Transmission of Swap Spreads and Volatilities in the Japanese Swap Market

YOUNG HO EOM, MARTI G. SUBRAHMANYAM, AND JUN UNO

YOUNG HO EOM
is an assistant professor of finance at the College of Business and Economics at Yonsei University in Seoul, Korea.
yeom@base.yonsei.ac.kr

MARTI G. SUBRAHMANYAM
is the Charles E. Merrill professor of finance, economics and international business, at the Leonard Stern School of Business at New York University in New York.
msubrahm@stern.nyu.edu

JUN UNO
is a professor in the department of commerce at Chuo University in Tokyo, Japan. When this article was written, he was with Nikkei Quick Information Technologies, Co., Ltd., in Tokyo, Japan.
juno@tamacc.chuo-u.ac.jp

The interest rate swap market has grown enormously since its inception about two decades ago. The notional outstanding amount of privately negotiated (over-the-counter) derivatives at the end of 2000 was over $95 trillion, of which interest rate derivatives accounted for over $65 trillion.

Given the importance of the yen in international trade and finance, it is not surprising that yen interest rate derivatives form a substantial proportion of this amount (about $13 trillion), third after Euro-denominated (about $21 trillion) and dollar-denominated (about $19 trillion) interest rate derivatives. Interest rate swaps represent a large proportion of the global market for interest rate derivatives ($49 trillion out of $65 trillion), with a similar fraction in each of the three major currencies.[1]

Swaps are negotiated as zero-value transactions when they are initiated, with the swap rate defined as the fixed rate to be exchanged for a floating rate such as LIBOR. Absent credit or liquidity risks, a standard ("plain vanilla") interest rate swap is equivalent to the exchange of a fixed-rate bond for a floating-rate bond.

Credit risk adds an important dimension, however, to the pricing of over-the-counter (OTC) derivative instruments, which are not backed by the guarantee of a clearing corporation and daily marking-to-market with margining. Hence, each of the two counterparties to an OTC transaction is exposed to the default risk of the other. This default risk is particularly important for long-dated instruments such as interest rate swaps.

We look at the transmission of credit risk between two of the world's largest swap markets. Given the linkages between global financial markets, we would expect the yen and dollar interest rate swap markets to be well integrated in terms of credit risk. That is, credit risk shocks in one market should be quickly transmitted to the other market, and credit risk should therefore be a global factor.

Since the late 1990s, the Japanese financial system has witnessed a series of failures of financial institutions, downgrading of its sovereign credit rating, and major structural and regulatory problems in the financial system. It was the failures of two long-term credit banks, Japan Long-Term Credit Bank and Nippon Credit Bank, that culminated in Moody's downgrading of Japan's sovereign credit rating from AAA in November 1998. Since then, there have been further downgrades, in September 2000 and November 2001.

From the perspective of regulators and market participants, it would be interesting to see whether the turmoil in the Japanese financial system was transmitted to the U.S. dollar market, i.e., if the two markets are well integrated. We thus examine the contemporaneous and causal relationship between yen and dollar interest swap spreads, both in terms of their levels and volatilities, using daily and weekly data from January 1990 through December 2000. We compute the spreads of swap rates over par bond yields of government bonds, for different maturities, as measures of credit risk in the swap market in each currency.

Theoretical models for the pricing of swaps show that interest rate swap spreads should reflect counterparty credit risk. Also, several empirical studies offer positive evidence that interest rate swap spreads do reflect the credit risk of counterparties.[2] Therefore, we use interest swap spreads as proxies for credit risk to analyze the lead-lag structure and the volatility structure of swap spreads in the two markets.

We also analyze the relationship between yen and dollar interest rate swap spreads and interest rate differentials in the two markets. The motivation for the analysis is to examine the impact of arbitrage and relative value trading activity between the two markets.

During the past decade, Japanese yen interest rates have been extremely low by historical standards. The low level of yen interest rates makes a spread position between Treasury bonds in the two countries attractive to relative-value traders such as hedge funds. For instance, traders could go long yen interest rate swaps and go short dollar interest rate swaps to construct a synthetic spread position between the Treasury bonds (usually in the respective futures contracts) in the two countries.

A well-publicized example serves to illustrate the widespread use of relative-value trades between swap spreads in different currencies. In the mid-nineties, Long-Term Capital Management (LTCM), a leading hedge fund, put on several relative-value trades between major European currencies. During 1995-1996, betting on convergence between the Italian Lira and the Deutsche Mark, LTCM bought the Lira swap spread and sold the Mark swap spread.

When Italy met the criteria for the Euro, the trade became very profitable. When this strategy was extended in 1997-1998 to other currencies such as the British pound versus the deutsche mark, however, the spread went against LTCM, and the fund lost money.

These and other losses threatened the solvency of LTCM and, eventually, given the dominant position of the fund in global markets, the integrity of global markets. Swap spreads, however, continue to be a motivation for relative-value trades between major currencies.

We examine the relationship between the yen and dollar swap spreads to study the efficacy of such transactions. In order to test whether swap spreads are affected by swap market-specific supply and demand factors, we perform Granger causality tests, using the lead-lag relationship between swap spreads and interest differentials between the two currencies. Such a causal link may be indicative of the profitability of relative-value trades.

We also investigate the transmission of shocks to the volatilities of the swap spreads in the two markets. Analysis of the dynamics of the volatility of swap spreads is important for credit risk management, since most risk management tools are based upon the volatilities and correlation structure of assets in a portfolio. Furthermore, understanding the volatility process is essential for examining market mechanisms, because the variance of price changes is related directly to the rate of information arrival, as argued by Ross [1989]. Most empirical studies in the literature to date focus on the dynamics of the swap spread itself, but do not explicitly incorporate information transmission or volatility spillovers.

I. RESEARCH ON INTEREST RATE SWAP SPREADS AND VOLATILITIES

A "plain vanilla" interest rate swap can be thought of as the exchange of a fixed-rate bond for a floating-rate bond, in the absence of factors such as default risk, tax and liquidity effects, and market frictions. The mark-to-market value of an existing swap on a reset date is therefore the difference between par and the present value of the cash flows on the fixed side, since the floating-rate bond on the reset date is valued at par when there is no risk of default. (On a date between resets, the floating side will include payment based on the last reset.)

The market swap rate is defined as the rate that sets the mark-to-market value of the swap to zero, which would be the same as the yield on a par (fixed-rate) bond of the same maturity. Hence, in the absence of credit risk and market frictions, the interest rate swap spread, defined as the difference between the swap rate and a comparable default-free rate, should be equal to zero.

In the presence of default risk, an important determinant of interest rate swap spreads is the credit quality of the counterparty, since spreads should reflect the risk of default. One approach to the measurement of credit risk is the "structural" model, first proposed by Merton [1974] in the context of risky zero-coupon debt. In this approach, the limited liability aspect of equity is modeled as an option on the firm's assets.

The other approach uses the "reduced form" of the underlying structure and does not directly deal with the capital structure. Under the reduced form approach, the price of a risky zero-coupon bond can be modeled in an arbitrage-free framework, based on the short-term risk-adjusted interest rate process for defaultable assets such as swaps.[3]

The other important determinant of swap spreads is the liquidity of the swap market relative to the government securities market. Grinblatt [2002] argues that the spreads are partly:

> … a compensation for a liquidity-based convenience yield associated with government notes. This convenience yield is lost to an investor wishing to receive fixed rate payments, who in lieu of purchasing a government note - enters into a swap to receive fixed payments [2002, p. 3].

In the context of a one-factor interest rate term structure model, Grinblatt shows that many realistic swap-spread term structures can be replicated using liquidity as a state variable.

Despite numerous theoretical models on the pricing of swaps, the empirical work on the behavior and determinants of interest rate swap spreads is rather sparse. Much of the literature tests whether swap rates reflect the default risk of counterparties in U.S. dollar interest rate swaps.

For example, Koticha [1993] postulates a negative relationship between the slope of the term structure and the spread between the swap rate and the yield on a Treasury bond of comparable maturity. For instance, in an upward- (downward-) sloping term structure environment, the fixed- (floating-) rate payer bears more default risk, since, in the early years, she pays more than she receives; hence, she demands a lower (higher) risk premium through a lower (higher) fixed rate.

By regressing the swap spreads on the slope of the term structure and a credit risk proxy, Koticha finds that the coefficient of the slope term is negative and significant. His empirical results indicate that interest rate swap spreads reflect counterparty credit risk.

Sun, Sundaresan, and Wang [1993] also test whether swap rates reflect the credit quality of swap dealers. Using quoted bids and offers from two swap dealers with different credit ratings for their long-term debt (AAA and A), they show that the bid-offer spread for the higher-rated dealer is higher than for the lower-rated one in the U.S. dollar swap market.

Mozumdar [1996] uses a non-linear specification for swap pricing, and estimates a parameter that proxies for the fraction of the promised cash flows that is not received in the event of default. Using two alternative sets of data from dollar and DM swaps during the period 1990 to 1996, he shows that the default risk parameter is positive and statistically significant in the case of dollar swaps.

In a study of U.S. dollar interest rate swaps, Minton [1997] also finds that swap rates are positively related to short-term interest rate volatility and suggests that the option to default is priced in the swap market.

In the case of yen swaps, in Eom, Subrahmanyam, and Uno [1998] we find that yen swap spreads are sensitive to credit risk in the Japanese market. Measuring yen swap spreads relative to estimated par bond yields on ten-year Japanese government bonds during the period 1990 to 1996, we show that the yen swap spread is positively related to corporate bond yields, negatively related to the level and slope of the term structure, and positively related to the curvature of the term structure. These results indicate that the credit "optionality" is priced into the yen swap rate.

While all this research shows that interest rate swap spreads reflect the credit risk of counterparties, there is also some empirical evidence that swap spreads reflect other factors such as market liquidity and other frictions. Brown, Harlow, and Smith [1994] test for the factors influencing swap rates in the context of a pure expectations model. They find that four variables explain the variation in swap rates, although less than fully: the spread between Treasury zero-coupon versus coupon bonds (a proxy for the slope of the term structure); the expectation of the Treasury-Eurodollar spread (a measure of the expected credit risk); the overnight bond repurchase (repo) rate (an index of hedging costs); and the volume of new issues of corporate bonds (a measure of hedging demand).

Duffie and Singleton [1997] also investigate the relative importance of liquidity and credit factors, using a multivariate vector autoregression (VAR) of the spreads. They find that both factors affect the temporal behavior of the spreads, but with very different time paths—the impact of liquidity factors is more short-lived. They conclude, however, that a substantial proportion of the variation in the swap spreads is left unexplained, so that further analysis of swap market activity is required to better understand the swap spreads.

Liu, Longstaff, and Mandell [2000] also examine the default risk and liquidity components of the dollar swap spread, using an affine multifactor model. Their empirical results show that the mean of the liquidity component is only a small proportion of the average value of the spread, but it is much more volatile than the credit risk component.

The empirical issue we examine is whether the yen and dollar interest rate swap markets are integrated in terms of credit risk. Given the increasing globalization of trade and finance, we would expect that international capital markets are fully integrated. Thus, if swap spreads mainly reflect counterparty credit risk and/or the default risk of large corporate issuers with global operations, credit risk should be, at least to some extent, a global factor.

Both theory and empirical evidence indicate that interest rate swap spreads should be determined by credit risk in the swap market. Thus, if swap spreads in the yen and the dollar are determined by credit risk, we would expect that both swap spreads should be highly correlated.

In this context, He [2000] argues that since the set of reference banks for all the major markets is virtually identical, swap spreads ought to be similar across currencies. The argument is based on the premise that the dynamics of short-term financing in the repo market are the main factor driving the term structure of swap spreads, which would be similar for the major players.

Although the contemporaneous relationship between yen and dollar swap spreads is important in characterizing the integration of swap markets, the lead-lag relationship between these spreads is essential to an assessment of market efficiency. Several studies examine the causal relationship between interest rate changes in the U.S. and the Eurodollar markets.

For instance, Fung and Isberg [1992] employ an error correction model to test the relationship between interest rates in the domestic and external markets. Their empirical results indicate that there was unidirectional causality leading from the domestic to external markets in earlier periods. More recently, however, they find that there is a significant reverse-causality, which may be due to the increased size of the Eurodollar market and the presence of enhanced arbitrage opportunities in the swap and futures markets.

Grinblatt and Jegadeesh [1996] investigate the timing of the flow of information across the Eurodollar forward and futures markets. They find that there is a two- or three-week delay in information flow from the futures market to the forward market. They find no evidence that there are delays in the flow of information from the forward market to the futures market.

Gupta and Subrahmanyam [2000] also examine whether timing differences in information flows between the swap market and the Eurocurrency futures market explain the differential between market swap rates and swap rates implied by Eurocurrency futures prices. If changes in one rate can predict future changes in the other rate, then the information relevant for future interest rates is not being incorporated into the swap and futures markets simultaneously.

Specifically, Gupta and Subrahmanyam test whether market swap rates predict the implied swap rate from the Eurocurrency futures contracts using lagged daily changes in market swap rates. Although they do find some evidence of predictability in futures rates, the overall empirical results indicate that the predictability is economically insignificant. They also test the predictability of market swap rates from implied swap rates using lagged daily changes in implied swap rates, and find that there are virtually no delays in the flow of information from the futures market to the swap market.

Several studies examine how news from one international market influences another market's volatility process. For instance, Engle, Ito, and Lin [1990] examine two types of volatility processes—heat waves and meteor showers—for the yen/dollar exchange rates. The heat wave hypothesis is consistent with the view that major sources of disturbances are changes in country-specific fundamentals, and that one large shock increases the conditional volatility but only for that country. The meteor shower hypothesis predicts that one large shock increases the conditional volatility in other countries.

Using a GARCH model to specify the heteroscedasticity, they find that empirical evidence is generally against the null hypothesis of the heat wave. They also test whether volatility in the foreign exchange market is due to meteor showers with worldwide news or meteor showers with country-specific news, and find that the news is country-specific, and Japanese news has the greatest impact on volatility spillovers of the yen/dollar exchange rates. These empirical findings are consistent with market dynamics that exhibit volatility persistence due to private information or heterogeneous beliefs, or with stochastic policy coordination or competition.

There is a related literature that addresses contagion effects in international stock markets. Hamao, Masulis, and Ng [1990] examine the transmission mechanisms of the conditional first and second moments in common stock prices across international stock markets including the U.S., U.K., and Japanese markets. Using a GARCH-M model, they find there are volatility spillover effects from return volatility in the foreign market to return volatility in the domestic market. Eliminating the post-October 1987 period, the effect becomes less pervasive, and only the effect from the U.S. stock market to the Japanese market is statistically significant.

Lin, Engle, and Ito [1994] also investigate how returns and volatilities of stock indexes are correlated between the Tokyo and New York markets. They extend the signal extraction model of King and Wadhwani [1990] by allowing time-varying volatility. Using intraday data, they find that foreign daytime returns can significantly influence domestic overnight returns, and that cross-market interdependence in returns and volatilities is generally bidirectional between the New York and Tokyo markets. Their empirical results are consistent with the contagion-effect hypothesis.

Tse and Booth [1996] analyze causal relationships via a volatility spillover mechanism between U.S. and Eurodollar interest rates. Using a bivariate EGARCH model that allows for an asymmetric volatility influence of the Treasury Eurodollar or TED spread (Eurodollar minus Treasury rate), they show that cross-market volatility spillover effects are insignificant, but that the lagged TED spread is the driving force of the volatility process.

Furthermore, they find that a change in the TED has an asymmetric impact on the volatility of both interest rates. That is, a positive change in the TED spread has a greater impact than a negative change.

II. CREDIT RISK AND INTERMARKET LINKAGES OF SWAP SPREADS

Empirical Models

We empirically examine the dynamic structure of swap spreads in order to better understand the transmission mechanisms of credit risk shocks in dollar and yen swap markets. As interest rate swap spreads reflect the credit risk in swap markets, we investigate the lead-lag relationship of credit risk shocks in the two markets, using interest swap spreads as proxies for credit risk.

We also examine the lead-lag relationship between swap spreads and the differential between dollar and yen interest rates, since swap spreads can be affected by relative-value trading activities between the two markets. During the past decade, Japanese yen interest rates have been extremely low by historical standards. The low level of yen interest rates makes a spread position between Treasury bonds in the two countries attractive to relative-value traders.[4]

To examine the lead-lag relationships of swap spreads and interest differentials, we perform a Granger causality test. Specifically, we assume a particular autoregressive lag of length p and estimate Equation (1) by ordinary least squares:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i x_{t-i} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \varepsilon_t \tag{1}$$

where y_t is the dependent variable on which the causality of the variable x is being tested, and coefficients α and β drive the lagged values. The subscripts stand for the date with appropriate lags.

We then conduct an F-test of the null hypothesis:

$$H_0 : \beta_1 = \beta_2 = \ldots = \beta_p = 0.$$

Specifically, the F-value for testing the null hypothesis is computed as follows:

$$F = \frac{(RSS_0 - RSS_1)/p}{RSS_1/(T - 2p - 1)} \tag{2}$$

where RSS_1 is the sum of squared residuals of Equation (1), and RSS_0 is the sum of the squared residuals with the restriction that $\beta_1 = \beta_2 = \ldots = \beta_p = 0$. The F-value is asymptotically distributed as $F(p, T - 2p - 1)$. If the null hypothesis is rejected, then x is said to "Granger-cause" y. In other words, shocks in one market are transmitted to another market, and subsequently cause the movements of swap spreads in another market.

We also investigate the transmission of volatility shocks in the two swap markets by analyzing the conditional second moments of swap spreads. The volatility process of swap spreads is directly related to the information process, and the volatility process in one market can be influenced by news or shocks from another market.

Specifically, we are interested in testing whether the shocks in swap spreads due to credit events in one swap market are transmitted to the swap market of a different currency. If shocks can spill over to the other market, it is reasonable to expect that a large shock to the swap spread in one market increases the conditional volatility of the swap spreads in another market.

The basic model was originally proposed by Glosten, Jagannathan, and Runkle [1989] (GJR) and Zakoian [1994] to capture the leverage effect of volatility in stock returns.[5] To model the time-varying volatility of swap spreads, we basically adopt a GJR-GARCH model, which has the form

$$y_t = a_0 + \sum_{i=1}^{p} b_i x_{t-i} + \sum_{i=1}^{p} a_i y_{t-i} + \varepsilon_t, \text{ with } \varepsilon_t \sim N(0, h_t) \tag{3}$$

$$h_t = \alpha_0 + \beta_1 h_{t-1} + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 \mathbf{1}_{(\varepsilon_{t-1} > 0)} \tag{4}$$

where y_t is the swap spread at time t; $\{x_{t-i}\}_{i=1}^{p}$ is the set of exogenous variables such as the swap spread of the other currency and the interest rate differential between the two currencies; ε_{t-1}^2 is the lagged squared shock of the swap spread; and $\mathbf{1}_{(\varepsilon_t - 1 > 0)}$ is the indicator function that takes the value of one when $\varepsilon_{t-1} > 0$ and zero otherwise.

For example, if $\alpha_2 > 0$, the volatility of the swap spread increases more when there is a positive shock, which increases the swap spread, than when there is a negative shock. Thus, the GJR-GARCH model captures the asymmetric effects in the volatility process.

Specifically, the equation for the asymmetric news impact curve for the proposed GJR model is

$$\begin{aligned} h_t &= \alpha_0 + \beta_1 \sigma^2 + (\alpha_1 + \alpha_2) \varepsilon_{t-1}^2, \text{ for } \varepsilon_{t-1} > 0, \text{ and} \\ &= \alpha_0 + \beta_1 \sigma^2 + \alpha_1 \varepsilon_{t-1}^2, \text{ for } \varepsilon_{t-1} < 0. \end{aligned} \tag{5}$$

where σ^2 is the unconditional variance.

If $\alpha_2 = 0$, the GJR-GARCH model becomes the standard GARCH model, in which the positive or negative past shock has the same impact on future volatility. The GJR-GARCH model by contrast allows the positive and negative past shocks to have an asymmetric impact on future volatility.

While the basic volatility model in (4) captures the heteroscedasticities in the swap spreads, the model is rather restrictive in the sense that it does not incorporate the spillover effects from other markets. To model cross-market volatility spillovers, we extend the volatility process of swap spreads with the relationship:

$$\begin{aligned} h_t = \alpha_0 + \beta_1 h_{t-1} + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 \mathbf{1}_{(\varepsilon_{t-1} > 0)} + \gamma_1 \xi_{t-1}^2 + \\ \gamma_2 \xi_{t-1}^2 \mathbf{1}_{(\xi_{t-1} > 0)} + \gamma_3 \eta_{t-1}^2 \end{aligned} \tag{6}$$

where ε_{t-1}^2 is the lagged squared shock of the swap spread; ξ_{t-1}^2 is the lagged squared shock of the swap spread of the other currency; and η_{t-1}^2 is the lagged squared shock of interest rate differentials.

Like the basic model, the extended model with the exogenous shock has the advantage of capturing the asymmetric volatility effect of the shock to the other market. For instance, as long as $\gamma_2 > 0$, when there is a large positive shock in the swap spread of the other currency, the volatility of the swap spreads will be greater than when there is a negative shock in other market.

In actual estimation of the basic and extended models, we perform the single equation estimation in each market, since we can still obtain consistent and efficient estimators when the information matrix is block-diagonal (see Engle, Ito, and Lin [1990] and Pagan and Schwert [1990]).[6]

Data and Summary Statistics

The yen swap rates used in this study are the daily quotations obtained from the Data Resources Inc. (DRI) database for maturities of two, three, five, seven, and ten years. These data are available for the period January 30, 1990–December 29, 2000.[7] To compute the swap spread, we use the par bond yields of Japanese government bonds (JGB) with corresponding maturities, also obtained from the DRI database. The dollar swap spreads are from the DRI database for the same period, while the constant-maturity Treasury bond (CMT) yield data are from the Federal Reserve Board's Release H15. The dataset consists of 570 weekly observations and 2,680 daily observations.

Exhibit 1 is a plot of the weekly observations of yen swap rates for January 30, 1990–December 29, 2000. These swap rates can be interpreted roughly as yields to maturity on bonds of the same maturity, priced at par.

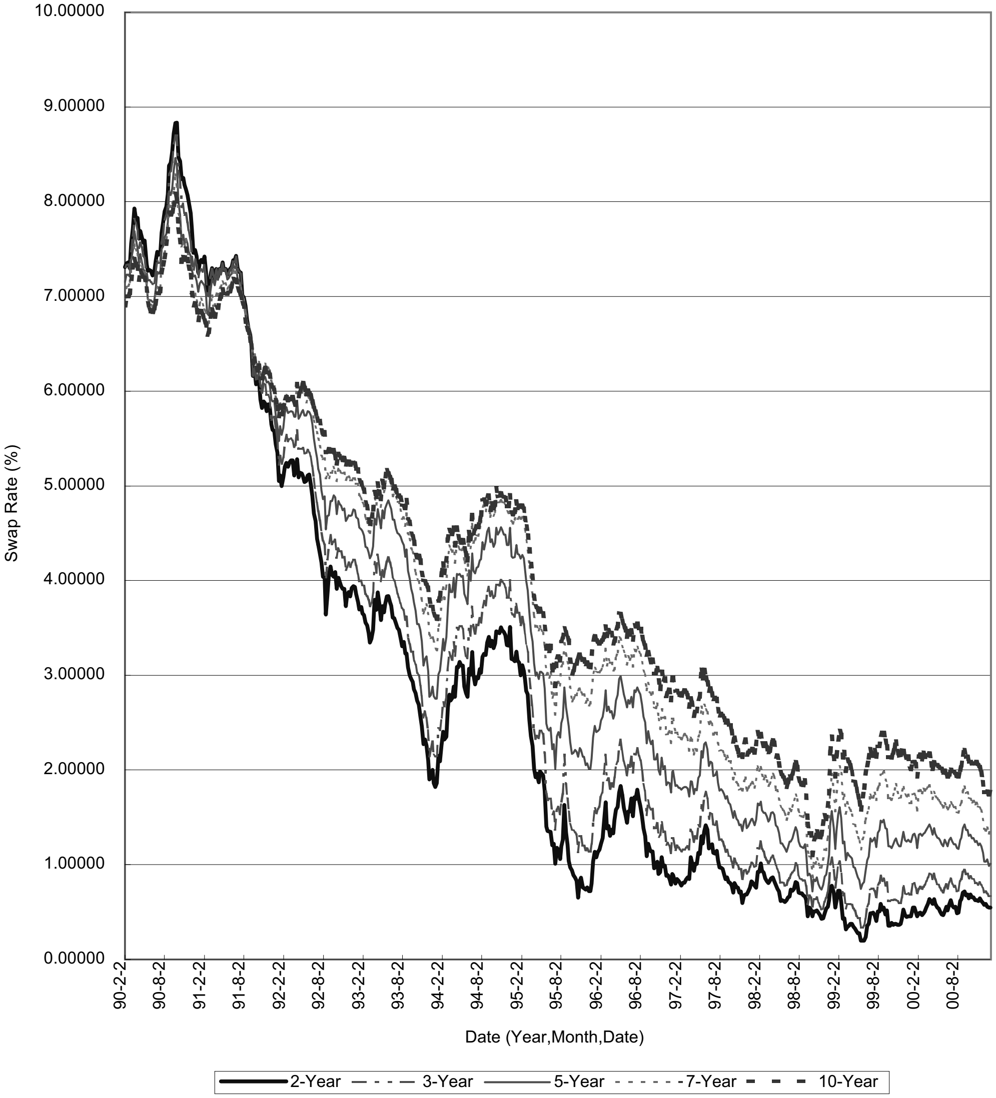
As the graph shows, yen swap rates, in general, declined during the sample period. Typically, swap rates have increased with maturity (on each date, cross-sectionally), similar to the Treasury term structure. Thus, for example, the ten-year curve lies above the two-year curve during most of the period.

In other words, the swap yield curve was upward-sloping during most of the sample period. It was inverted in 1990 and 1991, however; the ten-year rates were at or below the two-year rates during part of the period.

Panel A of Exhibit 2 provides summary statistics for the swap rates and the first differences (changes from one day to the next) of the daily yen interest rate swaps with maturities from two years to ten years for the period January 30, 1990–December 29, 2000. Panel B provides the same summary statistics for the weekly yen swap rates and their first differences.

EXHIBIT 1

Yen 2- and 10-Year Swap Rates—January 30, 1990–December 29, 2000



Source of swap quotations: Data Resources Inc. database.

As Exhibit 1 shows, the term structure of yen swap rates for the sample period is, on average, upward-sloping; i.e., the means increase with maturity. Also, the swap rates are persistent in a statistical sense and behave approximately like a random walk process, as is the case for yields in other markets. Although the autocorrelation coefficients of the swap rates are close to one, the rates may not exactly be a random walk process, since the standard deviations decline with swap maturity.

EXHIBIT 2

Summary Statistics of Yen Swap Rates

Panel A: Daily Observations

Maturity	MEAN	ST DEV	SKEWNESS	KURTOSIS	AUTO
Level					
2 year	2.77900	2.47593	0.90730	-0.49040	0.99907
3 year	3.03684	2.37526	0.77677	-0.70190	0.99903
5 year	3.47233	2.17331	0.58746	-0.95254	0.99898
7 year	3.79581	2.00409	0.46459	-1.06627	0.99899
10 year	4.01040	1.83061	0.44668	-1.05148	0.99896
First Differences					
2 year	-0.00250	0.04584	-0.07688	5.36345	0.05860
3 year	-0.00245	0.04720	0.14124	5.04466	0.07443
5 year	-0.00229	0.04809	0.10514	2.98516	0.02616
7 year	-0.00207	0.04731	0.22643	1.95221	-0.00727
10 year	-0.00189	0.04597	0.17976	1.88678	-0.02764

Panel B: Weekly Observations

Maturity	MEAN	ST DEV	SKEWNESS	KURTOSIS	AUTO
Level					
2 year	2.76718	2.46994	0.92311	-0.45181	0.99543
3 year	3.02575	2.36790	0.79210	-0.66859	0.99522
5 year	3.46304	2.16511	0.60079	-0.92450	0.99511
7 year	3.78900	1.99705	0.47552	-1.04175	0.99523
10 year	4.00397	1.82409	0.45604	-1.02709	0.99512
First Differences					
2 year	-0.01189	0.10320	-0.02355	1.64763	0.03364
3 year	-0.01167	0.10689	0.02769	1.72416	0.04463
5 year	-0.01079	0.10621	0.18852	1.40093	0.04321
7 year	-0.00986	0.09888	0.35393	1.24558	0.03508
10 year	-0.00900	0.09475	0.37104	1.56974	0.02547

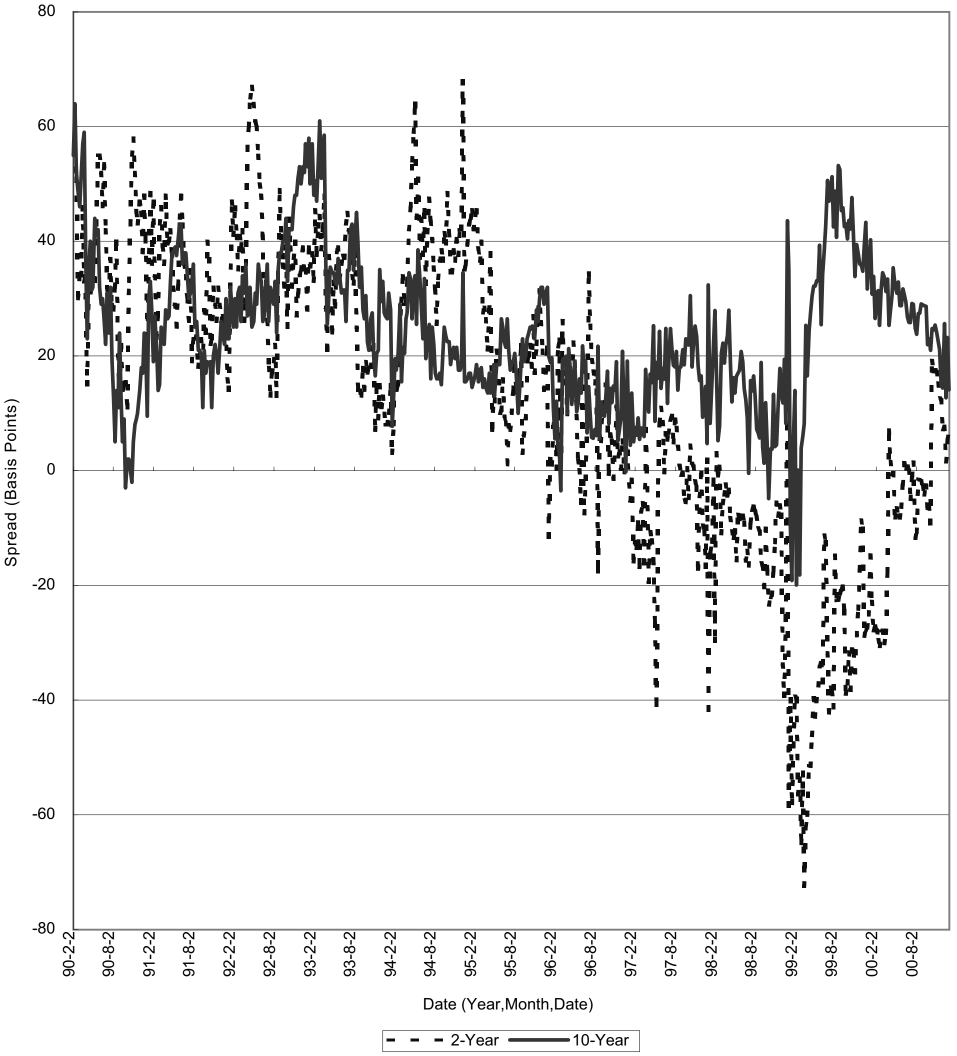
Source of quotations: Data Resources Inc. database. Daily observations: 2,680. Weekly observations: 570.

Panel B shows that autocorrelations of the weekly changes in the swap rates are somewhat higher than zero for all maturities, showing modest mean reversion. The degree of mean reversion is higher for the three-year maturity rates and lower for the ten-year maturity rates. The low degree of mean reversion of long-maturity yields is consistent with the evidence for Treasury yields in many currencies.

Panel B also suggests that changes in swap rates follow a non-normal distribution; hence, swap rates, like yields, in general, may not be well approximated by a lognormal process. Also, changes in the swap rates show (excess) positive skewness and kurtosis, compared to the normal distribution. The term structure of skewness increases as the maturity increases. One possible explanation for these characteristics may be the prevalence of

EXHIBIT 3

Yen 2- and 10-Year Swap Spreads—January 30, 1990–December 29, 2000



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discontinuous changes or jumps in the data, another common feature of interest rates.

We next analyze the spreads of yen interest rate swaps over the corresponding default-free rates measured on a constant-maturity par bond yield basis. Exhibit 3 presents the two- and ten-year yen swap spreads on a yield basis, i.e., the difference between the yen swap rates and the par bond yields of JGBs with the corresponding maturity.

As the graph shows, the two swap spreads moved together during most of the sample period, but they have behaved somewhat differently since mid-1997. Notice that the swap spreads for the ten-year maturity were positive during most of the sample period, although we do find a few cases of negative spreads in early 1990 and early 1999. The two-year swap spreads turn negative in many cases. Out of 570 observations, 30.53% and 1.75% of swap spreads are negative for the two- and ten-year maturities, respectively.[8]

EXHIBIT 4

Summary Statistics of Yen Swap Spreads

Panel A: Daily Observations

Maturity	MEAN	ST DEV	SKEWNESS	KURTOSIS	AUTO
Level					
2 year	0.12730	0.26595	-0.52540	-0.21702	0.97439
3 year	0.18688	0.34061	-0.34864	-0.32862	0.98437
5 year	0.25415	0.33521	-0.09863	-0.15389	0.98710
7 year	0.21005	0.20351	-0.15225	0.83637	0.96676
10 year	0.24504	0.12947	0.20798	0.49730	0.90539
First Differences					
2 year	-0.00017	0.05968	-0.08751	12.05798	-0.23084
3 year	-0.00020	0.05965	-0.48111	13.42077	-0.29588
5 year	-0.00022	0.05314	-0.43647	9.32425	-0.30681
7 year	-0.00010	0.05233	-0.07077	4.39170	-0.33273
10 year	-0.00007	0.05626	0.01759	7.37053	-0.30957

Panel B: Weekly Observations

Maturity	MEAN	ST DEV	SKEWNESS	KURTOSIS	AUTO
Level					
2 year	0.12877	0.26460	-0.51654	-0.17714	0.93103
3 year	0.18747	0.33775	-0.33331	-0.29174	0.96214
5 year	0.25412	0.33375	-0.08775	-0.15362	0.96931
7 year	0.21037	0.20309	-0.13627	0.89350	0.94213
10 year	0.24273	0.12935	0.23085	0.45199	0.83925
First Differences					
2 year	-0.00083	0.09673	-0.64085	6.93561	-0.31780
3 year	-0.00089	0.09156	-0.73179	5.70381	-0.27450
5 year	-0.00104	0.08077	-0.52239	5.27996	-0.16953
7 year	-0.00073	0.06787	-0.35332	3.06654	-0.21142
10 year	-0.00072	0.07213	-0.31598	4.81457	-0.34435

Source of quotations: Data Resources Inc. database. Daily observations: 2,680. Weekly observations: 570.

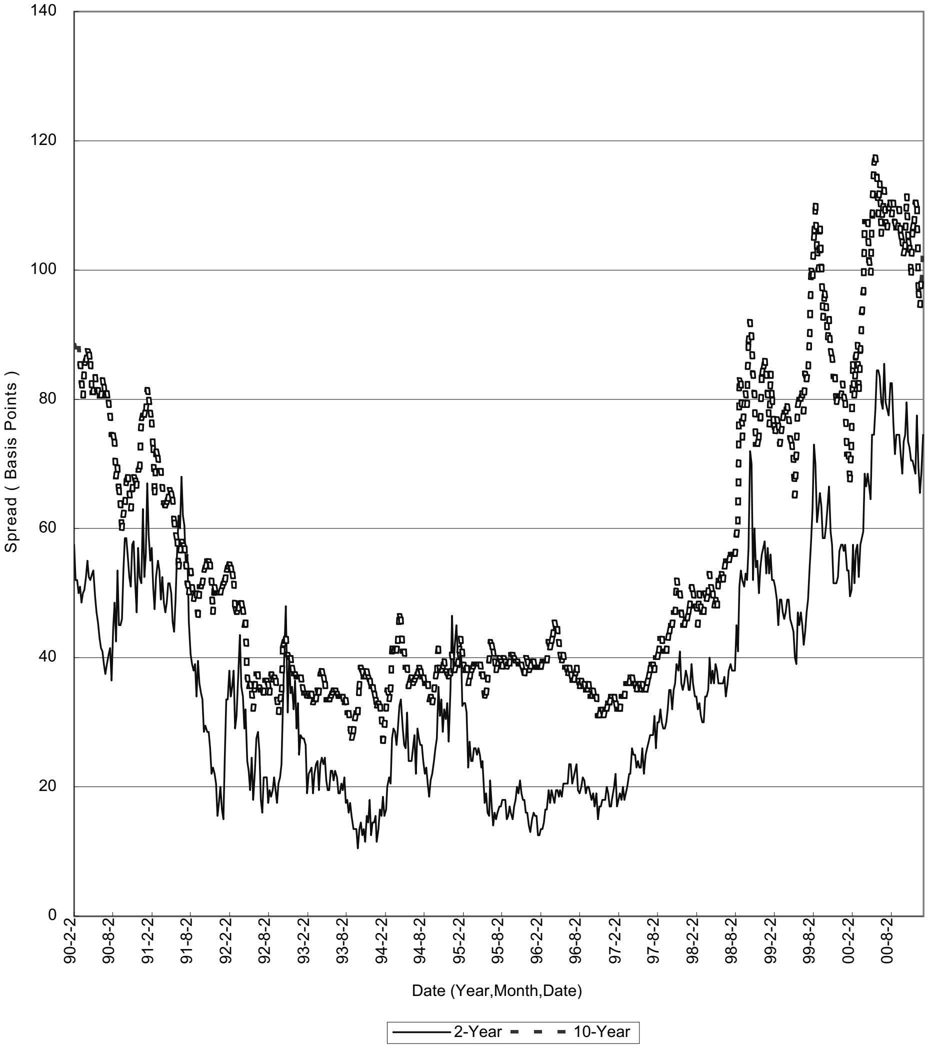
Panel A of Exhibit 4 provides means, standard deviations, and autocorrelation coefficients for the daily yen swap spreads on a yield basis and for the first differences for various maturities. Panel B provides the same statistics for weekly observations of yen swap spreads.

The average spreads of the yen interest rate swaps over the corresponding JGBs in terms of yields, as a function of maturity, show a slightly humped shape. The humped shape of the yen interest rate swap spread is very different from the empirical pattern of corporate bond spreads in the U.S., as documented by Sarig and Warga [1989] and Fons [1994]. Those authors find that the average credit yield spread for investment-grade firms is upward-sloping with maturity, while the credit yield spread is humped or inverted for speculative-grade firms. (Helwege and Turner [1999], however, find that the credit yield spread is, on average, upward-sloping even for BB- or B-rated firms when the sample selection bias problem is corrected.)

Also, swap spreads are persistent in a statistical sense,

EXHIBIT 5

Dollar 2- and 10-Year Swap Spreads—January 30, 1990–December 29, 2000



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and follow approximately a random walk process, as is the case for swap rates. The standard deviations of swap spreads decline as the swap maturity lengthens, indicating that swap spreads may not exactly be a random walk process. The first differences of the swap spreads also show negative autocorrelation, confirming that the swap spread itself is a mean-reverting process.

Exhibit 4 also suggests that swap spreads follow a non-normal distribution. Relative to the normal distribution, the swap spreads show negative (excess) skewness for most maturities except for the ten-year, and the term structure of skewness increases as the maturity increases. Changes in swap spreads show negative (excess) skewness and excess kurtosis, while the term structures of kurtosis in the first differences decrease with maturity.

Exhibit 5 presents the two- and ten-year dollar swap spreads on a yield basis. Note that the ten-year dollar swap spreads were higher than the two-year spreads during most of the period.

One noticeable pattern in the dollar swap spreads is that they have been on an increasing trend since mid-1997 when the Asian financial crisis erupted. The dollar swap spreads also show a sharp spike during August and September 1998, when Russia defaulted on its sovereign debt and LTCM, the hedge fund, hovered near collapse, threatening the integrity of global bond and swap markets. During

EXHIBIT 6

Summary Statistics of Dollar Swap Spreads

Panel A: Daily Observations

Maturity	MEAN	ST DEV	SKEWNESS	KURTOSIS	AUTO
Level					
2 year	0.36563	0.17833	0.65236	-0.55348	0.99294
3 year	0.44153	0.19248	0.47102	-0.91945	0.99447
5 year	0.47519	0.23287	0.75597	-0.64842	0.99674
7 year	0.52868	0.23248	0.99036	-0.08624	0.99701
10 year	0.56910	0.26014	1.15153	0.37280	0.99756
First Differences					
2 year	0.00004	0.01923	-0.07886	4.63833	-0.04135
3 year	0.00007	0.01834	-1.17376	11.18799	-0.03690
5 year	0.00006	0.01387	1.03714	15.64405	-0.00492
7 year	0.00005	0.01351	0.53598	15.50920	0.02365
10 year	0.00004	0.01404	0.85239	19.09804	0.01466

Panel B: Weekly Observations

Maturity	MEAN	ST DEV	SKEWNESS	KURTOSIS	AUTO
Level					
2 year	0.32928	0.14727	0.55479	-0.83208	0.96232
3 year	0.40524	0.16498	0.45942	-1.03331	0.97059
5 year	0.42769	0.19144	0.77209	-0.76183	0.98438
7 year	0.47710	0.17753	0.93210	-0.28339	0.98274
10 year	0.50853	0.18865	0.99706	-0.24416	0.98512
First Differences					
2 year	0.00029	0.03801	-0.02821	2.11567	-0.20811
3 year	0.00037	0.03788	-0.45757	3.52638	-0.18763
5 year	0.00037	0.02968	0.87560	6.66637	-0.02090
7 year	0.00036	0.02961	0.62128	6.79522	0.00038
10 year	0.00028	0.02947	0.81451	8.01853	0.07521

Source of spreads: Data Resources Inc. database.

2000, there was a noticeable increase in the dollar swap spreads, especially for the ten-year tenor, due to the potential shrinkage in the supply of U.S. Treasury bonds.

Another striking difference between dollar and yen swap spreads is that there are many cases of negative spreads in yen interest rate swaps, while dollar swap spreads are never negative in our sample period. As we have mentioned, negative spreads are more pronounced as maturity shortens. One possible explanation of negative spreads for the shorter-maturity swaps is the difference in liquidity between swaps and JGBs. In general, the yields of illiquid bonds should be higher than those of liquid bonds.

Empirical studies in the U.S. Treasury market such as Amihud and Mendelson [1991] and Elton and Green [1998] show that there is a significant price effect due to differences in the liquidity of bonds. This effect was especially important in the Japanese bond market until recently, since the liquidity effect was exacerbated due to the heavy concentration of trading in the ten-year benchmark bond.

Thus, illiquidity of non-benchmark bonds tends to increase the par bond yields of government bonds, while swap rates for the standard maturities are unaffected. This reduces interest rate swap spreads relative to government bond yields with corresponding maturities.

EXHIBIT 7

Relationship between Yen and Dollar Swap Spreads

Panel A: Total Period

	Corr(USspread,JPspread)	Corr(USspread,Diff)	Corr(JPspread,Diff)
2-year	0.01862	-0.01689	0.43617
3-year	0.09479	-0.00901	0.39118
5-year	0.00814	-0.08190	0.38698
7-year	-0.00170	-0.03407	0.31164
10-year	-0.01384	-0.02962	0.33065

Panel B: First Sub-period: 90.2 - 97.4

	Corr(USspread,JPspread)	Corr(USspread,Diff)	Corr(JPspread,Diff)
2-year	0.07292	0.12155	0.29328
3-year	0.13698	0.04798	0.30508
5-year	0.05418	0.02818	0.38192
7-year	0.02437	0.03940	0.31454
10-year	0.03404	0.09891	0.30451

Panel C: Second Sub-period: 97.5 - 00.12

	Corr(USspread,JPspread)	Corr(USspread,Diff)	Corr(JPspread,Diff)
2-year	-0.06680	-0.27182	0.66603
3-year	0.01926	-0.11673	0.56471
5-year	-0.05211	-0.21930	0.40475
7-year	-0.02998	-0.10989	0.30640
10-year	-0.04403	-0.13442	0.37654

Weekly observations of swap spreads and constant-maturity yields are based on data obtained from the Data Resources Inc. database for January 30, 1990–December 30, 2000.

Panel A of Exhibit 6 provides means, standard deviations, and autocorrelation coefficients for dollar swap spreads and first differences on a daily basis. The average spreads of dollar interest rate swaps show an upward-sloping shape, which is consistent with the empirical pattern of corporate bond yield spreads in the U.S. Interestingly, the average swap spreads of dollar interest rate swaps are about twice those of yen interest rate swaps.[9]

The standard deviations of the dollar swap spreads are much smaller than those of the yen swap spreads for most maturities, however, except for the ten-year maturity. Also, the dollar swap spreads are persistent, and follow approximately a random walk process; and the degree of mean reversion is somewhat smaller than that of yen swap spreads.

Panel B of Exhibit 6 shows that the changes in dollar swap spreads, relative to the normal distribution, show (excess) skewness and kurtosis.

III. EMPIRICAL EVIDENCE

Transmission of Swap Spreads

Exhibit 7 presents correlation coefficients for changes in the yen interest rate swap spreads, changes in the dollar interest rate swap spreads, and changes in the interest rate differentials between the U.S. and Japan. Recall that the interest rate differentials are based on the constant-maturity yields of government bonds of the same maturities with swaps. To avoid spurious correlation due to persistence in swap spreads, we analyze correlations between changes in these variables and not their levels.

Given the increasing globalization of trade and finance, we would expect international capital markets to be highly integrated. The relative-value trades of hedge funds such as LTCM are likely to accentuate this integration. Thus, if swap spreads reflect mainly the counterparty risk and/or default risk of large corporate issuers with global operations as well as international banks, the credit risk should be, at least to some extent, a global factor. Hence, swap spreads in yen and dollars should be highly correlated.

In fact, the actual correlations between swap spreads in yen versus dollar interest rate swaps are surprisingly low. For example, the correlation for the two-year swap spread is negligible at 0.01862. The correlations between swap spreads for other maturities are also quite low, ranging from –0.01384 to 0.09479.

The changes in the swap spreads for yen interest rate swaps are more correlated with the changes in interest rate differentials between the two markets. For example, the correlation coefficient between the two-year yen interest rate swap spread and the interest rate differential, which is defined as the two-year U.S. government par bond yield minus the two-year JGB par bond yield, is 0.43617. For other maturities, the coefficients of correlation range from 0.31164 to 0.39118.

The change in the spread of dollar interest rate swaps is, however, uncorrelated with the change in the interest rate differential. For example, the coefficient of correlation between the five-year dollar interest rate swap spread and the interest rate differential is –0.08190. For other maturities, the coefficients of correlation between the dollar swap spread and the interest rate differential are almost zero, ranging from –0.00901 to –0.03407.

A possible explanation for the high correlation between the yen interest rate swap spread and the interest rate differential is that arbitrageurs go long yen interest rate swaps and go short dollar interest rate swaps to construct a spread position between Treasury bonds (usually in the respective futures contracts) in the two countries. Such a spread is constructed to take advantage of the differential between the low long-term yields of JGBs and the high long-term yields of U.S. bonds.

For instance, international corporations borrow in yen, and then swap out of yen into dollars, using the proceeds for dollar investments. Hence, the yen swap rate is higher due to the demand for pay-fixed yen swaps.

To analyze the relationship between the two swap spreads further, we regress changes in the yen interest rate swap spreads on 1) their own lagged values, and 2) the lagged changes in the dollar interest rate swap spreads. Specifically, we perform a Granger causality test to see if the lagged changes in the spreads for dollar interest rate swaps cause the changes in the spreads of yen interest rate swaps.

Since the Granger causality test might be sensitive to the choice of number of lags, we perform the test for two, three, and four lags. Only the test results for two lags are reported in Panel A of Exhibit 8 for the entire sample period, because the overall test results for other choices of lags are qualitatively similar.

As Panel A shows, the *F*-value of the Granger causality test for the ten-year maturity is 3.41517, which is statistically significant at the 5% level. Thus, the lagged changes in the spreads for dollar interest rate swaps Granger-cause the changes in spreads of yen interest rate swaps for the ten-year maturities. The causality does not run the other way, however.

For the case of dollar interest rate swaps with a maturity of ten years, the lagged changes of spreads in yen interest rate swaps do not have the same impact on spreads in dollar interest rate swaps. Thus, for the long end of the swap curve, there are spillover effects from the changes of spreads in dollar interest rate swaps to the yen interest rate swap market. For other maturities, there is no significant evidence that the lagged changes in the spreads for dollar interest rate swaps Granger-cause the changes in spreads of yen interest rate swaps, and vice versa.

More important, the lagged changes of interest differentials Granger-cause the increase in the spreads of yen interest rate swaps for all maturities. For example, the *F*-value of the Granger causality test for the two-year maturity is 3.02474, which is statistically significant at the 5% significance level. For other maturities, F-values are statistically significant at the 1% significance level.

The lagged changes in the interest rate differentials do not Granger-cause the increase in spreads of dollar interest rate swaps for most maturities except for two-year swaps. The *F*-value of the Granger causality test for dollar swap spreads with maturity of two years is 4.55218, which is statistically significant at the 5% level. As F-values for other maturities range from 0.14199 to 1.02267, the hypothesis of no Granger causality cannot be rejected.

These results are consistent with the hypothesis that yen interest rate swaps are used as a part of a spread position created due to market frictions in the JGB market, e.g., the difficulty in going short JGBs. Hence, the demand for swaps induced by such frictions may have an impact on the swap rates. The frictions are fewer in the dollar market, since short sales restrictions are less binding in the U.S. Treasury bond market.

We have noted the significant credit events that rocked the global swap markets between the middle of 1997 and the end of 1998. Apart from the Asian financial crisis in the middle of 1997, the Russian default, and the problems of LTCM in August-October 1998, there were other events in the Japanese markets during this period.

EXHIBIT 8
Lead-Lag Relationship between Yen and Dollar Swap Spreads

Panel A: Total Period

	2 year	3 year	5 year	7 year	10 year
JPspread → USspread	0.09594 (0.90853)	1.91636 (0.14810)	0.15275 (0.85837)	1.24301 (0.28930)	1.65797 (0.19145)
JPspread → Diff	7.05438 (0.00094)	3.04197 (0.04852)	2.37522 (0.09392)	1.48038 (0.22843)	4.91378 (0.00766)
USspread → JPspread	0.48334 (0.61697)	0.98699 (0.37334)	0.51196 (0.59959)	0.69088 (0.50156)	3.41517 (0.03355)
USspread → Diff	0.19644 (0.82170)	0.54642 (0.57932)	0.31100 (0.73284)	0.03102 (0.96945)	0.22496 (0.79861)
Diff → JPspread	3.02474 (0.04936)	5.40327 (0.00473)	5.48226 (0.00438)	6.83515 (0.00116)	4.75793 (0.00893)
Diff → USspread	4.55218 (0.01093)	0.83231 (0.43557)	1.02267 (0.36030)	0.48869 (0.61368)	0.14199 (0.86766)

Panel B: First Sub-period: 90.2 - 97.4

	2 year	3 year	5 year	7 year	10 year
JPspread → USspread	0.17537 (0.83921)	1.63274 (0.19679)	0.12585 (0.88178)	0.16486 (0.84807)	0.32060 (0.72591)
JPspread → Diff	2.32624 (0.09908)	0.95070 (0.38741)	2.34042 (0.09771)	0.69621 (0.49912)	0.42323 (0.65524)
USspread → JPspread	0.19691 (0.82135)	0.63292 (0.53161)	0.80721 (0.44688)	0.07436 (0.92834)	0.56710 (0.56766)
USspread → Diff	0.45837 (0.63266)	1.80770 (0.16547)	3.30486 (0.03779)	3.61196 (0.02795)	2.82760 (0.06043)
Diff → JPspread	7.36662 (0.00072)	11.84393 (0.00001)	8.00672 (0.00039)	5.04518 (0.00689)	3.66729 (0.02647)
Diff → USspread	2.09942 (0.12398)	0.17797 (0.83704)	0.11391 (0.89237)	0.02708 (0.97328)	0.00433 (0.99567)

Panel C: Second Sub-period: 97.5 - 00.12

	2 year	3 year	5 year	7 year	10 year
JPspread → USspread	0.75935 (0.46940)	0.87369 (0.41910)	0.57906 (0.56142)	1.16203 (0.31509)	1.01686 (0.36371)
JPspread → Diff	4.00046 (0.01989)	1.90582 (0.15157)	0.78356 (0.45826)	0.67293 (0.51144)	6.23725 (0.00238)
USspread → JPspread	0.45210 (0.63698)	0.40695 (0.66626)	0.64808 (0.52421)	0.77989 (0.45994)	2.01766 (0.13585)
USspread → Diff	0.31119 (0.73295)	0.76428 (0.46711)	1.60723 (0.20319)	1.37674 (0.02795)	1.94517 (0.14584)
Diff → JPspread	0.82097 (0.44158)	1.08932 (0.33857)	0.57959 (0.56112)	3.91298 (0.02163)	4.55658 (0.01168)
Diff → USspread	6.16606 (0.00255)	5.25975 (0.00599)	1.73343 (0.17950)	0.68162 (0.50704)	0.18292 (0.83298)

Weekly observations of swap spreads and constant-maturity yields are based on data obtained from Data Resources Inc. database.

In 1997, the Japanese financial system underwent serious credit problems due to the Asian crisis and the failures of several major financial institutions. Its sovereign credit rating was downgraded from AAA in November 1998, with subsequent downgrades in September 2000 and December 2001. We therefore next split the sample period into two subperiods, through April 1997 (90.2-97.4) and from May 1997 (97.5-2000.12), and check

EXHIBIT 9

GJR-GARCH Model—10-Year Swap Spreads and Total Period

Panel A: VOLATILITY OF YEN SWAP SPREAD: TOTAL PERIOD

Log-Likelihood	4601.3653	4611.2529	4617.3230
α_0	7.27×10^{-5} (10.75)	3.39×10^{-5} (3.2678)	3.82×10^{-5} (3.6572)
β_1	0.8593 (95.6421)	0.8482 (95.1306)	0.8513 (97.0150)
α_1	0.1161 (10.6619)	0.1206 (10.4718)	0.1151 (10.3133)
α_2	-7.25×10^{-3} (-0.5594)	-0.0132 (-0.8962)	-0.0113 (-0.7739)
γ_1		0.0233 (3.4591)	-0.0624 (-3.9843)
γ_2			0.1323 (4.6661)
γ_3		0.0116 (5.8564)	0.0113 (5.6622)
Skewnesss	0.1647	0.1124	0.08796
Kurtosis	4.2725	3.9511	3.76013
Ljung-Box (8) for normalized residuals	18.3440	18.5775	18.4676
Ljung-Box (8) for normalized squared residuals	7.0992	7.6445	8.3770
BIC	-3.4293	-3.4308	-3.4324

Panel B: VOLATILITY OF DOLLAR SWAP SPREAD: TOTAL PERIOD

Log-Likelihood	8338.0714	8338.2042	8338.9938
α_0	2.59×10^{-6} (11.4119)	2.72×10^{-6} (8.1509)	2.60×10^{-6} (8.4313)
β_1	0.8534 (134.3981)	0.8553 (123.5108)	0.8605 (129.6314)
α_1	0.14685 (15.8849)	0.1447 (14.9685)	0.1395 (15.0948)
α_2	0.0142 (1.9908)	0.0150 (2.1038)	0.0173 (2.5085)
γ_1		4.14×10^{-5} (0.4378)	-2.97×10^{-4} (-2.0296)
γ_2			6.09×10^{-4} (2.0580)
γ_3		-5.55×10^{-5} (-1.1003)	-5.71×10^{-5} (-1.1677)
Skewnesss	0.7552	0.7499	0.7535
Kurtosis	10.8968	10.8664	10.8776
Ljung-Box (8) for normalized residuals	8.4823	8.4529	8.6957
Ljung-Box (8) for normalized squared residuals	13.7318	13.3645	13.7907
BIC	-6.2263	-6.2205	-6.2181

whether the empirical results of the Granger causality test are sensitive to the choice of the sample periods.

Panel B of Exhibit 8 shows the test results for the first period. Unlike the total sample period results, there is no evidence that the lagged changes in the spreads for dollar interest rate swaps Granger-cause the changes in the spreads of yen interest rate swaps for the ten-year maturity. There is strong evidence, though, that the lagged changes of the interest differentials between U.S. and Japanese Treasury yields Granger-cause the changes in the yen interest rate swap spreads for all maturities.

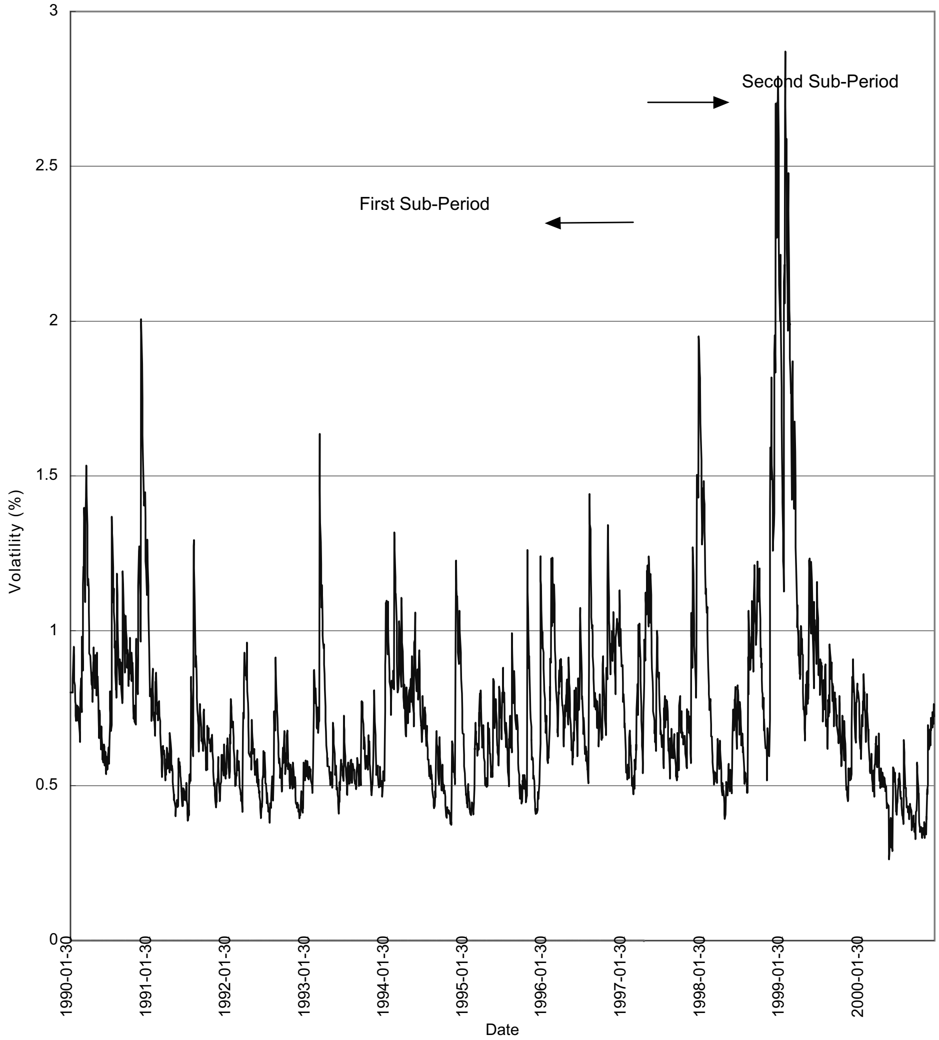
Panel C of Exhibit 8 shows the test results for the second period. The empirical results indicate that changes in the interest differentials Granger-cause the changes in the spreads of seven- and ten-year yen interest rate swaps. There is also some evidence that changes in the yen swap spreads Granger-cause the changes in the interest differentials for the two- and ten-year maturities.

Transmission of Swap Spread Volatilities

Exhibit 9 shows the results of our estimation of the basic model and the extended model using the ten-year yen and dollar swap spreads for the period January 30, 1990 – December 30, 2000. To measure the surprise element in the swap spreads, the conditional mean equations of the swap spreads are estimated using lagged swap spreads, lagged swap spreads of the other currency, and lagged interest rate differentials with lags up to seven. We also estimate the conditional mean equation with other choices of lags, but the results are omitted because the empirical results are qualitatively similar.

EXHIBIT 10

Volatility of 10-Year Yen Swap Spreads



Panel A of Exhibit 9 reports the estimation results for ten-year yen swap spreads, and shows that there is a strong GARCH effect in yen swap spreads. Most of the estimated coefficients are significant at the 1% level except for α_2, which captures the asymmetric effect of a positive shock in its own market.

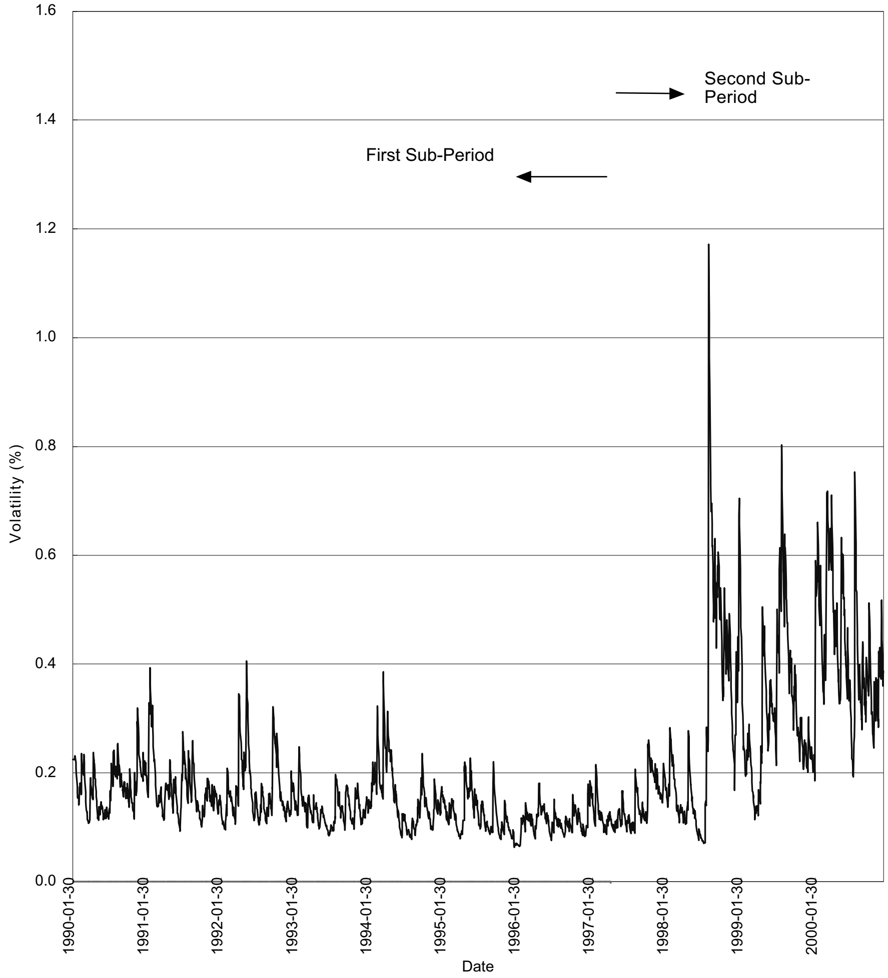
The log-likelihood value of the extended model in the last column of Panel A is 4617.3230, while the log-likelihood value of the basic model is 4601.3653. The value of the likelihood ratio (LR) test for the null hypothesis of $\gamma_1 = \gamma_2 = \gamma_3 = 0$ is equal to $-2[4601.3653 - 4617.3230]$ or 31.9154, which is asymptotically distributed with χ^2 (3).

Thus, the null hypothesis that there are no spillovers from other markets is rejected at the 1% significance level, indicating that there are strong volatility transmissions from the dollar swap spreads and interest differentials to the yen swap spreads. These spillover effects in volatility are consistent with the Granger causality test for ten-year yen swap spreads.

One of the interesting results in Panel A is that there is an asymmetric volatility effect of dollar swap spreads on yen swap spreads, while the asymmetric effect of the shock on the yen swap spread is insignificant. The estimates of γ_1 and γ_2 are -0.0624 and 0.1323, respectively, and both estimates are statistically significant at the 1% percent level. Thus, when there is a positive shock that increases dollar swap spreads, the yen swap spread becomes more volatile, while it becomes less volatile when there

EXHIBIT 11

Volatility of 10-Year Dollar Swap Spreads



is a negative shock in the dollar swap spread.

Panel B of Exhibit 9 reports our estimation of the volatility models using the ten-year dollar swap spreads for the sample period. As in the case of the yen swap spreads, there is a strong GARCH effect in the dollar swap spreads. All the coefficients in the basic model are significant, at least at the 5% level.

The estimation results of the volatility of the dollar swap spreads, however, are strikingly different from those for the yen swap spreads. First, the coefficients for α_2, which captures the asymmetric effect of a positive shock in its own market, are all significant in both basic and extended models.

Second, unlike the results in the yen swap spreads, there are almost no volatility spillover effects from the other market. The value of the likelihood ratio (LR) test for the null hypothesis of $\gamma_1 = \gamma_2 = \gamma_3 = 0$ is equal to $-2[8338.0714 - 8338.9938]$ or 1.8448, which is not significant at conventional significance levels, although the estimates of $\gamma_1$and γ_2 are statistically significant at the 5% level. These empirical results indicate that there are almost no, or weak if any, volatility spillovers from the yen swap spreads to the dollar swap spreads.

The diagnostic tests for residuals indicate no serious model misspecification. The kurtosis of the dollar swap spreads, however, is rather high. The relatively high kurtosis in the normalized residual indicates that jump components may be present in the dynamics of the swap spreads.

Exhibits 10 and 11 plot the estimated volatilities of the ten-year yen and dollar swap spreads for the entire period. The estimated results in both figures are based on the extended model. As Exhibit 11 shows, the dollar swap spreads are much more volatile in the second subperiod than in the

EXHIBIT 12

GJR-GARCH Model—10-Year Swap Spreads and Subperiods

Panel A: Volatility of Yen Swap Spread: Sub-Periods

	First Sub-Period	Second Sub-Period
Log-Likelihood	3125.2485	1509.1542
α_0	9.36×10^{-5} (4.1974)	1.95×10^{-5} (1.6266)
β_1	0.7904 (40.9505)	0.8888 (70.2981)
α_1	0.1383 (7.1110)	0.1158 (5.5304)
α_2	-0.0389 (-1.7272)	0.0032 (0.1311)
γ_1	-0.3867 (-2.6732)	-0.0041 (-0.2230)
γ_2	1.0542 (3.7071)	0.0613 (2.3559)
γ_3	0.0156 (5.4834)	-0.0068 (-1.9385)
Skewnesss	0.0102	0.1757
Kurtosis	4.2063	1.7001
Ljung-Box (8) for normalized residuals	23.0257	6.4099
Ljung-Box (8) for normalized squared residuals	7.3807	6.3376

Panel B: Dollar Swap Spread: Sub-Periods

	First Sub-Period	Second Sub-Period
Log-Likelihood	5992.0716	2384.6010
α_0	1.85×10^{-6} (3.7360)	4.27×10^{-6} (5.4407)
β_1	0.8961 (85.4578)	0.8126 (59.7684)
α_1	0.0767 (7.9231)	0.2296 (8.2700)
α_2	-0.006 (-0.5543)	0.0251 (1.2634)
γ_1	-0.0002 (-1.5741)	-0.0013 (-2.7972)
γ_2	0.0010 (3.2819)	-0.0005 (-0.7701)
γ_3	-4.66×10^{-6} (-0.0850)	0.0015 (4.7813)
Skewnesss	-0.0673	1.6111
Kurtosis	4.3380	14.4622
Ljung-Box (8) for normalized residuals	23.5336	6.1183
Ljung-Box (8) for normalized squared residuals	7.7836	6.2307

first subperiod. Dollar swap spreads have become dramatically more volatile since the LTCM crisis in 1998, remaining relatively volatile through 1999 and 2000.

Yen swap spreads are also more volatile in the second subperiod than in the first subperiod. Yen swap spreads were extremely volatile during the last quarter of 1998 and the first quarter of 1999.[10]

We perform the same estimation for the two subperiods to examine whether the estimated results for a volatility spillover effect from dollar swap spreads to yen swap spreads in Exhibit 9 are driven mostly by the second subperiod, when there was turmoil in the swap market due to credit events such as the Asian financial crisis, the Russian default, and the collapse of LTCM.

Panel A of Exhibit 12 reports the estimation results of the extended model for the ten-year yen swap spread in each subperiod. Panel B reports the estimation results of the same model for the ten-year dollar spread in each subperiod.

As can be seen in Panel A, the estimates of γ_1 and γ_2 for ten-year yen swap spreads in both subperiods are statistically significant, although the absolute values of the coefficients are higher in the first subperiod than in the second subperiod. The spillover effect from interest rate differentials to yen swap spreads is also significant in the first subperiod, but the relationship is reversed in the second subperiod.

These empirical results for yen swap spreads indicate

EXHIBIT 13

GJR-GARCH Model with Exogenous Shocks—2-Year and 5-Year Swap Spreads

Panel A: Volatility of Yen Swap Spread

	2-year	5-Year
Log-Likelihood	4288.6660	4483.2290
α_0	0.0001 (10.1725)	0.0001 (5.8922)
β_1	0.8288 (103.2965)	0.7601 (62.0455)
α_1	0.1743 (11.9492)	0.0906 (5.6787)
α_2	-0.0596 (-3.7242)	0.0791 (3.9650)
γ_1	-0.0875 (-4.5135)	-0.1317 (-2.8705)
γ_2	0.3193 (11.6447)	0.2731 (4.2282)
γ_3	-0.0023 (-1.0767)	0.0340 (14.9205)
Skewnesss	-0.4759	-0.3796
Kurtosis	7.5917	5.2373
Ljung-Box (8) for normalized residuals	9.0232	2.8823
Ljung-Box (8) for normalized squared residuals	3.5141	5.7973

Panel B: Volatility of Dollar Swap Spread

	2-year	5-year
Log-Likelihood	7162.5553	8137.9125
α_0	1.63×10^{-6} (3.4335)	1.99×10^{-6} (6.4943)
β_1	0.9536 (317.3000)	0.9283 (262.2258)
α_1	0.0043 (1.0906)	0.0283 (6.3265)
α_2	0.0799 (11.9326)	0.0775 (19.1192)
γ_1	-0.0002 (-1.7074)	-0.0002 (-2.2954)
γ_2	0.0005 (3.1884)	-4.03×10^{-5} (-0.2324)
γ_3	-0.0004 (-0.6399)	3.53×10^{-5} (0.7563)
Skewnesss	0.0535	0.6945
Kurtosis	2.8686	8.72201
Ljung-Box (8) for normalized residuals	4.5576	5.9285
Ljung-Box (8) for normalized squared residuals	6.8871	4.2473

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that the volatility spillover effects observed in the total period are not driven solely by the highly volatile period between May 1997 and December 2000. We might anticipate there would be volatility spillovers from the yen to the dollar swap spreads in the second subperiod, with the troubles in the Japanese financial system. The estimation results in Panel B of Exhibit 12 show that there was no transmission of credit risk in terms of volatility in the second subperiod, although the squared shocks in interest rate differentials are significant.

In order to test the robustness of our findings, we also estimate the same models using two-year and five-year swap spreads. The overall estimation results are similar to those for the ten-year swap spreads. Panel A of Exhibit 13 shows the estimation results for the yen swap spreads.

As in the case of the ten-year swap spreads, the spreads of both two-year and five-year yen swaps show strong volatility transmission from dollar swap spreads to yen swap spreads. There is also an asymmetric effect of the shock to the dollar swap spreads, which increases the volatility of the yen swap spreads more when there is a positive shock in the dollar swap spread, while the empirical results for the asymmetric effect of its own shock are mixed in the case of the two-year and five-year swap spreads.

The empirical results for the two-year and five-year dollar swap spreads are also quite similar to those of the five-year dollar swap spreads. There are strong asymmetric effects of the own lagged shock both for the two-year and the five-year dollar swap spreads, and there are no spillovers from the interest rate differentials to the dollar swap spreads.

The volatility spillovers from the yen swap markets are, however, somewhat mixed, since there is a significant negative relationship between the lagged squared shock of the yen swap spreads and the dollar swap spreads for the five-year dollar swap spreads. There is also a significant asymmetric volatility effect from the yen swap spread to the dollar swap spread, although the coefficient is much smaller than the coefficient of its own lagged shock.

IV. CONCLUSION

Our empirical examination of market integration between the Japanese yen and the U.S. dollar interest rate swap markets shows that, to the extent that swap spreads reflect credit risk, the credit risk factor in the swap markets is country-specific, rather than global in nature. There are low correlations between yen and dollar interest swap spreads. Furthermore, changes in the dollar interest rate swaps Granger-cause the changes in the yen interest rate swap spreads, at least for the ten-year maturities, indicating that yen swap markets may not be informationally efficient.

We do not find, however, any evidence that dollar swap spreads are affected by yen interest rate swap spreads. Instead, we find that yen swap spreads are highly correlated with the interest rate differentials between the two markets, while dollar swap spreads have virtually zero correlation with interest rate differentials. Interest rate differentials between these two markets also Granger-cause changes in the spreads of yen interest rate swaps across all maturities.

These empirical results imply that yen swap spreads are partly determined by market-specific activity in the yen fixed-income markets. When we test the sensitivity of our results for different subperiods, we find similar results. Our results seem to be robust to the choice of the sample period.

Our findings also show a strong transmission of volatility from the dollar swap spread and the interest rate differential to the yen swap spread, as well as an asymmetric volatility effect of dollar swap spreads on yen swap spreads. Contrary to the results for the yen swap spreads, we find weak volatility spillover effects, if any, from other markets to dollar swap spreads, and strong asymmetric effects of the own lagged shock in the dollar swap spreads.

This indicates that the increased dollar swap spread is a driving force of increased volatility in the dollar swap spreads and the yen swap spreads. These spillover effects are robust with respect to choice of sample period and swaps of different maturities.

Although we find some interesting results on the intermarket relationship between yen and dollar swap markets, there is a puzzling issue that needs to be addressed further. In the case of dollar swap spreads, we find no instance when interest swap spreads became negative; we do find that yen swap spreads were negative for a significant length of time, especially in early 1999.

Given that we find few cases of negative spreads for ten-year swaps, one possible explanation is that this phenomenon arises from the illiquidity of JGBs with maturities other than the on-the-run (often the benchmark) ten-year tenor. Since yen interest swap spreads are extremely low or even negative in that period, it would be important to measure the swap spreads using alternative par bond yields of JGBs to see if there were arbitrage opportunities in yen interest rate swap markets.

ENDNOTES

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[1] Source: Bank for International Settlements.

[2] There is some weak empirical evidence that swap spreads may reflect other factors such as liquidity and market frictions like short sales restrictions. See, for example, Eom, Subrahmanyam, and Uno [1998b] and Liu, Longstaff, and Mandell [2000] for details.

[3] This is modeled by, among others, Duffie and Huang [1996], Duffie and Singleton [1997], and Jarrow and Turnbull [1995, 1997].

[4] For instance, arbitrageurs could go long yen interest rate swaps and go short dollar interest rate swaps to construct a synthetic spread position between Treasury bonds (usually in the respective futures contracts) in the two countries. Such a spread is constructed to take advantage of the differential between the low long-term yields of JGBs and the high long-term yields of U.S. Treasury bonds.

[5] There are several approaches to modeling the asymmetric volatility effect, such as the EGARCH model of Nelson [1991], the asymmetric GARCH model and the non-linear asymmetric GARCH model of Engle and Ng [1993], and many others. We implemented these specifications as well as the model we adopt, and find that, in most cases, the GJR-GARCH model produces equal or better likelihood values.

[6] Estimation of the basic and extended model is performed by using the Berndt, Hall, Hall, and Hausman (BHHH) [1974] algorithm.

[7] The weekly data are from the end of the first week of daily data, i.e., February 2, 1990.

[8] For other maturities also, the yen swap spreads are negative during a significant proportion of the sample period. Neg-

ative spreads account for 32.81%, 22.98%, and 12.28% of the spreads with three-, five-, and seven-year maturities.

[9] This difference is accounted for by several factors. First, the supply of U.S. Treasury bonds had been shrinking while the supply of JGBs is growing. At the same time, the global appetite for U.S. Treasury bonds as a safe-haven asset is growing. These supply-demand effects cause a relative decline in U.S. Treasury yields and a relative increase in JGB yields. Second, the repo rate-LIBOR spread is lower in yen than dollars, creating a lower bound for the yen swap rate. Last, credit factors are different in the two currencies.

[10] In October 1998, the Diet passed the Financial Reconstruction Act and created the Financial Reconstruction Commission (FRC), which was to decide on the future of two of the three long-term credit banks in Japan. Rescue packages for the two banks were finalized in March 1999. Until then, Japanese investors were very nervous about the outcome of the decisions, since they might have caused the collapse of the Japanese financial system.

REFERENCES

Amihud, Y., and H. Mendelson. "Liquidity, Maturity and the Yields on U.S. Treasury Securities." *Journal of Finance*, 46 (1991), pp. 1411-1425.

Berndt, E., B. Hall, R. Hall, and J. Hausman. "Estimation and Inference in Nonlinear Structural Models." *Annals of Economic and Social Measurement*, Volume 3, Number 4 (1974), pp. 653-665.

Brown, K., W.V. Harlow, and D.J. Smith. "An Empirical Analysis of Interest Rate Swap Spreads." *The Journal of Fixed Income*, 3 (1994), pp. 61-68.

Duffie, D., and M. Huang. "Swap Rates and Credit Quality." *Journal of Finance*, 51 (1996), pp. 921-949.

Duffie, D., and K. Singleton. "An Econometric Model of the Term Structure of Interest-Rate Swap Yields." *Journal of Finance*, 52 (1997), pp. 1287-1321.

Elton, E.J., and C. Green. "Tax and Liquidity Effects in Pricing Government Bonds." *Journal of Finance*, 53 (1998), pp. 1533-1562.

Engle, R.F., T. Ito, and W.L. Lin. "Meteor Showers for Heat waves? Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market." *Econometrica*, 58 (1990), pp. 525-542.

Engle, R., and V. Ng. "Measuring and Testing the Impact of News on Volatility." *Journal of Finance*, 48 (1993), pp. 1749-1778.

Eom, Y.H., M.G. Subrahmanyam, and J. Uno. "Credit Risk and the Pricing of Japanese Yen Interest Rate Swaps." Working paper, NYU Salomon Center, New York University, 1998a.

——. "Coupon Effects and the Pricing of Japanese Government Bonds: An Empirical Analysis." *The Journal of Fixed Income*, 8 (1998b), pp. 69-86.

Fons, J. "Using Default Rates to Model the Term Structure of Credit Risk." *Financial Analysts Journal*, 50 (1994), pp. 25-32.

Fung, H., and S. C. Isberg. "The International Transmission of Eurodollar and U.S. Interest Rates: A Cointegration Analysis." *Journal of Banking and Finance*, 16 (1992), pp. 757-769.

Glosten, L., R. Jagannathan, and D. Runkle. "On the Relation Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks." *Journal of Finance*, 48 (1989), pp. 1779-1801.

Grinblatt, M. "An Analytic Solution for Interest-Rate Swap Spreads." Working paper, Yale University, 2002.

Grinblatt, M., and N. Jegadeesh. "Relative Pricing of Eurodollar Futures and Forward Contracts." *Journal of Finance*, 51 (1996), pp. 1499-1522.

Gupta, A., and M.G. Subrahmanyam. "An Empirical Examination of the Convexity Bias in the Pricing of Interest Rate Swaps." *Journal of Financial Economics*, 55 (2000), pp. 239-279.

Hamao, Y., R. Masulis, and V. Ng. "Correlations in Price Change and Volatility Across International Stock Markets." *Review of Financial Studies*, 3 (1990), pp. 281-308.

He, H. "Modeling Term Structures of Swap Spreads." Working paper, Yale University, 2000.

Helwege, J., and C.M. Turner. "The Slope of the Credit Yield Curve for Speculative-grade Issuers." *Journal of Finance*, 54 (1999), pp. 1869-1884.

Jarrow, R., and S. Turnbull. "Pricing Options on Financial Securities Subject to Default Risk." *Journal of Finance*, 50 (1995), pp. 53-86.

——. "When Swaps are Dropped." *Risk*, 10 (1997), pp. 70-75.

King, M., and S. Wadhwani. "Transmission of Volatility Between Stock Markets." *Review of Financial Studies*, 3 (1990), pp. 5-33.

Koticha, A. “Do Swap Rates Reflect Default Risk?” Ph.D. dissertation, New York University, 1993.

Lin, W.L., R.F. Engle, and T. Ito. “Do Bulls and Bears Move Across Borders? International Transmission of Stock Returns and Volatility.” *Review of Financial Studies*, 7 (1994), pp. 507-538.

Liu, J., F. Longstaff, and R.E. Mandell. “The Market Price of Credit Risk: An Empirical Analysis of Interest Rate Swap Spreads.” Working paper, UCLA, 2000.

Merton, R. “On the Pricing of Corporate Debt: The Risk Structure of Interest Rates.” *Journal of Finance*, 29 (1974), pp. 449-470.

Minton, B. “An Empirical Examination of Basic Valuation Models for Plain Vanilla U.S. Interest Rate Swaps.” *Journal of Financial Economics*, 44 (1997), pp. 251-277.

Mozumdar, A. “Essays on Swaps and Default Risk.” Ph.D. dissertation, Stern School of Business, New York University, 1996.

Nelson, D. “Conditional Heteroskedasticity in Asset Returns: A New Approach.” *Econometrica*, 59 (1991), pp. 347-370.

Pagan, A.R., and G.W. Schwert. “Alternative Models for Conditional Stock Volatility.” *Journal of Econometrics*, 45 (1990), pp. 267-290.

Ross, S. “Information and Volatility: The No-Arbitrage Martingale Approach to Timing and Resolution Irrelevancy.” *Journal of Finance*, 44 (1989), pp. 1-17.

Sarig, O., and A. Warga. “Some Empirical Estimates of the Risk Structure of Interest Rates.” *Journal of Finance*, 44 (1989), pp. 1351-1360.

Sun, T., S. Sundaresan, and C. Wang. “Interest Rate Swaps: An Empirical Investigation.” *Journal of Financial Economics*, 34 (1993), pp. 77-99.

Tse, Y., and G.G. Booth. “Common Volatility and Volatility Spillovers Between U.S. and Eurodollar Interest Rates: Evidence from the Futures Market.” *Journal of Economics and Business*, 48 (1996), pp. 299-312.

Zakoian, J.M. “Threshold Heteroskedastic Model.” *Journal of Economic Dynamics and Control*, 18 (1994), pp. 931-955.

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