

In the second step, the reduced form, VMA eq. (4), is converted to a structural VMA model:

$$\Delta Y_i = \mu + \sum_{i=0}^{\infty} \Theta_i v_{t-i} = \mu + \Theta(B)v_t \tag{6}$$

where $\Theta(B) = C(B)\Theta_0$ and $v_t \equiv (v_{1t}\ v_{2t})' = \Theta_0^{-1}e_t$ are $2 \times 1$ vectors of serially uncorrelated structural disturbances. To identify the common trend, KPSW restrict the matrix of long-run multipliers, $\Theta(1)$, as

$$\Theta(1) = \begin{pmatrix} 1 & 0 \\ 1 & 0 \end{pmatrix} \tag{7}$$

The values of the coefficients in the first column of $\Theta(1)$ are normalized to 1 to fix the scale of $v_{1t}$, which is identified to be the persistent shock (or shock to the common trend, $\omega_t$) with long-run multiplier of unity, while $v_{2t}$ is the transitory shock. That is, $v_{1t}$ has a long-run effect on $Y_t$, and $v_{2t}$ has only a temporary effect on $Y_t$. Moreover, the permanent shock is assumed to be uncorrelated with the transitory shocks, i.e., $E[v_{1t}\ v_{2t}] = 0$. Since $C(1)e_t = \Theta(1)v_t = (1\ 1)'v_{1t}$, the persistent shock, $v_{1t} = Ge_t$. The impulse responses associated with $v_{1t}$ are, therefore, given by the first column of $\Theta(B)$. The cumulative impulse responses (CIRs) and variance decomposition (VDC) are then calculated.

Two points about the KPSW model are worth noting. First, the shock is an innovation to the common trend, instead of each individual series as is commonly done in the conventional vector autoregressive (VAR) literature put forth by Sims (1980). Furthermore, the KPSW model is just-identified and the results do not depend on the ordering of variables in the model when there is only one common trend. Second, the problem of nonsynchronous trading (whereby the prices of different series are measured at different trading times) does not influence the results of Johansen tests and other cointegration tests (Engle and Granger, 1987). However, this problem may bias the results of the KPSW model and other models using the VDC approach. For example, the nonsynchronous closing prices of two markets are used and market 1 closes later than market 2. Even if both markets are equally efficient, on a given trading day, the closing price of market 1 will incorporate more information than market 2 merely because market 1 closes later than market 2. As a result, the variance of market 1 (market 2) will be substantially (insignificantly) derived from that of the common trend and market 1 will be mistakenly considered more efficient than market 2. This point is exemplified in more detail by the empirical results discussed below.

**TABLE III**

Forecast Error VDC and CIRs
January 1991–June 1996

| | *VDC* | | *CIR* | |
|---|---|---|---|---|
| *Horizons (days)* | *ΔLEM* | *ΔSEM* | *ΔLEM* | *ΔSEM* |
| | *A. LIFFE Close and SIMEX Close* | | | |
| 1 | 0.9918 | 0.7985 | 1.0023 | 0.7633 |
| 2 | 0.9918 | 0.6503 | 0.9694 | 0.9597 |
| 3 | 0.9904 | 0.6506 | 1.0352 | 1.0005 |
| 4 | 0.9888 | 0.6404 | 1.0103 | 0.9760 |
| 5 | 0.9888 | 0.6393 | 1.0133 | 1.005 |
| 10 | 0.9888 | 0.6389 | 1.0000 | 0.9996 |
| 20 | 0.9888 | 0.6389 | 1.0000 | 0.9996 |
| | *B. LIFFE Open and SIMEX Close* | | | |
| 1 | 0.8919 | 0.9980 | 0.9934 | 1.0433 |
| 2 | 0.8075 | 0.9979 | 1.0450 | 1.0318 |
| 3 | 0.8078 | 0.9975 | 0.9909 | 1.0006 |
| 4 | 0.8077 | 0.9968 | 0.9969 | 0.9992 |
| 5 | 0.8076 | 0.9968 | 1.0006 | 0.9993 |
| 10 | 0.8076 | 0.9968 | 1.0000 | 0.9993 |
| 20 | 0.8076 | 0.9968 | 1.0000 | 0.9993 |

Notes: Entries in the first two columns are the fractions of forecast error variance to forecast $\Delta Y_t$ that are due to the shocks to the common stochastic trend, $v_{1t}$, and the last two columns are the cumulative impulse responses of $\Delta Y_t$ to $v_{1t}$.

Results of the VDC and CIRs explained by $v_{1t}$ are presented in Table III. The point estimates in the first two columns of Table IIIA suggest that at the end of a 20-day horizon, 98.9% of the forecast error variance in ΔLEM and only 63.9% in ΔSEM can be attributed to the innovations to the common stochastic trend, $v_{1t}$. At the end of a 1-day horizon, the estimates are 99.2% and 79.9%, respectively, for ΔLEM and ΔSEM. The last two columns show the CIRs of $\Delta Y_t$ to $v_{1t}$. In response to a shock generated on day 1, both markets absorb more than 95% of $v_{1t}$ at day 2, indicating that the information transmission between markets is very quick (less than one day). Also, as expected, the long-run (or 20-day) CIRs of the permanent shock is unity for both markets (see TLB, 1996, p. 459). However, on day 1, the London market responds at 100%, with the Singapore market at only 76.3%. Both of the VDC and CIRs results may suggest that the common trend is mainly derived from the London market, and the London market drives the information transmission mechanism between markets.

Nevertheless, these results have to be interpreted with caution because of the nonsynchronous trading problem noted earlier: The two markets do not close at the same time. Since the London market closes five hours after the Singapore market on a given trading day, the LIFFE closing price is likely to incorporate more information than the SIMEX closing price and, consequently, the London market behaves as the common trend. To analyze the effects of this problem, the LIFFE *opening* price and SIMEX *closing* price are used for the whole estimation process. Note that the SIMEX closing price is revealed three hours later than the LIFFE opening price and, therefore, the SIMEX closing price may impound more information. As indicated in Table IIIB, when the LIFFE opening price is used (instead of the closing price), the VDC at the 20-day period becomes only 80.8% for the London market, while soaring up to 99.7% for the Singapore market. Both markets respond at about 100% on day 1. Hence, when the LIFFE opening price is used, the results might suggest that the common trend is mainly derived from the Singapore market.

Combining the results of Table IIIA and IIIB, neither of the London and Singapore Euromark futures can be described as the source of information flow or common stochastic trend on a daily basis. Instead, each market is informationally efficient and embodies all the information in the system. More specifically, the common trend is simply driven by the later trading price of the two markets (i.e., the LIFFE closing price when the LIFFE and SIMEX closings are used, or the SIMEX closing price when the LIFFE opening and SIMEX closing are used). Moreover, the responses of each market to an innovation to the common trend are fully settled within a day. These findings suggest that the two Euromark futures markets are closely informationally linked and active arbitrage activities between markets lead to very efficient information transmission.

To really examine which market is more efficient, synchronous trading data must be used. Transactions data of the LIFFE, which are time-stamped to the second, are available from July 1993 to June 1996.[9] The LIFFE and SIMEX prices recorded at 11:10 AM (which is also the SIMEX closing price) are collected. Studying this subperiod also ensures that the results are not affected by the exchange rate mechanism (ERM) crisis in September 1992.

In Table IVA and IVB, the VDC and CIR analyses for this subperiod are replicated by using the LIFFE close and SIMEX close and the LIFFE open and SIMEX close as in Table IIIA and IIIB, respectively. The results are virtually the same as in Table III. That is, the common trend is driven by the later trading price of the two markets. In Table IVC, where the main results of Table IV are presented, synchronous data at 11:10 AM London time are used. It shows that at the end of a 20-day horizon, 99.8%

[9]Transactions data of the following days are missing: 8 August 1993; 7–14 December 1993; 12 September 1994; 20 September 1995.

**TABLE IV**

Forecast Error VDC and CIRs
July 1993–June 1996

| | VDC | | CIR | |
|---|---|---|---|---|
| *Horizons (Days)* | *ΔLEM* | *ΔSEM* | *ΔLEM* | *ΔSEM* |
| | *A. LIFFE Close and SIMEX Close* | | | |
| 1 | 0.9968 | 0.7309 | 1.0162 | 0.8074 |
| 2 | 0.9964 | 0.6101 | 1.0108 | 1.0045 |
| 3 | 0.9958 | 0.6102 | 1.0024 | 0.9780 |
| 4 | 0.9957 | 0.6093 | 1.0014 | 0.9945 |
| 5 | 0.9957 | 0.6093 | 1.0004 | 0.9944 |
| 10 | 0.9957 | 0.6093 | 1.0000 | 0.9966 |
| 20 | 0.9957 | 0.6093 | 1.0000 | 0.9966 |
| | *B. LIFFE Open and SIMEX Close* | | | |
| 1 | 0.8708 | 0.9877 | 0.9829 | 1.0774 |
| 2 | 0.7718 | 0.9873 | 1.0135 | 1.0068 |
| 3 | 0.7709 | 0.9831 | 0.9912 | 0.9976 |
| 4 | 0.7703 | 0.9830 | 1.0000 | 0.9983 |
| 5 | 0.7703 | 0.9829 | 0.9999 | 0.9967 |
| 10 | 0.7703 | 0.9829 | 1.0000 | 0.9962 |
| 20 | 0.7703 | 0.9829 | 1.0000 | 0.9962 |
| | *C. LIFFE 11:10 AM and SIMEX Close[a] (Synchronous Trading)* | | | |
| 1 | 0.9983 | 0.8819 | 1.0425 | 0.9735 |
| 2 | 0.9982 | 0.8639 | 1.0050 | 0.9520 |
| 3 | 0.9982 | 0.8639 | 1.0053 | 0.9582 |
| 4 | 0.9982 | 0.8629 | 1.0045 | 0.9639 |
| 5 | 0.9982 | 0.8625 | 1.0039 | 0.9684 |
| 10 | 0.9982 | 0.8614 | 1.0017 | 0.9830 |
| 20 | 0.9982 | 0.8612 | 1.0002 | 0.9927 |

Note: See Table III for description.
[a]The SIMEX close is also at 11:10 AM London time.

of the forecast error variance in ΔLEM and 86.1% in ΔSEM can be attributed to the innovations to the common stochastic trend, $v_{1t}$. On day 1, the CIRs to $v_{1t}$ are almost 100% for both markets. Note that the VDC and CIR numerical results of SIMEX in Table IVC are between those of IVA and IVB. The results of Table IVA–C show that the information transmission between the two Euromark futures markets is very quick (within a day) and the London market is more informationally efficient than the Singapore market. The finding obtained from synchronous data at 11:10 that the London market is more efficient than the Singapore market may result from the much higher trading volume of LIFFE.

## INTRADAY VOLATILITY AND VOLUME OF LIFFE EUROMARK FUTURES

As pointed out in the Introduction, rapid information transmission between markets does not necessarily mean that the markets are informationally integrated. Market integration in an information sense (Werner and Kleidon, 1996) can be examined by the intraday patterns of volatility and trading volume. U-shaped patterns have been found by previous empirical research, e.g., Wood, McInish, and Ord (1985), Harris (1986), and Jain and Joh (1988). These intraday patterns can be explained by the sequential batch auction (asymmetric) information-based model (Admati and Pfleiderer, 1988) and the queuing disequilibrium market model of the continuous auction process with monopolistic market makers (Brock and Kleidon, 1992).

Werner and Kleidon (1996) argue that if the two markets with several overlapping trading hours, such as the Singapore and London markets, are integrated, their U-shaped curves (dotted) of intraday volatility and volume should merge to one (solid) curve as shown in Figure 1. Particularly, the close in Singapore and the open in London should not exhibit exceptional levels of volatility and volume. Since transactions data are not available for the Singapore markets, only the intraday volatility and volume of LIFFE are studied. Consider the London opening price. If the LIFFE and SIMEX are integrated and London or other international traders consider trading on the LIFFE the same as on the SIMEX, they do not need to rush to trade on the LIFFE when it starts trading in the morning. They may simply trade on the SIMEX one or two hours before the London market opens. The London open, therefore, should not exhibit high volatility and volume. In contrast, if the markets are segmented and London traders are not interested in trading on the Singapore market but only on the LIFFE, the volatility and volume in the London morning will be substantially higher than at midday.

A trading day of the LIFFE is divided into sixteen 30-minute intervals. The volatility of an interval is calculated as the variance of price changes during this interval, and volume is the number of contracts traded in the interval. The intraday bid–ask spread is not examined because the spread of Euromark futures, like other interest rate futures, is very small throughout the day, one or two ticks, and the spread pattern is, accordingly, flat. The intraday volatility and trading volume of London Euromark futures are illustrated in Figure 2 and Table V. The figure demonstrates the U-shaped (or, more precisely, reverse J-shaped) patterns with high volatility and volume at the open and close and a mild spike at

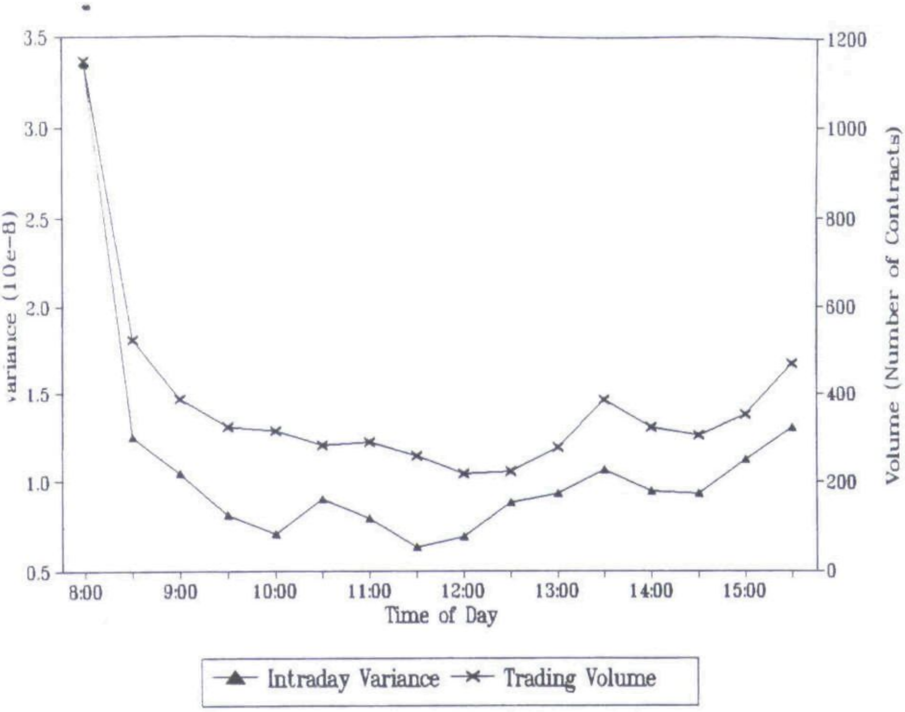


**FIGURE 2**
Intraday volatility and trading volume of LIFFE Euromark futures from July 1993 to June 1996.

13:30. Particularly, the volatility and volume at the opening interval (8:00–8:29) is five times greater than the midday interval (12:00–12:29).

The exceptionally high volatility and trading volume at the London open indicate that the London traders do not regard trading on the Singapore market as an alternative to trading on the LIFFE. Instead of trading on the SIMEX based on the public information revealed during Singapore trading hours, they wait for the London market to open and trade.[10] Note that Japanese macroeconomics news, which may influence Euromark and other foreign interest rates, is released during the trading hours of SIMEX [see, e.g., Bonser-Neal and Roley (1994) for a discussion about the cointegrating relationship between Japanese CD and Eurodollar rates]. To compare the intraday volatility during the U.S. trading day of European, Japanese, and American stocks listed on the NYSE or the AMEX, Chan, Fong, Kho, and Stulz (1996, p. 1163) also "suppose that

[10]The results showing the lack of integration between SIMEX and LIFFE are consistent with the finding of Ferguson, Mann, and Schneck (1997) that the introduction of foreign exchange futures contracts which have mutual offset with similar contracts on CME had no significant effect on the Chicago market.

**TABLE V**

Intraday Volatility and Trading Volume of LIFFE Euromark Futures
July 1993–June 1996

| *Interval* | *Time* | *Volatility (Variance 10e-8)* | *Volume (Number of Contracts)* |
|---|---|---|---|
| 1 | 8:00–8:29 | 3.345 | 1146 |
| 2 | 8:30–8:59 | 1.245 | 524 |
| 3 | 9:00–9:29 | 1.040 | 385 |
| 4 | 9:30–9:59 | 0.806 | 321 |
| 5 | 10:00–10:29 | 0.699 | 314 |
| 6 | 10:30–10:59 | 0.899 | 281 |
| 7 | 11:00–11:29 | 0.790 | 287 |
| 8 | 11:30–11:59 | 0.630 | 256 |
| 9 | 12:00–12:29 | 0.692 | 217 |
| 10 | 12:30–12:59 | 0.882 | 221 |
| 11 | 13:00–13:29 | 0.933 | 275 |
| 12 | 13:30–13:59 | 1.061 | 383 |
| 13 | 14:00–14:29 | 0.945 | 322 |
| 14 | 14:30–14:59 | 0.931 | 305 |
| 15 | 15:00–15:29 | 1.123 | 350 |
| 16 | 15:41–16:10 | 1.304 | 469 |

stock trading is segmented internationally, in the sense that investors trade a stock in their home country if they can."

Traders prefer the London Euromark futures market to the Singapore market for two other reasons. First, informed traders and discretionary (with respect to the timing of trades) liquidity traders in the Admati and Pfleiderer model may find the high trading volume at the LIFFE open more appealing than the thinly traded SIMEX, and may choose Euromark futures traded on the LIFFE. Second, the LIFFE Euromark futures contracts are more effective in currency risk and duration management. It is because LIFFE lists more short-term interest rate futures contracts denominated in major currencies, which allow for cross-market spread trading, and Bobl and Bund futures are not traded on the SIMEX. Accordingly, London traders, who try to establish optimal portfolios in the Brock and Kleidon (1992) model (particularly after the accumulation of overnight information), favor the LIFFE. All this results in segmentation of the Singapore market from the London market.

Several interesting aspects are suggested also by the intraday patterns shown in Figure 2. The first is that U.K. macroeconomics news is revealed at 9:30 and 11:30, and U.S. news at 13:30 London time. While the 13:30 interval provides a spike with higher volatility and volume than its surrounding intervals (i.e., from 12:30 to 14:30), the 9:30 and 11:30 intervals do not. These results indicate that the London Euromark futures prices are affected by U.S. news but not by U.K. news, a finding consistent with Becker, Finnerty, and Kopecky (1995). Based on a regression approach, they document that U.S. information has a significant influence on German, Japanese, and British interest rates, while U.K. information has negligible effect on foreign rates. Second, the Singapore market close at 11:10 does not affect the trading activity on the LIFFE. This result is not surprising because of the much smaller trading volume of the Singapore market. Third, although volatility and volume show a tendency to rise near the close, this increase is very small relative to the rise near the open. The reason may be that the London Euromark futures are traded actively also during the APT (Automated Pit Trading) hours from 16:25 to 17:59 after the market closes at 16:10.[11]

## CONCLUSIONS

This article studies the international transmission of information in the LIFFE and SIMEX Euromark futures markets and the degree of intraday market integration. A better understanding of the transmission mechanism and market integration may provide investors with more efficient strategies for hedging or speculating in interest rate risk associated with Euromark deposits. The article raises two questions: Which of the Euromark futures markets is more informationally efficient? Do traders consider trading on the SIMEX an alternative to trading on the LIFFE?

The futures prices of the two markets are cointegrated with one common stochastic trend that is assumed to be driven by information. Using opening and closing prices (which have the nonsynchronous trading problem) the KPSW model of VDC and impulse response functions shows that neither the London nor Singapore Euromark futures can be described as the dominant source of information flow or common stochastic trend. Put in another way, neither market can be considered more informationally efficient than the other on a daily basis. However, employing synchronous transactions data at 11:10, the London market is shown to be more informationally efficient than the Singapore market. Specifically, 99.8% of the long-run forecast error variance in the London futures price changes and 86.1% of the Singapore futures price changes can be attributed to the innovations to the common trend. Also, the impulse responses of both markets to the common trend are almost 100% immediately, suggesting very rapid information transmission between markets. The results

[11]The trading volume of the APT, an electronic trading system, is about 13% of the normal floor trading.

indicate that the two Euromark futures markets are closely informationally linked and active arbitrage activities between the markets result in efficient information transmission. Moreover, the much higher trading volume of the LIFFE results in higher efficiency than the SIMEX.

The intraday market integration is examined by the U-shaped patterns in volatility and volume of the LIFFE Euromark futures. The exceptionally high volatility and trading volume at the London open indicate that London traders do not regard trading on the Singapore market as an alternative to trading on the LIFFE. Instead of trading on the SIMEX based on the public information revealed during Singapore trading hours, they wait for the London market to open and trade. Informed traders and discretionary liquidity traders also prefer the London market, which is much more heavily traded. The overall results indicate that traders take a much less global view on trading than one might think given the relative ease by which information is transmitted between markets. Future research on the intraday volatility of the SIMEX is warranted when the transactions data are available.

## APPENDIX A

This appendix summarizes the estimation processes of the weighted symmetric (WS) estimators discussed in Pantula, Gonzalez-Farias, and Fuller (PGF) (1994). The WS estimator approach considers the following two symmetric AR(1) models:

$$x_t = \mu(1 - \rho) + \rho x_{t-1} + e_t \tag{A1}$$

$$x_t = \mu(1 - \rho) + \rho x_{t+1} + u_t \tag{A2}$$

The null hypothesis that $x_t$ has a unit root is $H_0$: $\rho = 1$. The symmetry between eqs. (A1) and (A2) results in considering estimators of $\rho$ that minimize

$$Q_w(\rho) = \sum_{t=2}^{T} w_t(y_t - \rho y_{t-1})^2 + \sum_{t=2}^{T} (1 - w_t)(y_{t-1} - \rho y_t)^2 \tag{A3}$$

where $y_t$ is the demeaned series of $x_t$, and $w_t = (t - 1)/T$ are the weights of the squared errors. Consider eqs. (A1) and (A2) of the $p$th order. Equation (A3) becomes

$$\begin{aligned} Q_w(\rho) = {} & \sum_{t=p+1}^{T} (t - p)\left[y_t - \rho y_{t-1} - \sum_{i=2}^{p} \pi_i \Delta y_{t-i+1}\right]^2 \\ & + \sum_{t=p+1}^{T} (T - t + p)\left[y_{t-p} - \rho y_{t-p+1} + \sum_{i=2}^{p} \pi_i \Delta y_{t-p+i}\right]^2 \end{aligned} \tag{A4}$$

The pivotal statistic can be obtained with the weighted OLS using the weights, dependent variable, and independent variables given in PGF (1994). The WS estimator is extended to the model with a time trend by using the detrended series derived from regressing $x_t$ on 1 and $t$.

## APPENDIX B

Vector Error-Correction Models

$$\Delta Y_t = \mu + \alpha z_{t-1} + \sum_{i=1}^{k-1} A_i \Delta Y_{t-i} + e_t$$

*where* $\Delta Y_t = (\Delta \mathrm{LEM}_t\ \Delta \mathrm{SEM}_t)'$ and $z_{t-1} = \mathrm{LEM}_{t-1} - \mathrm{SEM}_{t-1}$.

| | $\Delta LEM$ | | $\Delta SEM$ | |
|---|---|---|---|---|
| | *A. January 1991–June 1996, LIFFE Close and SIMEX Close* | | | |
| $z_{t-1}$ | −0.164 | (−1.499) | 0.657[b] | (5.997) |
| $\Delta\mathrm{LEM}_{t-1}$ | 0.146 | (1.556) | 0.223[b] | (2.811) |
| $\Delta\mathrm{LEM}_{t-2}$ | 0.169 | (1.744) | 0.266[b] | (3.694) |
| $\Delta\mathrm{SEM}_{t-1}$ | −0.185 | (−1.895) | −0.256[b] | (−3.245) |
| $\Delta\mathrm{SEM}_{t-2}$ | −0.081 | (−0.966) | −0.222[b] | (−3.110) |
| Constant (e-4) | 0.460[a] | (2.115) | 0.475[a] | (2.534) |
| | *B. January 1991–June 1996, LIFFE Open and SIMEX Close* | | | |
| $z_{t-1}$ | −0.663[b] | (−4.115) | 0.084 | (0.561) |
| $\Delta\mathrm{LEM}_{t-1}$ | −0.207[a] | (−1.975) | −0.118 | (−1.167) |
| $\Delta\mathrm{LEM}_{t-2}$ | −0.095 | (−1.141) | −0.063 | (−0.785) |
| $\Delta\mathrm{SEM}_{t-1}$ | 0.213[a] | (2.051) | 0.104 | (1.051) |
| $\Delta\mathrm{SEM}_{t-2}$ | 0.058 | (0.628) | 0.035 | (0.394) |
| Constant (e-4) | 0.474[a] | (2.151) | 0.504[a] | (2.320) |
| | *C. July 1993–June 1996, LIFFE Close and SIMEX Close* | | | |
| $z_{t-1}$ | −0.097 | (−1.532) | 0.650[b] | (7.000) |
| $\Delta\mathrm{LEM}_{t-1}$ | 0.053 | (1.028) | 0.184[b] | (3.067) |
| $\Delta\mathrm{SEM}_{t-1}$ | −0.048 | (−0.917) | −0.153[b] | (−2.754) |
| Constant (e-4) | 0.513[a] | (2.247) | 0.389 | (1.836) |
| | *D. July 1993–June 1996, LIFFE Open and SIMEX Close* | | | |
| $z_{t-1}$ | −0.543[b] | (−3.795) | 0.139 | (1.244) |
| $\Delta\mathrm{LEM}_{t-1}$ | −0.229[b] | (−2.671) | −0.125 | (−1.876) |
| $\Delta\mathrm{SEM}_{t-1}$ | 0.187 | (1.928) | 0.061 | (0.822) |
| Constant (e-4) | 0.560[a] | (2.476) | 0.517[a] | (2.213) |
| | *E. July 1993–June 1996, LIFFE 11:10* AM and SIMEX Close (Synchronous Trading) | | | |
| $z_{t-1}$ | −0.034 | (−0.524) | 0.149[b] | (3.156) |
| $\Delta\mathrm{LEM}_{t-1}$ | −0.027 | (−0.246) | 0.178 | (1.519) |
| $\Delta\mathrm{SEM}_{t-1}$ | −0.007 | (−0.066) | −0.222 | (−1.820) |
| Constant (e-4) | 0.529[a] | (2.192) | 0.454 | (1.923) |

Notes: The lag order, $k$, in the VECM is chosen by the SIC. $t$-statistics derived from White (1980) are in parentheses.
[a]Significant at the 5% level.
[b]Significant at the 1% level.

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