Available online at www.sciencedirect.com
ScienceDirect
Journal of International Money and Finance 26 (2007) 329−341
Journal of International Money and Finance
www.elsevier.com/locate/jimf

Volatility spillovers across international swap markets: The US, Japan, and the UK

Francis In*

Department of Accounting and Finance, Monash University, Clayton Campus, Victoria 3168, Australia

Abstract

This paper examines volatility spillovers across the three major international swap markets, namely, the US, Japan, and the UK. We apply a multivariate VAR-EGARCH model by incorporating the slope of term structure and corporate spread variables to capture the time-varying nature of swap spread volatility across countries. Our empirical findings show that the changes in the swap spreads are significantly influenced by the slope of term structure variable in all three currencies. We find that the US swap market has a major influence on the Japanese and UK swap markets, but *not* vice versa. We also find that reciprocal spillovers exist between Japanese and the UK swap markets. In almost all cases, the degree of volatility persistence is fairly strong, and in many cases we find asymmetric volatility spillovers across maturity and country.

JEL classification: E43; G14

Keywords: Volatility spillovers; Swap spread; International linkages

1. Introduction

The globalization of international trade and finance, financial regulation, and advances in information technology have strengthened the international connections between national financial markets. In particular, recent deregulation of financial markets within a rapidly expanding

* Tel.: +61 3 9905 1561; fax: +61 3 9905 5475.
E-mail address: francis.in@buseco.monash.edu.au

0261-5606/$ - see front matter
doi:10.1016/j.jimonfin.2006.11.007

global financial system has created an increased need for market participants, regulators, and academic researchers to investigate the extent of volatility linkages between financial markets. A clearer understanding of the nature of cross-market linkages and interactions is now an essential consideration of investors and policy makers.[1]

Numerous recent studies have investigated the linkages between financial markets in different countries and the processes by which information flows between these markets. Important studies include Hamao et al. (1990), Theodossiou and Lee (1993), Susmel and Engle (1994), Koutmos and Booth (1995), Koutmos (1996), Booth et al. (1997), Bodart and Reding (1999), and In et al. (2001). While the finance literature on international transmission has tended to concentrate on equity returns, there is also substantial literature on interest rate linkages between countries. Examples of this literature include Dutton (1993), Goodwin and Grennes (1994), Chinn and Frankel (1995), and Monadjemi (1997). However, nearly all of this research has studied long-term trends in real interest rates and, in particular, the research has focused on the question of whether real interest rates are equal between countries.

Despite the huge size of the global swap market,[2] there are very few studies on the international linkages between swap markets. Examples of recent literature include Fehle (2000), Eom et al. (2001, 2002), Lekkos and Milas (2001, 2004), and In et al. (2003, 2004). Fehle (2000) investigates the impact that US swap spreads have on British, German, French, Japanese, Spanish, and Dutch swap markets, whereas Eom et al. (2002) examine the relationship between Japanese yen and US dollar interest rate swap spreads, using weekly data. Lekkos and Milas (2001) use weekly data to investigate linkages between the US and the UK swap markets in the 1990s. They find that in both currencies the largest proportion of the change in the swap spread is due to its own variance, followed by the slope of the domestic risk-free term structure. Lekkos and Milas (2004), using a nonlinear VAR approach, find evidence in support of the existence of common risk factors in the US and the UK interest rate swap markets. In the analysis of the links between interest rate swap markets in the US, the UK, and Japan, In et al. (2003) report that across all swap maturities and in all three currencies, the slope of the risk-free term structure makes the greatest contribution, and the contribution is greater for longer term to maturity.

To the best of our knowledge, *volatility spillover* effects within the international swap markets have not yet been reported in the literature. Yet it is an intriguing area of study, because it

[1] This is due to at least two reasons. First, from the investor's point of view, increased knowledge of how markets influence one another is important in the determination of hedging and diversification of their international investment. For example, when an international financial crisis happens, it changes the relationships between financial markets. Therefore, the strength of some of the linkages between markets suggests that investors have to diversify away nonsystematic portfolio risk by investing in more isolated markets. Second, from the policy maker's point of view, financial instability is an important issue because a financial crisis, such as bank collapse and stock market crash, directly influences a country's general economic well-being. If a stock market is highly integrated with other countries' stock markets, domestic stability depends on the financial stability in the other countries.

[2] The size and growth of both interest rate and currency swap markets are phenomenal, although the growth in interest rate swaps has been by far the more dramatic. Interest rate swaps are one of the major financial innovations since the 1980s. According to the Bank for International Settlements (1996, 2002), the notional amount outstanding of interest rate swaps grew from US$3.0 trillion in December 1991 to US$51.4 trillion in June 2001. In terms of amounts outstanding, interest rate swaps dominate all other derivative products in the market place. Several surveys, such as the Institutional Investor Survey (1992), Bodnar et al. (1995), and Phillips (1995), have found that interest rate swaps are the most popular derivative contracts used by US firms.

provides insight into information transmission, volatility impacts, and the pricing of the swap with different maturities.

This paper aims to contribute to the literature on volatility spillovers by focusing on the three major international swap markets,[3] namely New York, Tokyo, and London. We introduce two *innovations*. This paper is the *first* to investigate the issue of volatility spillovers across the three major international swap markets. This helps to deepen our understanding of the dynamic interaction of information flows between the major international swap markets such as those in the US, Japan, and the UK. The results therefore should be of interest to both international and local investors, as well as the monetary and regulatory authorities. Second, our paper differs from the variance decomposition and impulse response analysis employed by Lekkos and Milas (2001)[4] in that we use a multivariate vector autoregressive-exponential generalized autoregressive conditional heteroskedasticity (VAR-EGARCH) model for the volatility spillovers of swap spreads. The multivariate VAR-EGARCH methodology which incorporates the slope of the term structure and corporate spread variables is adopted to investigate volatility spillovers across international swap markets. For example, the multivariate VAR-EGARCH modeling will capture the time-varying nature of swap spread volatility and provide evidence on the volatility transmission mechanism. Unlike univariate GARCH models, EGARCH models permit volatility interactions to be *fully* investigated and analyzed in a one-step estimation procedure. Also, the hypothesis that innovation within and across different swap spreads influences volatility *asymmetrically* can be explicitly tested (Brown et al., 2002).

The remainder of the paper is organized as follows. Section 2 discusses the data and provides descriptive statistics. Section 3 outlines the methodology used. Section 4 presents the empirical results and discusses the findings. Finally, Section 5 provides a summary and conclusion.

2. Data and descriptive statistics

We use daily closing mid-rate data on swap maturities of 3, 5, and 10 years, for the US, Japan, and the UK in the period from January 8, 1996 to June 29, 2001, giving a sample size of 1366 observations for each swap maturity. The swap spread is calculated by subtracting the Treasury bond rate from the swap rate for the same maturity. All three countries' data were collected from Datastream. The slope of the term structure is proxied by the difference between the 10-year Treasury bond rate and the 90-day Treasury bill rate. The spread between the yield on a portfolio of medium-maturity AAA-rated corporate bonds and the yield on comparable BAA-rated corporate bonds is used as a proxy for the corporate spread or the default premium (see Duffie and Singleton, 1997).

[3] The motivation for considering these markets arises from the fact that (in addition to the German and French markets) New York, Tokyo, and London represent the world's major centers for the trading of swap markets. For example, the most common currencies used to dominate interest rate swaps were US dollars (25.5% of the total), Japanese yen (19.2%), and British pound sterling (8.6%) at the end of June 1998. For currency swaps, the US dollar (76.8% of the total), Japanese yen (28.7%), and British pound sterling (11.7%) were the most commonly swapped currencies.

[4] As far as we are aware, the study of Lekkos and Milas (2001) is the only study that investigates short-run international linkages between swap rates. Using weekly data, the Lekkos and Milas study supports strong linkages between the US and the UK swap markets in both directions. However, the use of weekly data can be a potential weakness of the study. In et al. (2003, 2004) argue that due to recent advances in telecommunication and computer technologies, international influences can be rapidly transmitted from one swap market to another, and hence the more frequently the data are observed, the more reliable will be the estimated effects.

The descriptive statistics for the US, Japan, and the UK swap rates and swap spreads for three different maturities are reported in Table 1. As shown in Table 1, on average the yield curves for swaps and swap spreads are upward sloping in the three countries during the sample period. The variances range from 0.230 to 0.808 for swap rates and from 0.010 to 0.109 for swap spreads.

The measures for skewness and kurtosis are also reported to indicate whether swap rates or swap spreads are normally distributed or not. The sign of skewness varies between countries and maturities. The Jarque–Bera (denoted by JB) statistic rejects normality at any level of statistical significance in all cases. The Ljung–Box statistics for 15 lags applied on swap rates and swap spreads (denoted by LB(15) and squared term ($LB^2(15)$)) indicate that significant linear and nonlinear dependencies exist. Nonlinear dependencies can be captured satisfactorily by autoregressive conditional heteroskedasticity models.

Panel C in Table 1 presents the cross correlation for swap rates for three different maturities in the US, Japan, and the UK. The correlation structure of these swap markets is probably the most important feature from the point of view of investors and portfolio managers. Hedging and diversification strategies invariably involve some measure of correlation (In et al., 2001). Overall, the correlation of swap rates between markets increases relative to maturity. According to Panel C of Table 1, the strongest correlation is observed between the UK and Japan, followed by the US and the UK, and the US and Japan.

3. Methodology

To investigate dynamic interdependence and volatility transmission across selected interest rate swap markets, we employ the multivariate VAR-EGARCH model, which has a few distinctive features.

First, a VAR-EGARCH model is more advantageous than the two-step univariate technique because the simultaneous estimation involved in the former allows for the utilization of the information in the entire variance–covariance matrix of the errors (Koutmos, 1996). Second, the multivariate VAR-EGARCH model can explicitly test the hypothesis that innovations within and across markets influence volatility asymmetrically. In many cases, volatility spillovers are asymmetric in the sense that bad news in one market has a greater effect on the volatility of another market than good news (In et al., 2001).

The multivariate VAR-EGARCH model is written as follows:

$$\begin{aligned}\Delta SS_{i,t}^{US} = {} & \beta_{i,0} + \beta_{i,1}\Delta SS_{i,t-1}^{US} + \beta_{i,2}\Delta SS_{i,t-2}^{US} + \beta_{i,3}\Delta SS_{i,t}^{JP} + \beta_{i,4}\Delta SS_{i,t-1}^{JP} + \beta_{i,5}\Delta SS_{i,t}^{UK} \\ & + \beta_{i,6}\Delta SS_{i,t-1}^{UK} + \beta_{i,7}\Delta \mathrm{slope}_{i,t}^{US} + \beta_{i,8}\Delta \mathrm{slope}_{i,t-1}^{US} + \beta_{i,9}\Delta \mathrm{Corpspread}_{i,t}^{US} \\ & + \beta_{i,10}\Delta \mathrm{Corpspread}_{i,t-1}^{US} + \varepsilon_{i,t} \quad \text{for } i = 1,2,3 \end{aligned} \tag{1}$$

$$\begin{aligned}\Delta SS_{i,t}^{JP} = {} & \beta_{i,0} + \beta_{i,1}\Delta SS_{i,t-1}^{US} + \beta_{i,2}\Delta SS_{i,t-2}^{US} + \beta_{i,3}\Delta SS_{i,t-1}^{JP} + \beta_{i,4}\Delta SS_{i,t-2}^{JP} + \beta_{i,5}\Delta SS_{i,t-1}^{UK} \\ & + \beta_{i,6}\Delta SS_{i,t-2}^{UK} + \beta_{i,7}\Delta \mathrm{slope}_{i,t}^{JP} + \beta_{i,8}\Delta \mathrm{slope}_{i,t-1}^{JP} + \beta_{i,9}\Delta \mathrm{Corpspread}_{i,t}^{JP} \\ & + \beta_{i,10}\Delta \mathrm{Corpspread}_{i,t-1}^{JP} + \varepsilon_{i,t} \quad \text{for } i = 1,2,3 \end{aligned} \tag{2}$$

Table 1
Preliminary statistics

	US			Japan			UK		
	3 years	5 years	10 years	3 years	5 years	10 years	3 years	5 years	10 years
Panel A. Descriptive statistics of swap rates									
Mean	6.169	6.333	6.573	0.996	1.498	2.295	6.632	6.666	6.659
Variance	0.438	0.392	0.345	0.230	0.346	0.373	0.432	0.510	0.808
Skewness	−0.072	−0.084	−0.159	0.855	0.707	0.461	−0.828	−0.434	0.379
Kurtosis	−0.584	−0.743	−0.914	0.266	−0.025	−0.438	−0.524	−0.726	−0.936
JB	20.598	33.064	53.271	170.254	113.848	59.253	171.694	72.804	82.491
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LB(15)	18 878.3	18 922.2	18 926.2	19 226.3	19 255.0	19 165.4	19 419.8	19 534.9	19 822.9
for R_t	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LB(15)	18 921.1	18 904.6	18 870.5	19 163.3	19 450.6	19 366.4	19 323.4	19 483.3	19 836.3
for R_t^2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Panel B. Descriptive statistics of swap spreads									
Mean	0.493	0.590	0.705	0.184	0.187	0.267	0.454	0.560	0.649
Variance	0.044	0.070	0.091	0.021	0.010	0.011	0.042	0.058	0.109
Skewness	0.241	0.211	0.493	0.041	−0.471	0.146	0.261	0.207	0.264
Kurtosis	−1.195	−1.364	−0.913	−0.861	−0.245	0.074	−0.314	−1.256	−1.323
JB	94.473	116.034	102.737	42.606	53.978	5.144	21.132	99.563	115.593
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.076)	(0.000)	(0.000)	(0.000)
LB(15)	18 717.5	19 250.8	19 471.8	16 491.7	12 097.6	13 446.8	18 430.6	19 134.4	19 814.1
for R_t	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LB(15)	18 406.9	18 857.3	19 217.0	16 143.3	9057.8	12 950.2	17 537.7	18 324.5	19 452.8
for R_t^2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Panel C. Cross correlations of swap rates

	US	US ($t-1$)	Japan	Japan ($t-1$)	UK	UK ($t-1$)
Panel C.1. 3-year swap rates						
US	1.000	0.996	0.266	0.264	0.562	0.560
US ($t-1$)		1.000	0.263	0.263	0.560	0.561
Japan			1.000	0.997	0.634	0.634
Japan ($t-1$)				1.000	0.632	0.633
UK					1.000	0.997
UK ($t-1$)						1.000
Panel C.2. 5-year swap rates						
US	1.000	0.996	0.360	0.359	0.572	0.570
US ($t-1$)		1.000	0.357	0.357	0.570	0.571
Japan			1.000	0.998	0.795	0.794
Japan ($t-1$)				1.000	0.794	0.794
UK					1.000	0.997
UK ($t-1$)						1.000
Panel C.3. 10-year swap rates						
US	1.000	0.995	0.465	0.465	0.538	0.536
US ($t-1$)		1.000	0.463	0.463	0.536	0.537
Japan			1.000	0.998	0.884	0.883
Japan ($t-1$)				1.000	0.884	0.884
UK					1.000	0.998
UK ($t-1$)						1.000

Significance levels are in parentheses.

$$\begin{aligned}\Delta \mathrm{SS}_{i,t}^{\mathrm{UK}} = {} & \beta_{i,0} + \beta_{i,1}\Delta \mathrm{SS}_{i,t-1}^{\mathrm{US}} + \beta_{i,2}\Delta \mathrm{SS}_{i,t-2}^{\mathrm{US}} + \beta_{i,3}\Delta \mathrm{SS}_{i,t}^{\mathrm{JP}} + \beta_{i,4}\Delta \mathrm{SS}_{i,t-1}^{\mathrm{JP}} + \beta_{i,5}\Delta \mathrm{SS}_{i,t-1}^{\mathrm{UK}} \\ & + \beta_{i,6}\Delta \mathrm{SS}_{i,t-2}^{\mathrm{UK}} + \beta_{i,7}\Delta \mathrm{slope}_{i,t}^{\mathrm{UK}} + \beta_{i,8}\Delta \mathrm{slope}_{i,t-1}^{\mathrm{UK}} + \beta_{i,9}\Delta \mathrm{Corpspread}_{i,t}^{\mathrm{UK}} \\ & + \beta_{i,10}\Delta \mathrm{Corpspread}_{i,t-1}^{\mathrm{UK}} + \varepsilon_{i,t} \quad \text{for } i = 1,2,3 \end{aligned} \tag{3}$$

$$\begin{aligned} h_{i,t}^{\mathrm{US}} = {} & \exp\left\{\alpha_{i,0} + \alpha_{1,1} f\left(Z_{i,t-1}^{\mathrm{US}}\right) + \alpha_{1,2} f\left(Z_{i,t}^{\mathrm{JP}}\right) + \alpha_{1,3} f\left(Z_{i,t}^{\mathrm{UK}}\right) + \gamma_i \ln\left(h_{i,t-1}^{\mathrm{US}}\right)\right\} \\ & \text{for } i = 1,2,3 \end{aligned} \tag{4}$$

$$\begin{aligned} h_{i,t}^{\mathrm{JP}} = {} & \exp\left\{\alpha_{i,0} + \alpha_{2,1} f\left(Z_{i,t-1}^{\mathrm{US}}\right) + \alpha_{2,2} f\left(Z_{i,t-1}^{\mathrm{JP}}\right) + \alpha_{2,3} f\left(Z_{i,t-1}^{\mathrm{UK}}\right) + \gamma_i \ln\left(h_{i,t-1}^{\mathrm{JP}}\right)\right\} \\ & \text{for } i = 1,2,3 \end{aligned} \tag{5}$$

$$\begin{aligned} h_{i,t}^{\mathrm{UK}} = {} & \exp\left\{\alpha_{i,0} + \alpha_{3,1} f\left(Z_{i,t-1}^{\mathrm{US}}\right) + \alpha_{3,2} f\left(Z_{i,t}^{\mathrm{JP}}\right) + \alpha_{3,3} f\left(Z_{i,t-1}^{\mathrm{UK}}\right) + \gamma_i \ln\left(h_{i,t-1}^{\mathrm{UK}}\right)\right\} \\ & \text{for } i = 1,2,3 \end{aligned} \tag{6}$$

$$f\left(Z_{i,t-1}^{\mathrm{US}}\right) = \left(\left|Z_{i,t-1}^{\mathrm{US}}\right| - E\left(\left|Z_{i,t-1}^{\mathrm{US}}\right|\right) + \delta_i Z_{i,t-1}^{\mathrm{US}}\right) \quad \text{for } i = 1,2,3 \tag{7}$$

$$f\left(Z_{i,t-1}^{\mathrm{JP}}\right) = \left(\left|Z_{i,t-1}^{\mathrm{JP}}\right| - E\left(\left|Z_{i,t-1}^{\mathrm{JP}}\right|\right) + \delta_i Z_{i,t-1}^{\mathrm{JP}}\right) \quad \text{for } i = 1,2,3 \tag{8}$$

$$f\left(Z_{i,t-1}^{\mathrm{UK}}\right) = \left(\left|Z_{i,t-1}^{\mathrm{UK}}\right| - E\left(\left|Z_{i,t-1}^{\mathrm{UK}}\right|\right) + \delta_i Z_{i,t-1}^{\mathrm{UK}}\right) \quad \text{for } i = 1,2,3 \tag{9}$$

$$h_{i,jk,t} = \rho_{i,jk}\sqrt{h_{i,t}^{j} h_{i,t}^{k}} \quad \text{for } j,k = \text{US, JP, UK and } j \neq k \tag{10}$$

where $\Delta \mathrm{SS}_{i,t}^{j}$ (j = US, JP, UK) indicate the change in the swap spread on day t for swap maturities $i = 1, 2, 3$. For example, in this study, 1, 2, and 3 refer, respectively, to swaps with maturities of 3, 5, and 10 years. Note that Eqs. (1)–(3) describe the change in swap spread as a function of its own lagged swap spread, the lagged swap spread of other countries, and its own lagged slopes and corporate spreads, respectively.[5]

Hence, the coefficients ($\beta_{i,1}$,…,$\beta_{i,6}$) capture the swap spread spillover effects between the three countries as well as own country's past influence. For example, a statistically significant $\beta_{i,1}$ and $\beta_{i,2}$ in Eq. (2) suggest a swap spread spillover effect from the US to Japan, whereas a significant $\beta_{i,3}$ and $\beta_{i,4}$ in Eq. (1) indicate a swap spread spillover effect from Japan to the US. Note that as the Japanese swap market is closed before the US swap market opens for a given calendar day, spillover effects from the former to the latter, if any, could occur in the same day t. Bi-directional spillover exists if all four coefficients are statistically significant. The term $h_{i,t}^{j}$ indicates the conditional variance for countries j (j = US, JP, UK) and swap maturities i ($i = 1, 2, 3$). The $Z_{i,t}^{j}$ is the standardized innovation (i.e., $\varepsilon_{i,t}/\sqrt{h_{i,t}}$) for countries j (j = US, JP, UK), and $\varepsilon_{i,t}$ is the innovation at time t.

[5] Recent empirical work (see Lekkos and Milas, 2001, 2004; Ang and Bekaert, 2002) has shown that the slope of the term structure (as a prediction of future economic conditions) has an important effect on the determination of swap spreads. Lekkos and Milas (2001, 2004) further show that this effect may be different for shorter and longer maturities. Lekkos and Milas (2001) also find that the corporate bond spread affects long-maturity swap spreads, while the liquidity premium has an impact on short-term swap spreads. Therefore, the *joint* estimation of the conditional mean and variance requires a more reliable and comprehensive swap model such as the VAR-EGARCH model using these variables.

Eqs. (4)–(6) specify the conditional variance of swap spread in each swap market (i.e., US, Japan, and UK) as an exponential function of its own lagged standardized innovations, the standardized innovations from the other countries, and own lagged conditional variance, respectively.

Volatility spillover of the swap spread is present if the $\alpha_{i,j}$s, $i \neq j$, in Eqs. (4)–(6) are significant. For example, a significant $\alpha_{1,2}$ suggests a volatility spillover from the Japanese swap market to the US swap market, whereas a significant $\alpha_{2,1}$ is indicative of a volatility spillover from the US swap market to the Japanese swap market. Since volatility reflects the rate of information flow, a statistically significant $\alpha_{i,j}$, $i \neq j$, suggests information transmission between two markets i and j. The coefficient γ_i in Eqs. (4)–(6) measures the degree of volatility persistence. A high value of γ_i indicates that an information shock tends to persist for some time into the future. The parameter δ_i in Eqs. (7)–(9) measures the asymmetric volatility transmission mechanism. For example, note that a statistically significant coefficient $\alpha_{2,1}$ in Eq. (5) indicates the volatility spillovers from the US (market 1) to Japan (market 2). Whether or not these spillovers are asymmetric is measured by δ_i in Eq. (7). A negative and statistically significant δ_i in Eq. (7) indicates that negative shocks in the US increase volatility in Japan more than positive shocks.

Eq. (10) provides the specification for the conditional covariance, where $h_{i,jk,t}$ is the conditional covariance and $\rho_{i,jk}$ is the cross-market correlation coefficient of the standardized residuals between market j and market k (j, k = US, JP, UK and $j \neq k$). We follow Bollerslev et al. (1992) and assume constant conditional correlations over time. Under a conditional normality assumption and given a sample of T observations, the log likelihood function for the multivariate VAR-EGARCH model is

$$L(\theta) = -0.5(NT)\ln(2\pi) - 0.5\Sigma\left(\ln|H| + \varepsilon_t' H_t^{-1} \varepsilon_t\right). \tag{11}$$

4. Empirical results

The empirical results of the multivariate VAR-EGARCH model are presented in this section. To investigate the swap market linkages and volatility interactions across the countries, we estimate the full version of maximum likelihood estimates of the VAR-EGARCH model for three different maturities in the three major swap markets. First, we focus on the parameters describing the swap spread spillovers from Panel A.1 of Table 2. We find that changes in the swap spreads in each market are influenced by the own past swap spread changes for 3-year, 5-year, and 10-year swap spread maturity. Swap spread own-variations are almost all significant in all three currencies (i.e., 17 out of 18 cases of significant coefficients). Furthermore, for the 5-year swap spread, from Panel B.1 of Table 2, we find that there are some significant multidirectional lead–lag relationships between swap spread spillovers. For example, the change in the swap spreads in Japan is influenced not only by the own past swap spreads ($\beta_{2,3}$ and $\beta_{2,4}$) but also by the past US and UK swap spreads ($\beta_{2,1}$ and $\beta_{2,6}$). Similarly, the UK is influenced not only by the own past swap spreads ($\beta_{3,5}$ and $\beta_{3,6}$) but also by the past US swap spreads ($\beta_{3,1}$ and $\beta_{3,2}$) and Japanese swap spreads ($\beta_{3,3}$). Finally, the change in the US swap spreads is influenced by the past UK swap spreads ($\beta_{1,5}$ and $\beta_{1,6}$) and Japanese swap spread ($\beta_{1,3}$) for the 5-year swap spread. For the 10-year swap spread (Panel C.1), the multidirectional lead–lag relationships are fairly significant in the US and the UK swap markets. For example, significant reciprocal swap spread spillovers exist between the UK and the US ($\beta_{1,5,}$ $\beta_{1,6}$ and $\beta_{3,1}$ are significant).

Regarding the effect of the slope on the swap spread, the changes in the swap spreads in all three currencies are influenced by the slope of that currency's term structure. Especially, we find that the changes in the swap spreads in both the US and the UK, regardless of the maturity, are significantly influenced by the slope of the term structure. It is interesting to observe that, in general, as the maturity of the swap lengthens (e.g., to the 10-year swap spread), the contribution of the slope of the term structure becomes significant for all three markets. One explanation for the importance of the slope of the term structure is its association with an economy's growth rate and business conditions, which in turn affect credit quality and thus the swap spread. This result is consistent with those reported by Duffie and Singleton (1997) and Lekkos and Milas (2001). Our results show that the effect of corporate spreads on the swap spread depends on the swap maturity and country. For the 3-year swap spread, the change in the swap spreads in Japan and the UK are influenced by the own corporate spreads ($\beta_{2,9}$, $\beta_{2,10}$ and $\beta_{3,9}$ are significant).

Regarding the volatility spillovers, first note that the conditional variance in each swap spread is significantly affected (positively) by its own past standardized innovations in all maturities (for example, we find that for the 3-year swap spread, $\alpha_{1,1} = 0.260$, $\alpha_{2,2} = 0.218$ $\alpha_{3,3} = 0.375$, for the 5-year swap spread, $\alpha_{1,1} = 0.300$, $\alpha_{2,2} = 0.299$, and $\alpha_{3,3} = 0.317$, and for the 10-year swap spread, $\alpha_{1,1} = 0.257$, $\alpha_{2,2} = 0.432$, and $\alpha_{3,3} = 0.472$).

Second, another important empirical finding is that there are significant volatility spillovers from the US to Japan (i.e., $\alpha_{2,1} = 0.087$ for 3-year swap maturity, $\alpha_{2,1} = 0.093$ for 5-year swap maturity, and $\alpha_{2,1} = 0.122$ for 10-year swap maturity are all statistically significant), but *not*

Table 2
Dynamic interaction between international swap spreads

Mean

$$\Delta SS_{i,t}^{US} = \beta_{i,0} + \beta_{i,1}\Delta SS_{i,t-1}^{US} + \beta_{i,2}\Delta SS_{i,t-2}^{US} + \beta_{i,3}\Delta SS_{i,t}^{JP} + \beta_{i,4}\Delta SS_{i,t-1}^{JP} + \beta_{i,5}\Delta SS_{i,t}^{UK} + \beta_{i,6}\Delta SS_{i,t-1}^{UK} + \beta_{i,7}\Delta \mathrm{slope}_{i,t}^{US} + \beta_{i,8}\Delta \mathrm{slope}_{i,t-1}^{US} + \beta_{i,9}\Delta \mathrm{Corpspread}_{i,t}^{US} + \beta_{i,10}\Delta \mathrm{Corpspread}_{i,t-1}^{US} + \varepsilon_{i,t}$$

$$\Delta SS_{i,t}^{JP} = \beta_{i,0} + \beta_{i,1}\Delta SS_{i,t-1}^{US} + \beta_{i,2}\Delta SS_{i,t-2}^{US} + \beta_{i,3}\Delta SS_{i,t-1}^{JP} + \beta_{i,4}\Delta SS_{i,t-2}^{JP} + \beta_{i,5}\Delta SS_{i,t-1}^{UK} + \beta_{i,6}\Delta SS_{i,t-2}^{UK} + \beta_{i,7}\Delta \mathrm{slope}_{i,t}^{JP} + \beta_{i,8}\Delta \mathrm{slope}_{i,t-1}^{JP} + \beta_{i,9}\Delta \mathrm{Corpspread}_{i,t}^{JP} + \beta_{i,10}\Delta \mathrm{Corpspread}_{i,t-1}^{JP} + \varepsilon_{i,t}$$

$$\Delta SS_{i,t}^{UK} = \beta_{i,0} + \beta_{i,1}\Delta SS_{i,t-1}^{US} + \beta_{i,2}\Delta SS_{i,t-2}^{US} + \beta_{i,3}\Delta SS_{i,t}^{JP} + \beta_{i,4}\Delta SS_{i,t-1}^{JP} + \beta_{i,5}\Delta SS_{i,t-1}^{UK} + \beta_{i,6}\Delta SS_{i,t-2}^{UK} + \beta_{i,7}\Delta \mathrm{slope}_{i,t}^{UK} + \beta_{i,8}\Delta \mathrm{slope}_{i,t-1}^{UK} + \beta_{i,9}\Delta \mathrm{Corpspread}_{i,t}^{UK} + \beta_{i,10}\Delta \mathrm{Corpspread}_{i,t-1}^{UK} + \varepsilon_{i,t}$$

Variance

$$h_{i,t}^{US} = \exp\{\alpha_{i,0} + \alpha_{1,1}f(Z_{t-1}^{US}) + \alpha_{1,2}f(Z_t^{JP}) + \alpha_{1,3}f(Z_t^{UK}) + \gamma_i \ln(h_{t-1}^{US})\}$$

$$h_{i,t}^{JP} = \exp\{\alpha_{i,0} + \alpha_{2,1}f(Z_{t-1}^{US}) + \alpha_{2,2}f(Z_{t-1}^{JP}) + \alpha_{2,3}f(Z_{t-1}^{UK}) + \gamma_i \ln(h_{t-1}^{JP})\}$$

$$h_{i,t}^{UK} = \exp\{\alpha_{i,0} + \alpha_{3,1}f(Z_{t-1}^{US}) + \alpha_{3,2}f(Z_t^{JP}) + \alpha_{3,3}f(Z_{t-1}^{UK}) + \gamma_i \ln(h_{t-1}^{UK})\}$$

$$f(Z_{t-1}^j) = (|Z_{t-1}^j| - E(|Z_{t-1}^j|) + \delta_i Z_{t-1}^j) \quad \text{for } j = \text{US, JP, UK}$$

$$\sigma_{j,k,t} = h_{i,jk,t} = \rho_{i,jk}\sqrt{h_{i,t}^j h_{i,t}^k} \quad \text{for } j,k = \text{US, JP, UK and } j \neq k$$

Notes: As preliminary tests, we use two methods for the test of unit roots: Augmented Dicky–Fuller (ADF) and Park–Choi (PC). The RATS statistical package was used to carry out these tests for all swap spreads, slopes and corporate spreads in all three currencies. Both tests support the unit root hypotheses at the 5% significance level for all data series. Hence, the VAR-EGARCH swap models were conducted using first differences (see In et al., 2003, 2004). To conserve space, we do not present results, but complete results of the unit root tests are available from the author on request. The two lags for VAR-EGARCH model specification was supported by Akaike–Schwartz lag length criteria test.

Panel A.1
Estimated coefficients for 3-year swap spread

US		Japan		UK	
$\beta_{1,0}$	0.000 (0.001)	$\beta_{2,0}$	0.000 (0.001)	$\beta_{3,0}$	0.000 (0.001)
$\beta_{1,1}$	−0.483* (0.027)	$\beta_{2,1}$	−0.016 (0.023)	$\beta_{3,1}$	0.014 (0.016)
$\beta_{1,2}$	−0.240* (0.028)	$\beta_{2,2}$	0.027 (0.022)	$\beta_{3,2}$	0.003 (0.016)
$\beta_{1,3}$	−0.030 (0.048)	$\beta_{2,3}$	−0.243* (0.028)	$\beta_{3,3}$	0.095* (0.036)
$\beta_{1,4}$	0.007 (0.025)	$\beta_{2,4}$	−0.150* (0.028)	$\beta_{3,4}$	0.021 (0.020)
$\beta_{1,5}$	−0.108 (0.076)	$\beta_{2,5}$	−0.002 (0.033)	$\beta_{3,5}$	−0.179* (0.031)
$\beta_{1,6}$	−0.066 (0.041)	$\beta_{2,6}$	−0.011 (0.030)	$\beta_{3,6}$	−0.066* (0.023)
$\beta_{1,7}$	−0.157* (0.013)	$\beta_{2,7}$	−0.008 (0.005)	$\beta_{3,7}$	−0.072* (0.007)
$\beta_{1,8}$	0.044* (0.016)	$\beta_{2,8}$	0.000 (0.007)	$\beta_{3,8}$	−0.014 (0.008)
$\beta_{1,9}$	0.030 (0.018)	$\beta_{2,9}$	0.043* (0.009)	$\beta_{3,9}$	0.039* (0.007)
$\beta_{1,10}$	−0.035 (0.025)	$\beta_{2,10}$	0.029* (0.011)	$\beta_{3,10}$	0.011 (0.008)
$\alpha_{1,0}$	−0.579 (0.136)	$\alpha_{2,0}$	−0.481* (0.055)	$\alpha_{3,0}$	−6.142* (0.100)
$\alpha_{1,1}$	0.260* (0.033)	$\alpha_{2,1}$	0.087* (0.016)	$\alpha_{3,1}$	0.004 (0.032)
$\alpha_{1,2}$	0.013 (0.024)	$\alpha_{2,2}$	0.218* (0.024)	$\alpha_{3,2}$	0.040 (0.027)
$\alpha_{1,3}$	0.020 (0.025)	$\alpha_{2,3}$	0.092* (0.018)	$\alpha_{3,3}$	0.375* (0.036)
δ_1	0.037 (0.071)	δ_2	0.366* (0.077)	δ_3	0.225* (0.071)
γ_1	0.910* (0.021)	γ_2	0.925* (0.008)	γ_3	0.966* (0.013)
$\rho_{1,2}$	0.077 (0.146)	$\rho_{1,3}$	0.188* (0.082)	$\rho_{2,3}$	−0.145* (0.073)

Notes: This table reports the estimated coefficients for the 3-year swap spreads of three countries. * indicates significance at 5% level. The heteroskedasticity-adjusted standard errors are reported in parentheses.

Panel A.2
Diagnostic tests for standardized innovations

	US	Japan	UK
Mean	0.017	0.005	0.006
Variance	0.966	1.075	1.046
Skewness	−0.091	0.011	−0.133
Kurtosis	1.613	7.974	9.208
LB(20) for $Z_{i,t}$	54.612 (0.000)	43.942 (0.000)	11.742 (0.816)
LB(20) for $Z_{i,t}^2$	24.863 (0.098)	22.298 (0.174)	5.468 (0.996)

Notes: This table illustrates the summary statistics for the standardized innovations. The standardized innovations are calculated by $Z_t^j = \varepsilon_t^j / \sqrt{h_t^j}$ for $j =$ US, JP, UK. LB(n) is the Ljung–Box statistic for up to n lags, distributed as χ^2 with n degrees of freedom. Skewness and kurtosis are defined as $E[(R_t - \mu)]^3$ and $E[(R_t - \mu)]^4$, respectively, where μ is the sample mean.

Panel A.3
Correlation matrix for standardized innovations

	US	Japan	UK
US	1.000	0.071	0.154
Japan		1.000	−0.078
UK			1.000

Panel B.1
Estimated coefficients for 5-year swap spread

US		Japan		UK	
$\beta_{1,0}$	0.000* (0.000)	$\beta_{2,0}$	0.000* (0.000)	$\beta_{3,0}$	0.000 (0.001)
$\beta_{1,1}$	−0.510* (0.024)	$\beta_{2,1}$	−0.070* (0.023)	$\beta_{3,1}$	0.052* (0.016)
$\beta_{1,2}$	−0.213* (0.024)	$\beta_{2,2}$	−0.010 (0.021)	$\beta_{3,2}$	0.036* (0.015)
$\beta_{1,3}$	−0.191* (0.039)	$\beta_{2,3}$	−0.302* (0.026)	$\beta_{3,3}$	0.134* (0.029)
$\beta_{1,4}$	−0.032 (0.022)	$\beta_{2,4}$	−0.167* (0.026)	$\beta_{3,4}$	0.029 (0.019)
$\beta_{1,5}$	−0.236* (0.067)	$\beta_{2,5}$	−0.041 (0.039)	$\beta_{3,5}$	−0.200* (0.029)
$\beta_{1,6}$	−0.137* (0.037)	$\beta_{2,6}$	0.084* (0.035)	$\beta_{3,6}$	−0.101* (0.023)
$\beta_{1,7}$	−0.195* (0.011)	$\beta_{2,7}$	−0.011 (0.007)	$\beta_{3,7}$	−0.076* (0.007)
$\beta_{1,8}$	0.050* (0.012)	$\beta_{2,8}$	0.004 (0.007)	$\beta_{3,8}$	−0.053* (0.007)
$\beta_{1,9}$	0.023 (0.012)	$\beta_{2,9}$	0.006 (0.008)	$\beta_{3,9}$	0.038* (0.007)
$\beta_{1,10}$	−0.029 (0.021)	$\beta_{2,10}$	0.022* (0.009)	$\beta_{3,10}$	−0.001 (0.008)
$\alpha_{1,0}$	−0.976* (0.162)	$\alpha_{2,0}$	−1.504* (0.111)	$\alpha_{3,0}$	−2.871* (0.225)
$\alpha_{1,1}$	0.300* (0.035)	$\alpha_{2,1}$	0.093* (0.024)	$\alpha_{3,1}$	0.188* (0.030)
$\alpha_{1,2}$	−0.009 (0.019)	$\alpha_{2,2}$	0.299* (0.034)	$\alpha_{3,2}$	0.157* (0.028)
$\alpha_{1,3}$	0.020 (0.028)	$\alpha_{2,3}$	0.249* (0.023)	$\alpha_{3,3}$	0.317* (0.029)
δ_1	0.151* (0.056)	δ_2	0.073 (0.055)	δ_3	0.044 (0.051)
γ_1	0.852* (0.025)	γ_2	0.773* (0.017)	γ_3	0.907* (0.031)
$\rho_{1,2}$	0.228* (0.048)	$\rho_{1,3}$	0.299* (0.107)	$\rho_{2,3}$	−0.150* (0.066)

Notes: This table reports the estimated coefficients for the 3-year swap spreads of three countries. * indicates significance at 5% level. The heteroskedasticity-adjusted standard errors are reported in parentheses.

Panel B.2
Diagnostic tests for standardized innovations

	US	Japan	UK
Mean	0.024	0.017	0.015
Variance	1.076	1.091	1.053
Skewness	0.000	0.579	0.373
Kurtosis	1.382	8.946	4.421
LB(20) for $Z_{i,t}$	34.730 (0.007)	46.767 (0.000)	25.123 (0.092)
LB(20) for $Z_{i,t}^2$	26.174 (0.071)	97.391 (0.000)	22.309 (0.173)

Notes: This table illustrates the summary statistics for the standardized innovations. The standardized innovations are calculated by $Z_t^j = \varepsilon_t^j / \sqrt{h_t^j}$ for $j =$ US, JP, UK. LB(n) is the Ljung–Box statistic for up to n lags, distributed as χ^2 with n degrees of freedom. Skewness and kurtosis are defined as $E[(R_t - \mu)]^3$ and $E[(R_t - \mu)]^4$, respectively, where μ is the sample mean.

Panel B.3
Correlation matrix for standardized innovations

	US	Japan	UK
US	1.000	0.229	0.226
Japan		1.000	−0.116
UK			1.000

Panel C.1
Estimated coefficients for 10-year swap spread

US		Japan		UK	
$\beta_{1,0}$	−0.001* (0.000)	$\beta_{2,0}$	−0.001* (0.000)	$\beta_{3,0}$	0.000 (0.001)
$\beta_{1,1}$	−0.475* (0.024)	$\beta_{2,1}$	−0.018 (0.015)	$\beta_{3,1}$	0.042* (0.012)
$\beta_{1,2}$	−0.213* (0.022)	$\beta_{2,2}$	−0.006 (0.015)	$\beta_{3,2}$	0.022 (0.012)
$\beta_{1,3}$	−0.050 (0.055)	$\beta_{2,3}$	−0.366* (0.028)	$\beta_{3,3}$	0.019 (0.018)
$\beta_{1,4}$	−0.030 (0.028)	$\beta_{2,4}$	−0.224* (0.028)	$\beta_{3,4}$	0.012 (0.013)
$\beta_{1,5}$	−0.377* (0.083)	$\beta_{2,5}$	−0.040 (0.027)	$\beta_{3,5}$	−0.131* (0.025)
$\beta_{1,6}$	−0.132* (0.038)	$\beta_{2,6}$	0.010 (0.027)	$\beta_{3,6}$	−0.004 (0.020)
$\beta_{1,7}$	−0.218* (0.011)	$\beta_{2,7}$	−0.017* (0.006)	$\beta_{3,7}$	−0.085* (0.007)
$\beta_{1,8}$	0.059* (0.013)	$\beta_{2,8}$	−0.012* (0.005)	$\beta_{3,8}$	−0.038* (0.007)
$\beta_{1,9}$	0.031* (0.015)	$\beta_{2,9}$	−0.034* (0.007)	$\beta_{3,9}$	0.020* (0.007)
$\beta_{1,10}$	−0.023 (0.018)	$\beta_{2,10}$	−0.004 (0.007)	$\beta_{3,10}$	0.001 (0.006)
$\alpha_{1,0}$	−1.456* (0.197)	$\alpha_{2,0}$	−0.776* (0.057)	$\alpha_{3,0}$	−6.437* (0.079)
$\alpha_{1,1}$	0.257* (0.025)	$\alpha_{2,1}$	0.122* (0.023)	$\alpha_{3,1}$	−0.003 (0.040)
$\alpha_{1,2}$	−0.007 (0.027)	$\alpha_{2,2}$	0.432* (0.034)	$\alpha_{3,2}$	0.059* (0.026)
$\alpha_{1,3}$	0.103* (0.041)	$\alpha_{2,3}$	0.078* (0.021)	$\alpha_{3,3}$	0.472* (0.044)
δ_1	−0.045 (0.065)	δ_2	0.120* (0.048)	δ_3	−0.050 (0.060)
γ_1	0.783* (0.031)	γ_2	0.886* (0.008)	γ_3	0.948* (0.010)
$\rho_{1,2}$	0.128 (0.131)	$\rho_{1,3}$	0.343* (0.110)	$\rho_{2,3}$	−0.020 (0.045)

Notes: This table reports the estimated coefficients for the 3-year swap spreads of three countries. * indicates significance at 5% level. The heteroskedasticity-adjusted standard errors are reported in parentheses.

Panel C.2
Diagnostic tests for standardized innovations

	US	Japan	UK
Mean	0.036	0.025	0.027
Variance	1.184	1.055	1.110
Skewness	0.167	0.159	1.317
Kurtosis	1.278	4.235	12.963
LB(20) for $Z_{i,t}$	22.108 (0.181)	45.866 (0.000)	36.820 (0.004)
LB(20) for $Z_{i,t}^2$	19.649 (0.293)	27.252 (0.054)	24.489 (0.107)

Notes: This table illustrates the summary statistics for the standardized innovations. The standardized innovations are calculated by $Z_t^j = \varepsilon_t^j / \sqrt{h_t^j}$ for $j =$ US, JP, UK. LB(n) is the Ljung–Box statistic for up to n lags, distributed as χ^2 with n degrees of freedom. Skewness and kurtosis are defined as $E[(R_t - \mu)]^3$ and $E[(R_t - \mu)]^4$, respectively, where μ is the sample mean.

Panel C.3
Correlation matrix for standardized innovations

	US	Japan	UK
US	1.000	0.042	0.289
Japan		1.000	−0.004
UK			1.000

vice versa. Insignificant coefficients ($\alpha_{1,2}$) for all swap maturities indicate that there are no direct volatility spillovers from Japan to the US. Furthermore, there are (relatively less significant) reciprocal volatility spillovers between the US and the UK (i.e., from the US to the UK for 5-year swap spread, $\alpha_{3,1} = 0.188$ and from the UK to the US for 10-year swap spread, $\alpha_{1,3} = 0.103$).

In contrast, in many cases, there are strong reciprocal volatility spillovers between the Japanese and the UK swap markets. For example, for 5-year swap spread maturity, reciprocal volatility spillovers are found to exist between the UK and Japanese swap markets (i.e., coefficients $\alpha_{2,3} = 0.249$ and $\alpha_{3,2} = 0.157$ are significant for 5-year swap maturity — note that $\alpha_{3,2} = 0.059$ and $\alpha_{2,3} = 0.078$ for the 10-year swap spread, and for 3-year swap spread, there is one way volatility spillover from the UK to Japan ($\alpha_{2,3} = 0.092$)).

As shown in Panels A.1, B.1 and C.1 of Table 2, the degree of volatility persistence (measured by γ_i) is fairly large in all three currencies and maturities. The estimated coefficients are all statistically significant for 3-, 5-, and 10-year swap maturities, ranging from 0.910 to 0.966 for 3-year swap maturity, from 0.773 to 0.907 for 5-year swap maturity, and from 0.783 to 0.948 for 10-year swap maturity. In many cases, volatility spillovers are asymmetric (measured by δ_i), evidenced by $\delta_2 = 0.366$ and $\delta_3 = 0.225$ for the 3-year swap spread, $\delta_1 = 0.151$ for the 5-year swap spread, and $\delta_2 = 0.120$ for the 10-year swap spread.

Overall, we conclude that the main empirical results support our decision to use the VAR-EGARCH approach to model volatility spillovers of change in the swap spread.

5. Concluding remarks

The main purposes of this empirical research are to investigate the issue of volatility spillovers across the three major international swap markets, namely, the US, Japan, and the UK, and to document and measure the direction and strength of the linkage between these markets. In this paper, we have developed a multivariate VAR-EGARCH model which incorporates the slope of term structure and corporate spread variables and have tested for volatility spillovers across the three major international swap markets by modeling the time-varying nature of the swap spread volatility across countries.

Analysis using a multivariate VAR-EGARCH approach supports five conclusions. First, regarding the effect of the slope on the swap spread, the changes in the swap spreads in all three currencies are significantly influenced by the slope of the domestic term structure of interest rates, and the longer the maturity of the swap, the greater its contribution. Second, overall, the US swap market has a dominant influence on the Japanese and UK swap markets, but *not* vice versa. Third, during the sample period, we find that there are significant reciprocal volatility spillovers between the Japanese and the UK swap markets, but relatively less significant reciprocal volatility spillovers between the US and the UK swap markets, depending on the swap maturity. Fourth, the degree of volatility persistence is fairly strong in all three currencies and maturities and in many cases, close to one. Fifth, in many cases, volatility spillovers are asymmetric both across maturity and country.

References

Ang, A., Bekaert, G., 2002. Regime switches in interest rates. Journal of Business and Economics Statistics 20, 163−182.

Bank for International Settlements, 1996. BIS Quarterly Review Statistical Annex, August, Table 17A.

Bank for International Settlements, 2002. Table D-2. <www.bis.org/statistics/otc_hy0201det.pdf> (Website accessed 01.05.02.).

Bodart, V., Reding, P., 1999. Exchange rate regime, volatility and international correlations on bond and stock markets. Journal of International Money and Finance 18, 133–151.

Bodnar, G.M., Hayt, G.S., Marston, R.C., Smithson, C.W., 1995. Wharton survey of derivatives usage by US non-financial firms. Financial Management 24, 104–114.

Bollerslev, T., Chou, R., Kroner, K., 1992. ARCH modeling in finance: theory and empirical evidence. Journal of Econometrics 37, 5–59.

Booth, G.G., Chowdhury, M., Martikainen, T., Tse, Y., 1997. Intraday volatility in international stock index futures markets: meteor showers or heat waves? Management Science 43, 1564–1576.

Brown, R., In, F., Fang, V., 2002. Modeling the determinants of swap spreads. The Journal of Fixed Income 12, 29–40.

Chinn, M.D., Frankel, J.A., 1995. Who drives real interest rates around the Pacific Rim: the USA or Japan? Journal of International Money and Finance 14, 801–821.

Duffie, D., Singleton, K.J., 1997. An econometric model of the term structure of interest-rate swap yields. Journal of Finance 52, 1287–1321.

Dutton, M.M., 1993. Real interest rate parity: new measures and tests. Journal of International Money and Finance 12, 62–77.

Eom, Y.H., Subrahmanyam, M.G., Uno, J., 2001. Credit risk and the yen interest rate swap market. Working paper 042, Stern Business School, New York.

Eom, Y.H., Subrahmanyam, M.G., Uno, J., 2002. The international linkages of interest rate swap spreads: the yen–dollar markets. Journal of Fixed Income 12, 6–28.

Fehle, F., 2000. The components of interest rate swap spreads: theory and international evidence. Unpublished manuscript, University of South Carolina.

Goodwin, B.K., Grennes, T.J., 1994. Real interest rate equalization and the integration of international financial markets. Journal of International Money and Finance 13, 107–124.

Hamao, Y.R., Masulis, W., Ng, V.K., 1990. Correlations in price changes and volatility across international stock markets. Review of Financial Studies 3, 281–307.

In, F., Brown, R., Fang, V., 2003. Links among interest rate swap markets: US, UK, and Japan. Journal of Fixed Income 13, 84–95.

In, F., Brown, R., Fang, V., 2004. Australian and US interest rate swap markets: comparison and linkages. Accounting and Finance 44, 45–56.

In, F., Kim, S., Yoon, J.H., Viney, C., 2001. Dynamic interdependence and volatility transmission of Asian stock markets: evidence from the Asian crisis. International Review of Financial Analysis 10, 87–96.

Institutional Investor Survey, 1992. Which derivatives do CFOs really use? Institutional Investor 26, 141.

Koutmos, G., 1996. Modeling the dynamic interdependence of major European stock markets. Journal of Business Finance and Accounting 23, 975–988.

Koutmos, G., Booth, G.G., 1995. Asymmetric volatility transmission in international stock markets. Journal of International Money and Finance 14, 747–762.

Lekkos, I., Milas, C., 2001. Identifying the factors that affect interest-rate swap spreads: some evidence from the United States and the United Kingdom. Journal of Futures Markets 21, 737–768.

Lekkos, I., Milas, C., 2004. Common risk factors in the US and UK interest rate swap markets: evidence from a non-linear vector autoregression approach. Journal of Futures Markets 24, 221–250.

Monadjemi, M.S., 1997. International interest rates linkages: evidence from OECD countries. International Review of Financial Analysis 6, 229–240.

Phillips, A.L., 1995. Derivatives practices and instruments survey. Financial Management 24, 115–125.

Susmel, R., Engle, R.F., 1994. Hourly volatility spillovers between international equity markets. Journal of International Money and Finance 13, 3–25.

Theodossiou, P., Lee, U., 1993. Mean and volatility spillovers across major national stock markets: further empirical evidence. Journal of Financial Research 16, 337–350.