The Components of Interest Rate Swap Spreads: Theory and International Evidence

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Abstract:

This paper contains both a theoretical and empirical analysis of the components of interest rate swap spreads defined as the difference between the fixed swap rate and the riskfree rate of equal maturity. The components are determined by expected LIBOR spreads, default risk, and market structure. A model of the swap market incorporating debt market imperfections and corporate financing choices is used to explain participation by both swap buyers and sellers. The model also motivates an empirical relationship between swap spreads and the slope of the riskfree term structure. The paper then provides empirical evidence on the cross-sectional and time-series variation of swap spreads in seven international markets. The evidence is consistent with the suggested components across both markets and swap maturities as well as over time.

I. Introduction

Plain vanilla interest rate swaps (hereafter swaps) are over-the-counter agreements between two counterparties to exchange periodic interest rate payments based on a predetermined notional amount. One counterparty (hereafter swap buyer) makes a fixed interest payment, typically called the swap rate or swap coupon, whereas the second counterparty (hereafter swap seller) makes its interest payment based on a floating-rate index such as the London interbank offered rate (LIBOR). Since the first occurrence of swaps in the early eighties, swap markets have experienced tremendous growth both in the U.S. and around the world. Total notional principal outstanding was \$6.08 trillion for swaps denominated in U.S. dollars, and the equivalent of \$16.21 trillion for swaps denominated in other currencies at the end of 1997.[1]

The main pricing variable in swap markets is the swap spread, usually defined as the difference between the n-year swap rate and the n-year government par-bond yield. Arbitrage arguments show that in the absence of swap default risk and market imperfections, the swap rate for a swap with a default-free reference rate should equal the default-free par bond yield

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of maturity equal to the swap, implying a swap spread of zero. However, U.S. Dollar swap spreads average 27 to 44 basis points for different maturities, with a cross-maturity average of 36 basis points between 1992 and 2000. In other currencies, averages range from 11 to 42 basis points.

Besides the size of the swap market, there is another reason why understanding the components of the swap spread is of increasing importance: there is a growing trend in financial markets to use the swap curve rather than the government curve for the pricing of bonds and other derivative securities. Swap markets are viewed by many market participants as more liquid than the corresponding government bond markets making swaps more efficient in reflecting changes in underlying interest rates. Daily turnover in worldwide swap markets was estimated as the U.S. Dollar equivalent of $150 billion in 1998 by the Bank for International Settlements. While the existing OTC dealer market for swaps is considered to be quite efficient, recently several electronic trading platforms such as TreasuryConnect, BrokerTec, and SwapsWire have been developed which should further increase liquidity and price transparency. Also unlike government bond markets, swap markets do not rely on continued issuance by a single borrower. This point is particularly important in light of the fact that many governments, foremost the U.S. government, have significantly reduced issuance of new debt in recent years.

While much early research focused on swap counterparty default risk as the main driver of swap spreads, recent theoretical and empirical work by Duffie and Huang (1996), Minton (1997) and Cossin and Pirotte (1997) has shed doubt on the ability of default risk alone to explain the magnitude and behavior of observed swap spreads. Default risk contributions to swap spreads can be expected to be smaller than the comparable bond credit spreads between the counterparties for two main reasons. First, the cash flow at risk in a swap is lower, since only net interest payments are being owed, as compared to both principal and full interest on a bond. Second, the default probability on the swap may be lower, since it is jointly determined by the probability of counterparty default and the probability of the swap having negative value to the defaulting counterparty.[2]

This paper examines the importance of two other components which can cause positive swap spreads even in the absence of default risk: LIBOR spreads, and swap market structure

effects. The LIBOR spread component is introduced by Brown, Harlow, and Smith (1994) and Nielsen and Ronn (1996): the arbitrage arguments mentioned previously rely on the assumption that the floating reference rate of the swap is free of default risk. LIBOR rates, however, are typically higher than the yields of government securities of the same maturity; the difference is often referred to as the LIBOR spread. Thus swap sellers expect to pay a rate which is higher (by the amount of the LIBOR spread) than the floating rate used in the arbitrage arguments, and all else equal need to be compensated via a higher fixed rate resulting in a positive swap spread.

The swap market structure component is based on the idea that supply and demand for swaps affect the swap spread. This relationship is studied in a model which motivates swap market participation by buyers with debt market imperfections. Wall (1989) and Titman (1992) show that for some borrowers, who face debt market imperfections such as asymmetric information, and financial distress costs, preferable financing strategies exist which involve paying the fixed rate of a swap. Eliminating part or all of the debt market imperfections creates economic gains, which originally accrue to the swap buyer; these gains can be shared via a positive swap spread to induce participation by swap sellers. Lang, Litzenberger, and Liu (1998) and Li (1998) argue that this component of swap spreads varies with the supply and demand for swaps.

While the Wall (1989) and Titman (1992) models rationalize demand for fix-for-floating swaps as part of a borrowing strategy, these models have difficulties explaining supply in a similar manner. This paper presents a different setting in which swap sellers have no external incentive, such as a need to borrow, to participate in the swap market. A fully financed firm can be induced to participate as a swap seller by either a strategy which involves hedging the interest rate risk of the swap or a strategy in which the interest rate risk of the swap is borne by the swap seller. The second strategy is hereafter referred to as a naked swap.

A naked swap has a positive expected return to the swap sellers: naked swaps provide payoffs similar to so-called leveraged bond strategies in which the purchase of a long term bond is financed with short term borrowing which is rolled over from period to period.

Leveraged strategies have positive expected returns since yield curves are typically upward-sloping. As a result, implied forward rates are upward-biased predictors of future short term

rates. This upward bias is often referred to as the term premium. Explanations of the term premium between long-dated bonds and short-dated bonds are often attributed to both an interest rate risk premium (longer-dated bonds are more sensitive to changes in discount rates than shorter-dated bonds) and a liquidity premium (markets for longer-dated bonds are less liquid than markets for shorter-dated bonds). Amihud and Mendelson (1991) and Elton and Green (1998) document liquidity effects in the pricing of government securities, while Boudoukh, Richardson, Smith, and Whitelaw (1999) is a recent example of papers analyzing interest rate risk.

If an investor wishes to engage in a term premium strategy, swaps are likely to have lower transaction costs than leveraged strategies which require borrowing of the full notional amount. Since swap markets are very liquid and existing swaps can be closed out easily during the life of the swap, it is also possible that naked swap sellers earn the liquidity premium portion of the term premium without taking on all of the associated liquidity risk.

In addition to the term premium, a naked swap sellers also receives the market structure component of the swap spread in the sense that the swap buyer is willing to pay a swap rate which is higher than the rate which adjusts for LIBOR spreads and swap default risk.

If a term premium change increases (decreases) the supply of swap sellers, then the other incentive, the swap spread, can be reduced (has to be increased) leading to a relationship between the term premium and swap spreads.

The empirical analysis uses a weekly panel dataset of swaps denominated in seven currencies between 1992 and 2000 representing approximately 80 percent of world-wide notional outstanding in 1997. The study uses both the longest U.S. Dollar swap time-series as well as the most internationally comprehensive dataset in the literature to date. Evidence supportive of all three swap spread components, default risk, LIBOR spreads, and market structure, is found across all swap maturities and denominating currencies. The findings are generally robust over time.

The contribution of this paper is three-fold: with respect to swap default risk and LIBOR spreads, the paper extends existing evidence for the U.S. swap markets to several international markets; in addition the paper explicitly tests for robustness over time which is typically not addressed in the existing literature. Secondly, the paper contributes a theo-

retical model of swap market structure which motivates a new component of swap spreads. Finally, the paper provides new empirical evidence consistent with the model.

Section II provides a brief discussion of swap default risk and the related literature. The linkage between LIBOR spreads and swap spreads is presented in section III. The following section IV discusses existing empirical evidence. The model of the swap market and its resulting hypotheses are given in section V. Section VI lists data sources and provides summary statistics. Base case results and related robustness checks regarding all three swap spread components are shown in section VII; this section also outlines the estimation and hypothesis testing techniques. Section VIII concludes and suggests directions for future research. Proofs are contained in the appendix.

II. Swap Default Risk and Swap Spreads

It is a well known result that a swap between two counterparties that have no default risk should have a swap spread of zero. Compare this case to a swap in which only the swap buyer may default. The swap seller is promised to receive fixed swap payments. However, the swap buyer may default on these payments. If this default risk is priced, then all else equal a higher swap spread is required. Similarly, a swap in which only the swap seller may default will all else equal carry a lower swap spread. Allowing for bilateral default risk, one arrives at the following hypothesis:

Hypothesis 1: There is a positive relationship between swap spreads and the default risk differential (quality spread) between swap buyer and swap seller.

Bilateral default risk is at least partially off-setting in an interest rate swap, which implies that negative swap spreads are theoretically possible, if the swap seller has sufficiently higher default risk than the swap buyer. In a study of the Japanese Yen swap market from 1990 to 1996 Eom, Subrahmanyam, and Uno (2000) find that a small percentage of observed swap spreads are negative.

To further analyze swap default risk, it is useful to model the short rate process and default events jointly to determine the relevant default rates depending on which counterparty is out-of-the-money on the swap. Duffie and Huang (1996) provide such a treatment and give simulation results showing that default risk will contribute approximately one basis point to

the swap spread given that the bond yield (of maturity comparable to the swap) of the swap buyer is 100 basis points higher than the bond yield of the swap seller.[3] These results are in line with similar results by Huge and Lando (2000). The theoretical default risk component of swap spreads is smaller than bond credit spreads since only the differential of two interest rates is at risk in a swap. Secondly, swap default occurs only in a subset of bond default states: the counterparty to which the swap has positive market value will not default on the swap even if it is in bond default. Few actual defaults in swaps have been observed, and both Brown and Smith (1993) and Abken (1993) report loss rates of less than one hundredth of a percent of notional value.

Sun, Sundaresan, and Wang (1993) provide the earliest empirical investigation of swap default risk and swap spreads by looking at quoted bids and offers from two swap dealers with different credit rating for their debt (AAA and A respectively). If default risk is priced, then the higher-rated dealer should have a larger bid-offer spread than the lower-rated one, which is what Sun, Sundaresan and Wang (1993) find in their data for the U.S. Dollar market from October 1988 to April 1991.

Another test can be based on the relationship between swap spreads and proxies of default risk such as corporate bond spreads. Minton (1997) examines U.S. Dollar swaps and finds that a 100 basis point increase in the bond spread of BBB rated bonds leads to a 12 to 15 basis point increase in the swap spread. Lang, Litzenberger, and Liu (1998) use data on U.S. Dollar five-year and ten-year swap spreads, and find a positive relationship between U.S. government agency bond spreads and swap spreads. Similarly, Eom, Subrahmanyam, and Uno (2000) find a positive relationship between Yen swap spreads and long term corporate bond spreads. Minton (1997) also uses a corporate quality spread between BBB rated and AAA rated bonds, but finds no significant relationship between the quality spread and swap spreads. Cossin and Pirotte (1997) study a small sample of actual swap transactions (rather than dealer quotes) and find limited evidence that default risk as proxied by the counterparty's credit rating is priced.

III. LIBOR Spreads and Swap Spreads

Most interest rate swaps use LIBOR as the floating reference rate. LIBOR rates are

not necessarily equal and are typically higher than the rates of government securities of similar maturity which may be attributed to default risk on LIBOR deposits. This LIBOR spread can cause a positive swap spread even in the absence of default risk for the swap counterparties.

Consider selling an n-year swap where the floating rate is the (default-free) short term rate r_s plus a non-negative random variable s_{LIBOR} which models the LIBOR spread. Each period the expected cash flows from the swap are $r_l + ss - E[r_s] - E[s_{LIBOR}]$, where r_l is the (default-free) long term rate and ss is the swap spread. Now, borrow for n years and roll over successive short term investments at the default-free rate: the expected cash flows each period are $E[r_s] - r_l$. Combining the cash flows yields the following present value:

$$\sum_{i=1}^{n} \left[r_l + ss - E\left[r_s^i\right] - E\left[s_{LIBOR}^i\right] + E\left[r_s^i\right] - r_l \right] * df^i, \tag{1}$$

where df is a discount factor.[4]Dropping the risk-free rates this can be rearranged to

$$\sum_{i=1}^{n} \left[ss - E\left[s_{LIBOR}^i\right] \right] * df^i. \tag{2}$$

If the present value of the swap is zero at initiation, then the above swap spread is a discount factor weighted average of the expected LIBOR spreads. This result is due to Brown, Harlow, and Smith (1994) and Nielsen and Ronn (1996). Thus positive expected LIBOR spreads can cause swap spreads to be positive even on a swap which has no default risk.

Instead of investing at the default-free short term rate $E[r_s]$ in the off-setting portfolio, one might choose to invest at the LIBOR rate $E[r_s] + E[s_{LIBOR}]$. In this case, the promised returns from the investment would be exactly sufficient to cover the payments on the swap. However, investing at the LIBOR rate introduces default risk to the off-setting portfolio, since the LIBOR borrower might default. If the swap seller is to be compensated for this default risk, it would require a higher swap spread which also leads to a positive relationship between LIBOR spread and swap spread.

Since standard swaps are paid in arrears, the current LIBOR rate is used to determine the first swap settlement. Thus, all else equal, higher current LIBOR spreads will lead to higher swap spreads:

Hypothesis 2: There is a positive relationship between swap spreads and LIBOR spreads.

Brown, Harlow, and Smith (1994) study U.S. Dollar swaps from 1985 to 1991 and find a positive relationship between LIBOR spread and swap spreads. Eom, Subrahmanyam, and Uno (2000) find a positive relationship between three-month TIBOR (Tokyo Interbank Offered Rate) spreads and Japanese Yen swap spreads in their study.

Since the above representation of the swap spread is a discount factor weighted average of the LIBOR spreads, the current LIBOR spread should have a stronger impact the shorter the maturity of the swap e.g. on a two-year swap with annual settlement there are only two LIBOR spreads to be considered, one of which is the current LIBOR spread. On a five-year swap with annual settlement there are five LIBOR spreads to be considered, and thus the impact of the current LIBOR spread would be weaker.

Hypothesis 3: The positive relationship between swap spreads and LIBOR spreads weakens as swap maturity increases.

Note that neither hypothesis relies on the idea that current LIBOR spreads hold information about future LIBOR spreads, they are simply due to the in-arrears payment feature.

IV. Existing Empirical Evidence

In addition to the studies mentioned in the previous two sections, there are several other empirical studies which study implied rather than directly observed swap spreads. Duffie and Singleton (1997) calculate implied swap spreads as follows: a multi-factor model of swap rates is estimated using weekly U.S. data from 1988 to 1994; the fitted swap rates are then used to calculate swap spreads implied by the model. Duffie and Singleton (1997) then estimate vector autoregressions (VAR) for the implied ten-year swap spreads, and proxies of credit risk and liquidity. They report a positive relationship between liquidity shocks and swap spreads, and a negative relationship between credit spreads and swap spreads. The second relationship represents evidence with respect to hypothesis 1 mentioned above: the reported negative relationship is consistent with the idea that swap sellers have on average more default risk than swap buyers.

Liu, Longstaff, and Mandell (2001) extend Duffie and Singleton (1997) by jointly estimating multi-factor models of U.S. Dollar denominated swap rates and U.S. treasury rates. Among other results this estimation yields an implied process for the spread between the

instantaneous discount rate applicable to U.S. treasuries and the instantaneous discount rate applicable to swap rates. Assuming that there is no swap default risk, this implied spread can be interpreted similar to the discount factor weighted average of the expected LIBOR spreads in the previous section. Thus Liu, Longstaff, and Mandell (2001) provide evidence consistent with hypothesis 2.

Collin-Dufresne and Solnik (2000) also model swap rates but focus on the spread between swaps and corporate bond yields. They show that swap rates should lie below corporate bond yields of equal maturity even when the corporate bond is of LIBOR credit quality. This spread between LIBOR bonds and swap rates is due to the fact that, as argued in the previous section, swap spreads reflect a weighted average of expected LIBOR spreads which are refreshed every six months. In this interpretation swap spreads are equal to the credit spread of a hypothetical corporate bond whose credit quality is certain to be unchanged over its life. The credit spreads of traded corporate bonds on the other hand also reflect the possibility that the borrowers credit quality may deteriorate below LIBOR quality over the life of the bond.

Besides methodological differences (direct examination of observed rather than implied swap spreads), the present paper extends the above mentioned studies with respect to hypotheses 1 and 2 by studying several large swap markets in addition to the U.S. Dollar swap market, and indeed finds that the importance of LIBOR spreads for swap spreads is quite variable internationally. Hypothesis 3 is not directly addressed by the above mentioned studies.

Duffie and Singleton (1997) also note that, even after accounting for liquidity and credit effects, a substantial fraction of the variation in swap spreads is left unexplained, and point towards exploration of supply and demand effects in swap markets as a potential explanation. The model in the following section addresses the demand and supply for swaps and its potential effects on observed swap spreads.

V. Swap Market Structure and Swap Spreads

In the following a model of the swap market is presented which motivates participation by both swap buyers and swap sellers. The modelling of the swap buyers starts with the

Flannery (1986) idea that borrowers with favorable private information prefer short term debt. These borrowers expect to be able to borrow at better terms when their private information becomes public and they, therefore, prefer not to lock in a fixed long term rate today. In a world with interest rate risk, the problem is more complicated. Titman (1992) argues that the presence of financial distress costs creates a dilemma for borrowers with favorable private information. If such a borrower finances long term, it is pooled with other, less-creditworthy firms and thereby locks in a long term credit spread, which is too high given the true quality of the firm. If the borrower finances short term, it is subject to interest rate risk and thus faces higher expected costs of financial distress. Wall (1989) provides a related model motivating the disincentive to finance long term by the well-known underinvestment problem instead of asymmetric information.

It can then be shown that the borrower described above may prefer the following financing strategy over straight long term or short term borrowing: roll over a sequence of short term loans and pay the fixed rate of an interest rate swap. This strategy avoids pooling with bad firms in the long term debt market while the swap eliminates the interest rate risk of short term borrowing. Consistent with the idea that swap buyers may have favorable private information, Wall and Pringle (1989) report that in a sample of U.S. corporations using swaps, swap buyers are significantly more likely than other firms to experience subsequent debt rating upgrades.

An explanation of swap sellers' participation can be based on the fact that in both the Titman (1992) and Wall (1989) models, swaps are not a zero-sum game for the swap buyer. Swaps provide swap buyers with economic gains from cheaper debt market financing. These gains can be shared with swap sellers via a positive swap spread.

A. Model Setup

The model has two periods with dates 0, 1, and 2. There are three types of risk-neutral firms, good (G), bad (B), and seller (SELL), which can borrow short and long term, and can enter into interest rate swaps. All firms make choices to maximize the value of their equity.

Borrowing long term a firm fixes the interest rate for two periods at $r_L = r_l + d_l$, where r_l is the long term default-free rate of interest and d_l is a default premium. Rolling over short

term loans creates a liability stream $\tilde{r}_{St} = \tilde{r}_{st} + \tilde{d}_{st}$, where $\tilde{r}_{St}$ is the short term risk-free rate and $\tilde{d}_{st}$ is a default premium. Interest rate uncertainty is modeled via a binary distribution, where r_{High} is the riskless interest rate in the high state, and similarly r_{Low} is the riskless interest rate in the low state. Finally, a default-free fix-for-floating swap creates a liability stream $r_{Swap} - \tilde{r}_{st}$, where r_{Swap} is the fixed rate on the swap. Swap sellers can borrow in the debt markets with default premia d_l^{SELL} and $\tilde{d}_{st}^{SELL}$, and there is no asymmetric information about their quality.

Firms of type G and B must raise \$1 at time 0 to finance a project with a payoff at time 2. Even though funding decisions occur at time 0, the project's riskiness is chosen by the borrower at time 1, but is revealed to lenders only at time 2. The type of a firm is known to the firm at time 0, but is revealed to lenders between time 0 and 1.

The safe project provides a payoff $R_G > R_B > R_l$ depending on the type of firm where capitalized R denotes $1 + r$ throughout the model. The risky project has positive expected payoffs that are lower than the respective safe payoffs by a constant c and exhibits a noise term ε. The constant is less than R_B. The noise term has mean zero and a lower bound equal to the constant less R_B. The noise term and the short term risk-free rate are assumed to be independent. Thus the risky payoffs are $\widetilde{R_G} = R_G - c + \varepsilon$ and $\widetilde{R_B} = R_B - c + \varepsilon$. Assume that R_B is sufficiently large and that c is sufficiently small such that at time 1 both projects for both types of firms have values that exceed their respective costs. Thus both types of firms can borrow at the risk-free rate in the first period. Without loss of generality assume the rate to be zero.

A good firm chooses the risky project when the following inequality holds:

$$D = E\left[\max\left(\widetilde{R_G} - R_{Loan}, 0\right)\right] - (R_G - R_{Loan}) > 0, \tag{3}$$

where R_{Loan} is the loan obligation from the firm's financing strategy. Since D increases with R_{Loan}, one can define a critical value R_G^* below which a firm chooses the riskless project. From $R_G > R_B$ and the definition of the risky project it follows that $R_G^* > R_B^*$. Thus, all else equal, bad firms are more likely to choose the risky project.

Finally assume $R_G^* < R_{High}$. This condition implies that a firm wishing to borrow at time 1 is certain to choose the risky project, if the high interest rate state occurs. Thus default

is possible and firms will have to borrow at a rate $r'_H > r_H$ giving rise to financial distress costs. Since firm type is revealed before lending occurs in the second period, r'_H is higher for bad firms than for good firms.

Figure 1 shows a time line of the model. Titman (1992) shows that there are no separating equilibria in which type G borrows long term and type B borrows short term creating the previously described dilemma for good firms. It follows that the long term rate is always a pooling rate.

B. Swap Buyers and Swap Spreads

Define the pooling default premium as d_l^P and the pooling interest rate as r_L^P. Define the swap spread $ss = r_{swap} - r_l$. The following proposition is an extension of Proposition 3 in Titman (1992).

Proposition 1 Suppose $R_H > R_G^* > R_{Swap} > R_l$, then

(a) for $R_l^P > R_{swap}$ and $E\left[\tilde{R}'_S\right] > R_{Swap}$ for G types, type G firms borrow short term and enter into a fix-for-floating swap; type B firms borrow short term and enter into a fix-for-floating swap if $R_B^* > R_{Swap}$.

(b) For $R_l^P < R_{swap}$, or $E\left[\tilde{R}'_s\right] < R_{Swap}$ for G types, type B and type G firms do not enter into a fix-for-floating swap.

Proof : given in appendix.∎

Titman (1992) models the swap rate equal to the riskless long term rate (implying a swap spread of zero), and shows that the good firms use such "fairly" priced swaps. However, the above proposition makes a stronger statement: demand to buy swaps may exist even when swap spreads are positive i.e. the swap alone has negative value to the swap buyer. Good firms can avoid pooling at the long term rate while hedging interest rate risk through the swap. The economic gains from this financing strategy can be shared via a positive swap spread.

Since the interest rate swap eliminates the ability of bad firms to pool with good firms at the long term rate, bad firms have no particular incentive to finance long term. However, bad firms may use the interest rate swap to eliminate interest rate risk which in turn reduces their financial distress costs. This strategy occurs in case (a) when $R_B^* > R_{Swap}$.

C. Swap Sellers and Swap Spreads

Swap sellers are assumed to enter into the swap naked e.g. the swap is not part of a debt market financing strategy as is the case for G and B firms. Thus a potential swap seller has no external incentive to enter into a swap. However, as shown in the previous section swap buyers may be willing to offer swaps that have positive value to the swap seller.

One course of action a SELL firm can take is to hedge its interest rate exposure from the swap by borrowing long term at $r_l + d_l^{SELL}$, and using the proceeds to invest short term at $\tilde{r}_{st}$. The total cash flow from this strategy is $r_l + ss - E\left[\tilde{r}_{st}\right] + E\left[\tilde{r}_{st}\right] - \left(r_l + d_l^{SELL}\right)$. After cancelling the riskless rates from the hedge with the riskless rates on the swap, the outflow or cost of this strategy is d_l^{SELL}, while the inflow is the swap spread ss.

Proposition 2 For $ss > d_l^{SELL}$ type SELL firms enter into floating-for-fix swaps.

Proof : given in appendix.∎

The proposition suggests that if the swap spread is equal to any small number in addition to the long term credit spread participation by swap sellers can be expected. In the current setting (symmetric information about the SELL firm; swap buyers are free of default risk) d_l^{SELL} should equal zero since the swap is free of default risk. However, extensions of the model are possible in which the swap cannot be separated from the SELL firms other financing activities, and thus d_l^{SELL} would be positive. In this case one would expect a positive relationship between bond spreads and swap spreads. By the same argument, one would then expect highly rated counterparties with low long term credit spreads to be candidates to pay the floating side of the swap. Wall and Pringle (1989) and Jagtiani (1996) study U.S. firms using swaps and find evidence that swap sellers are more likely to be the higher-rated counterparty.

Alternatively, the SELL firm may hold the swap as an investment vehicle similar to a leveraged bond strategy. Note that for a firm that wishes to pursue such a strategy, swaps are likely to have lower transaction cost than the alternative of buying long term bonds and issuing a series of short term bonds.

The firm expects to pay a series of future short rates $E\left[\tilde{r}_{st}\right]$ while receiving today's long-rate r_l and the swap spread. The total cash flow from this strategy is $r_l + ss - E\left[\tilde{r}_{st}\right]$. When

the expected cash flow is positive, risk-neutral swap sellers participate. One can rearrange:

Proposition 3 For $ss > E\left[\tilde{r}_{st}\right] - r_l$, type SELL firms enter into floating-for-fix swaps.

  Proof : given in appendix.∎

If a SELL firm expects the series of future short rates to be smaller than the series of today's implied forwards, it may enter into the floating-for-fix swap without hedging, since in this case the expected cash flows from the swap are positive even with a swap spread of zero.

Fama (1984) and Buser, Karolyi, and Sanders (1996) among others document that implied forward rates are on average higher than future spot rates. Thus on average, swap sellers receive an overall positive cash flow.

There is evidence such as Fama and Bliss (1987) that the relationship between current term structure slope and future short term rates while positive is less than one-to-one. Thus as the term structure steepens and implied forward rates increase, future short term rates tend to increase, but by less than the change in the implied forward rate. In this case an increase in the current slope of the term structure translates into an increase in $E\left[\tilde{r}_{st}\right] - r_l$. Thus for a risk-neutral counterparty, a steeper current term structure makes swap selling more attractive and the increased supply of swap sellers drives down the market structure component of the swap spread.

Hypothesis 4: There is a negative relationship between swap spreads and the slope of the term structure (measured over the swap's maturity).

Without the assumption of risk-neutrality for swap sellers, the direction of the relationship between term premia and the supply of swap sellers is unclear. If swap sellers are risk-averse, and the term premium is in part compensation for time-varying interest rate risk, then increases in the term premium (which attract swap sellers) might be off-set by increases in corresponding interest rate risk.

However, even in the risk-averse case, participation by naked swap sellers is still ensured by a positive swap spread, as long as the term premium is an appropriate compensation for interest rate risk. Furthermore, changes in the risk-return characteristics (as measured by the slope of the term structure) of naked swaps may still affect the supply of swap sellers,

but the direction of the relationship between term structure slope and swap spreads is not necessarily expected to be negative. Thus hypothesis 4 would simply state that there is a relationship between term structure slope and swap spreads.

Minton (1997) finds a positive relationship between two-year and five-year U.S. Dollar swap spreads and her measure of the term structure slope which is the difference of the 30-year treasury yield and the three-month treasury yield. However, this measure may be a poor proxy of the effect suggested in hypothesis 4 as the relevant segment of the term structure slope is only up to the swap's maturity. Eom, Subrahmanyam, and Uno (2000) use a more appropriate measure by taking the difference of the n-year and the one-year Japanese government yield to explain the n-year Japanese Yen swap spread; they find a significant negative relationship between term structure slope and swap spreads across all swap maturities.

Similar to hypothesis 4 Lang, Litzenberger, and Liu (1998) argue that supply-demand imbalances between swap buyers and swap sellers may vary with the business cycle, which may in turn affect the swap sellers' ability to extract the gains which originally accrue to the swap buyers. Given that the shape of the term structure varies with the business cycle, one should expect a relationship between the term structure and swap spreads.

While other factors such as risk premia and liquidity may also potentially lead to a relationship between term structure slope and swap spreads, it is important to note that the model is quite specific in the hypothesis it implies: it is precisely the slope of the term structure measured over the swap's maturity that is expected to be in a negative relationship with swap spreads. To distinguish the model from alternative explanations such as risk premia and liquidity, several additional hypotheses are developed next.

Similar to hypothesis 3 one can expect the importance of the current slope of the term structure to decrease with swap maturity. Since the swap is paid in arrears a positively sloped current term structure leads to a positive cash flow received by the swap seller on the first settlement. Given the same term structure slope naked swap sellers may thus prefer swaps of shorter maturity as the first settlement represents a larger share of the overall cash flows.

Hypothesis 5: The negative relationship between swap spreads and the slope of the term

structure weakens as swap maturity increases.

Hypothesis 5 also distinguishes the model in this paper from an alternative rationale for hypothesis 4 as a secondary effect of swap counterparty default risk. This idea is due to Sorensen and Bollier (1994) and Duffie and Huang (1996). Consider the example of an upward-sloping yield curve: in the early stages of the contract the floating rate is known (for the first payment) or can be expected to be lower than the swap rate. Thus the swap sellers owns a series of European-style options to default during the later stages of the swap contract having already received its payments from the swap buyer during the early stages of the swap contract. The swap buyer thus bears more default risk, and is compensated via a lower swap spread. Mozumdar (1997) points out that if the negative relationship between term structure slope and swap spreads is based on swap default risk, the relationship should strengthen as swap maturity increases. Thus a weakening of the relationship between swap spreads and the slope of the term structure as swap maturity increases would present evidence against this alternative explanation.

While none of the previous studies explicitly test for this, the coefficients in Eom, Subrahmanyam, and Uno (2000) monotonically decrease in magnitude from the two-year to the seven-year swap maturity, and then increase again for the ten-year maturity.

If some swap sellers participate in the market to earn a series of term premia as suggested above, it is also conceivable that supply-demand conditions translate across swap maturities and denominating currencies. Swap sellers which initially prefer to be in the short end of the market may be enticed to engage in longer-term swaps, if the term structure slope is steep in the medium and long term. As an example consider swap sellers in the two-year swap market. If the term structure is very steep between years two and five, swap sellers may switch from two-year to five-year swaps, reducing supply in the two-year market, and thereby driving up swap spreads in that market.

Hypothesis 6: There is a positive relationship between swap spreads and the slope of the term structure (measured beyond the swap's maturity).

This hypothesis might be an explanation for the positive relationship found by Minton (1997) whose proxy intermingles hypotheses 4 and 6. Also note that this hypothesis follows directly from the model while it is unclear how liquidity or risk premia effects would generate

the hypothesized relationship.

Swap sellers may also switch denominating currencies for the swaps, if the term structure in the other currency steepens, which again would lead to reduced supply in the original swap market thereby driving the corresponding swap spreads up.

Hypothesis 7: There is a positive relationship between swap spreads and the slope of the term structure in other currencies.

The last three hypotheses all rest on the idea that supply of potential swap sellers (and their respective swap volume) is limited. Given the typical size of swap transactions, and the fact that financial institutions incur costs for naked swaps in the form of risk-based equity capital requirements, this assumption appears reasonable, but is ultimately an empirical question to be answered by the data.

As argued above, even in the risk-averse case, changes in the risk-return characteristics of naked swaps may still affect the supply of swap sellers, but the direction of the relationship between term structure slope and swap spreads is not necessarily expected to be negative. Thus hypothesis 4 would simply state that there is a relationship between term structure slope and swap spreads. In this case hypotheses 6 and 7 could be restated to test the market structure component: the direction of the relationships postulated in 6 and 7 is expected to be opposite to the direction found for the relationship postulated in hypothesis 4.

VI. Data

Weekly swap quotations are obtained from Datastream International for the following seven currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). The swap rates are closing middle rates for swaps with maturities of two, five, and ten years. The fixed legs of all swaps settle annually with the exception of the British Pound and the Japanese Yen which settle semi-annually. The floating rate on the swaps is six-month LIBOR with semi-annual settlement of the floating leg. The swap rates are not transaction data but quotations which reflect the swap rate that a typical AA-rated counterparty could obtain. Therefore changes in the quotes may not perfectly reflect changes in actual rates.

Weekly one-year British Banker's Association LIBOR fixings are also obtained from Datas-

tream International. These fixings represent offered yields for the seven currencies above. Weekly par bond bid yields for government bonds, AAA-rated bonds, and AA/A-rated bonds are obtained from Bloomberg Online's Fair Market Value Bond Index. The yields are obtained for maturities of one, two, five, and ten years.

The country datasets contain between 126 (Dutch Guilder) and 383 (U.S. Dollar) weekly observations sampled in the time period between November 1992 and May 2000.

A. Swap Spreads

Summary statistics of the government par bond yields can be found in table I. All term structures are on average upward-sloping with the ten-year slope ranging from 85 basis points for the British Pound to 254 basis points for the Dutch Guilder. Average one-year yields range from .95 percent for the Japanese Yen to 7.44 percent for the Spanish Peseta. Autocorrelation coefficients are close to one for all currencies and maturities.

Swap spreads are measured as the difference of swap rates and government par bond yields of maturity equal to the swap. Figure 2 provides plots of the U.S. Dollar swap spreads for two-year and ten-year swaps. Summary statistics of the swap spreads are shown in table II. To assess the quality of the data, swap spreads were also obtained from a different source, Bloomberg Online, for the U.S. Dollar, British Pound, and Japanese Yen series. Summary statistics and plots of the Bloomberg series closely resemble the data used in this study. Eom, Subrahmanyam, and Uno (2000) also compute swap spreads over implied spot rates in their study of the Japanese Yen swap market, and find only minor differences in their empirical results between the spot and par bond measures of swap spreads.

Sample averages for swap spreads range from 5 basis points for the Dutch Guilder two-year swap to 44 basis points for the U.S. Dollar ten-year swap and the British Pound five- and ten-year swap. The swap spread term structure for the Japanese Yen is humped, and the swap spread term structure for the Spanish Peseta is downward sloping while the remaining five currencies have upward sloping term structures of swap spreads.

The series typically exhibit positive autocorrelation (results not shown) even at long lags such as 12 weeks. Most autocorrelation coefficients approach zero at a lag of 24 weeks. Since the autocorrelation coefficients exhibit no clear break, no attempt is made to specify

a time-series model for the original series. Instead first-differenced series are used for all estimations.

B. LIBOR Spreads and Bond Spreads

Table III provides summary statistics for LIBOR spreads and bond spreads. LIBOR spreads are measured as the difference of one-year LIBOR and the one-year government yield. One-year rather than six-month LIBOR spreads are used due to unavailability of six-month government yields for some currencies. LIBOR spreads range from 3 basis points for the Dutch Guilder to 51 basis points for the British Pound.

Bond spreads are measured as the difference of corporate bond yields and government bond yields for AAA ratings and A ratings (AA ratings are used for Japanese Yen and Spanish Peseta as the lower rating category because A ratings are unavailable on Bloomberg). For AAA ratings only the U.S. Dollar term structure is upward-sloping, while British Pound, Japanese Yen, and French Franc are slightly U-shaped, and German Mark, Spanish Peseta, and Dutch Guilder are slightly humped. Yields of A rated bonds are considerably higher than AAA rated yields for all currencies and maturities.

VII. Swap Spread Components: Empirical Evidence

Similar to previous studies such as Minton (1997), the initial proxy for the counterparty default risk component from hypothesis 1 is the corporate quality spread q_n defined as the difference between the n-year A rated bond yield and the n-year AAA rated bond yield, where n is the maturity of the respective swap spread. If swap sellers (swap buyers) are on average riskier, one should expect a negative (positive) relationship between the quality spread and swap spreads, since the default risk contribution of the swap seller (swap buyer) drives swap spreads down (up).

The current LIBOR spread s_{LIBOR} is used to assess hypotheses 2 and 3 suggesting a positive relationship between swap spreads and LIBOR spreads which weakens as swap maturity increases.

The proxy for the market structure component is based on hypothesis 4 as suggested by Proposition 3: the current slope of the term structure slo_n defined as the difference of the n-year government par bond yield and the one-year government par bond yield is expected

to be negatively related to swap spreads.

Swap spreads are modelled via the following specification estimated for each currency and maturity:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot q_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \varepsilon_n^t, \tag{4}$$

where ss_n is the n-year swap spread, t is a time index, α_n, β_n^1 through β_n^3 are coefficients, and ε is an error term.

Initial ordinary least squares (OLS) regressions (results are not shown) reveal that with the exception of the Japanese Yen and German Mark ten-year regression none of the coefficients for the corporate quality spread are significant. There are several reasons why the corporate quality spread may not pick up counterparty default risk in swaps: first, there might be no persistent differences in credit quality between swap buyers and swap sellers. Secondly, even if there were persistent differences in credit quality, they might no be represented well by A and AAA ratings.

An alternative test can be based on the idea that only the default risk of one side of the swap is priced. As discussed in section II, previous studies have found a positive relationship between bond spreads and swap spreads. A bond spread can be interpreted as a quality spread between a counterparty with default risk and a counterparty without default risk. Thus a positive relationship between bond spreads and swap spreads can be interpreted as evidence that only the default risk of swap buyers is priced in the swap market. In order to test for such a relationship the corporate quality spread is replaced with either one of its components, the A bond spread and the AAA bond spread to obtain the following regression equations:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \varepsilon_n^t, \tag{5}$$

$$ss_n^t = \alpha_n + \beta_n^1 \cdot A_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \varepsilon_n^t, \tag{6}$$

where AAA_n is the n-year bond spread for AAA rated bonds, A_n is the n-year bond spread for A rated bonds, β_n^1 through β_n^3 are coefficients, and all other variables are defined as before.

Tests of the OLS residuals also show that for all three specifications at least half the regressions suffer from heteroskedasticity, and all regressions suffer from serially correlated errors. To account for heteroskedasticity, and serial correlation standard errors are adjusted

as in Newey and West (1987a) by way of GMM estimation. Thus for each currency a system of three equations (one for each maturity) is estimated, in which each maturity equation generates moment conditions which are exactly identified. Since the model is linear, the only effect of GMM is the robustness of the covariance matrix.

The above methodology requires the choice of a lag truncation parameter to adjust for serial correlation. Although data driven bandwidth selection procedures such as in Andrews (1991) exist, their finite sample performance is unclear. Thus the lag truncation parameters is chosen for each currency based on a Box and Jenkins (1976) identification procedure of the residuals from the OLS regressions. A lag of 12 weeks appears to be sufficient for all series. All estimations were repeated for a low choice (4) and a high choice (30) of the lag truncation parameter for all currencies with minor differences to the results shown.

Since the base case regressions are exactly identified, hypothesis testing is relatively straightforward in this setting: the Lagrange multiplier statistic from Newey and West (1987b) is numerically identical to the test of overidentifying restrictions by Hansen (1982) which is obtained from estimation of the restricted model. Throughout this test is referred to as χ^2-test. The results of the regressions are discussed next.

A. Swap Default Risk and Swap Spreads: Empirical Evidence

Table IV contains the coefficient estimates for each of the default risk proxies. As discussed above the quality spread is significant only for the German Mark and Japanese Yen ten-year swap with the expected positive sign.

For U.S. Dollar, British Pound, Japanese Yen, German Mark, and French Franc all but one of the coefficient estimates for the bond spreads are positive and significant. For Spanish Peseta and Dutch Guilder the estimates are positive but generally not significant.

For the same maturity and currency the significant coefficient estimates for AAA and A spreads are generally close in magnitude. While in the majority of cases the coefficient for the AAA spread is larger than the corresponding coefficient for the A spread, the χ^2-tests in table IV reveal that one cannot reject the null hypothesis of the two coefficients being equal in all but one case, the Japanese Yen two-year spread. Thus only the AAA spread is used in the remainder of the analysis and the results from specification (5) are presented.

When comparing the significant coefficients of the AAA spread across maturities within the same currency the following picture emerges: the coefficients increase in magnitude from the two-year to the five-year level with the exception of the U.S. Dollar. However, χ^2-tests in table V show that the increase is significant only for German Mark swaps; from the five-year to the ten-year level there is no persistent pattern, and the only statistically significant change is for the U.S. Dollar swaps.

It appears that swap spreads are sensitive to bond spreads in most currencies and maturities. However, no clear patterns exist across bond spreads from different rating categories or across swap maturities. The evidence is consistent with the idea that the default risk of swap buyers dominates the default risk of swap sellers.

B. LIBOR Spreads and Swap Spreads: Empirical Evidence

As predicted by hypothesis 2 LIBOR spreads have a positive significant coefficient in most of the regressions in table V. For the two-year and five-year swap spreads the LIBOR spread coefficient is significant in all cases with the exception of the Dutch Guilder five-year spread. The results are weaker for the ten-year swap spreads: the LIBOR spread coefficient is only significant for U.S. Dollar and Japanese Yen.

As predicted by hypothesis 3 the magnitude of the coefficients decreases from the two-year to the five-year maturity for all currencies. χ^2-tests in table V show that the decreases are statistically significant in all cases but the U.S. Dollar. The changes in magnitude from the five-year to the ten-year maturity are not significant with the exception of the Dutch Guilder.

C. Swap Market Structure and Swap Spreads: Empirical Evidence

In accordance with hypothesis 4 the coefficient measuring the slope of the government term structure (over the maturity of the swap) is negative and significant for all currencies and swap maturities with the exception of the French Franc swaps which have negative but insignificant coefficients in table V. As discussed in section V.C counterparty default risk could also lead to a negative relationship between term structure slope and swap spreads. However, the evidence indicates that the observed negative relationship is not a secondary effect of default risk but rather a separate component for several reasons.

First, the magnitude of the coefficients is much larger than what could be expected from theoretical models of swap default risk. Duffie and Huang (1996) provide simulation results for five-year swaps, and show that under a typical term structure the impact of a 650 basis point variation in the slope of the term structure is a mere 2 basis points on the default risk component of the swap spread. These results are based on a swap in which the bond yields of the counterparties are 100 basis points apart indicating rather high default risk asymmetry.

Secondly, there are several regressions, German Mark two-year swaps, all Spanish Peseta and Dutch Guilder swaps, in which neither of the three bond spread measures of swap default risk from table IV is significant while the coefficient for the slope of the term structure is negative and significant. Also there seems to be no apparent relationship between the impact of default risk as measured by the magnitude of the bond spread coefficient, and the strength of the relationship between term structure slope and swap spreads. If the relationship is based on the swap default risk one would expect to see a positive albeit possibly nonlinear relationship between the magnitudes of the coefficients.

Finally, as discussed earlier, swap default risk predicts that the negative relationship between term structure slope and swap spreads should strengthen with swap maturity. Inconsistent with this argument but consistent with hypothesis 5, table V shows that from the two-year to the five-year maturity all coefficient estimates decline in magnitude. χ^2-tests show that the declines are statistically significant for four out of the six cases in which the coefficient estimates are significant. The declines are insignificant for U.S. Dollar, and Spanish Peseta. However, in the case of the Spanish Peseta, there is a significant decline from the five-year to the ten-year maturity. The four currencies which show significant declines from two years to five years do not show significant declines from five years to ten years indicating possible nonlinearity of the effect. The lone exception to hypothesis 5 comes from the U.S. Dollar which shows a significant increase in the magnitude of the coefficient from five years to ten years.

D.   Swap Spread Components: Robustness

Generally the base case results are consistent with hypotheses 1 through 4 indicating support for all three swap spread components: swap default risk, LIBOR spreads, and

market structure. Adjusted fit averages 25.7 percent for all currencies, and 32.2 percent for the currencies with longer time series, U.S. Dollar, British Pound, Japanese Yen, and German Mark.

This section investigates whether the parameter estimates are stable over time. As a first step the four currencies with the longest time series are used to obtain evenly split sample GMM estimates. The split date varies somewhat across currencies due to data availability but lies either in 1995 or 1996 for all currencies.

Estimations for the earlier and the later sample are shown in table VI. The results for either period are generally consistent with the previous evidence using the entire sample. For the AAA bond spread 20 out of 24 coefficients are positive and significant at least at the ten percent level. For the LIBOR spread 17 out of 24 estimates are positive and significant at least at the ten percent level. All term structure slope coefficients are negative and significant at the one percent level. For the U.S. Dollar adjusted fit improves markedly from the earlier to the later period by an average of 28.5 percent; adjusted fit worsens for the Japanese Yen by an average of 26 percent.

While none of the significant pairs of estimates switch signs between the early and the late sample period, the magnitude of the coefficients varies between the periods. To assess the significance of these changes one can test for parameter stability using a method introduced by Andrews (1993).

While the above evenly split sample estimates serve to illustrate potential parameter changes, there is no particular reason to expect the change point of the parameter change to lie in the middle of the time series. Thus a test for parameter stability with an unknown time of change in the interval $[0, T]$ is used, where T is the total number of observations. Define the time of change as πT, where π is a parameter in the interval $[0, 1]$ and referred to as the change point.

The null hypothesis of parameter stability for each swap maturity n is stated as:

$$H_0 : \beta_{nt} = \beta_{n0} \text{ for all } t \geq 1 \text{ for some } \beta_{n0} \in R^3, \tag{7}$$

where β_n is a 3×1 vector of the coefficients from (5). Note that there is no test for structural change in the intercept since the data is first-differenced. For an unknown change point the

alternative hypothesis is:

$$H_1 : \beta_{ns} = \beta_{nt} \text{ for some } s, t \geq 1. \tag{8}$$

The test statistic in Andrews (1993) is of the form:

$$\sup_{\pi \in \Pi} LM_T(\pi), \tag{9}$$

where Π is a pre-specified subset of $[0, 1]$, and LM_T is a Lagrange Multiplier (LM) statistic of the form:

$$LM_T(\pi) \cong \frac{T}{\pi(1-\pi)} \overline{m}'_{1T} \widehat{S}^{-1} \overline{m}_{1T}, \tag{10}$$

where $\widehat{S}^{-1}$ is the covariance estimator of the sample moment conditions, and

$$\overline{m}_{1T} = \frac{1}{T} \sum_{1}^{\pi T} m_t, \tag{11}$$

where m are the sample moment conditions.

Intuitively the test evaluates how well the full sample parameter estimates fulfill the moment conditions over a subset of the sample up to πT. Under the null hypothesis the parameters do not change, and thus the moment conditions over any subset have expectation of zero. Thus larger values of the test statistic indicate rejection of parameter stability.

The highest value of the LM statistic over all π is then used to evaluate the null hypothesis. Based on $\Pi = [.15, .85]$ as suggested by Andrews (1993) table VI provides the value of $\sup LM_T$ for all currencies and maturities. Critical values for this case are: 12.27 for the ten percent level, 14.15 for the five percent level, 17.68 for the one percent level.[5] The only estimations which reject parameter stability are the Japanese Yen two-year swap at the five percent level, and the Japanese Yen ten-year swap at the ten percent level.

For the Japanese Yen the LM statistics of all three maturities attain their supremum at the same π which corresponds to the sample date of May 5, 1995. On April 14, 1995, the Japanese government approved an emergency package, designed to boost the economy, in conjunction with a 75 basis point discount rate cut by the Bank of Japan which brought the rate to a new historic low of one percent. Arguably this date represents the beginning of Japan's zero discount rate policy, and thus might be the cause of the parameter shift.

E. Swap Market Structure and Swap Spreads: Cross-Maturity and Cross-Currency

Linkages

Hypothesis 6 is based on the idea that, given the same term structure slope, some swap sellers prefer the shorter segment of the term structure, and thus shorter swap maturities. As the term structure steepens on the longer end, longer-dated swaps becomes more attractive and thus some swap sellers switch, reducing supply for the shorter swap maturities and thereby drive up swap spreads for the short maturities.

To test this hypothesis, a measure of the term structure slope for the segment which is directly adjacent outside the respective swap's maturity is introduced. Thus the two-year swap specification now contains a variable measuring the slope of the term structure between years two and five, while the five-year swap specification contains a measure of the slope between years five and ten. The ten-year swaps are excluded from this analysis, since the data does not contain yields beyond maturity of ten years. The new specification is:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \beta_n^4 \cdot outslo_n^t + \varepsilon_n^t, \qquad (12)$$

where $outslo_n$ is defined as the difference of the five-year and the two-year government par bond yield for n equal to two, and $outslo_n$ is defined as the difference of the ten-year and the five-year government par bond yield for n equal to five.[6]

Hypothesis 6 predicts β^4 to be positive. Table VII shows the GMM estimation results for specification (12). With the exception of the five-year U.S. Dollar swap spread, and the two-year Japanese Yen swap spread all coefficient estimates are significant and positive. The inclusion of the outside slope measure improves adjusted fit by an average of approximately 3 percent across currencies and maturities.

Hypothesis 6 is based on the idea that swap sellers may switch between swap maturities depending on the shape of the term structure over a particular maturity segment. Hypothesis 7 tests a similar idea in that swap sellers may also switch denominating currencies if another currency's term structure steepens.

Eom, Subrahmanyam, and Uno (2000) study the linkage between U.S. Dollar swap spreads and Japanese Yen swap spreads, and find a positive relationship between Japanese Yen swap spreads and the interest rate differential between the two currencies, as measured by the difference of U.S. Dollar government bond yields and Japanese Yen government bond

yields. This finding is broadly consistent with hypothesis 7: all else equal, an increase in this differential implies that the U.S. Dollar yield curve has become steeper relative to the Japanese Yen yield curve which leads some swap sellers to switch from Japanese Yen to U.S. Dollar swaps driving up Japanese Yen swap spreads. Eom, Subrahmanyam, and Uno (2000) do not find a similar relationship for U.S. Dollar swap spreads being affected by the Japanese Yen term structure, which might be due to the fact that the U.S. Dollar swap market is considerably larger (by about 50 percent) than the Japanese Yen swap market.

Based on the idea that larger swap markets affect the supply-demand conditions in smaller swap markets the U.S. Dollar (representing the world's largest swap market) term structure slope is used as the proxy for the foreign slope resulting in the following specification for the other six currencies:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \beta_n^4 \cdot USDslo_n^t + \varepsilon_n^t, \qquad (13)$$

where $USDslo_n$ is defined as the n-year U.S. Dollar government yield less the one-year U.S. Dollar government yield, and all other variables are defined as previously. According to hypothesis 7 one expects β^4 to be positive as increases in the U.S. Dollar slope make the U.S. Dollar swap market more attractive and reduce supply of swap sellers in the other currencies thereby driving up their respective swap spreads.

Table VIII shows the GMM estimation results for specification (13). All coefficient estimates are positive. Across currencies and maturities approximately two thirds of the coefficient estimates are significant at least at the ten percent level. Consistent with the model the larger swap markets in the group, Japanese Yen, German Mark, and French Franc appear to be the less affected by U.S. Dollar swap spreads with three out of nine coefficients being significant. For the smaller swap markets, British Pound, Spanish Peseta, and Dutch Guilder, all coefficients with the exception of the five-year Dutch Guilder swap are significant.[7]

VIII. Conclusion

Interest rate swaps are an integral part of today's financial markets and arguably the most successful financial innovation of the past twenty years. Much of the literature on swaps has been devoted to pricing in swap markets with default risk. However, recent empirical and theoretical work indicates that default risk alone is not sufficient to rationalize the magnitude

and statistical properties of observed swap spreads.

Another strand of the literature on swaps examines the incentives of firms to transact in the swap market. The motivation literature shows that debt market imperfections may motivate firms to transact in the swap market.

Little research has been done to bridge pricing and motivation literature. This study is a step in providing this missing link between the derivatives and the corporate finance view of swaps. The pricing literature shows that at the swap spread, which adjusts for swap market imperfections, potential swap sellers are indifferent about their participation in the swap market. Thus the economic gains to swap buyers suggested by the motivation literature may be shared with swap sellers to induce their participation. The study explicitly takes into account the behavior of the swap sellers, and how it might affect observed prices i.e. swap spreads. From the model one can motivate a relationship between the slope of the term structure and swap spreads.

The empirical work in section VII uses a comprehensive dataset of international swap rates and interest rates. The evidence is generally consistent with all three swap spread components suggested in the paper. Future empirical tests of the model can be designed by looking at the characteristics of swap buyers versus swap sellers.

The paper's ideas may be applicable to other derivative securities. There is a growing literature, such as Leland (1985) and related papers, which extends derivatives pricing results to models with imperfections. Typically, such pricing generates arbitrage bounds within which derivatives prices lie. However, there is little work on how imperfections affect the structure of derivatives markets, such as the number and characteristics of buyers and sellers, on the effects of differential transactions costs, and on the effects of market structure on the price process within the arbitrage bound.

It is conceivable that, similar to swap markets, options or futures markets exhibit imbalances in the number of counterparties wishing to take a particular side of the transaction. Thus observed prices may contain a component which induces participation of other counterparties. The analysis of a market structure component in these markets may provide further insight into empirical anomalies such as option volatility smiles.

Appendix

Proposition 1 : Suppose $R_H > R_G^* > R_{Swap} > R_l$, then

(a) For $R_l^P > R_{swap}$ and $E\left[\tilde{R}_s'\right] > R_{Swap}$ for G types, type G firms borrow short term and enter into a fix-for-floating swap; type B firms borrow short term and enter into a fix-for-floating swap if $R_B^* > R_{Swap}$.

Proof : By assumption $R_G > R_B > R_l$, $\widetilde{R_G} = R_G - c + \varepsilon$ and $\widetilde{R_B} = R_B - c + \varepsilon$, both G and B borrow at the risk-free rate period 1. At date 1 firm type is revealed and G can again borrow at the risk-free rate, if borrowing cost is less than R_G^*. With the swap the net borrowing cost is R_{Swap}, since the short term risk-free rates cancel each other out. Thus lenders' beliefs that the safe project will be chosen are consistent and they are willing to lend at the short term risk-free rate in the second period.

The borrowing cost of straight long term borrowing is $R_l^P > R_{Swap}$.

The borrowing cost of straight short term borrowing is $E\left[\tilde{R}_s'\right] > R_{Swap}$.

The borrowing cost of long term borrowing combined with the fix-for-floating swap is R_l^P plus the value of the swap. Since the swap spread is positive by assumption, the swap alone must have negative economic value to the swap buyer. Thus this strategy is costlier than straight long term borrowing.

Given that G borrows short term, any long term borrower is revealed to be B. If a type B firm borrows short term, its type is revealed before borrowing in the second period occurs. Thus borrowing costs with either alternative are the same as under symmetric information. From $R_l^P > R_{swap}$ it then follows that $R_l^B > R_{swap}$, where R_l^B is the cost of long term borrowing for bad firms. One needs to show that given $R_B^* > R_{Swap}$, short term borrowing combined with the fix-for-floating swap has the lowest net borrowing cost for bad firms.

By assumption $R_G > R_B > R_l$, $\widetilde{R_G} = R_G - c + \varepsilon$ and $\widetilde{R_B} = R_B - c + \varepsilon$, both G and B borrow at the risk-free rate period 1. At date 1 firm type is revealed and B can again borrow at the risk-free rate, if borrowing cost is less than R_B^*. With the swap the net borrowing cost is R_{Swap}, since the short term risk-free rates cancel each other out. Thus lenders' beliefs that the safe project will be chosen are consistent and they are willing to lend at the short term risk-free rate in the second period.

The borrowing cost of straight long term borrowing is $R_l^B > R_{Swap}$.

The borrowing cost of straight short term borrowing is $E\left[\tilde{R}_s'\right] > R_{Swap}$.

The borrowing cost of long term borrowing combined with the fix-for-floating swap is R_l^B plus the value of the swap. Since the swap spread is positive by assumption, the swap alone must have negative economic value to the swap buyer. Thus this strategy is costlier than straight long term borrowing.

(b) For $R_l^P < R_{swap}$, or $E\left[\tilde{R}_s'\right] < R_{Swap}$ for G types, type B and type G firms do not enter into a fix-for-floating swap.

Proof : Rolling over short term loans in conjunction with the swap has a borrowing cost of $E\left[\tilde{R}_s'\right] + R_{Swap} - E\left[\tilde{R}_s\right]$ which is at least as big as R_{Swap}. Thus either straight long term borrowing or straight short term borrowing or both are preferable by the condition.

The borrowing cost of long term borrowing combined with the fix-for-floating swap is R_l^P plus the value of the swap. Since the swap spread is positive by assumption, the swap must have negative economic value to the swap buyer. Thus this strategy is costlier than straight long term borrowing. Thus straight long term borrowing is always preferred to this strategy.∎

Proposition   2 : For $ss > d_l^{SELL}$, type SELL firms enter into floating-for-fix swaps.

Proof : For $ss > d_l^{SELL}$ consider the strategy for firm SELL of entering into a floating-for-fixed swap at r_{swap} resulting in the following cash flow: $r_l + ss - E\left[\tilde{r}_{st}\right]$. In addition, let the firm borrow long term and invest short term at the risk-free rate resulting in the following cash flow: $E\left[\tilde{r}_{st}\right] - \left(r_l + d_l^{SELL}\right)$. Combined cash flows are: $r_l + ss - E\left[\tilde{r}_{st}\right] + E\left[\tilde{r}_{st}\right] - \left(r_l + d_l^{SELL}\right)$, which nets to $ss - d_l^{SELL} > 0$, which is free of default or interest rate risk.

Proposition   3 : For $ss > E\left[\tilde{r}_{st}\right] - r_l$, type SELL firms enter into floating-for-fixed swaps.

Proof : For $ss > E\left[\tilde{r}_{st}\right] - r_l$ consider the strategy for firm SELL of entering into a floating-for-fixed swap at r_{swap}. The expected cash flows are $r_l + ss - E\left[\tilde{r}_{st}\right]$, which are positive by the condition, and thus a risk-neutral SELL firm will enter into the floating-for-fixed swap.∎

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1. Source: International Swaps and Derivatives Association

2. This argument is discussed in Hull (1989) and Duffie and Huang (1996).

3. For a five-year maturity, this bond yield spread corresponds approximately to a AAA credit rating for the pay-floating counterparty and a BB credit rating for the pay-fix counterparty based on average bond yield spreads obtained from Standard and Poors.

4. Note that if investors are risk-averse, the discount factor should contain a risk correction.

5. The critical values are based on Monte Carlo simulation results by Andrews (1993).

6. Summary statistics for the outside slope measure are available upon request.

7. For the two-year and five-year swaps a model (results not shown) which includes both $outslo_n$ and $USDslo_n$ is also estimated with largely unchanged results.

Figure 1. Model Time Line. Figure 1 presents a time line of the model describing swap buyers.

```
Firm learns| Lender| Firm chooses | Project payoff;
its type;  | learns| project type;| Lender learns
Firm       | firm  | Firm may     | project type
finances   | type  | refinance
      |------------------|---------------|
Time  0                  1               2
```
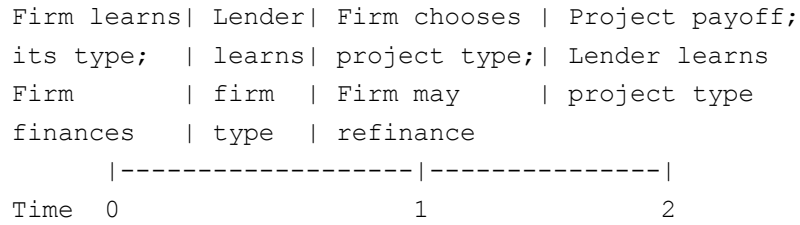
Figure 2. U.S. Dollar Swap Spreads. Figure 2 presents the two- and ten-year swap spreads: the difference between the U.S. dollar swap rates and the U.S. government par bond yields with corresponding maturity. The swap rates are middle rates from Datastream International. The government yields are from Bloomberg Online's Fair Market Yield Curves. Data is sampled weekly from 11/13/92 to 5/5/00.

37
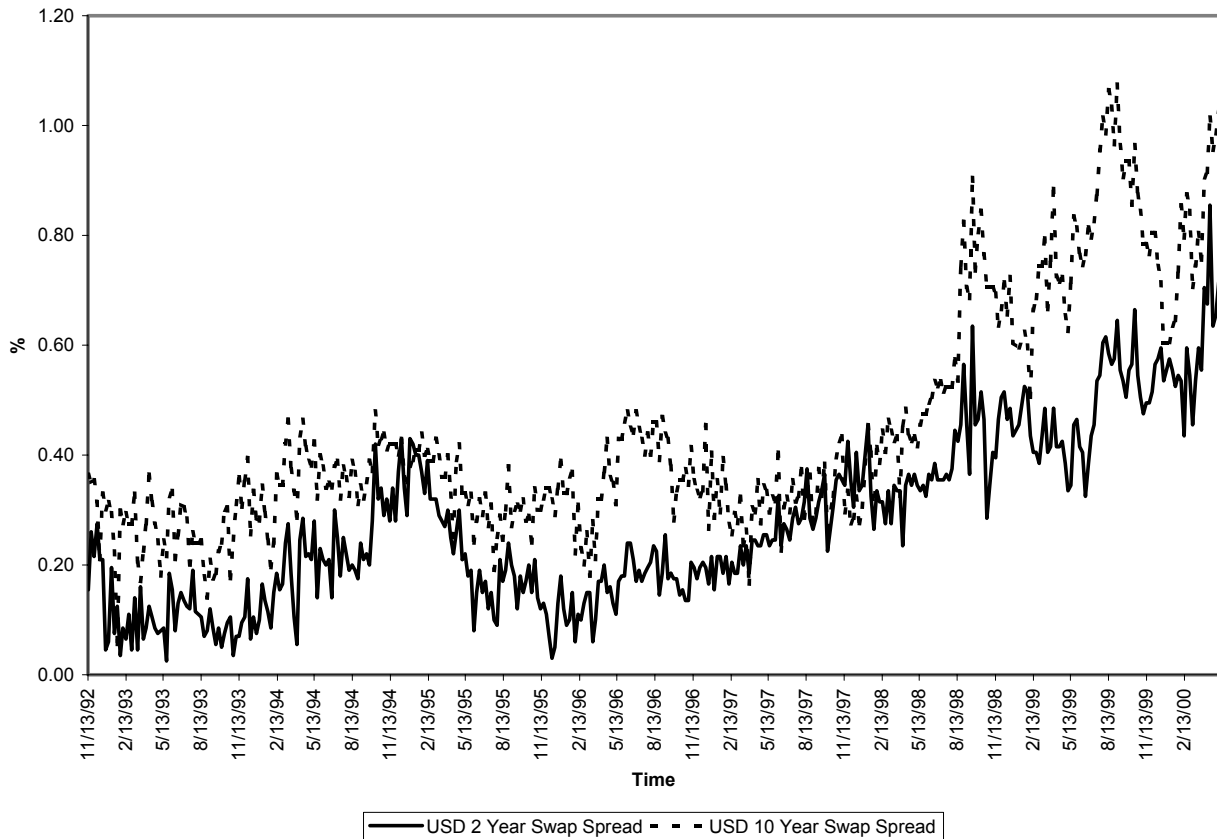
I. Summary Statistics: Government Bond Yields

The table shows means, standard deviations, autocorrelation coefficients, number of observations, and sample periods for weekly 1-year government par bond yield (r_1), 2-year government par bond yield (r_2), 5-year government par bond yield (r_5), and 10-year government par bond yield (r_{10}) for each of the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). The data was obtained from Bloomberg Online's Fair Market Yield Curves. All yield data is in percent.

	USD	GBP	JPY	DEM	FRF	ESP	NLG
	MEAN						
r_1	5.34	6.09	.95	4.35	4.60	7.44	3.48
r_2	5.56	6.38	1.21	4.72	4.92	7.65	3.98
r_5	5.97	6.76	2.11	5.65	5.71	8.24	5.14
r_{10}	6.26	6.95	2.89	6.42	6.47	8.74	6.02
	STANDARD DEVIATION						
r_1	.94	.70	.88	1.01	1.24	2.08	.37
r_2	.86	.76	.95	.95	1.21	2.28	.37
r_5	.74	1.07	1.07	.76	1.03	2.32	.37
r_{10}	.72	1.30	1.07	.63	.85	2.12	.41
	AUTOCORRELATION						
r_1	.99	.97	.99	.99	.99	.99	.99
r_2	.98	.98	.99	.99	.99	.99	.99
r_5	.98	.99	.99	.99	.99	.99	.99
r_{10}	.99	.99	.99	.99	.99	.99	.99
Observations	383	346	351	234	156	155	126
Period	11/92-5/00	3/93-5/00	6/93-5/00	6/93-1/98	1/95-1/98	1/95-1/98	8/95-1/98

II. Summary Statistics: Swap Spreads

The table shows means, standard deviations, autocorrelation coefficients, number of observations, sample periods, and market size for weekly 2-year swap spread (ss_2), 5-year swap spread (ss_5), and 10-year swap spread (ss_{10}) for each of the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). Swap spreads are calculated as the difference of swap middle rates from Datastream International and government par bond yields of equal maturity from Bloomberg Online's Fair Market Yield Curves. All swap spread data is in basis points. Market size is the U.S. Dollar equivalent of total notional outstanding in billions at the end of 1997 obtained from International Swaps and Derivatives Association.

	USD	GBP	JPY	DEM	FRF	ESP	NLG
	MEAN						
ss_2	27	39	19	12	9	15	5
ss_5	36	44	23	18	16	10	14
ss_{10}	44	44	18	21	16	8	20
	STANDARD DEVIATION						
ss_2	15	18	10	7	6	7	6
ss_5	15	27	13	6	6	9	5
ss_{10}	20	30	10	7	5	9	5
	AUTOCORRELATION						
ss_2	.92	.89	.71	.73	.75	.89	.69
ss_5	.94	.96	.81	.72	.96	.93	.96
ss_{10}	.94	.97	.73	.74	.98	.96	.98
Observations	383	346	351	234	156	155	126
Period	11/92-5/00	3/93-5/00	6/93-5/00	6/93-1/98	1/95-1/98	1/95-1/98	8/95-1/98
Market Size	6.078	1.457	4.313	3.278	2.378	.420	.188

III. Summary Statistics: LIBOR Spreads and Bond Spreads

The table shows means, standard deviations, number of observations, and sample periods for weekly LIBOR spread (s_{LIBOR}), 2-year AAA spread (AAA_2), 5-year AAA spread (AAA_5), 10-year AAA spread (AAA_{10}), 2-year A spread (A_2), 5-year A spread (A_5), 10-year A spread (A_{10}) for each of the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). LIBOR spreads are calculated as the difference of British Banker's Association 1-year LIBOR offered rate from Datastream International and 1-year government yield from Bloomberg Online's Fair Market Yield Curves. AAA (A) spreads are calculated as the difference of AAA (A) rated corporate par bond yield and government par bond yield of equal maturity from Bloomberg Online's Fair Market Yield Curves. For JPY and ESP a AA bond yield is used in place of the A bond yield. All spread data is in basis points.

	USD	GBP	JPY	DEM	FRF	ESP	NLG
	MEAN						
s_{LIBOR}	21	51	17	12	13	10	3
AAA_2	29	39	11	15	12	14	13
AAA_5	35	42	12	9	15	7	11
AAA_{10}	51	45	6	20	12	7	15
A_2	58	73	16	48	35	20	27
A_5	69	88	17	45	47	13	36
A_{10}	81	107	17	47	42	14	49
	STANDARD DEVIATION						
s_{LIBOR}	16	20	10	8	13	9	5
AAA_2	18	17	12	8	7	10	6
AAA_5	18	21	15	8	8	6	5
AAA_{10}	26	21	7	7	6	9	4
A_2	25	21	15	16	12	11	7
A_5	26	24	17	13	11	7	8
A_{10}	26	23	15	10	7	11	10
Observations	383	346	351	234	156	155	126
Period	11/92-5/00	3/93-5/00	6/93-5/00	6/93-1/98	1/95-1/98	1/95-1/98	8/95-1/98

IV. Swap Default Risk and Swap Spreads

The table shows coefficient estimates, robust t-statistics (in parentheses), χ^2-tests and associated P-values (in brackets), and number of observations per maturity for GMM estimations of swap spreads in the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). Three specifications (S1, S2, S3) are estimated:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot DEF_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \varepsilon_n^t, \qquad (14)$$

where ss_n^t is the swap spread (swap rate less government yield), $DEF_n = q_n$, (S1), AAA_n (S2), A_n (S3), q_n is the corporate quality spread (A rated bond yield less AAA rated bond yield), AAA_n is the AAA spread (AAA rated bond yield less government yield), A_n is the A spread (A rated bond yield less government yield), s_{LIBOR}^t is the LIBOR spread (1-year LIBOR less 1-year government yield), slo_n^t is the term structure slope (n-year government yield less 1-year government yield), n is maturity, t is a time index, α_n, β_n^1 through β_n^3 are coefficients, and ε is an error term. Maturities: 2, 5, 10 years. Only β_n^1 is shown from each specification. χ^2 is a Lagrange multiplier test of equal coefficients for AAA_n and A_n. All swap and LIBOR rates from Datastream International; all other data from Bloomberg Online (for JPY and ESP yields of AA rated bonds were used instead of A rated bonds). All data is weekly. All series are first-differenced. Data collected between 11/92 and 5/00.

Two-Year Swaps							
	USD	GBP	JPY	DEM	FRF	ESP	NLG
Quality Spread	-.01	.02	-.05	.01	.21	-.21	.09
	(-.3)	(.6)	(-.5)	(.2)	(1.8)	(-1.6)	(1.0)
AAA Spread	.18	.28	.22	.09	.34	.11	.12
	(2.4)	(3.2)	(3.3)	(1.0)	(3.2)	(1.1)	(.8)
A Spread	.17	.27	.14	.06	.31	.03	.16
	(2.2)	(4.8)	(2.4)	(.9)	(3.0)	(.3)	(1.4)
χ^2 (AAA=A)	.00670	.00008	2.93229	.11480	.06437	.96089	.11000
P-Value	[.94]	[.99]	[.09]	[.74]	[.80]	[.33]	[.74]
Observations	383	346	351	234	156	155	126

Five-Year Swaps							
	USD	GBP	JPY	DEM	FRF	ESP	NLG
Quality Spread	-.01	.01	.08	-.06	.13	-.19	.11
	(-.2)	(.1)	(.5)	(-.8)	(1.0)	(-1.2)	(.8)
AAA Spread	.17	.32	.42	.35	.46	.17	.04
	(2.6)	(2.9)	(5.9)	(3.1)	(3.0)	(1.2)	(.3)
A Spread	.13	.22	.40	.18	.38	.05	.11
	(2.4)	(2.9)	(6.9)	(1.9)	(2.5)	(.4)	(1.0)
χ^2 (AAA=A)	.00199	.05448	.00646	.12082	1.53506	.69644	.19157
P-Value	[.96]	[.82]	[.94]	[.73]	[.22]	[.40]	[.66]
Observations	383	346	351	234	156	155	126

Ten-Year Swaps							
	USD	GBP	JPY	DEM	FRF	ESP	NLG
Quality Spread	-.09	-.14	.19	.12	.15	-.04	.02
	(-1.6)	(-1.2)	(2.4)	(2.3)	(1.4)	(-.3)	(.2)
AAA Spread	.32	.36	.38	.23	.36	.07	.20
	(4.5)	(3.7)	(5.0)	(2.2)	(2.5)	(.6)	(1.6)
A Spread	.36	.14	.29	.25	.38	.06	.10
	(5.3)	(1.7)	(4.8)	(3.8)	(3.0)	(.4)	(1.0)
χ^2 (AAA=A)	.33067	2.12096	2.55681	.05117	.03685	.00961	.15307
P-Value	[.57]	[.15]	[.11]	[.82]	[.85]	[.92]	[.70]
Observations	383	346	351	234	156	155	126

V. Swap Spread Components: Swap Default Risk, LIBOR Spreads, and Swap Market Structure

The table shows coefficient estimates (constant term not shown), robust (heteroskedasticity and serial correlation up to lag 12) t-statistics (in parentheses), χ^2-tests and associated P-values (in brackets), adjusted R^2, and number of observations per maturity for GMM estimations of swap spreads in the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). Specification:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \varepsilon_n^t, \tag{15}$$

where ss_n^t is the swap spread (swap rate minus government yield), AAA_n is the AAA spread (AAA rated corporate bond yield minus government yield), s_{LIBOR}^t is the LIBOR spread (1-year LIBOR minus 1-year government yield), slo_n^t is the term structure slope (n-year government yield minus 1-year government yield), n is maturity, t is a time index, α_n, β_n^1 through β_n^3 are coefficients, and ε is an error term. Maturities: 2, 5, 10 years. χ^2 is a Lagrange multiplier test of equal coefficients for adjacent maturities (2 and 5 years; 5 and 10 years). All swap and LIBOR rates from Datastream International; all other data from Bloomberg Online. All data is weekly. All series are first-differenced. Data collected between 11/92 and 5/00.

	USD			GBP			JPY			DEM		
	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr
AAA Sp.	.18	.17	.32	.28	.32	.36	.22	.42	.38	.09	.35	.23
	(2.4)	(2.6)	(4.5)	(3.2)	(2.9)	(3.7)	(3.3)	(5.9)	(5.0)	(1.0)	(3.1)	(2.2)
χ^2 (Mat.)		.02	4.82		.11	.13		2.37	.38		4.87	.80
P-Value		[.88]	[.03]		[.74]	[.72]		[.12]	[.54]		[.03]	[.37]
LIBOR Sp.	.18	.13	.18	.47	.13	.06	.66	.47	.42	.53	.18	.17
	(3.2)	(3.7)	(4.3)	(6.8)	(2.3)	(1.2)	(10.3)	(7.0)	(5.5)	(5.1)	(1.7)	(1.3)
χ^2 (Mat.)		1.69	2.69		13.59	1.65		6.96	1.34		12.84	.08
P-Value		[.19]	[.10]		[.00]	[.20]		[.01]	[.25]		[.00]	[.78]
Slope	-.23	-.16	-.24	-.56	-.24	-.20	-.68	-.46	-.39	-.45	-.24	-.27
	(-4.0)	(-4.7)	(-6.6)	(-6.4)	(-3.6)	(-4.7)	(-8.0)	(-7.5)	(-5.2)	(-7.9)	(-4.0)	(-4.0)
χ^2 (Mat.)		2.60	5.16		7.82	.57		6.67	1.87		5.92	.18
P-Value		[.11]	[.02]		[.01]	[.45]		[.01]	[.17]		[.02]	[.67]
Adj. R^2	18.3	17.1	33.7	59.1	20.6	23.1	55.4	51.7	39.7	26.0	19.5	21.8
Obs.	383	383	383	346	346	346	351	351	351	234	234	234

	FRF			ESP			NLG		
	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr
AAA Sp.	.34	.46	.36	.11	.17	.07	.12	.04	.20
	(3.2)	(3.0)	(2.5)	(1.1)	(1.2)	(.6)	(.8)	(.3)	(1.6)
χ^2 (Mat.)		1.06	.91		.53	.69		.21	1.89
P-Value		[.30]	[.34]		[.47]	[.41]		[.65]	[.17]
LIBOR Sp.	.25	.09	.04	.38	.17	.11	.25	.04	-.05
	(4.9)	(1.9)	(.9)	(4.5)	(2.3)	(1.3)	(2.8)	(.5)	(-.6)
χ^2 (Mat.)		5.34	1.87		6.44	2.22		5.02	3.4
P-Value		[.02]	[.17]		[.01]	[.14]		[.03]	[.07]
Slope	-.16	-.03	-.01	-.52	-.45	-.33	-.46	-.10	-.09
	(-1.1)	(-.4)	(-.1)	(-4.9)	(-4.1)	(-4.0)	(-4.9)	(-2.3)	(-2.1)
χ^2 (Mat.)		1.56	.28		.67	5.32		7.71	.05
P-Value		[.21]	[.60]		[.41]	[.02]		[.01]	[.82]
Adj. R^2	25.5	20.1	11.9	27.5	21.9	14.2	26.9	.9	5.5
Obs.	156	156	156	155	155	155	126	126	126

VI. Swap Spread Components: Robustness for USD, GBP, JPY, and DEM

The table shows sample periods, coefficient estimates (constant term not shown), robust (heteroskedasticity and serial correlation up to lag 12) t-statistics (in parentheses), adjusted R^2, number of observations per maturity, and $\sup LM$-tests for GMM estimations of swap spreads in the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM). For each currency the following specification was estimated over the earlier and later half of the entire sample:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \varepsilon_n^t, \tag{16}$$

where ss_n^t is the swap spread (swap rate minus government yield), AAA_n is the AAA spread (AAA rated corporate bond yield minus government yield), s_{LIBOR}^t is the LIBOR spread (1-year LIBOR minus 1-year government yield), slo_n^t is the term structure slope (n-year government yield minus 1-year government yield), n is maturity, t is a time index, α_n, β_n^1 through β_n^3 are coefficients, and ε is an error term. Maturities: 2, 5, 10 years; $\sup LM$ is a Lagrange multiplier test of parameter stability with unknown change point (asymptotic critical values are 12.27 at 10% level indicated with *, 14.15 at 5% level indicated with **, 17.68 at 1% level indicated with ***). All swap and LIBOR rates from Datastream International; all other data from Bloomberg Online. All data is weekly. All series are first-differenced. Data collected between 11/92 and 5/00.

	USD						GBP					
	2-Year		5-Year		10-Year		2-Year		5-Year		10-Year	
	92-96	96-00	92-96	96-00	92-96	96-00	93-96	96-00	93-96	96-00	93-96	96-00
AAA Sp.	-.01	.37	.02	.36	.17	.50	.25	.25	.23	.52	.37	.32
	(-.2)	(3.7)	(.5)	(3.7)	(2.5)	(6.3)	(2.7)	(1.7)	(1.7)	(4.0)	(3.0)	(2.4)
LIBOR Sp.	.09	.30	.08	.24	.12	.25	.50	.45	.18	.07	.09	.01
	(1.4)	(5.8)	(2.2)	(5.7)	(2.5)	(5.0)	(5.3)	(4.6)	(2.4)	(.9)	(1.4)	(.2)
Slope	-.16	-.36	-.15	-.19	-.24	-.23	-.66	-.39	-.30	-.16	-.24	-.17
	(-2.4)	(-5.3)	(-3.5)	(-4.0)	(-4.5)	(-4.9)	(-5.6)	(-5.1)	(-2.9)	(-2.3)	(-3.3)	(-4.2)
Adj. R^2	5.3	43.8	9.4	32.8	23.7	47.2	65.5	42.2	18.1	26.6	24.6	19.6
Obs.	192	191	192	191	192	191	173	173	173	173	173	173
$\sup$ **LM**	11.22		9.97		8.62		8.29		10.29		10.90	
	JPY						DEM					
	2-Year		5-Year		10-Year		2-Year		5-Year		10-Year	
	93-96	96-00	93-96	96-00	93-96	96-00	93-95	95-98	93-95	95-98	93-95	95-98
AAA Sp.	.20	.24	.37	.29	.35	.38	.16	-.14	.36	.30	.23	.33
	(2.7)	(2.8)	(4.7)	(2.4)	(3.9)	(2.8)	(1.7)	(-1.1)	(2.3)	(2.1)	(1.5)	(2.5)
LIBOR Sp.	.70	.64	.57	.35	.50	.30	.69	.20	.33	-.11	.32	-.14
	(9.7)	(5.3)	(7.7)	(3.4)	(6.5)	(1.7)	(8.5)	(1.3)	(3.5)	(-.7)	(2.0)	(-.9)
Slope	-.77	-.40	-.58	-.27	-.50	-.28	-.47	-.38	-.23	-.29	-.31	-.22
	(-8.0)	(-6.6)	(-7.7)	(4.2)	(-4.7)	(-2.9)	(-7.3)	(-4.4)	(-2.6)	(-3.9)	(-2.8)	(-5.6)
Adj. R^2	60.5	43.0	61.6	23.6	48.8	26.2	42.2	6.6	27.3	16.2	23.3	27.3
Obs.	175	176	175	176	175	176	117	117	117	117	117	117
$\sup$ **LM**	14.79**		10.10		12.69*		10.21		9.35		7.44	

VII. Swap Market Structure and Swap Spreads: Cross-Maturity Linkages

The table shows coefficient estimates (constant term not shown), robust (heteroskedasticity and serial correlation up to lag 12) t-statistics (in parentheses), adjusted R^2, and number of observations per maturity for GMM estimations of swap spreads in the following currencies: U.S. Dollar (USD), British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). Specification:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \beta_n^4 \cdot outslo_n^t + \varepsilon_n^t, \tag{17}$$

where ss_n^t is the swap spread (swap rate minus government yield), AAA_n is the AAA spread (AAA rated corporate bond yield minus government yield), s_{LIBOR}^t is the LIBOR spread (1-year LIBOR minus 1-year government yield), slo_n^t is the term structure slope (n-year government yield minus 1-year government yield), $outslo_n$ is the difference of 5-year and 2-year government yield for $n = 2$, and the difference of 10-year and 5-year government yield for $n = 5$, n is maturity, t is a time index, α_n, β_n^1 through β_n^4 are coefficients, and ε is an error term. Maturities: 2, 5 years. All swap and LIBOR rates from Datastream International; all other data from Bloomberg Online. All data is weekly. All series are first-differenced. Data collected between 11/92 and 5/00.

	USD		GBP		JPY		DEM	
	2-Yr	5-Yr	2-Yr	5-Yr	2-Yr	5-Yr	2-Yr	5-Yr
AAA Sp.	.16	.17	.21	.28	.21	.38	.02	.32
	(2.1)	(2.7)	(2.4)	(2.6)	(3.1)	(5.0)	(.3)	(3.0)
LIBOR Sp.	.18	.14	.44	.12	.66	.46	.49	.18
	(3.3)	(3.8)	(7.3)	(2.1)	(10.3)	(7.1)	(4.6)	(1.8)
Slope	-.23	-.16	-.55	-.23	-.68	-.43	-.41	-.24
	(-3.9)	(-4.7)	(-7.2)	(-3.8)	(-8.1)	(-7.4)	(-7.4)	(-4.0)
Out-Slope	.26	-.04	.22	.16	.06	.14	.26	.15
	(4.4)	(-.7)	(4.0)	(2.1)	(1.0)	(2.3)	(5.3)	(2.5)
Adj. R^2	22.2	17.1	62.3	22.7	55.5	52.8	32.0	20.9
Obs.	383	383	346	346	351	351	234	234

	FRF		ESP		NLG	
	2-Yr	5-Yr	2-Yr	5-Yr	2-Yr	5-Yr
AAA Sp.	.26	.34	.05	.09	.01	.02
	(2.2)	(2.4)	(.4)	(.67)	(.1)	(.1)
LIBOR Sp.	.27	.09	.38	.14	.25	-.01
	(5.8)	(2.2)	(4.5)	(1.7)	(2.9)	(-.1)
Slope	-.17	-.07	-.52	-.44	-.41	-.09
	(-1.3)	(-1.1)	(-4.9)	(-4.3)	(-5.9)	(-2.2)
Out-Slope	.30	.33	.14	.29	.35	.17
	(4.5)	(2.1)	(1.7)	(2.9)	(2.7)	(1.8)
Adj. R^2	31.9	24.5	28.8	24.4	31.3	.7
Obs.	156	156	155	155	126	126

VIII. Swap Market Structure and Swap Spreads: Cross-Currency Linkages

The table shows coefficient estimates (constant term not shown), robust (heteroskedasticity and serial correlation up to lag 12) t-statistics (in parentheses), adjusted R^2, and number of observations per maturity for GMM estimations of swap spreads in the following currencies: British Pound (GBP), Japanese Yen (JPY), German Mark (DEM), French Franc (FRF), Spanish Peseta (ESP), and Dutch Guilder (NLG). Specification:

$$ss_n^t = \alpha_n + \beta_n^1 \cdot AAA_n^t + \beta_n^2 \cdot s_{LIBOR}^t + \beta_n^3 \cdot slo_n^t + \beta_n^4 \cdot USDslo_n^t + \varepsilon_n^t, \qquad (18)$$

where ss_n^t is the swap spread (swap rate minus government yield), AAA_n is the AAA spread (AAA rated corporate bond yield minus government yield), s_{LIBOR}^t is the LIBOR spread (1-year LIBOR minus 1-year government yield), slo_n^t is the term structure slope (n-year government yield minus 1-year government yield), $USDslo_n$ is the n-year U.S. Dollar government yield less the 1-year U.S. Dollar government yield, n is maturity, t is a time index, α_n, β_n^1 through β_n^4 are coefficients, and ε is an error term. Maturities: 2, 5, 10 years. All swap and LIBOR rates from Datastream International; all other data from Bloomberg Online. All data is weekly. All series are first-differenced. Data collected between 11/92 and 5/00.

	GBP			JPY			DEM		
	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr
AAA Sp.	.28	.31	.36	.22	.45	.39	.09	.36	.21
	(3.5)	(2.8)	(3.7)	(3.4)	(6.2)	(4.9)	(1.0)	(3.1)	(1.9)
LIBOR Sp.	.49	.16	.08	.66	.47	.42	.54	.20	.18
	(7.5)	(3.2)	(1.5)	(10.4)	(7.4)	(5.5)	(5.6)	(2.2)	(1.4)
Slope	-.57	-.27	-.22	-.68	-.46	-.39	-.45	-.25	-.28
	(-6.9)	(-4.1)	(-4.7)	(7.9)	(-7.6)	(-5.3)	(-7.7)	(-4.0)	(-4.1)
USD Slope	.12	.13	.08	.04	.12	.01	.08	.10	.08
	(2.6)	(2.4)	(1.7)	(1.2)	(3.1)	(.3)	(1.2)	(1.6)	(1.3)
Adj. R^2	59.8	22.5	23.9	55.3	53.4	39.6	26.4	20.8	22.7
Obs.	344	344	344	349	349	349	232	232	232
	FRF			ESP			NLG		
	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr	2-Yr	5-Yr	10-Yr
AAA Sp.	.33	.46	.35	.11	.15	.10	.11	.04	.20
	(3.1)	(3.3)	(2.6)	(1.1)	(1.1)	(.8)	(.8)	(.4)	(1.7)
LIBOR Sp.	.25	.09	.04	.39	.21	.12	.23	.04	-.05
	(4.6)	(2.1)	(.9)	(4.6)	(2.4)	(1.2)	(2.5)	(.6)	(-.7)
Slope	-.19	-.04	-.01	-.55	-.49	-.32	-.49	-.15	-.12
	(-1.4)	(-.8)	(-.3)	(-4.7)	(-4.6)	(-3.6)	(-5.3)	(-2.5)	(-3.1)
USD Slope	.11	.19	.10	.19	.36	.20	.15	.14	.13
	(1.2)	(2.5)	(1.8)	(2.7)	(3.5)	(1.8)	(1.7)	(1.5)	(2.1)
Adj. R^2	26.6	27.4	14.9	30.2	30.1	15.6	29.0	2.6	9.1
Obs.	154	154	154	153	153	153	124	124	124