Interest rate swaps are, without a doubt, one of the major financial innovations of the 1980s. The swap market is immense; total notional principal in U.S. dollar swaps outstanding is now measured in the trillions of dollars. In a 1993 survey by the trade publication *Treasury and Risk Management*, 83% of corporate respondents indicated that they expected to use interest rate swaps in the coming year, while only 17% expected to use listed interest rate futures and options.

In a typical swap agreement, two counterparties exchange streams of fixed- and floating-rate interest payments, such that underlying fixed-rate debt can be transformed into floating-rate debt, and vice versa. Essentially, then, an interest rate swap is a series of forward contracts on some reference interest rate, such as LIBOR (the London Interbank Offered Rate). Beideman [1991] has provided an extensive analysis of the development of these agreements.

There has been little empirical research on interest rate swaps in the academic literature. An obstacle to this line of inquiry surely has been the general dearth of data, due in large part to the fact that swaps are transacted in private, over-the-counter markets.

While the International Swap Dealers Association, an industry trade group, provides survey data on an aggregate basis, there has been no public source for swap price and transaction quotations. In this study we use an extensive data set of weekly swap rate quotations compiled between 1985 and 1991 at Salomon Brothers Inc.

Our objective is to analyze and empirically explain volatility in the *swap spread*, which is the main pricing variable in an interest rate swap. More precisely, the swap spread is defined as the difference between

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KEITH C. BROWN is associate professor of finance at the Graduate School of Business of the University of Texas at Austin.

W.V. HARLOW is a senior research analyst with Fidelity Investments in Boston.

DONALD J. SMITH is associate professor of finance and economics at the School of Management of Boston University.

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the fixed rate on the swap and the comparable-maturity Treasury yield.\(^2\)

Volatility in the swap spread is important because it, along with the Treasury yield, determines the value of a swap position to both the market maker and the corporate end-users of the agreement. For corporations, price risk arises from an unexpected change in the fixed rate on a replacement swap having the same terms as the one it currently holds.

For instance, a lowered fixed rate on comparable swaps makes the economic value of the agreement negative to its fixed-payer, who is thereby paying an “above-market” fixed rate for receipt of LIBOR. That negative mark-to-market value for the swap represents an unrealized loss, which might have to be reported on financial statements. Moreover, the fixed-receiver then has an unrealized gain of equivalent magnitude and, subsequently, is exposed to possible default by the counterparty. The key point is that volatility in the swap spread translates directly to volatility in the mark-to-market value of the swap position.

For market makers who hedge unmatched positions in their swap books with Treasury securities in both the cash and futures markets, this volatility creates a somewhat different problem. Because unexpected movements in the Treasury component of the swap’s fixed rate can be offset with any of several available instruments, the remaining source of risk is an unexpected change in the swap spread. Given that dealers operate on very narrow bid/offer margins — often no greater than 0.05% — a change in the swap spread of but a few basis points can have a dramatic effect on profitability.

Therefore, if the swap spread were to have stable and predictable relationships with other market-determined rates, it might be possible to develop effective cross-hedges mitigating this exposure. Of course, any residual risk resulting from the market maker’s inability to create such a hedge will be priced into its bid/offer spread and ultimately affect the cost to corporations using swaps in their interest rate risk management programs.

In Section I, we outline several factors that theoretically determine the equilibrium swap spread. We start by assuming a “pure expectations” setting, implying that expectations alone determine the shape and level of the term structure of interest rates and that swaps are priced such that the present value of the fixed-rate payments equals the present value of expected floating-rate payments. This leads to an initial hypothesis that the swap spread equals the sum of the coupon bias in the Treasury yield curve, represented by the difference between the yields on a pure discount and a par value bond of the same maturity, and the expected average level of the spread between LIBOR and the Treasury bill rate over the lifetime of the swap (i.e., the expected mean TED spread).

We then extend this simple model by considering the implications of a market maker in interest rate swaps having to hedge an open position. The result is that the overnight repo rate should be a factor in determining the price of the swap.

Next, default risk premiums also are shown to determine the size of the swap spread, in particular, the difference between the corporate funding spread over Treasuries in the long-term bond market and the funding spread over LIBOR in the short-term credit market. Finally, we discuss the impact that a change in the supply of new corporate bonds might have on swap spreads.

These hypotheses are tested in Section II. Our empirical investigation of the basic pure expectations model shows that while many of its predictions are satisfied, the general level of explanatory power of the model is particularly low for swaps with longer maturities. Hedging costs, proxied by the overnight repo rate, have much more of an impact on longer-term swap prices than on shorter-term ones, and more of an impact early in our sample period than later.

For reasons of data unavailability, we test only the relationship between the swap spread and corporate bond funding spreads (rather than the difference in bond and credit market spreads) and find a strong connection between the two. On the other hand, the relationship between the swap spread and the issuance of new corporate debt is tenuous at best.

I. DETERMINANTS OF THE SWAP SPREAD

A Pure Expectations Model of the Swap Spread

Consider a “plain vanilla” interest rate swap: Firm A agrees to receive a fixed rate of T + SS from Firm B, where T is the relevant Treasury yield and SS is the swap spread, and to pay a floating-rate index, i.e., LIBOR. The cash flows to this standard swap agreement are displayed in Exhibit 1. Periodic net settlement
payments will be made from one counterparty to the other according to the difference in the fixed and floating rates, multiplied by the notional principal (NP) for the transaction:

$$Net\ Settlement = (T + SS - LIBOR) \times NP \quad (1)$$

The notional principal is merely a scale factor for converting the rate differential to a cash payment and for any settlement period less than a full year, Equation (1) is prorated accordingly. An interest rate swap represents an exchange of coupon cash flows, one floating and one fixed, but not an exchange of principal.

As a starting point in the analysis of swap spread determinants, assume that Firms A and B are risk-neutral and of the same degree of creditworthiness. The first assumption allows us to conclude that the swap will be priced at origination so that the expected value of the transaction is zero for each counterparty, a notion developed more formally in Bansal, Ellis, and Marshall [1993]. This is clearly a simplification, as swaps are used by firms expressly to manage interest rate risk — an activity not likely undertaken by a truly risk-neutral firm.

The second assumption implies that the counterparties will not need to adjust the swap spread (or, alternatively, require collateral) to compensate for any difference in their respective credit qualities.\(^3\)

Finally, assume for now that there are no transaction and information costs to entering the swap. In practice, most non-financial corporations enter swap agreements with a money center commercial or investment bank as the market maker. We will later consider the effect that the cost of financial intermediation has on the swap spread.

Given these assumptions, the swap spread set by market participants will be such that the present value of the expected cash flows generated by the fixed-rate and floating-rate sides of the transaction will be equal.

In general, for an N-period agreement, the fixed rate \(T_N + SS_N\) should equal the anticipated “average” level of LIBOR over the lifetime of the contract.

In fact, it will obtain by solving the expression:

$$\left[ \frac{T_N + SS_N}{(1 + Z_1)^1} + \frac{T_N + SS_N}{(1 + Z_2)^2} + \ldots + \frac{T_N + SS_N}{(1 + Z_N)^N} \right] \times NP =$$

$$\left[ \frac{LIBOR_0}{(1 + Z_1)^1} + \frac{E(LIBOR_1)}{(1 + Z_2)^2} + \ldots + \frac{E(LIBOR_{N-1})}{(1 + Z_N)^N} \right] \times NP \quad (2)$$

where \(Z_1, Z_2, \ldots, Z_N\) are zero-coupon discount rates corresponding to each settlement date and \(E(\cdot)\) is the expectations operator.

This equation indicates that in order to avoid arbitrage under these conditions, the present value of the known fixed-rate stream of payments will equal the present value of the expected floating-rate stream. Notice that the typical interest rate swap settles “in arrears” in that the net exchange to be made on date \(t\) depends on LIBOR determined earlier at date \(t - 1\). So, current LIBOR establishes the initial exchange, which will be based on the difference between \(T_N + SS_N\) and \(LIBOR_0\). Subsequent exchanges are known only to the level of the expected value for LIBOR.

We define the solution to Equation (2), solving for \(T_N + SS_N\), as \(E_N(LIBOR)\):

$$T_N + SS_N =$$

$$\frac{LIBOR_0}{(1 + Z_1)^1} + \frac{E(LIBOR_1)}{(1 + Z_2)^2} + \ldots + \frac{E(LIBOR_{N-1})}{(1 + Z_N)^N} =$$

$$\frac{1}{(1 + Z_1)^1} + \frac{1}{(1 + Z_2)^2} + \ldots + \frac{1}{(1 + Z_N)^N} \quad (3)$$

Where \(E_N(\cdot)\) denotes that the expectations cover \(N\) periods.

**EXHIBIT 1** Cash Flows on the Swap Agreement

- **Fixed-Receiver on the Swap**: Firm A
- **Floating-Rate LIBOR**: Fixed on the Swap
- **Fixed-Payer on the Swap**: Firm B
- **T + SS**: Fixed-Rate
Therefore, the pure expectations equilibrium condition is that the swap fixed rate equals the “average” of the expected future LIBOR path, an average in the sense of equivalent present values. Next, we decompose LIBOR for each date into the Treasury bill (TB) rate for that date and the spread over that rate, known commonly as the spot market TED spread (TEDS):

\[ T_N + SS_N = E_N(TB + TEDS) = E_N(TB) + E_N(TEDS) \]  

(4)

This, in turn, can be rearranged as follows:

\[ SS_N = [E_N(TB) - T_N] + E_N(TEDS) \]  

(5)

which says that in this market the swap spread should be set so as to equal the difference between the expected average value of the future sequence of T-bill rates and the Treasury bond yield plus the anticipated average value of the future TED spreads.

Of course, according to the pure expectations theory of the term structure of interest rates, \( E_N(TB) \) should equal the yield for an N-period zero-coupon Treasury bond, which can be represented as \( Z_N \). That is, rolling over a sequence of one-period Treasury bills for N periods, each at its expected yield (expected as of date 0), would generate the same compound rate of return as an investment in an N-period zero-coupon Treasury bond that yields \( Z_N \).

Substituting this into Equation (5), we obtain:

\[ SS_N = [Z_N - T_N] + E_N(TEDS) \]  

(6)

Equation (6) suggests that the swap spread is comprised of two components. Notice that the first term on the right-hand side of (6) is simply the “coupon bias” inherent in the Treasury yield curve. Barring differences in taxation and liquidity, a ten-year zero-coupon bond will have a higher (lower) yield than a ten-year par-value coupon bond when the overall shape to the yield curve is upward-sloping (downward-sloping). A steepening yield curve, therefore, would increase \( Z_N - T_N \) and so increase \( SS_N \), other things being equal.

Second, an increase in the expected future levels of the TED spread, as summarized by the average level, also would increase the swap spread. Of course, the expected future path for LIBOR need not parallel that of Treasury bills, so the TED spread could be expected to either rise or fall.

The Cost of Financial Intermediation

An implicit assumption about the swap presented in Exhibit 1 is that Firms A and B are able to negotiate with one another without any form of financial intermediation. This is not the way swaps are typically transacted; both Brown and Smith [1988] and Campbell and Kracaw [1991] have noted that the presence of swap market makers produces a more efficient form of contracting.

It also has been suggested that the costs necessary to support the participation of a market maker can significantly affect the swap agreement’s price, particularly when there is an imbalance on the pay-fixed and receive-fixed sides of the transaction. For instance, Evans and Parente-Bales [1991] and Sood [1988] argue that the cost to the swap dealer of hedging open positions is a key factor in explaining shifts in the swap spread. As detailed below, the prevailing rate on overnight repurchase agreements serves as an excellent proxy for this cost.

Exhibit 2 incorporates a swap market maker into the basic transaction shown in Exhibit 1. In Panel A, we assume that the intermediary is able to negotiate simultaneous swaps with Firms A and B. In such a “matched” case, there is no explicit interest rate exposure to hedge, so the bid/offer differential to the swap spread should reflect only compensation for bearing credit risk and incurring information costs about the end-users. A corollary of this is that in a swap market where there is at all times a natural offset between pay-fixed and receive-fixed end-users, the swap spread will not reflect a cost for hedging the intermediary’s interest rate risk.

Suppose now, however, that the market maker books just the transaction in which it will pay the fixed rate to Firm A. As shown in Panel B, this leaves the market maker exposed to a lower fixed swap rate, due to a decline in either the Treasury yield T or the bid swap spread SS. If swap rates were to fall subsequent to entering the agreement, the market maker would then be paying an above-market fixed rate for the receipt of LIBOR. In other words, the mark-to-market value of the swap would be negative.

Given a temporary imbalance in the demand for pay-fixed and receive-fixed swap positions, a hedge
could be achieved by purchasing Treasury securities in the cash market. As a practical matter, this position would be held only until a matching swap (such as that with Firm B) is available and can be financed with a series of overnight positions in the market for sale-repurchase agreements.

The key point is that the higher the level of the "repo" rate, the greater the cost of the cash market hedge. Regardless of the competitive structure of the swap market, raising the cost of the hedge should induce the individual market maker to widen its bid/offer spread by lowering the fixed rate paid on the swap.

Conversely, suppose the market maker is asked by Firm B to price a receive-fixed swap, as shown in the last panel of Exhibit 2. If the transaction is consummated, the ensuing exposure to the market maker would be to a higher fixed swap rate.

Similarly, this risk could be hedged by short-selling the cash market Treasury note and investing the proceeds in a sequence of overnight reverse repos, which are equivalent to a collateralized investment. Here, though, a higher repo rate raises the return on the investment, which, in a competitive market, might well induce the individual market maker to narrow its bid/offer spread by decreasing the receive-fixed rate on the swap.

Notice that in each case the exposure is to the fixed rate on the swap while the hedge covers only the Treasury component of that rate; the market maker would remain exposed to changes in the swap spread — ample motivation for wanting to understand the factors that correlate to movements in that spread.

Therefore, higher costs to hedge the intermediary's exposure should tend to narrow the swap spread. Additionally, as an alternative to buying and selling Treasury notes in the cash market, the market maker can also hedge its rate exposure with appropriate positions in Eurodollar futures contracts.

However, because these futures contracts have a limited number of delivery dates, it is unlikely that they provide effective hedges for long-term swaps with maturities beyond three to five years. Thus, we would expect that the hedging cost variable proxied by the repo rate will be a more significant factor in explaining movements in longer-term swap spreads.

**The Role of Default Risk in the Swap Spread**

Bicksler and Chen [1986] argue that firms are motivated to enter swap agreements in order to trans-

**EXHIBIT 2** Hedging Costs and the Role of the Swap Market Maker

**Panel A. A Matched Set of Swaps**

- Firm A LIBOR
- Market Maker T + Bid SS
- Firm B LIBOR T + Offer SS

**Panel B. Hedging a Pay-Fixed**

- Firm A LIBOR
- Market Maker
- Long Bond Position

Net Exposure: Decreasing T + SS Financing Cost: Repo Rate

**Panel C. Hedging a Receive-Fixed**

- Short Bond Position LIBOR
- Market Maker
- Firm B T + Offer SS

Financing Cost: −(Repo Rate) Net Exposure: Increasing T + SS

form a regular floating-rate bond into a synthetic fixed-rate security, or vice versa. The anticipated benefit of this restructuring comes from generating a lower funding cost than that obtainable with "straight" debt issues.

In an efficient capital market, however, it should be the case that a swap is priced so that a firm cannot expect to gain by the synthetic structure relative to the straight alternative. This result assumes a highly developed swap market in which market participants understand the product and its risks and, in particular, that the synthetic structure involving the swap requires bearing the credit risk of the counterparty, while simply issuing debt does not. As Smith, Smithson, and Wakeman [1988] argue, while it might have been possible for firms to arbitrage the swap market when the product was fairly new, it is unlikely that such gains can persist over time.

To see the consequence of this in the present context, suppose that Firms A and B in Exhibit 1 can each issue short-term one-period debt at LIBOR + CS, where CS stands for credit spread, or long-term N-period debt at T_N + BS_N, where BS_N stands for bond spread. Note that there is no particular reason to assume that CS equals BS_N because the former is a default risk premium vis-à-vis LIBOR, a single-period money
market rate that already contains a risk factor, and the latter is a multiperiod premium with respect to the Treasury rate.

Assuming that Firms A and B face the same costs of funds requires that we assume each has equal access to capital markets in addition to being equally creditworthy. Given these assumptions, we can conclude that in a pure expectations market, the expected cost of floating-rate funds over N periods will equal the known fixed-rate cost of funds:

$$E_N(\text{LIBOR} + \text{CS}) = E_N(\text{LIBOR}) + E_N(\text{CS})$$

$$= T_N + BS_N$$  \hspace{1cm} (7)

Substituting in Equation (3), and rearranging terms, we obtain:

$$SS_N = BS_N - E_N(\text{CS})$$  \hspace{1cm} (8)

In equilibrium, meaning the absence of an arbitrage opportunity created by issuing one type of debt and swapping into another, the swap spread should equal the difference in the default risk premiums across the two markets.

If the firm issues and intends to roll over a one-period security, the swap spread is the bond spread (over the N-period Treasury) less the expected average credit spread (over LIBOR) for the N periods. However, if the firm issues an N-period floating-rate note, locking in some CS for the entire time to maturity, the swap spread is merely the bond spread less that known credit spread.

In principle, strengthened (or weakened) creditworthiness should lower (or raise) $E_N(\text{CS})$ and $BS_N$ to an equal degree. Certainly, it is reasonable to posit that $BS_N$ and $E_N(\text{CS})$ will at least be positively correlated. Notice that even this milder assumption implies that the swap spread should be less volatile than both the fixed-rate and floating-rate default premiums, which can be inferred from Equation (8), given that $\text{Var}[SS_N] = \text{Var}[BS_N] + \text{Var}[E_N(\text{CS})] - 2\text{Cov}[BS_N, E_N(\text{CS})]$.

**The Supply of Corporate Debt and the Size of the Swap Spread**

The swap spread, as the price of the transaction, is also likely to be subject to a number of demand and supply influences. Other things being equal, factors that increase the quantity of firms seeking to pay (receive) the fixed rate will tend to raise (lower) the swap spread.

Walmsley [1988] focuses on the supply of new fixed-rate debt issues as an important factor in explaining movements in the swap spread. The connection between the swap spread and the new-issue capital market can be developed as follows.

Suppose that there is an increase in the supply of potential fixed-receivers on swaps because of a wave of new fixed-rate Eurobond issues responding to a perceived window of funding opportunity. At least some of these borrowers presumably seek to swap into synthetic floating-rate funding. If the supply of fixed-payers remains the same, competitive pressures could narrow the swap spread (subject, of course, to the market maker’s willingness and ability to hedge in the cash market for Treasury securities). Thus, an increase in the market supply of fixed-rate securities should tend to lower the swap spread. This, of course, assumes that it is the issuers of debt, rather than the buyers of debt, that seek to transform the cash flows via a swap transaction.

**II. EMPIRICAL RESULTS**

**Testing the Pure Expectations Model**

**DATA AND VARIABLE CONSTRUCTION.** To test the model summarized by Equation (5), we need data on swap spreads, yields on the “on-the-run” Treasury securities, yields on zero-coupon Treasuries, and expected future levels of the TED spread. The first two variables determine the fixed rate on the swap agreement by definition; the second two are the elements of the pure expectations model.

The yield on the zero-coupon Treasury is equivalent to the average of the current Treasury bill and expected future Treasury bill rates, only given the assumption that expectations alone determine the level and shape of the term structure. Therefore, our empirical test of (5) will be, in fact, a test of joint hypothesis of the expectations model for swap pricing and the expectations theory of the term structure.

Our swap spread ($SS_N$) data were obtained from Salomon Brothers Inc for the period between January 2, 1985, and May 1, 1991. Specifically, we use weekly observations of Salomon’s Wednesday closing quotes on swaps with maturities of one, three, five, seven, and ten years. While both bids and offers are available for most dates, we chose to use the bid (pay-fixed) quotes, stated in basis points, to insure uniformity. These swaps
were standard fixed versus three-month LIBOR transactions. Exhibit 3 illustrates the time series of these spread data for the one- and ten-year swap maturities.

We also obtained from Salomon the contemporaneous weekly bid yields on the Treasuries (T_N) against which the various maturity swaps are priced. Comparable data for the constant-maturity, zero-coupon Treasuries (Z_N) corresponding to the five swap maturities were obtained from Fidelity Investments. These were calculated using an algorithm based on the work of Hodges and Schaefer [1977] and Schaefer [1982] for generating the underlying term structure of interest rates from the observed Treasury yield curve.

Data to construct our estimates of the expected future level of the TED spread were based on Treasury bill and Eurodollar futures prices obtained from the Chicago Mercantile Exchange. A total of 330 common weekly observations were available on all the variables employed in the study.6

Estimating the expected average level of future TED spreads, E_N(TEDS), was more challenging. During the sample period, delivery dates on Treasury futures extended out one to two years and on Eurodollar futures out to three years. Since we needed both futures prices to have an estimate for the future TED spread, we were constrained by the limited number of T-bill futures contracts.

Given that limitation, we assume that the best date t forecast of the expected future TED spread can be inferred by the difference in the geometric averages of the settlement yields on exchange-traded Eurodollar and Treasury bill futures contracts for various maturities as well as the current spot rates. Consequently, for each period t we estimated E_N(TEDS) by the equation:

\[
\text{TEDS}_{t} = \text{M}_{t+1} \prod_{m=0}^{M_{t}} (1 + \text{EDBY}_{j,m+1,t}) - \prod_{m=0}^{M_{t}} (1 + \text{TBBY}_{j,m+1,t})
\]

Here EDBY_{j,m+1} and TBBY_{j,m+1} are the semiannually compounded bond-equivalent yields corresponding, respectively, to the settlement prices for Eurodollar and Treasury bill contracts maturing at date j, and M_t is the number of maturity dates common to both contracts as of a given date t.7 Also, for both LIBOR and the Treasury bill yields, the notation BY_{t,1} refers to the ninety-day spot rates prevailing at date t.

Notice that in (9) no subscript referring to the swap’s maturity date is used. This is because the available futures data are shorter in duration than the tenors of all but the nearest-term swap contract we examine (i.e., M_t ≤ two years for all t) and, consequently, the same forecast is used for each of the swap maturities in our sample. That is, we assume that the best estimate of the anticipated average TED spread is derived by using market-determined prices looking as far into the future as possible, and that this forecast does not depend on how much farther than that the swap agreement is binding.8

**TESTABLE HYPOTHESES AND REGRESSION RESULTS.** A testable form of the pure expectations swap pricing equation can be generated by rewriting (5) as follows:

\[
[E_N(TB)_{t} - T_N] + E_N(TEDS)_{t} = \\
\beta_0 + \beta_1 \text{SS}_{Nt}
\]

(10)

Here the subscript t refers to observations drawn on date t. Recognizing that E_N(TB)_{t} and E_N(TEDS)_{t} are measured with error by Z_Nt and TEDS^\ast_{t}, respectively, rearranging (10) leaves:

\[
\{(Z_Nt - T_N) + TEDS^\ast_{t}\} = \\
\beta_0 + \beta_1 \text{SS}_{Nt} + \epsilon_{Nt}
\]

(11)

Notice that Z_Nt measures E_N(TB) with error to

**EXHIBIT 3 Swap Spread Data for One- and Ten-Year Swap Maturities**
the extent that the pure expectations theory does not accurately describe how the shape and level of the yield curve is determined. TEDS* measures $E_N(TB)$ with error because of the limitations to the information set. The regression in (11) allows for a direct test of (6) where $\beta_1 = 0$ and $\beta_1 = 1.0$. Also, by specifying the observed value of $SS_N$ as a regressor, Equation (11) lets the swap spread impound errors that market participants make in the estimation of $Z_N$ and TEDS$. ^9

To allow for an assessment of how the relationships between swap spreads and the underlying determinants have evolved over time, we also split the entire sample period into three non-overlapping subintervals of roughly equal length: 1) January 1985 to December 1986; 2) January 1987 to December 1988; and 3) January 1989 to May 1991. Accordingly, Equation (11) is modified as follows:

\[
\{ [Z_{Nt} - T_{Nt}] + TEDS^*_{t} \} = [\beta_0 + \sum_{j=2,3} (D_j \beta_{0j})] + [\beta_1 SS_{Nt} + \sum_{j=2,3} (D_j \beta_{1j} SS_{Nj})] + \epsilon_{Nt} \tag{12}
\]

where $D_3$ and $D_4$ assume the value of 1 if observation $t$ is the second and third subintervals, respectively, and 0 otherwise. In this format, $\beta_0$ and $\beta_1$ capture the structural relationship during the first subperiod while $\beta_{02}$, $\beta_{12}$ and $\beta_{03}$, $\beta_{13}$ represent the incremental changes during the latter two.

Exhibit 4 summarizes the output from these regressions for all five of the swap spread maturity classes. For each maturity, the first row reports estimated coefficients and the probability levels of these estimates for the whole sample period [i.e., Equation (11)], while the second row lists the findings for the regressions that include the structural change dummy variables [i.e., Equation (12)]. ^10

The findings are, at best, only partly consistent with predictions of the pure expectations swap model.

| EXHIBIT 4 | Regressions of Treasury Yield Variables and TED Spreads on Swap Spreads |
|-----------|---------------------------------|-------------------|-------------------|-----------------|-----------------|
| Maturity  | $\beta_0$ ^a                  | $D_2 \beta_{02}$ | $D_3 \beta_{03}$ | $\beta_1$ ^b    | $D_2 \beta_{12}$ | $D_3 \beta_{13}$ | Adjusted $R^2$ |
| One Year  | 0.1444 (0.0003)                | -                 | -                 | 1.2984 (0.0000) | -               | -               | 0.603           |
|           | 0.3726 (0.0312)               | -0.2635 (0.4192) | -0.0908 (0.0273) | 0.9200 (0.0089) | 0.5523 (0.7432) | -0.0690 (0.0078) | 0.702           |
| Three Years | -0.7186 (0.0001)           | -                 | -                 | 2.4028 (0.0000) | -               | -               | 0.472           |
|           | 0.7441 (0.0029)               | -1.0122 (0.0011) | -1.7297 (0.0011) | -0.0489 (0.0001) | 2.0343 (0.0001) | 2.8862 (0.0001) | 0.658           |
| Five Years | 0.2519 (0.0266)              | -                 | -                 | 0.9135 (0.5799) | -               | -               | 0.101           |
|           | 0.8559 (0.0001)              | -0.7689 (0.1104) | -0.3763 (0.0090) | -0.0694 (0.0001) | 1.5858 (0.0001) | 0.4393 (0.3280) | 0.480           |
| Seven Years | 0.4525 (0.0001)             | -                 | -                 | 0.5650 (0.0000) | -               | -               | 0.074           |
|           | 0.8379 (0.0001)              | -0.7446 (0.1601) | -0.3179 (0.0000) | -0.1626 (0.0000) | 1.5019 (0.0001) | 0.3916 (0.0000) | 0.440           |
| Ten Years | 0.7713 (0.0001)             | -                 | -                 | 0.1590 (0.0000) | -               | -               | 0.005           |
|           | 1.0186 (0.0001)              | -0.6087 (0.3115) | 0.2365 (0.0000)  | -0.2694 (0.0000) | 1.1400 (0.0001) | -0.4085 (0.0000) | 0.344           |

^aP-values reporting the probability of observing a larger test statistic under the null hypothesis are listed parenthetically; the intercept terms and all dummy variables are relative to a null hypothesis that the value is zero.

^bP-values for $SS_N$ are reported relative to a null hypothesis that the coefficient equals 1.0.
For instance, when viewed on a samplewide basis, the parameters for the SS variable are all positive and, although not shown in the display, significantly different from zero at conventional levels. However, it is also apparent from the reported p-values that for only one of five tenors (i.e., five-year swaps) can we fail to reject the strict prediction of the coefficient being equal to one.

Further, all of the intercept terms differ significantly from zero, which suggests that there are systematic pricing influences that are not being captured by the simple model. Of course, a more direct indication of this last point is that values of the adjusted coefficients of determination vary substantially across the five maturity groups: from 60.3% for the one-year swaps to just 0.5% for the ten-year contracts.

In fact, it appears that the ability of the pure expectations model to explain swap spreads across the entire sample period is inversely related to the tenor of the agreement, with the one- and three-year samples offering substantially more explanatory power than the three longest-term maturity classes.

With regard to the temporal stability of the pure expectations model, the dummy variable coefficient estimates from (12) listed in Exhibit 4 indicate that, in general, the dynamics of this swap pricing regime have changed greatly over time. For instance, with the exception of the one-year sample, in the first subperiod there is very little evidence that swap prices were set in a manner that was at all consistent with the theoretical model. In fact, the slope coefficients (i.e., $\beta_k$ in the second row of each maturity class) in the other four swap maturity classes are actually negative, with the three longest-term maturities easily confirmed as also significantly different from zero at the 5% level or better.

On the other hand, it appears that portions of the swap market have become more integrated into the capital market since December 1986. To see this, recall that adding $\beta_{12}$ or $\beta_{13}$ to $\beta$, expresses the total relationship between $\{Z_N - T_N\} + TEDS^*$ and $SS_N$ in the second and third subperiods, respectively. In all but one case (i.e., the third subperiod for ten-year swaps), the incremental slope coefficients reverse the negative values of $\beta$, for the three-, five-, seven-, and ten-year maturities. Further, all five of the estimates of $\beta_{12}$ are significantly different from zero at conventional levels, while the same is true for only one of the five $\beta_{13}$ values.

Perhaps the best indication that swap spread pricing dynamics have evolved over time comes from examining the difference in the coefficients of determination generated by Equations (11) and (12). Overall, the dummy variable regression produces higher adjusted $R^2$ statistics, suggesting that estimating a single, periodwide relationship is not as efficient as allowing for three separate ones.

While this is true for all of the maturity classes, the gain in explanatory power is particularly dramatic for the five-, seven-, and ten-year swaps, which see their adjusted $R^2$ levels go from a range of 0.5% to 10.1% to a range of 34.4% to 48.0%. This result is entirely consistent with the argument that short-term swaps and long-term swaps should be priced differently, a notion we examine in more detail below.

From these initial findings, therefore, it is possible to draw three tentative conclusions:

1. Under no circumstances has the simple pure expectations model provided a complete explanation for swap spread movements.
2. The dynamics of the one- and three-year pricing equations are different than those for the three longer-term swap tenors.
3. Short-term swap spreads have become more closely linked with their theoretical determinants over time.\textsuperscript{11}

Finally, as with virtually all time series examinations of interest rate movements, there is evidence that the estimated disturbances from (11) are autocorrelated; Durbin-Watson statistics for the five swap maturities over the whole period range from 0.3 to 0.6. Thus, the least squares estimates reported in Exhibit 4, though unbiased, may have overstated significance levels.

To insure that this possibility did not drive any of the preceding conclusions, we recalculated the parameters of the regression using two separate generalized procedures. First, we adjusted the weekly observations using Yule-Walker estimates of the autocorrelation coefficients (with two lags) as outlined in Gallant and Goebel [1976]. This process, while generating qualitatively identical findings with somewhat reduced significance, was not sufficient to eliminate the slow-moving lag structure in the data.

Next, we reestimated (11) using unadjusted and adjusted versions of both monthly observations and

---

\textsuperscript{11}
monthly averages of the weekly observations. These approaches created lags in the data sufficient either to reduce substantially or eliminate the serial correlation problem and produced results that were even stronger than those using the adjusted weekly data. These gains, however, came at the considerable cost of losing roughly three-quarters of the data sample.

Therefore, given that the overall conclusions reached in this section (and the ones to follow) can be made without loss of generality, we present the findings based on the approach that preserves the largest sample size possible.

**Testing the Pure Expectations Model with Hedging Costs**

Because the empirical model developed above specifies the swap spread as a regressor, it is not possible simply to include a hedging cost variable on the right-hand side of (11). Instead, we need a structure that allows for a direct evaluation of the correlation between swap spreads and hedging costs incurred by an intermediary to the transaction.

Consequently, our tests for the influence of this additional factor on swap pricing involve adapting (11) to its more intuitive form and then including the overnight repo rate (REPO) as an independent variable. That is, for each swap maturity, we estimate the regression:

\[ SS_{Nt} = \gamma_0 + \gamma_1 (Z_{Nt} - T_{Nt}) + \gamma_2 (TEDS^*) + \gamma_3 (REPO) + \omega_{Nt} \]  

(13)

Consistent with the hypothesized inverse relationship between SS and REPO, the expectation is that \( \gamma_3 \) would be negative. The data for the REPO variable were measured as the Wednesday yields on overnight repurchase agreements and were obtained from Salomon Brothers for the entirety of the January 1985-May 1991 sample period.

Exhibit 5 presents estimates for two different forms of (13). The first uses only \((Z_{Nt} - T_{Nt})\) and TEDS* as explanatory variables and represents an alternative form of the theoretical model in (11), while the second also includes the proxy variable for a market maker's hedging costs. Although the regressions were run using dummy variables for the various subintervals, to conserve space we report results only for the entire sample period.

With minor exceptions, the estimated parameters for the two-variable regressions strongly confirm those shown in Exhibit 4, suggesting that our earlier conclusions are not overly sensitive to errors created by using proxies for \( E_N(TB) \) and \( E_N(TEDS) \). In fact, it appears from the adjusted coefficients of determination that additional predictive power is gained by treating \((Z_{Nt} - T_{Nt})\) and TEDS* as separate right-hand side variables.\(^{12}\)

Several changes occur when the REPO variable is added to (13) as a regressor. Foremost, in the four longest-term swap maturity classes the estimated value of \( \gamma_3 \) is negative and statistically significant at the 0.01% level or better; \( \gamma_3 \) for the one-year contract is significantly positive, though small.

Further, both the absolute magnitude and significance of the estimated coefficients tend to increase substantially with the tenor of the swap agreement. This finding is consistent with our earlier observation that the importance of a variable proxying for the cost of hedging a swap book in the cash market for Treasury securities should increase as the number of hedging alternatives (e.g., interest rate futures contracts) declines. In fact, given Kaufler's [1989] demonstration of how short-term swaps can be effectively replicated with a strip of Eurodollar futures contracts— which have had maturities as long as three years since 1987—it is not surprising to see the relationships between SS\(_3\) and SS\(_5\) with REPO as the least meaningful of the five maturity groups.

This conclusion is amplified by the adjusted \( R^2 \) values, which show that while the incremental gain in explanatory power provided by REPO is proportionally quite large for the five-, seven-, and ten-year swaps, it is a minor factor for the short-term samples. This dichotomy is at least partly due to the fact that yields on Eurodollar futures contracts form part of the basis of our TEDS* forecast, a variable that assumes its largest economic and statistical significance for the two shortest-term swap samples.\(^{13}\)

Another consequence of adding the hedging cost regressor apparent from Exhibit 5 is that the sign of the \((Z_{Nt} - T_{Nt})\) variable changes for two of the five swap tenors (i.e., five and seven years). This undoubtedly is caused by the high degree of negative correlation between \((Z_{Nt} - T_{Nt})\) and REPO: \(-0.55, -0.71, -0.71, -0.64, \) and \(-0.43, \) respectively, for the five maturity classes. This simply indicates that the yield curve tends to be more upward-sloping, the lower the level of the short-term rate.
Although this amount of collinearity does not invalidate the overall explanatory power of three-variable regression, it does create a legitimate concern that the estimated relationship between $SS_N$ and REPO may be spurious. To guard against this possibility, we estimated the equation $w_{N_t} = \alpha_1 + \alpha_2 REPO_t + \nu_{N_t}$, where $w_{N_t}$ is the date $t$ residual from the regression $SS_{N_t} = \gamma_0 + \gamma_1 (Z_{N_t} - T_{N_t}) + \gamma_2 (TEDS^*_t) + \omega_{N_t}$. Further, to assess the temporal stability of the structure, we also calculated this residual-based regression using the previously defined dummy variables for the subperiods January 1987-December 1988 and January 1989-May 1991.

These results are summarized in Exhibit 6, with the coefficients of determination now interpreted as the percentage of the residual variation from the two-variable regression that can be explained by the hedging cost argument. In general, both these values and the estimated slope parameters show quite clearly that while the incremental contribution of REPO is genuine, it varies across both swap maturity class and time.

For instance, the adjusted $R^2$ statistics once again provide direct evidence of the increasing importance of REPO as the swap maturities lengthen beyond the limits of the market for exchange-traded futures contracts. Further, it is also apparent that REPO has become a less significant influence on swap pricing over time, inasmuch as the largest absolute slope coefficients were always generated in the first subperiod for each tenor.\textsuperscript{14} A potential explanation for this latter phenomenon can be found in Wakeman [1991], who notes that rather than attempting to match or otherwise hedge each individual swap position (as illustrated in Exhibit 2), swap market makers are now concentrating their hedging programs on just the net exposure of their entire swap portfolio. This practice, widely adopted since 1987, has the effect of muting the relationship between swap spreads and the repo rate, especially given that the shorter-term portion of the residual swap risk is more likely to be hedged with futures contracts than in the cash market for Treasury securities.

Ample evidence of this occurrence is that four of the five REPO coefficients are statistically insignificant — and the other of marginal positive significance — during the most recent sample partition.\textsuperscript{15} Given the

<table>
<thead>
<tr>
<th>Swap Maturity</th>
<th>Intercept</th>
<th>$(Z_N - T_N)$</th>
<th>TEDS*</th>
<th>Repo</th>
<th>Adjusted $R^2$</th>
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<tr>
<td>One Year</td>
<td>0.1411</td>
<td>0.2206</td>
<td>0.5072</td>
<td>—</td>
<td>0.626</td>
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<td>(0.0003)</td>
<td>(0.0001)</td>
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<td>0.5023</td>
<td>0.0318</td>
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<td>(0.0001)</td>
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<tr>
<td>Seven Years</td>
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<td>0.1261</td>
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<td>1.3796</td>
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<tr>
<td>Ten Years</td>
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<td>(0.0001)</td>
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P-values reporting the probability of observing a larger test statistic under the null hypothesis that the value is zero are listed parenthetically.
### EXHIBIT 6 ■ Regressions of Swap Spread Residuals on Treasury Variables, TED Spreads, and Repo Rates

<table>
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<tr>
<th>Swap Maturity</th>
<th>Intercept</th>
<th>Independent Variable:</th>
<th>REPO:</th>
<th>Adjusted R²</th>
</tr>
</thead>
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<tr>
<td></td>
<td>( \alpha_0 )</td>
<td>( D_2\alpha_{02} )</td>
<td>( D_3\alpha_{03} )</td>
<td>( \beta_1 )</td>
</tr>
<tr>
<td>One Year</td>
<td>-0.1737</td>
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<td>—</td>
<td>0.0233</td>
</tr>
<tr>
<td></td>
<td>(0.0011)</td>
<td>—</td>
<td>—</td>
<td>(0.0010)</td>
</tr>
<tr>
<td></td>
<td>-0.4891</td>
<td>0.4902</td>
<td>0.4990</td>
<td>0.0615</td>
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<td>(0.0001)</td>
<td>(0.0025)</td>
<td>(0.0006)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>Three Years</td>
<td>0.1066</td>
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<td>—</td>
<td>-0.0143</td>
</tr>
<tr>
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<td>(0.0002)</td>
<td>—</td>
<td>—</td>
<td>(0.0002)</td>
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<td></td>
<td>0.2384</td>
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<td>(0.0001)</td>
<td>(0.2185)</td>
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<td>(0.0001)</td>
</tr>
<tr>
<td>Five Years</td>
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<td>—</td>
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<td>(0.0001)</td>
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<tr>
<td></td>
<td>1.1618</td>
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<td></td>
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<td>(0.0001)</td>
<td>(0.0001)</td>
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<tr>
<td>Seven Years</td>
<td>0.5334</td>
<td>—</td>
<td>—</td>
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<td></td>
<td>1.7905</td>
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<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
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<tr>
<td>Ten Years</td>
<td>0.7202</td>
<td>—</td>
<td>—</td>
<td>-0.0966</td>
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<td>—</td>
<td>—</td>
<td>(0.0001)</td>
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<td></td>
<td>1.8713</td>
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<td>-1.8124</td>
<td>-0.2639</td>
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<td></td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
</tr>
</tbody>
</table>

P-values reporting the probability of observing a larger test statistic under the null hypothesis that the value is zero are listed parenthetically.

The strength of the early period results, however, it must be concluded that over the entire sample period, the market maker's cost of hedging has been an economically significant factor in explaining swap spread volatility.

**Testing the Default Risk Model**

Because credit spreads over LIBOR are determined in the non-public market (e.g., bank loans) or relatively illiquid over-the-counter markets (e.g., floating-rate notes), a lack of available data prevented us from directly testing the relationship in Equation (8). What we can examine, however, is the association between SS₂ and BS₂. We do this by regressing two distinct dependent variables on a measure of BS₂: 1) SS₂ itself, and 2) the residuals \( w_{Nt} \) from the regression SS₂ = \( \gamma_0 + \gamma_1(Z_{Nt} - T_{Nt}) + \gamma_2(TEDS^*) + \gamma_3(REPO) + \omega_{Nt} \).

The purpose of this second procedure is to assess the incremental impact that changes in bond default risk premiums have in explaining swap spread movements. From the earlier analysis, we expect the coefficient on BS₂ to be positive, but, because \( E_0(CS) \) is an omitted variable, we were not able to test any specific hypotheses about the presence of arbitrage opportunities in the swap market.

Weekly data on the average bond funding spread for each of several different bond portfolios varying by maturity and credit class were obtained from Salomon Brothers Inc. The set of portfolios for which the average levels of BS were available can be stratified as follows: 1) three-year AA financial bonds; 2) five-year AA financial bonds; 3) seven-year BBB, A, AA, and AAA utility bonds; and 4) ten-year BBB, A, AA, and AAA industrial bonds, and ten-year A, AA, and AAA financial bonds.

Although a full set of regression results were produced for each of these industry and default classes, they are all qualitatively comparable. Consequently, Exhibit 7 lists the findings for only the four different ten-year industrial bond credit grade groups.

The results reported in Panel A support the conclusion that SS₁₀ and BS₁₀ are significantly positively
correlated. Further, as should be the case, the stronger the credit grade, the larger the value of the estimated slope coefficients. Thus, for example, if the funding spread on AAA-grade debt were always one-half that of A-grade debt, the slope coefficient would be twice as large.

Notice also that adjusted $R^2$ values indicate that bond default spreads impart a considerable influence on swap spreads, particularly for the strongest credit grades. Of course, given that $BS_N$ might be serving as nothing more than an instrumental variable for $(Z_{10} - T_{10})$, TEDS*, and REPO, a better test of its unique predictive power comes from the residual regressions.

These findings are summarized in Panel B of Exhibit 7. They reveal that the default risk variable generates significantly positive slope coefficients, which, as before, increase in magnitude with the credit quality of the firm. More importantly, however, $BS_{10}$ can account for between 25% and 40% of the residual variation in ten-year swap spreads.

These numbers are roughly comparable to the influence that REPO has (as reported in Exhibit 6), although it should be kept in mind that with REPO included in the regression that generates the residuals, there is a smaller amount of incremental variation for $BS_{10}$ to explain. Nevertheless, these data confirm the hypothesis that default premiums in the swap and bond markets are linked in a significant and predictable manner.

Finally, the data in this subsection also provide for a direct test of Litzenberger’s [1992] supposition that swap spreads are less volatile than the funding spreads in the bond market. Specifically, assuming that $\Delta BS_N$ and $\Delta E_{N(CS)}$ are positively correlated, it should then be true that $\Delta SS_N < \Delta BS_N$.

We examine this possibility by reestimating the regressions in Panel A using natural logarithms of the dependent and independent variables. This transformation allows us to interpret the parameter of the independent variable [i.e., ln($BS_N$)] as an elasticity coefficient, which must be less than one to support the conjecture.

Although not shown here in detail, these results indicate that all of the estimated slope parameters were simultaneously: 1) significantly positive, and 2) significantly less than one at probability levels of less than 0.005. Thus, we find in favor of the joint hypothesis that swap spreads are less volatile than bond funding spreads, and that bond and credit market spreads are positively correlated.

### EXHIBIT 7 - Regressions of Ten-Year Swap Spreads on Bond Funding Spreads

<table>
<thead>
<tr>
<th>Credit Grade</th>
<th>Independent Variable:</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept</td>
<td>BS</td>
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#### Panel A. $SS_{10}$ as the Dependent Variable

<table>
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<tr>
<th>Grade</th>
<th>Intercept</th>
<th>BS</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>0.2671</td>
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<tr>
<td>AA</td>
<td>0.2385</td>
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<td>A</td>
<td>0.3118</td>
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<td>BBB</td>
<td>0.3772</td>
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#### Panel B. Residuals ($w_{10}$) as the Dependent Variable

<table>
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<td>(0.0001)</td>
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</table>

P-values reporting the probability of observing a larger test statistic under the null hypothesis that the value is zero are listed parenthetically.

### Testing the Supply of New Corporate Debt Hypothesis

To investigate the hypothesis that an increase in the supply of bonds should tend to lower the swap spread, we gathered statistics on the new-issue activity in the corporate bond market during our sample period. These data, obtained from Securities Data Company, were aggregated on a monthly basis from over 20,000 separate transactions and included the total amount of fixed-rate, dollar-denominated securitized debt issued in both the U.S. domestic and Eurobond markets. We also required that each bond in the sample have a default rating given by at least one of the leading agencies.

Because of gaps in the data series for bonds with specific maturity dates, we collected issuance data in two broader classes: 1) bonds maturing in five years or less,
and 2) bonds maturing in five to ten years. In the empirical analysis below, the one-, three-, and five-year swap spreads were tested against the former, while the seven- and ten-year spreads were tested against the latter.

Following the procedure developed in the last subsection, we test for the predicted negative correlation between swap spreads and new bond volume in two ways. First, a direct assessment of this relationship is established by estimating the regression:

\[
SS_{nt} = \theta_0 + \theta_1 \Delta BV_t + \sum_{j=1}^{4} \theta_{j+1} \Delta BV_{t-j} + \nu_t
\]

(14)

where \( \Delta BV_{t-j} \) is the difference in new bond volume for a given maturity class between months \( t-j \) and \( t-j-1 \). Notice that using lagged differences in bond volume as independent variables allows for the possibility that the bond issuers do not transform the interest rate sensitivity of their new debt issues via the swap market until some time after the initial launch.

Second, to assess the incremental impact of the bond issuance factor, the independent variables in (14) are also regressed against the residuals from the regression \( SS_{nt} = \gamma_0 + \gamma_1 (Z_{nt} - T_{nt}) + \gamma_2 (TEDS^*) + \gamma_3 (REPO) + \omega_{nt} \), where all of the variables were altered to be averages of the weekly observations during a given month \( t \). Both sets of results were calculated over the entire sample period and are summarized in Exhibit 8.

Panel A reports the results of the direct regression of \( SS_{nt} \) on \( \Delta BV \). These findings provide only partial support for the supply of debt hypothesis. On the one hand, the estimated coefficients for the five-, seven-, and ten-year swap samples are uniformly negative, with several parameters for the two longest-term tenors being significantly so at conventional levels. Further, the \( R^2 \) values (adjusted for the degrees of freedom) for these latter two regressions are positive, although small.

On the other hand, the overall explanatory power is negligible for the three shortest-term maturity class regressions. Generally, this pattern is confirmed by the estimated coefficients from the swap spread residual regressions that are listed in Panel B.

Once again, it appears that the \( \Delta BV \) do have some incremental ability to predict the seven- and ten-year swap spread movements; in these maturity classes several of the parameters are significant, and the adjusted \( R^2 \) values are again positive. These gains in predictive ability are modest, however, relative to those associated with the inclusion of the default risk premium variable just considered. Thus, we conclude that changes in fixed-rate debt issuance activity lead to economically detectable imbalances in the demand for just those interest rate swap agreements with the longest maturities.

III. SUMMARY AND CONCLUSIONS

We have used an extensive data base consisting of weekly and monthly quotes for the spread over the Treasury yield on swaps of five different maturity classes to test several relationships designed to explain the historical pattern of variation in these spreads. After extending our model of how swap spreads should move in a pure expectations setting to include hedging costs, default risk, and new debt issuance, we find four economically and statistically significant factors.

Listed in the order in which they were considered, these are 1) the difference in levels of the Treasury yield curves for zero-coupon and coupon-bearing securities; 2) forecasts of the spread between three-month LIBOR and Treasury bill yields; 3) the overnight rate on repurchase agreements; and 4) a proxy for default risk in the corporate bond market. The relationship between swap spread movements and changes in the supply of fixed-rate corporate debt proved to be of a more tenuous nature.

Our two main results are that: 1) short-term, one-, and three-year swaps are priced differently from longer-term, five-, seven-, and ten-year swaps; and 2) the pricing dynamics for all five swap maturities changed substantially during the period spanning January 1985 to May 1991. In particular, we demonstrated that the best fit for the pure expectations model is provided by the one- and three-year swap spread samples, with the explanatory power of these equations becoming stronger after December 1986.

On the other hand, the intermediary's hedging cost argument is far more compelling for swaps that had maturities beyond those for exchange-traded interest rate futures contracts.

The influence of the overnight repurchase agreement rate, however, appeared to be fully dissipated by the end of the sample period. Finally, we show
that the incremental impact of changes in bond default premiums on swap spread movements is considerable when measured for the ten-year maturity class across the entire sample period.

On balance, these findings provide strong support for the fundamental premise underlying this study: namely, that the market for interest rate swaps works in an orderly and efficient manner. There is considerable evidence suggesting that the dynamics of the swap market are well-integrated — although not statically so — with those of other affiliated securities, most notably Treasury notes and bills, repurchase agreements, and Eurodollar and Treasury bill futures contracts.

Given that the factors we examine do not provide a complete explanation of swap spread movements in any maturity class, however, it is clear that this price remains a difficult risk for the market maker to hedge. That the variables corresponding to the pricing of interest rate swap agreements of different maturities appear to have evolved differently over time as the market has developed presents a challenge to further empirical analysis.

ENDNOTES

The authors would like to thank Peter Abken, Richard McEnally, Richard Rendleman, Rene Stulz, Scha Tinic, and Larry Wall for their comments on an earlier draft of this article, which was begun while W.V. Harlow was employed by Salomon Brothers Inc. The opinions and analyses presented herein are those of the authors and do not necessarily represent the views of either Salomon Brothers or Fidelity Investments.

1Exceptions are McNulty's [1990] examination of data from the early swap market (1982-1984), Kim and

<p>| EXHIBIT 8 ■ Regressions of Swap Spreads on Changes in New Debt Issuance |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Swap Maturity</th>
<th>Intercept</th>
<th>ΔBV</th>
<th>ΔBV&lt;sub&gt;-1&lt;/sub&gt;</th>
<th>ΔBV&lt;sub&gt;-2&lt;/sub&gt;</th>
<th>ΔBV&lt;sub&gt;-3&lt;/sub&gt;</th>
<th>ΔBV&lt;sub&gt;-4&lt;/sub&gt;</th>
<th>Adjusted R&lt;sup&gt;2&lt;/sup&gt;</th>
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<td>Panel A. SS&lt;sub&gt;N&lt;/sub&gt; as Dependent Variable</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>One Year</td>
<td>0.6082</td>
<td>0.0226</td>
<td>0.0120</td>
<td>0.0113</td>
<td>−0.0049</td>
<td>0.0009</td>
<td>−0.065</td>
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<td></td>
<td>(0.0001)</td>
<td>(0.6613)</td>
<td>(0.8388)</td>
<td>(0.8348)</td>
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<td>(0.9856)</td>
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<tr>
<td>Three Years</td>
<td>0.6431</td>
<td>0.0013</td>
<td>0.0014</td>
<td>0.0119</td>
<td>0.0133</td>
<td>0.0026</td>
<td>−0.064</td>
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<td></td>
<td>(0.0001)</td>
<td>(0.9518)</td>
<td>(0.9524)</td>
<td>(0.6199)</td>
<td>(0.5779)</td>
<td>(0.9043)</td>
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<tr>
<td>Five Years</td>
<td>0.7329</td>
<td>−0.0434</td>
<td>−0.0466</td>
<td>−0.0380</td>
<td>−0.0219</td>
<td>−0.0115</td>
<td>−0.024</td>
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<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.1329)</td>
<td>(0.1472)</td>
<td>(0.2350)</td>
<td>(0.4885)</td>
<td>(0.6831)</td>
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<tr>
<td>Seven Years</td>
<td>0.7444</td>
<td>−0.0627</td>
<td>−0.0821</td>
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<td>−0.0730</td>
<td>−0.0494</td>
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<td>(0.0001)</td>
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<td>(0.0314)</td>
<td>(0.0346)</td>
<td>(0.1245)</td>
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<tr>
<td>Ten Years</td>
<td>0.7854</td>
<td>−0.0689</td>
<td>−0.0950</td>
<td>−0.0926</td>
<td>−0.0881</td>
<td>−0.0594</td>
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<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0364)</td>
<td>(0.0075)</td>
<td>(0.0100)</td>
<td>(0.0139)</td>
<td>(0.0741)</td>
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<td>Panel B. Residuals (w&lt;sub&gt;N&lt;/sub&gt;) as Dependent Variable</td>
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<td></td>
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<td></td>
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<tr>
<td>One Year</td>
<td>−0.0050</td>
<td>0.0189</td>
<td>0.0212</td>
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<td>(0.7769)</td>
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<td>(0.4606)</td>
<td>(0.4065)</td>
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<td>0.0067</td>
<td>0.0101</td>
<td>0.0164</td>
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<td>(0.6162)</td>
<td>(0.4932)</td>
<td>(0.2672)</td>
<td>(0.5154)</td>
<td>(0.8761)</td>
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<tr>
<td>Five Years</td>
<td>0.0203</td>
<td>−0.0324</td>
<td>−0.0385</td>
<td>−0.0412</td>
<td>−0.0263</td>
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<td>(0.1714)</td>
<td>(0.1389)</td>
<td>(0.1144)</td>
<td>(0.0907)</td>
<td>(0.2741)</td>
<td>(0.4583)</td>
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<tr>
<td>Seven Years</td>
<td>0.0338</td>
<td>−0.0252</td>
<td>−0.0482</td>
<td>−0.0533</td>
<td>−0.0558</td>
<td>−0.0405</td>
<td>0.044</td>
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<td>(0.0613)</td>
<td>(0.2789)</td>
<td>(0.0550)</td>
<td>(0.0369)</td>
<td>(0.0291)</td>
<td>(0.0889)</td>
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<tr>
<td>Ten Years</td>
<td>0.0438</td>
<td>−0.0365</td>
<td>−0.0620</td>
<td>−0.0709</td>
<td>−0.0675</td>
<td>−0.0510</td>
<td>0.114</td>
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<tr>
<td></td>
<td>(0.0139)</td>
<td>(0.1100)</td>
<td>(0.0120)</td>
<td>(0.0049)</td>
<td>(0.0072)</td>
<td>(0.0290)</td>
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</tr>
</tbody>
</table>

P-values reporting the probability of observing a larger test statistic under the null hypothesis that the value is zero are listed parenthetically.
Koppenhaver's [1993] investigation of commercial bank activity in the swap market, Simpson's [1993] test of the credit arbitrage rationale for using these contracts, and Sun et al. [1993], who examined the consistency of bid-ask quotes issued by swap dealers of different credit quality. There is, however, a well-developed theoretic literature focusing on the motivations for using swaps in corporate finance and on the default risk of swap contracts; see Arak et al. [1988], Wall [1989], Brown and Smith [1990], Solnik [1990], Cooper and Mello [1991], Titman [1992], and Rendleman [1993]. Wall and Pringle [1989] summarized the initial swap literature and have provided some statistics on the corporate usage of these agreements.

The spread swap is usually the only number that a market maker needs to quote in order to convey a sufficient amount of information to complete a U.S. dollar-denominated swap. For example, a market maker might quote five-year swaps against three-month LIBOR as: pay-fixed (the bid rate) at 40 basis points (bp) and receive-fixed (the offer rate) at 45 bp. Then, if the yield on the five-year Treasury note is currently 5.00%, the market maker stands ready to enter swaps as a fixed-payer at 5.40% and as a fixed-receiver at 5.45%. The swap spread would then be 40 bp on the bid side and 45 bp on the offer side. Notice that the floating-rate side of the agreement is typically quoted flat (i.e., without a margin added or subtracted from the index), while the fixed-rate side is raised or lowered to reflect market conditions. Thus, given the Treasury yield, the swap spread is the "price" of the transaction.

See Brown and Smith [1993] for a discussion of ways in which firms deal with the inevitable credit risk on swap contracts. In practice, credit risk on a swap depends on the joint probability of a counterparty defaulting and an adverse movement in interest rates. For example, in Exhibit 1 Firm A would lose only if Firm B defaulted and the fixed rate on a replacement swap (i.e., one having the same terms and remaining maturity as the original agreement) is less than T + SS. See Sorensen and Bollier [1994] for a more detailed analysis of swap default risk.

This is the sense in which Turnbull [1987] argues that swaps are "zero-sum" games. Rendleman [1993] carries this line of reasoning forward by showing how risks that are typically ignored in calculating the "gains" to a swap are shared among the participants to the transaction.

This analysis also supports what appears to be some conventional wisdom about swap spread movements. Litzenberger [1992], in one of his stylized facts about interest rate swaps, observes that: "Swap spreads, the difference between term swap rates (the fixed rate on a term swap against a floating rate of LIBOR, flat) and the on-the-run government yields, do not display the volatile cyclical behavior evidenced by corporate bond spreads."

We are grateful to Kris Mahabir of Fidelity Investments for providing us with the Treasury term structure estimates (i.e., \( Z_{Nk} \)) and to Todd Petzel of the Chicago Mercantile Exchange for furnishing the Eurodollar and Treasury bill futures settlement prices. The futures data contained a minimum of four and a maximum of eight common contract maturity dates during the January 1985 to May 1991 sample period.

2Dollar-denominated LIBOR and the Treasury bill rate are quoted on a bank add-on and discount basis, respectively, and are not directly comparable. Further, given that the Eurodollar and Treasury bill contracts traded at the Chicago Mercantile Exchange's International Monetary Market are standardized to use ninety-day securities, these rates are stated on a virtual quarterly compounded basis. To make these quotes comparable to one another as well as the semiannually compounded Treasury bond yield, we perform two necessary conversions. First, both LIBOR and TB contract settlement yields are changed to a bond-equivalent basis as follows: \( EDBY = [(365 \times LIBOR) + 360] \) and \( TBBY = [(365 \times TB) + (360 - [TB \times 90])] \). Second, the compounding basis for both of these yields was adjusted to \((1 + [90 \times BY + 365])^{365+180} - 1 \times 2\).

Because there is no natural proxy for \( E_N(TEDS) \), as \( Z_N \) is for \( E_N(TB) \), we tried estimating Equation (9) with values of \( M_k \) ranging from zero (i.e., just the difference in the current spot rates) to four, which is the maximum number of common contracts for each day during our sample period. Although these variations generate qualitatively comparable results in tests of the empirical form of (5), we found that the set of estimates using \( M_k = 1 \) (i.e., an equally weighted average of the current spot and near-term futures yields) had the greatest explanatory power; this is the only set presented.

A more intuitive approach to testing (6) would involve the regression \( SS_{Nk} = \gamma_0 + \gamma_1[Z_{Nk} - T_{Nk}] + \gamma_2(TEDS) + \omega_{Nk} \), with the prediction that \( \gamma_0 = 0 \), \( \gamma_1 = 1.0 \), and \( \gamma_2 = 1.0 \). The problem in starting our investigation with this form, however, is that if \( \gamma_1 \) or \( \gamma_2 \neq 1.0 \) we won't know whether there are more variables involved in the swap pricing process or that we simply misestimated \( E_N(TB) \) and \( E_N(TEDS) \). Thus, from an econometric standpoint, (11) is a superior test of the pure expectations swap model in that only an observable variable appears on the right-hand side. This design is analogous to Fama's [1975] test of the ability of short-term interest rates to predict inflation.

10Recall that the hypotheses tested by (11) are \( \beta_0 = 0 \) and \( \beta_1 = 1 \). Thus, the p-values listed in Exhibit 4 are calculated to measure the significance of the intercept and SS relative to zero and one, respectively. Further, for Equation (12), the p-values for the dummy variables are computed relative to a null hypothesis of zero since these coefficients simply measure incremental, rather than absolute, relationships. A null hypothesis of zero is also used for all subsequent
parameter significance tests.

Because these conclusions are based on swap spread data reported by a single market maker (Salomon Brothers), it is possible that they do not reflect pricing behavior pervasive throughout the industry. To insure that this is not the case, we also obtained data for the bid-side swap spread quotes of another intermediary, Fulton Prebon, and reestimated the regression parameters in this and all subsequent subsections. These new swap quotes, which were available only for the three-, five-, seven-, and ten-year maturities for the period beginning in July 1987, produced sample-wide results as strong as those we report and do not cause us to alter any of our conclusions.

The coupon bias variable, \( (Z_N - T_N) \), in the two-variable version of (13) also allows for an indirect examination of the extent to which swap spreads are influenced by changes in the slope of the Treasury yield curve. In the absence of liquidity premiums and tax effects, \( Z_N \) and \( T_N \) would be equal only if the yield curve were perfectly flat from period 0 through period \( N \); if \( Z_N \) is greater (less) than \( T_N \), the yield curve is upward- (downward-) sloping. For the shortest four swap maturities reported in Exhibit 2, the relationship between swap spreads and yield curve slope is significantly positive, suggesting that these swap spreads increased as the yield curve steepened. A significantly negative coefficient appears for the ten-year sample.

It is possible that the degree of explanatory power for the three-variable regressions reported in Exhibit 5 is artificially low because of estimation "noise" caused by the use of weekly observations on the relevant variables. To test this, we reestimated these equations using monthly averages of each variable (i.e., a total of seventy-six observations). Consistent with this argument, these runs generated respective adjusted \( R^2 \) values of 0.708, 0.616, 0.417, 0.469, and 0.509, which represent improvements in each of the five swap tenors.

To see this, recall that for the dummy variable regressions \( \alpha_1 \) represents the coefficient for the January 1985-December 1986 subperiod and \( \alpha_{12} \) and \( \alpha_{13} \) are then added to \( \alpha_1 \) to establish the relationships for the latter two subperiods. For example, the total slope coefficient values for the five-year swap sample in the January 1987-December 1988 and January 1989-May 1991 intervals are 0.0684 (\( = -0.1615 + 0.0931 \)) and 0.0305 (\( = -0.1615 + 0.1920 \)), respectively. Notice also that nine of the ten dummy variables across the five maturity classes are statistically significant, and all ten attenuate the original value of \( \alpha_1 \) toward zero.

We established this result, which is not shown in Exhibit 6, by estimating \( w_N = \alpha_1 + \alpha_{12} \text{REPO}_N + \alpha_{13} \text{V}_N \) separately for each of the three subintervals; these regressions had 104, 104, and 122 observations, respectively. The estimated values for \( \alpha_1 \) in the January 1989-May 1991 interval for the one-, three-, five-, seven-, and ten-year swap samples (along with their associated p-values) are: 0.0009 (0.9432); -0.0000 (0.9980); 0.0050 (0.5117); 0.0018 (0.7996); and 0.0126 (0.0820).

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