An empirical examination of basic valuation models for plain vanilla U.S. interest rate swaps

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Abstract

This paper examines empirical implications of recently developed models for pricing contracts that swap fixed-for variable-rate interest payment streams. Valuation models based on replicating portfolios of consecutive three-month Eurodollar futures contracts that span the life of the swap perform relatively well, as do pricing models based on replicating portfolios of noncallable corporate par bonds. Neither set of models, however, is completely empirically consistent with the implications of differential counterparty risks. These anomalous results call into question the appropriateness of either the simplifying assumptions of the arbitrage-based models or the proxies used for counterparty default risk.

Keywords: Swap pricing; Eurodollar futures pricing; Interest rate swaps; Bond pricing

JEL classification: G12; G13

1. Introduction

A plain vanilla interest rate swap is an agreement between two parties to swap periodic net interest rate payments on predetermined settlement dates. One stream of interest payments is fixed, and the other is based on a floating-rate index such as the six-month London interbank offer rate (LIBOR). Since the introduction of U.S. dollar interest rate swaps, activity has grown to the...
point that the notional principal amount outstanding of interest rate swaps was $3.23 trillion at the end of 1994 (International Swaps and Derivatives Association). Despite this dramatic growth, there is only a small and slowly growing amount of theoretical research on the pricing of interest rate swaps, with limited empirical evidence.¹

In this paper, I empirically test the implications of two classes of models presented in Smith et al. (1988) to price plain vanilla interest rate swaps (henceforth, swaps). At each settlement date, the net cash flow to the fixed-rate payer, for example, is the difference between the floating- and fixed-rate interest payments. This payoff is equivalent to the payoff on a basic forward contract on the floating interest rate with a delivery price equal to the fixed interest rate. Thus, the first class of models replicates the cash flows of an at-the-market (or par) swap by constructing a portfolio of consecutive short-term interest rate forward contracts that span the life of the swap. The second class of models replicates the cash flows of a swap through a long position in a floating-rate bond and a simultaneous short position in a fixed-rate bond, with both bonds noncallable and equal to the swap in par value and maturity.

To test the first class of models, I rely on the near equivalence of forward and futures contracts, and directly test the analogy between a swap and a portfolio of consecutive three-month Eurodollar futures contracts (henceforth, a Eurodollar strip). Over-the-counter (OTC) swap rates and swap rates derived from Eurodollar futures prices are highly correlated over time. Regression results, however, show that OTC swap rates do not move one-for-one with analogous swap rates derived from Eurodollar futures prices.

One explanation for the breakdown in the equivalence between OTC swaps and corresponding Eurodollar strips is that simple valuation models ignore the fact that because the clearinghouse of the futures exchange acts as the counterparty to every transaction, and because all futures positions are marked to market daily, counterparty default risk is effectively nonexistent in the futures market. While credit enhancements such as margins and marking to market might be required in the OTC swap market, quoted swap rates for plain vanilla interest rate swaps assume no type of credit enhancement. In fact, the difference between short-term OTC swap rates and swap rates derived from Eurodollar futures prices is positively related to proxies for counterparty default risk.

¹Prior empirical research on interest rate swaps includes Sun et al. (1993) who examine the effect of swap dealers' credit qualities on quoted bid-and-offer rates; Brown et al. (1994) and their empirical analysis of the variation in swap spreads as explained by a pure expectations pricing model and various supply and demand factors; Simpson's (1992) test of the credit arbitrage rationale for using swaps; and Kim and Koppenhaver (1993) who examine commercial banks' participation in the swap market. For an overview of theories explaining why firms use swaps see Wall and Pringle (1988) and Kuprianov (1994). See also Group of Thirty (1993) for a comprehensive survey of swap market participants' practices.
Thus, while the basic payoff profiles of swaps and corresponding Eurodollar strips are similar, the amount of counterparty default risk in a swap is greater than that in a futures contract.

To test the second class of models, in which swaps are priced as portfolios of bonds, I examine the relation between the determinants of corporate bond prices and the levels of par U.S. interest rate swap spreads. Consistent with the structure of these models, which assume no counterparty default risk and stochastic interest rates, I find that par swap rates are related to factors that are proxies for the shape of the yield curve. In particular, ten-year swap rates are positively related to the slope of the term structure and the level of ten-year Treasury yields. In separate regressions, ten-year U.S. interest rate swap rates are also positively related to ten-year corporate bond yields. However, counter to the predictions of simple valuation models, ten-year swap rates do not move one-for-one with these corporate bond yields, again suggesting that default risk in a swap, while greater than that in a Eurodollar futures contract, is less than that in a bond because of the settlement features of the swap.

Pricing models based on replicating portfolios of bonds that incorporate counterparty default risk imply that the differential probability of counterparty default as well as proxies for the option to default might be important determinants of swap rates. Consistent with the predictions of these models, I find that swap rates are positively related to proxies for differential counterparty default risk and short-term interest rate volatility. The positive relation between swap rates and short-term interest rate volatility suggests that an embedded option to default is being priced within a swap, and that this option is more valuable to the fixed-rate counterparty than to the floating-rate counterparty (assuming that the value of this default option depends on short-term interest rates). Because the swap rate represents the rate paid by the fixed-rate party in return for receiving the variable interest rate, these two results suggest that the market prices swaps as if the fixed-rate payer is the lower-rated party in a swap.

The paper proceeds as follows. Section 2 discusses and directly tests the pricing implications of the valuation analogy between swaps and Eurodollar strips. Section 3 discusses the pricing implications of the valuation analogies between swaps and portfolios of noncallable bonds, and estimates the empirical determinants of par swap rates as indirect tests of these analogies. Section 4 summarizes the major findings.

2. Swaps as portfolios of short-term interest-rate forward contracts: Theory and evidence

Smith et al. (1988) show that the cash flows of a par swap can be replicated by the cash flows of a portfolio of consecutive three-month forward contracts on
LIBOR. At each settlement date of the swap, the gain or loss in the currently maturing implicit forward contract is realized.

Forward prices are not available. However, with zero correlation between interest rates and futures prices, and no transaction costs, the payoff profiles of forward and futures contracts are identical (Cox et al., 1987). In practice, interest rates are stochastic. However, the sufficiently low correlation between interest rates and most futures prices warrants the approximation of forward contracts with futures contracts. Using this equivalence, swap pricing models based on analogies to portfolios of consecutive three-month forward contracts on LIBOR replicate the cash flows of a swap with those of a portfolio of consecutive three-month Eurodollar futures contracts. Specifically, these models show that the cash flows to the seller of a Eurodollar strip are equivalent to the cash flows to a fixed-rate payer in a swap, because each is obliged to sell (buy) a series of LIBOR cash flows at a predetermined price (rate). Similarly, the cash flows to a Eurodollar strip buyer are equivalent to the cash flows to a swap’s floating-rate payer. These models show that the fair-value swap rate is a fixed rate that equates the present value of the fixed-rate leg to the present value of the floating-rate leg. The fixed rate serves as a proxy for a swap dealer’s midmarket par swap rate.

This valuation analogy between swaps and Eurodollar strips predicts that OTC swap rates and swap rates derived from Eurodollar futures prices should be equal in each period. Specifically, the analogy predicts that in the following regression of $n$-year par OTC swap rates at time $t$, $\text{OTC}_{\text{Swap}_{n,t}}$, on $n$-year swap rates derived from Eurodollar futures prices at time, $\text{FUT}_{\text{Swap}_{n,t}}$,

$$\text{OTC}_{\text{Swap}_{n,t}} = \beta_0 + \beta_1 \text{FUT}_{\text{Swap}_{n,t}} + \epsilon_t,$$

the slope estimate should equal unity and the intercept should equal zero. If OTC par swap rates are not exactly equal to swap rates derived from Eurodollar futures prices in each period, but instead move one-for-one with swap rates derived from Eurodollar futures prices, then the slope estimate should also equal unity.

The sample of at-the-market U.S. interest rate swap rates used in this study consists of average broker midmarket par swap rates for fixed-for-floating U.S. dollar interest rate swaps for maturities of two, three, four, five, seven and ten years. In quoting the swap rates, it is assumed that the non-broker investor has a credit rating of single-A or higher and that the floating-rate index is six-month.

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2See Kawaller (1991), Nadler (1991), Bansal et al. (1993), and Burghardt and Hoskins (1994). The Eurodollar futures contract is based on LIBOR for three-month dollar-denominated time deposits. Its price is equal to an index derived by subtracting an (annualized) interest rate from 100. On the last trading day, the settlement price is based on an average of three-month LIBOR quotes obtained from a survey of London banks. See Burghardt et al. (1991) and Petzel (1989).
LIBOR flat (i.e., no spread). Appendix A contains detailed descriptions of variable definitions and data sources. I calculate an n-year swap rate derived from Eurodollar futures prices as an n-year semiannual bond-equivalent yield of a Eurodollar strip rate in which the strip rate equals the implied effective annual LIBOR for the full period covered by the swap. I calculate these swap rates by using daily spot one- to three-month LIBOR rates and the closing prices for the three-month Eurodollar futures contract traded on the Chicago Mercantile Exchange. (Appendix B describes in detail the methodology used to calculate these swap rates.) Because Eurodollar futures contracts extend only four years during the sample period, the equivalence of a swap to a Eurodollar strip is examined at maturities of two, three, and four years.

As a result of futures market features that reduce default risk, however, we would expect to see a difference between OTC swaps and swap rates derived from Eurodollar prices. To examine this proposition, the difference between an OTC par swap rate and a swap rate derived from Eurodollar futures prices with comparable maturity is regressed on two proxies for the differential probability of counterparty default, as follows:

\[ \text{OTCSwap}_{n,t} - \text{FUTSwap}_{n,t} = \beta_0 + \beta_1 CQSP_{Baa - Aaa,t} + \varepsilon_t \]  
(2)

and

\[ \text{OTCSwap}_{n,t} - \text{FUTSwap}_{n,t} = \beta_0 + \beta_1 ADSP_{Baa - TRY,t} + \varepsilon_t. \]  
(3)

In Eqs. (2) and (3), \( \text{OTCSwap}_{n,t} - \text{FUTSwap}_{n,t} \) is the difference between an n-year OTC swap rate and an n-year swap rate derived from Eurodollar futures prices at time \( t \). \( CQSP_{Baa - Aaa,t} \) is the corporate quality spread, measured as the difference between the time \( t \) yields on portfolios of Moody’s Baa-rated corporate debt and Moody’s Aaa-rated corporate debt. (At the end of 1985, the average maturity of Aaa-rated bonds was 19.75 years and 20.1 years for Baa-rated bonds.) \( ADSP_{Baa - TRY,t} \) is the aggregate default spread, measured as the time \( t \) difference between the yield on a portfolio of Moody’s Baa-rated corporate bonds and the time \( t \) average of the ten- and thirty-year U.S. Treasury yields that matches the maturity of the Baa-rate corporate yield. The first proxy (the corporate quality spread) corresponds to a swap with bilateral default risk because it is the difference between two corporate bond yields. The second proxy corresponds to a swap with unilateral default risk because it is the difference between a corporate bond yield and a Treasury yield. Because of the credit enhancements that are associated with Eurodollar strips but not with plain vanilla OTC swaps, the coefficient estimates on the proxies for differential probability of counterparty default in Eqs. (2) and (3) should be positive.

Even in the absence of default risk, the practice of daily resettlement in the Eurodollar futures market limits the valuation analogy between swaps and Eurodollar strips. Burghardt and Hoskins (1994) show numerically that swap rates derived from Eurodollar futures prices are higher (lower) than comparable maturity OTC swap rates when the Eurodollar futures rate yield curve is
upward (downward) sloping. This sloped term structure induces correlations between interest rates and Eurodollar futures prices. Given these correlations, receipt or payment of the daily settlement amount in the futures market causes the present value of the cash flows of the OTC swap and the Eurodollar strip to differ. Because of the practice of daily resettlement in the futures market but not in the swap market, we would expect OTC swap rates and comparable maturity swap rates derived from Eurodollar future prices to be unequal if the Eurodollar futures rate yield curve is not flat during the sample period.

2.1. Empirical evidence

Table 1 presents descriptive statistics for OTC par swap rates, swap rates derived from Eurodollar futures prices, and the differentials of these two sets of rates for maturities of two, three, and four years for the period from July 1985 to December 1992. In general, swap rates derived from Eurodollar futures prices are statistically greater than OTC swap rates. The largest average differential is equal to about four basis points. The lower OTC swap rates are consistent with the practice of daily resettlement in the futures market (but not in the swap market) during a period in which the Eurodollar futures rate yield curve was generally upward sloping.\(^3\)

To examine the ability of OTC swap rates to track swap rates derived from Eurodollar futures prices during the sample period, I calculate correlation coefficient estimates between the levels of (changes in) OTC swap rates and levels of (changes in) swap rates derived from Eurodollar futures prices. Although not reported, the correlation coefficients between the levels of (changes in) the two series range from 0.995 to 0.999 (0.845 to 0.875). Consistent with the pricing implications of the analogy between swaps and Eurodollar strips, these correlation coefficients are not statistically different from one, indicating that the levels of (changes in) short-term OTC swap rates are highly correlated with the levels of (changes in) swap rates derived from Eurodollar futures prices.

Sun et al. (1993) examine how well par swap offer rates track LIBOR par bond yields by estimating the correlation coefficients for changes in swap offer rates for AAA-rated dealers with changes in LIBOR par bond yields, which they calculate by using weekly spot interbank data from October 11, 1988 to April 15, 1991. For this period, Sun et al. (1993) report correlation coefficients between 0.65 and 0.71. In contrast, my estimated correlation coefficients between changes in OTC swap rates and changes in swap rates derived from Eurodollar futures

\(^3\)These statistical differences could also be due to the fact that the data were collected at different times during the day. The swap rates are early morning New York quotes, while the futures derived swap rates and spreads are calculated using closing prices of the previous day. This procedure could result in some level of measurement error, although it is not clear in which direction.
Table 1
Descriptive statistics for OTC par swap rates, swap rates calculated using Eurodollar futures prices, and the difference between these rates for maturities of two, three, and four years. A swap rate derived from Eurodollar futures prices is calculated as the semiannual bond-equivalent yield of a Eurodollar strip rate where the strip rate equals the implied effective annual LIBOR for the full period covered by the swap. Monthly data from July 1985 to December 1992

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Two-year</th>
<th>Three-year</th>
<th>Four-year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: OTC par swap rates (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>7.79</td>
<td>8.13</td>
<td>8.36</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.50</td>
<td>1.33</td>
<td>1.21</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.00</td>
<td>4.67</td>
<td>5.20</td>
</tr>
<tr>
<td>Maximum</td>
<td>10.69</td>
<td>10.45</td>
<td>10.49</td>
</tr>
<tr>
<td><strong>Panel B: Swap rates derived from Eurodollar futures prices (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>7.83</td>
<td>8.16</td>
<td>8.39</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.53</td>
<td>1.35</td>
<td>1.23</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.02</td>
<td>4.71</td>
<td>5.29</td>
</tr>
<tr>
<td>Maximum</td>
<td>10.79</td>
<td>10.51</td>
<td>10.65</td>
</tr>
<tr>
<td><strong>Panel C: OTC swap rates – swap rates derived from Eurodollar futures prices (basis points)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>−4.42*</td>
<td>−3.88*</td>
<td>2.83*</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>6.63</td>
<td>8.17</td>
<td>12.6</td>
</tr>
<tr>
<td>Minimum</td>
<td>−27.22</td>
<td>−27.25</td>
<td>−18.76</td>
</tr>
<tr>
<td>Maximum</td>
<td>12.47</td>
<td>21.49</td>
<td>41.24</td>
</tr>
</tbody>
</table>

*Statistically different from zero at the 1% significance level.

...prices for the 1988–91 period (using weekly data) are similar to those reported for the full sample period. The differences in the two sets of correlation coefficients are probably related to the dissimilar markets in which the alternate financial instrument trades. Sun et al. (1993) assume that as an alternative to making fixed-rate interest payments in a swap, end-users and swap dealers can issue a fixed-rate bond in the spot interbank market. In contrast, the alternative to a swap in the current analogy is the purchase or sale of a series of LIBOR-based cash flows in the Eurodollar futures market. The higher weekly correlation coefficients between changes in swap rates and changes in swap rates derived from Eurodollar futures prices reflect, in part, the more accurate and competitive information about forward rates in the Eurodollar futures market than in the spot interbank market.

To further test the equivalency of a swap to a Eurodollar strip, I estimate Eq. (1), which regresses OTC swap rates on swap rates derived from Eurodollar futures prices. I perform Dickey–Fuller (1979) tests and augmented Dickey–Fuller...
Table 2
Univariate regressions of monthly changes in OTC par swap rates ($\Delta$OTCSwap$_{m,t}$) on monthly changes in swap rates derived from Eurodollar futures prices ($\Delta$FUTSwap$_{n,t}$) for maturities of two, three and four years. A swap rate derived from Eurodollar futures prices is calculated as the semiannual bond-equivalent yield of a Eurodollar strip rate where the strip rate equals the implied effective annual LIBOR for the full period covered by the strip; $t$-statistics are reported in parentheses. The sample period is from September 1985 to December 1992

$$\Delta$$OTCSwap$_{m,t} = \beta_0 + \beta_1 \Delta$$FUTSwap$_{n,t} + \epsilon_t$$

(1)

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Two-year ($\Delta$OTCSwap$_{2,t}$)</th>
<th>Three-year ($\Delta$OTCSwap$_{3,t}$)</th>
<th>Four-year ($\Delta$OTCSwap$_{4,t}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.055 (0.066)</td>
<td>-0.047 (-0.059)</td>
<td>-0.319 (-0.369)</td>
</tr>
<tr>
<td>$n$-year swap rate derived from Eurodollar futures prices ($\Delta$FUTSwap$_{n,t}$)</td>
<td>0.953$^a$ (49.341)</td>
<td>0.942$^a$ (48.891)</td>
<td>0.917$^a$ (42.252)</td>
</tr>
<tr>
<td>$H_0$: $\beta_1 = 1$</td>
<td>2.241$^b$ (0.056)</td>
<td>3.010$^b$ (0.013)</td>
<td>3.832$^b$ (0.000)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.965</td>
<td>0.964</td>
<td>0.953</td>
</tr>
<tr>
<td>No. of observations</td>
<td>89</td>
<td>89</td>
<td>89</td>
</tr>
</tbody>
</table>

$^a$Statistically different from zero at the 1% level.
$^b$Statistically different from zero at the 5% level.

tests to determine whether the various times series of swap rates are non-stationary. The null hypothesis of a nonstationary series fails to be rejected for OTC swap rates and swap rates derived from Eurodollar futures prices at all maturities. Thus, because the swap rates are nearly integrated over time, I estimate Eq. (1) using first differences.

Table 2 reports the results for this regression. In general, the regression results also suggest that the pricing of OTC swaps and corresponding Eurodollar strips is closely related during the sample period. Almost all the variation in short-term OTC swap rates can be explained by variation in short-term swap rates derived from Eurodollar futures prices. As Table 2 shows, the coefficient estimates on the swap rates derived from Eurodollar futures prices are statistically different from zero. However, these coefficient estimates are also statistically different from unity at all maturities. Thus, while highly correlated over time, OTC swap rates do not move one-for-one with swap rates derived from
Eurodollar futures prices. Lastly, the null hypothesis that OTC swap rates are equal to swap rates derived from Eurodollar futures prices each period ($\beta_0 = 0$ and $\beta_1 = 1$) is rejected at all maturities.

Because OTC swap rates derived from Eurodollar futures prices may be unequal because of credit enhancements that are present only in the futures market, Table 3 presents the results for regressions (2) and (3) which incorporate proxies for the differential probability of counterparty default. These proxies, while not statistically significant determinants of the two-year differential of OTC swap rates and swap rates derived from Eurodollar futures prices, are significant determinants of the three- and four-year differentials. These positive coefficients are consistent with the credit enhancements that exist in the Eurodollars futures markets, but not in the OTC swap market. The coefficient estimates for the proxies for differential counterparty default also increase with the maturity of the swap. A ten-basis-point increase in the corporate quality spread, for example, yields a 1.22- and 3.02-basis-point increase, respectively, in the differential between three- and four-year OTC swap rates and swap rates derived from Eurodollar futures prices. These results suggest that while counterparty default risk is not important in short-term swaps, it becomes important as the maturity of the swap lengthens.

Finally, the intercept term, while insignificant in the two-year regression, is negative and significant in the three- and four-year regressions. These negative coefficients indicate that, on average, OTC swap rates are lower than swap rates derived from Eurodollar futures prices conditional on the mean of the proxy for counterparty default risk. Similar to the results for the difference in means for these two series (presented in Table 1), this result is consistent with the practice of daily resettlement in the futures market (but not in the swap market) during a period in which the Eurodollar futures rate yield curve is generally upward sloping.

In short, the results in this section suggest that while the pricing of OTC swaps and corresponding Eurodollar strips is highly correlated over time, a swap is not equivalent to a Eurodollar strip. This equivalency breaks down partly because of the institutional dissimilarities between the OTC swap and Eurodollar futures markets. Also, daily resettlement in the latter market, which does not exist in the former market, results in higher short-term swap rates derived from Eurodollar futures prices.

3. Swaps as portfolios of noncallable bond

Smith et al. (1988), among others, show that a par swap can also be replicated by a portfolio of noncallable bonds with the same par value and maturity as the swap. The net cash flows of a fixed-rate payer in a par swap, for example, can be
Table 3
Univariate regressions of the difference between an OTC par swap rate and a swap rate derived from Eurodollar futures prices (OTCSwap-FUTSwap<sub>n,t</sub>) for maturities or two, three, and four years on a proxy for differential counterparty default risk. In Eq. (2), this proxy is the corporate quality spread (ΔCQSP<sub>Bas−TBR</sub>). In Eq. (3), this proxy is the aggregate corporate default spread (ΔADSP<sub>Bas−TRY</sub>).

\[
\text{OTCSwap} - \text{FutSwap}_{n,t} = \beta_0 + \beta_1 \text{CQSP}_{Bas−TBR} + \epsilon_n, \quad n = 2, 3, \text{ and } 4. \tag{2}
\]

\[
\text{OTCSwap} - \text{FutSwap}_{n,t} = \beta_0 + \beta_1 \text{ADSP}_{Bas−TRY} + \epsilon_n, \quad n = 2, 3, \text{ and } 4. \tag{3}
\]

A swap rate derived from Eurodollar futures prices is calculated as the semiannual bond-equivalent yield of a Eurodollar strip rate where the strip rate equals the implied effective annual LIBOR for the full period covered by the swap. Regressions are estimated correcting for first-order serially correlated residuals using Beach and MacKinnon's (1978) maximum likelihood procedure; t-statistics are reported in parentheses. The sample period is from August 1985 to December 1992.

<table>
<thead>
<tr>
<th>Maturity</th>
<th>Two-year</th>
<th>Three-year</th>
<th>Four-year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eq. (2)</td>
<td>Eq. (3)</td>
<td>Eq. (2)</td>
</tr>
<tr>
<td>Intercept</td>
<td>1.895</td>
<td>-6.722</td>
<td>17.520&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(0.445)</td>
<td>(-1.473)</td>
<td>(-2.479)</td>
</tr>
<tr>
<td>Corporate quality spread (CQSP&lt;sub&gt;Bas−TBR&lt;/sub&gt;)</td>
<td>-0.058</td>
<td>0.122&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.302&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Aggregate corporate default spread (ADSP&lt;sub&gt;Bas−TRY&lt;/sub&gt;)</td>
<td>0.012</td>
<td>0.104&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.149&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Estimated slope coefficient from the regression of (\gamma_1) on (\epsilon_{t-1})</td>
<td>0.186&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.261&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.558&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Adjusted (R^2)</td>
<td>0.053</td>
<td>0.034</td>
<td>0.300</td>
</tr>
<tr>
<td>No. of observations</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

<sup>a</sup> Statistically different from zero at the 1% level.
<sup>b</sup> Statistically different from zero at the 5% level.
<sup>c</sup> Statistically different from zero at the 10% level.
replicated by a combination of a long position in a variable noncallable LIBOR bond that sells at par on reset dates and a simultaneous short position in a noncallable bond of equal par value that makes fixed-rate interest rate payments on the same reset dates. Given this structure, the fair value of the swap rate is the fixed rate that, when swapped against the LIBOR flat rate, results in the portfolio of bonds having zero market value on the effective date of the swap for a given term structure of interest rates. Therefore, the par swap rate must equal the coupon rate on the fixed-rate bond issued at par, assuming corresponding settlement and reset dates and no swap default, no arbitrage, no transaction costs, and no taxes or other market frictions.

As in the previous section, this analogy between swaps and portfolios of noncallable corporate bonds makes predictions about the relation between swap and bond pricing. Direct tests of the prediction that an OTC swap rate equals the coupon rate on a fixed-rate bond of comparable maturity require pricing data on swaps and bonds with the same credit risk, par value, and issue and maturity dates. These pricing data were not available for this study. Instead, this paper examines the relation between U.S. interest rate par swap rates and corporate bond yields and between U.S. interest rate par swap rates and the determinants of corporate bond prices. Thus, I can indirectly test valuation analogies between swaps and portfolios of noncallable corporate bonds. Sun et al. (1993) directly test the equivalence of a swap to a portfolio of LIBOR par bonds and find that OTC swap rates are highly correlated with swap rates derived from the spot LIBOR data.

In particular, the valuation analogy between swaps and portfolios of bonds in which the floating-rate note pays a coupon of LIBOR flat implies that swap rates will move directly with fixed-rate corporate yields of comparable maturity for a given term structure of interest rates. I examine this proposition by regressing ten-year OTC swap rates on corporate bond yields for newly issued ten-year noncallable corporate (coupon) bonds, as follows:

\[ \text{OTC\textit{Swap}}_{10,t} = \beta_0 + \beta_1 \text{CORP}_{j,t} + \epsilon_t, \]  

(4)

where \( \text{OTC\textit{Swap}}_{10,t} \) is the ten-year OTC par swap rate at time \( t \) and \( \text{CORP}_{j,t} \) is the \( j \)-rated yield on a newly issued ten-year noncallable corporate (coupon) bond (\( j = \text{AAA}, \text{AA}, \text{and A} \)) at time \( t \). Because the swap rates, which are used in this study, are quoted for counterparties with credit ratings of single-A or higher. I estimate Eq. (4) using AAA-, AA-, and A-rated yields on a newly issued ten-year noncallable corporate (coupon) bond. If ten-year swap rates move one-for-one with ten-year fixed-rate corporate bond yields, the slope estimate should equal unity.

\[ \text{See also Turnbull (1987), Kopprash et al. (1991), Litzenberger (1992), and Sun et al. (1993).} \]
In the presence of stochastic interest rates, these simple valuation analogies also predict that proxies for changes in the shape of the yield curve should be important empirical determinants of swap rates because of consequent changes in the present values of the bonds, other things equal (Sundaresan, 1989). To examine this proposition, I regress ten-year OTC swap rates on the slope of the term structure and the ten-year Treasury yield, as follows:

\[ \text{OTCSwap}_{10,t} = \beta_0 + \beta_1 \text{Slope}_{30-25,t} + \beta_2 \text{TRY}_{10,t} + \varepsilon_t \]  
(5)

In Eq. (5), \( \text{Slope}_{30-25,t} \) is the slope of the term structure at time \( t \), measured as the difference between the time \( t \) yield on the thirty-year U.S. Treasury bond and the time \( t \) yield on the three-month U.S. Treasury bill. Fama and French (1989) document that the slope of the term structure is a business cycle variable that captures business condition risk resulting from discount rate shocks. Eq. (5) also includes the ten-year Treasury yield at time \( t \), \( \text{TRY}_{10,t} \), as a proxy for the level of the \( n \)-year risk-free interest rate. Longstaff and Schwartz (1993) show that long-term corporate credit spreads are negatively related to the level of the interest rate. This negative relation implies that corporate bond yields move less than one-for-one with Treasury yields with the same maturity. If, like corporate bond yields, par swap rates also move less than one-for-one with Treasury yields of comparable maturity, we would expect the regression coefficient estimate of the ten-year Treasury yield, \( \beta_2 \), to be less than one, other things equal. (Similarly, we would expect swap spreads to be negatively related to Treasury yields of comparable maturity.)

Because ten-year corporate yields are very highly correlated with ten-year U.S. Treasury yields, I also estimate the following regression:

\[ \text{OTCSwap}_{10,t} = \beta_0 + \beta_1 \text{Slope}_{30-25,t} + \beta_2 \text{TRY}_{10,t} + \text{RESIDCorp}_{j,t} + \varepsilon_t, \]  
(6)

where, \( \text{RESIDCorp}_{j,t} \) is the residual from the regression of \( \text{CORP}_{j,t} \) on \( \text{TRY}_{10,t} \) (\( j = \text{AAA}, \text{AA}, \text{and A} \)).

3.1. Counterparty default risk

As with valuation analogies between swaps and Eurodollar strips, analogies between swaps and portfolios of noncallable corporate bonds ignore the different default implications of bonds and swaps. Because a swap is characterized by the periodic exchange of only net interest payments, the amount of cash flow at risk is lower than that of a par bond of comparable maturity. The probability of default in a swap is also lower than that in a corporate bond because the former’s probability of default is equal to the joint probability of the firm being financially distressed and the swap having negative value to the firm (Hull, 1989; and Smith et al., 1990).
Moreover, almost all swap documentation stipulates that in the event of default, counterparties engage in ‘close-out netting’ to settle all contracted, but not-yet-due, net liabilities. Counterparties must choose between the ‘First Method’ (limited two-way payment) and the ‘Second Method’ (full two-way payment) for calculating the net termination payment. Under the second (full two-way payment) method, the nondefaulting party is required to make a close-out net payment if it is owed to the defaulting party. Under the first (limited two-way payment) method, however, the nondefaulting party is not obligated to make a close-out net payment to the defaulting party. In contrast, bankruptcy (at least in the U.S.) results in the offsetting netting of the fixed- and floating-rate debt obligations in the portfolio of bonds (Litzenberger, 1992). Cunningham and Casper (1993) and Tucker (1991) provide detailed discussions of the main features of the 1992 ISDA Master Agreements and the treatment of swaps under the U.S. Bankruptcy Code.

Partly as a result of these contractual features, the probability of default in swaps, while greater than that on Eurodollar futures contracts, is less than that on bonds. Consequently, swap rates, instead of moving one-for-one with corporate fixed rates, will rise and fall by less, other things equal, and the coefficient estimate, \( \beta_1 \), in Eq. (4), which regresses OTC swap rates on corporate bond yields, should be less than one.

Longstaff and Schwartz (1993) and Cooper and Mello (1991) value a swap with counterparty default risk by pricing the promised gross payment by each counterparty separately, and then adding the two together. Duffie and Huang (1996), however, show numerically that this method of calculating default risk overstates the default risk in a swap because only the net promised cash flow is exchanged in a swap. The numerical simulations of Cooper and Mello (1991), Longstaff and Schwartz (1993), and Duffie and Huang (1996) confirm that default premiums on fixed- and floating-rate bonds differ by a significant amount and indicate that this differential should be an important empirical determinant of swap rates.

To examine the findings of these numerical simulations, I incorporate into the regression analysis the two proxies for the difference between the default premiums in the fixed- and floating-rate corporate bond markets: the corporate quality spread \((\text{CQSP}_{\text{Baa}} - \text{Aaa})\) and the aggregate business default spread \((\text{ADSP}_{\text{Baa}} - \text{TRY})\). As previously stated, the corporate quality spread measures bilateral counterparty default risk, while the aggregate default spread measures unilateral counterparty default risk. The sign of the coefficient estimates on these proxies of counterparty default risk will depend on the relative default risk of the swap counterparties, other things equal. If, for example, the fixed-rate payer is the lower-rated counterparty, the coefficient estimates should be positive, because the swap rate is the interest rate paid by the fixed-rate payer in return for receiving LIBOR.

Because the corporate quality and aggregate default spreads are crude measures for counterparty default risk, I include monthly industrial production
growth in the regressions to capture independent business cycle effects. Counterparty default risk in a swap might depend on the expected path of business conditions over the life of the swap, conditions that are not fully controlled for by either the slope of the term structure or the aggregate default spread. Because output follows a random walk (Campbell and Mankiw, 1987), current monthly industrial production growth is used as a measure of expected business conditions over the life of the swap. Industrial production is a coincident series with cyclical movements that come close to one-to-one correspondence with business expansions and contractions (Zarnowitz, 1992). If swap rates are procyclical, then the estimated regression coefficients will be positive.

Lastly, I include a proxy for a swap counterparty's option to default. In the presence of counterparty default risk, a swap can also be replicated by a portfolio of noncallable bonds (a default-free swap) and an option to default (Akben, 1993; Litzenberger, 1992; Smith et al., 1990; and Sorensen and Bollier, 1994). The fixed-rate payer in the swap, for example, is long an option that he will default and short an option that the floating-rate payer will default. Although both parties have default options, these options are typically more valuable to one party than to the other, because any time after the initiation of the swap, the swap can become either an asset or a liability. Because of the default option, these models suggest that proxies for the value of the option should be important empirical determinants of swap rates.

Sorensen and Bollier (1994) demonstrate numerically that the values of the default options depend on the term structure of interest rates. This dependence results because, in their model, the shape of the term structure reflects expectations about future interest rates besides a risk premium. Therefore, the slope of the term structure predicts when the swap will become a net liability to either counterparty. Thus, their model implies that par swap rates depend on the slope of the term structure. The sign of the coefficient estimate will depend on the relative probability of counterparty default.

Short-term interest rate volatility will also be an important economic determinant of interest rate swap rates if the value of the default option depends on short-term interest rates. Interest rate volatility is measured as the implied standard deviation from the nearest-to-expiration, at-the-money call option on the Treasury bond futures contract. Implied standard deviations are computed using the Barone-Adesi and Whaley (1987) model.\(^5\)

\(^5\)The option on the Treasury bond futures contract is an American option. Moreover, the futures contract has an embedded quality option due to the seller's right to deliver the 'cheapest-to-deliver bond'. The Barone-Adesi and Whaley (1987) model calculates the implied deviations for an American option. Because the underlying futures price is a weighted average of the prices of the bonds that are expected to be the 'cheapest-to-deliver', it is assumed that the futures price satisfies the assumptions of the Black-Scholes model (Burghardt and Belton, 1994).
I expand Eq. (5) to indirectly test the valuation analogies between swaps and portfolios of noncallable corporate bonds in the presence of counterparty default risk for two, five, and ten-year swap rates, as follows:

\[
\text{OTC\text{Swap}}_{n,t} = \beta_0 + \beta_1 \text{Slope}_{\text{TRY30-TRY0.25},t} + \beta_2 \text{TRY}_{n,t} + \beta_3 \text{DEFAULT}_{n,t} + \beta_4 \text{IRVOL}_t + \beta_5 \text{IPG}_t + \epsilon_t, \tag{7}
\]

where \(\text{OTC\text{Swap}}_{n,t}\) is the \(n\)-year OTC par swap rate at time \(t\); \(\text{Slope}_{\text{TRY30-TRY0.25},t}\) is the slope of the term structure at time \(t\); \(\text{TRY}_{n,t}\) is the \(n\)-year Treasury yield at time \(t\) \(\text{DEFAULT}_{n,t}\) is the difference between the default premiums in the fixed- and floating-rate corporate bond markets, measured by the corporate quality spread (CQSP_{Baa-Aaa,t}) and the aggregate default spread (ADSP_{Baa-TRY,t}) at time \(t\); \(\text{IRVOL}_t\) is short-term interest rate volatility at time \(t\); and \(\text{IPG}_t\) is monthly industrial production growth at time \(t\).

3.2. Descriptive statistics

Table 4 and Figs. 1–3 provide selected descriptive statistics for U.S. dollar interest rate swap rates and proxy variables used in the regression analysis. These statistics serve as a benchmark against which to consider the regressions.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Selected descriptive statistics on all variables used in tests of the valuation analogies between swaps and portfolios of noncallable bonds. The sample period is from July 1985 to December 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. dollar interest rate swap rates (%)</td>
<td>Mean</td>
</tr>
<tr>
<td>Two year</td>
<td>7.79</td>
</tr>
<tr>
<td>Five-year</td>
<td>8.53</td>
</tr>
<tr>
<td>Ten-year</td>
<td>8.95</td>
</tr>
<tr>
<td>Treasury yields (%)</td>
<td></td>
</tr>
<tr>
<td>Two-year</td>
<td>7.25</td>
</tr>
<tr>
<td>Five-year</td>
<td>7.83</td>
</tr>
<tr>
<td>Ten-year</td>
<td>8.21</td>
</tr>
<tr>
<td>All other variables</td>
<td></td>
</tr>
<tr>
<td>Slope of the term structure (basis points, b.p.)</td>
<td>207.51</td>
</tr>
<tr>
<td>Aggregate default spread (b.p.)</td>
<td>195.00</td>
</tr>
<tr>
<td>Corporate quality spread (b.p.)</td>
<td>109.50</td>
</tr>
<tr>
<td>AAA-rated corporate bond yield (%)</td>
<td>8.67</td>
</tr>
<tr>
<td>AA-rated corporate bond yield (%)</td>
<td>8.83</td>
</tr>
<tr>
<td>A-rated corporate bond yield (%)</td>
<td>9.07</td>
</tr>
<tr>
<td>Short-term interest rate volatility (%)</td>
<td>11.79</td>
</tr>
<tr>
<td>Month industrial production growth</td>
<td>0.177</td>
</tr>
</tbody>
</table>
estimated to test the bond portfolio valuation analogy. During the July 1985 to December 1992 sample period, average par swap rates ranged from 7.79% at the two-year maturity to 8.95% at the ten-year maturity. Fig. 1 plots the two-, five-, and ten-year par swap rates for this period, representative of short-, medium-, and long-term par swap rates, respectively. As the graph shows, swap rates in general have declined since July 1985. Short-term swap rates peaked above long-term swap rates when the yield curve was inverted during the
first half of 1989. The yield curve is defined as inverted when the difference between the ten-year Treasury yield and the two-year Treasury yield is negative.

Figs. 2 and 3 graph ten-year par swap rates against some of the regresses during the sample period. As Fig. 2 shows, ten-year swap rates move very closely with ten-year AAA- and A-rated corporate yields. In addition, the ten-year swap rates are within the band defined by the AAA-rated and A-rated corporate bond yields except for the period from June 1986 to July 1988. Fig. 3 graphs the ten-year swap rates against the corporate quality spread and the slope of the term structure. Ten-year swap rates are positively correlated with the corporate quality spread and the slope of the term structure during the sample period.

3.3. Empirical evidence

I estimate Eqs. (4)–(6) for ten-year U.S. dollar interest rate swap rates to indirectly test the valuation analogy between swaps and portfolios of noncallable corporate bonds in the absence of counterparty default risk. Again, I perform Dickey–Fuller tests and augmented Dickey–Fuller tests to determine whether the time series of ten-year swap rates is nonstationary. The null hypothesis of a nonstationary series fails to be rejected. Consequently, because ten-year swap rates are nearly integrated over time, Eqs. (4)–(6) are estimated using first differences in all variables (denoted by ‘Δ’ in Table 5).

Table 5 reports the results of these regressions. Panel A indicates that ten-year swap rates are statistically and positively related to ten-year corporate bond yields, consistent with the pricing models that value a swap as a portfolio of
Table 5
Panel A: Univariate regression estimates of monthly changes in ten-year interest rate swap rates \((\Delta OTCSwap_{10j})\) on the monthly changes in ten-year corporate bond yields \((\text{CORP}_j, j = \text{AAA}, \text{AA}, \text{and A})\) and the level of the ten-year interest rate \((\text{TRY}_{10j})\). Regressions are estimated correcting for first-order serially correlated residuals using Beach and Mackinnon’s (1978) maximum likelihood procedure; \(t\)-statistics are reported in parentheses. Sample period is from September 1985 to December 1992.

\[
\Delta OTCSwap_{10j} = \beta_0 + \beta_1 \Delta \text{CORP}_{ij} + \epsilon_i, j = \text{AAA}, \text{AA} \text{ and A}.
\]

<table>
<thead>
<tr>
<th>Independent variable (monthly changes)</th>
<th>Regression 1</th>
<th>Regression 2</th>
<th>Regression 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \text{CORP}_{ij})</td>
<td>0.945*</td>
<td>0.959*</td>
<td>0.943*</td>
</tr>
<tr>
<td>((31.181))</td>
<td>((31.166))</td>
<td>((28.682))</td>
<td></td>
</tr>
<tr>
<td>(H_0: \beta_1 = 1)</td>
<td>-1.808b</td>
<td>-1.405</td>
<td>-1.730b</td>
</tr>
<tr>
<td>(t)-statistic</td>
<td>(-3.660)</td>
<td>(-4.430)</td>
<td>(-3.704)</td>
</tr>
<tr>
<td>Estimated slope coefficient from the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>regression of (\epsilon_i) on (\epsilon_{i-1})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted (R^2)</td>
<td>0.905</td>
<td>0.911</td>
<td>0.890</td>
</tr>
<tr>
<td>No. of observations</td>
<td>89</td>
<td>89</td>
<td>89</td>
</tr>
</tbody>
</table>

*Statistically different from zero at the 1% level.

\(b\)Coefficient estimate is statistically different from one at the 10% significance level.

Panel B: Univariate multiple regression estimates of monthly changes in ten-year interest rate swap rates \((\Delta OTCSwap_{10j})\) on monthly changes in term spread \((\Delta \text{Slope}_{\text{TRY}_{30\text{-}25}})\), the level of the ten-year interest rate \((\text{ATRY}_{10j})\), and the residual from a regression of a ten-year \(j\)-rated corporate bond yield on the changes in the ten-year interest rate \((\text{RESIDC}_{\text{CORP}_{j}}, j = \text{AAA}, \text{AA} \text{ and A})\); \(t\)-statistics are reported in parentheses. The sample period is from September 1985 to December 1992.

\[
\Delta OTCSwap_{10j} = \beta_0 + \beta_1 \Delta \text{Slope}_{\text{TRY}_{30\text{-}25}}, \beta_2 \Delta \text{ATRY}_{10j} + \epsilon_i.
\]

\[
\Delta OTCSwap_{10j} = \beta_0 + \beta_1 \Delta \text{Slope}_{\text{TRY}_{30\text{-}25}}, \beta_2 \Delta \text{ATRY}_{10j} + \beta_3 \text{RESIDC}_{\text{CORP}_{j}} + \epsilon_i, j = \text{AAA}, \text{AA} \text{ and A}.
\]

<table>
<thead>
<tr>
<th>Independent variable (monthly change)</th>
<th>Regression (5)</th>
<th>Regression (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\text{RESIDC}<em>{\text{CORP}</em>{j}} = \text{RESIDC}<em>{\text{CORP}</em>{j}})</td>
<td>(\text{RESIDC}<em>{\text{CORP}</em>{j}} = \text{RESIDC}<em>{\text{CORP}</em>{j}})</td>
</tr>
<tr>
<td>Slope of the term structure</td>
<td>0.048b</td>
<td>0.043c</td>
</tr>
<tr>
<td>((\Delta \text{Slope}<em>{\text{TRY}</em>{30\text{-}25j}}))</td>
<td>((2.148))</td>
<td>((1.878))</td>
</tr>
<tr>
<td>Ten-year interest rate</td>
<td>0.918c</td>
<td>0.918c</td>
</tr>
<tr>
<td>((\text{ATRY}_{10j}))</td>
<td>((43.075))</td>
<td>((43.132))</td>
</tr>
<tr>
<td>Standardized ten-year</td>
<td>0.082</td>
<td>0.151b</td>
</tr>
<tr>
<td>corporate rate</td>
<td>((1.182))</td>
<td>((2.426))</td>
</tr>
<tr>
<td>(\text{RESIDC}<em>{\text{CORP}</em>{j}})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted (R^2)</td>
<td>0.963</td>
<td>0.963</td>
</tr>
<tr>
<td>No. of observations</td>
<td>89</td>
<td>89</td>
</tr>
</tbody>
</table>

*Statistically different from zero at the 1% level.

\(b\)Statistically different from zero at the 5% level.

\(c\)Statistically different from zero at the 10% level.
noncallable corporate bonds in the absence of counterparty default risk. A ten-basis-point increase in AAA-, AA-, and A-rated corporate bond yields result in a 9.45-, 9.59-, and 9.43-basis-point increase, respectively, in ten-year swap rates. Panel A also reports the t-statistics for the null hypothesis that the estimated coefficient for the corporate bond yield equals one, and shows that the null hypothesis is rejected at the 10% significance level for AAA- and A-rated corporate bond yields. These coefficient estimates of less than one are consistent with previous arguments that swap rates are not as sensitive to the credit risk inherent in corporate bonds of comparable maturity. This is due to the contractual features of swaps such as the exchange of only net interest payments. However, the null hypothesis for AA-rated corporate bonds fails to be rejected, indicating that ten-year OTC swap rates move one-for-one with AA-rated corporate bonds during the sample period.

Panel B, Table 5, reports the regression results for Eq. (5), which regresses swap rates on the slope of the term structure and Treasury yields. The results in panel B confirm the relations between swap rates and proxies for changes in the shape of the yield curve implied by valuation models in a stochastic interest rate environment. Consistent with Fig. 3, changes in ten-year par swap rates are positively related to changes in the slope of the term structure (ΔSlope_{T^{30}\rightarrow T^{0.25}}). This positive association implies that as the yield curve steepens, ten-year swap rates increase. The increase, however, is very small. A ten-basis-point increase in the slope of the term structure corresponds to less than a one-basis-point increase in ten-year swap rates.

Besides being related to the slope of the yield curve, ten-year par swap rates are also significantly and positively related to the yield on a ten-year U.S. Treasury note. Unlike the relation between the slope of the term structure and ten-year swap rates, this relation is more economically significant. A 100-basis-point change in the ten-year U.S. Treasury yield corresponds to a statistically significant change of about 91 basis points in ten-year swap rates. Additionally, the coefficient estimate is statistically less than one, indicating that ten-year par swap rates do not move one-for-one with ten-year Treasury yields.

Panel B also reports the regression results for Eq. (6), which examines the relation between ten-year swap rates and the part of the ten-year corporate bond yield that is not explained by the ten-year Treasury yield (henceforth, standardized corporate bond yields). At the same time, the regressions control for the effects of the term structure and the ten-year Treasury yield on ten-year swap rates. Consistent with the results presented in panel A, the relation between ten-year swap rates and ten-year standardized corporate bond yields is statistically significant for AA- and A-rated corporate bond yields. In these cases, a ten-basis-point increase in standardized ten-year corporate bond yields results in about a 1.50-basis-point increase in ten-year swap rates.
3.3.1. Counterparty default risk

To indirectly test the valuation models based on replicating portfolios of bonds in the presence of counterparty default risk, I estimate Eq. (7) for two-, five-, and ten-year U.S. dollar interest rate swap rates. Dickey–Fuller tests and augmented Dickey–Fuller fail to reject nonstationarity for OTC swap rates at all maturities. Again, because these swap rates are nearly integrated over time, Eq. (7) is estimated using first differences in all variables (denoted by 'Δ' in Table 6).

I also perform Breusch–Pagan (1979) and White (1980) tests for heteroskedasticity for all the regressions. The null hypothesis of homoskedasticity is rejected at the 5% significance level for the five- and ten-year swap rates regressions that include the corporate quality spread as a proxy for the differential probability of counterparty default. Consequently, the standard errors in these regressions are corrected for heteroskedasticity by White’s (1980) method.

Table 6 reports the regression results using the corporate quality spread and the aggregate default spreads as proxies for counterparty default spread. The results for the proxies for changes in the yield curve remain. Swap rates are statistically and positively related to comparable maturity Treasury yields at all maturities. The slope of the term structure, however, is a statistically significant determinant of only two- and five-year swap rates.

As Table 6 reports, the differential probability of counterparty default risk is a statistically significant determinant of OTC par swap rates. Specifically, par swap rates are statistically and positively related to the aggregate default spread, but not statistically related to the corporate quality spread. Together, these results indicate that swap rates are related to unilateral counterparty default risk but not bilateral counterparty default risk. As Table 6 shows, a ten-basis-point increase in aggregate corporate default spread results in a 1.24-, 1.54-, and 1.40-basis-point widening in two-, five- and ten-year swap rates, respectively. These findings suggest that while the swap rates used in this paper are not quoted for specific credit ratings, on average, they are related to the differential probability of default for lower- and higher-rated firms. Finally, the positive coefficient estimates suggest that because the swap rate is the fixed rate paid in exchange for LIBOR, the market prices swaps as if the fixed-rate payer is the lower-rated counterparty in a swap.

Proxies for the value of the default option are also statistically significant determinants of OTC swap rates. As Table 6 reports, implied short-term interest rate volatility is a statistically significant empirical determinant of swap rates. An increase in interest rate volatility yields statistically significant increases in swap rates at all maturities. If the value of the default option depends on

---

6The results for regressions estimated for two-, five- and ten-year par swap spreads (rather than rates) were qualitatively similar.
Table 6

Univariate multiple regression estimates of monthly changes in n-year interest rate swap rates \((\Delta \text{OTCswap}_n)\) on monthly changes in the slope of the term structure \((\Delta \text{Slope}_{T30-TR0.25})\), the aggregate corporate default spread \((\Delta \text{ADSP}_{\text{Bas-TRY}})\), the corporate quality spread \((\Delta \text{CQSP}_{\text{Bas-Asa}})\), the level of the n-year interest rate \((\Delta \text{TRY}_n)\), implied short-term interest rate volatility \((\Delta \text{IRVOL})\), and monthly industrial production growth \((\Delta \text{IPG})\). Standard errors in the five- and ten-year regressions, which include corporate quality spread, are corrected for heteroscedasticity by the method of White (1980); t-statistics are reported in parentheses. The sample period is from August 1985 to December 1992.

\[
\begin{align*}
\Delta \text{OTCswap}_n &= \beta_0 + \beta_1 \Delta \text{Slope}_{T30-TR0.25} + \beta_2 \Delta \text{TRY}_n + \beta_3 \Delta \text{CQSP}_{\text{Bas-Asa}} + \\
& \quad + \beta_4 \Delta \text{IRVOL} + \beta_5 \Delta \text{IPG} + \epsilon_n \\
\Delta \text{OTCswap}_n &= \beta_0 + \beta_1 \Delta \text{Slope}_{T30-TR0.25} + \beta_2 \Delta \text{TRY}_n + \beta_3 \Delta \text{ADSP}_{\text{Bas-TRY}} + \\
& \quad + \beta_4 \Delta \text{IRVOL} + \beta_5 \Delta \text{IPG} + \epsilon_n
\end{align*}
\]  

<table>
<thead>
<tr>
<th>Independent variable (monthly changes)</th>
<th>Two-year swap rates ((\Delta \text{OTCswap}_{2,1}))</th>
<th>Five-year swap rates ((\Delta \text{OTCswap}_{5,1}))</th>
<th>Ten-year swap rates ((\Delta \text{OTCswap}_{10,1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope of the term structure ((\Delta \text{Slope}_{T30-TR0.25}))</td>
<td>0.112* (3.837)</td>
<td>0.131* (4.421)</td>
<td>0.044* (2.031)</td>
</tr>
<tr>
<td>n-year interest rate ((\Delta \text{TRY}_n))</td>
<td>1.064* (42.607)</td>
<td>1.098* (33.853)</td>
<td>0.937* (48.087)</td>
</tr>
<tr>
<td>Corporate quality spread ((\Delta \text{ADSP}_{\text{Bas-Asa}}))</td>
<td>0.054 (0.471)</td>
<td>0.132 (1.413)</td>
<td>0.166 (1.426)</td>
</tr>
<tr>
<td>Aggregate corporate default spread ((\Delta \text{ADSP}_{\text{Bas-TRY}}))</td>
<td>0.124* (1.665)</td>
<td>0.154* (2.974)</td>
<td>0.140* (2.524)</td>
</tr>
<tr>
<td>Implied interest-rate volatility ((\Delta \text{IRVOL}_n))</td>
<td>1.196* (3.596)</td>
<td>1.012* (2.959)</td>
<td>0.744* (2.976)</td>
</tr>
<tr>
<td>Monthly industrial Production growth ((\Delta \text{IPG}))</td>
<td>0.009 (0.685)</td>
<td>0.002 (0.119)</td>
<td>0.017* (1.827)</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.955</td>
<td>0.958</td>
<td>0.972</td>
</tr>
</tbody>
</table>

No. of observations | 89 | 89 | 89 |

*Statistically different from zero at the 1% level.

bStatistically different from zero at the 5% level.

Statistically different from zero at the 10% level.

short-term interest rates, the significant coefficient estimates are consistent with an embedded default option being priced in a swap. The positive coefficient estimates suggest that this option is more valuable to the fixed-rate payer than to the floating-rate payer.
As previously stated, the slope of the term structure is a statistically significant determinant of two- and five-year swap rates. Table 6 reports that a ten-basis-point increase in the slope of the term structure results in less than a two-basis-point increase in two-year swap rates, and about a 0.5-basis-point increase in five-year swap rates. The small but positive coefficient estimates are consistent with Sorensen and Bollier (1994) in whose model the slope of the term structures determines the default option in a swap. This interpretation, however, relies heavily on the assumption that the slope of the term structure reflects expectations about future interest rates besides a risk premium, that the fixed-rate payer is the riskier counterparty, that the firms' cash flows are not correlated with short-term interest rates, and that there is unilateral default risk.

Lastly, OTC swap rates, in general, are not related to contemporaneous industrial production growth. Table 6 reports that the coefficient estimate is only statistically significant at the 10% significance level in the regression that uses five-year swap rates and the corporate quality spread as a proxy for the differential probability of counterparty default.

Overall, the results in Section 3.2 suggest that although swap pricing appears to be closely related to the pricing of corporate bonds, a swap is not, as simple valuation models suggest, equivalent to a portfolio of two noncallable corporate bonds. Furthermore, the results appear to reject the hypothesis that differences in counterparty credit risk are unimportant. It is, however, important to note that the proxies used for the differential probability of counterparty default are crude proxies. They implicitly assume that the differences in the premiums in long-term (greater than 15 years) corporate fixed-rate debt markets are indicative of those in the two-, five- and ten-year debt markets and that nonfinancial corporations are the end-users of swaps. In practice, swap rates (including those used in this paper) are quoted for nonfinancial corporations, financial institutions, government agencies, and supranational entities. This larger universe of end-users suggests that the proxies for the differential probability of counterparty default used in this paper are limited.

4. Conclusion

This paper directly tests the analogy between short-term swaps and Euro-dollar strips and finds that fair-value short-term swap rates exist in the Eurodollar futures market. However, proxies for differential probability of counterparty default are statistically significant determinants of the difference between OTC swap rates and swap rates derived from Eurodollar futures prices for maturities of three and four years. These results are consistent with the implications of the credit enhancements that exist in the futures market, but not in the OTC swap market.
This paper indirectly tests valuation analogies between swaps and replicating portfolios of bonds by estimating common empirical determinants of U.S. interest rate swap rates. As predicted by the valuation analogy in a stochastic interest rate environment, swap rates are related to the slope of the term structure and the level of interest rates. In addition, in separate regressions, ten-year swap rates are positively related to various ten-year corporate bond yields. However, these coefficient estimates are statistically different from unity, suggesting that the contractual features and treatment of a swap in the event of default reduce the credit risk of a swap compared to that of a corporate bond with the same maturity.

Tests of the pricing implications of more recent valuation models, which use a bond pricing framework and allow for default, show that swap rates are positively related to short-term interest rate volatility. If the value of the default option in a swap depends on short-term interest rates, the positive coefficients are interpreted as evidence that the option to default, and therefore counterparty default risk, is being priced in a swap, and that this option is more valuable to the fixed-rate payer. This paper also documents that swap rates are positively related to the aggregate default spread. These results suggest that the pricing implications of swap counterparty default risk need to be examined more closely.

Overall, this paper finds that swap pricing is closely related to corporate bond and Eurodollar futures pricing. Neither set of models, however, is fully consistent with the precise implications of differential counterparty default risks. These anomalous results call into question the appropriateness of either the simplifying assumptions of the arbitrage-based models or the proxies used for counterparty default risk. Yet differences in credit risk are not the only reasons that swap pricing can deviate from the pricing of bonds and Eurodollar futures contracts. Other possible (nonexclusive) explanations include transaction costs, differences in the end-users of each instrument, and variations in the regulatory, institutional, and microstructural features of these markets. Further research (using transaction data) is needed to examine the effects of these factors on swap pricing.

Finally, the conclusion that swap pricing is highly correlated with Eurodollar futures pricing suggests that firms can use interest-rate futures instead of swaps. Institutional and microstructural differences in the swap and futures markets and the resulting differences in the costs of using each instrument are the focus of current research explaining why firms use swaps (Minton, 1994).

### Appendix A. Proxy variables and data sources

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Variable description and data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTCSwap&lt;sub&gt;n&lt;/sub&gt;</td>
<td>(N)-year average OTC broker mid-market swap rate, (n = 2, 3, 4, 5, 7, \text{ and } 10). Swap rates and semiannual</td>
</tr>
</tbody>
</table>
bond equivalent (SABE) yields on U.S. Treasury notes
were obtained from an anonymous New York bank
that maintains a database from the quotation service
of Telerate.

\( \text{FUTSwap}_n \)

\( N \)-year swap rate derived from Eurodollar futures
prices calculated as the SABE yield of an \( n \)-year Euro-
dollar strip rate, \( n = 2, 3, \) and 4. \( \text{FUTSwap}_n \) are
calculated using one- and three-month spot LIBOR
quotes and prices for Eurodollar futures contracts
traded on the Chicago Mercantile Exchange. LIBOR
quotes are from the bond market research department
of Salomon, Inc. Daily closing Eurodollar futures pri-
ces are from the Chicago Mercantile Exchange.

\( \text{OTCSwap}_n - \text{FUTSwap}_n \)

Difference between an \( n \)-year OTC swap rate and an
\( n \)-year swap rate derived from Eurodollar futures
prices, \( n = 2, 3, \) and 4.

\( \text{ADSP}_{\text{Baa} - \text{TRY}} \)

Difference between time \( t \) yield on a portfolio of Baa-
rated corporate bonds and the time \( t \) weighted average
of the 10- and 30-year U.S. Treasury yields. Baa-rated
corporate bond yields are from various weekly issues
of Moody's Bond Survey.

\( \text{CQSP}_{\text{Baa} - \text{Aaa}} \)

Difference between time \( t \) yield on a portfolio of Baa-
rated corporate bonds and the time \( t \) yield on a
portfolio of Aaa-rated corporate bonds. Aaa-rated
corporate bond yields are from various weekly issues
of Moody's Bond Survey.

\( \text{TRY}_n \)

SABE yield on an \( n \)-year U.S. Treasury note with the
same maturity as the swap rate used in the regression
equation.

\( \text{Slope}_{\text{TRY}, 30 - \text{TRY}, 0.25} \)

Slope of the term structure. Difference between the
time \( t \) SABE yield on the 30-year U.S. Treasury bond
and the time \( t \) SABE yield on the three-month U.S.
Treasury bill. Interest rate data are from the bond
market research department of Salomon, Inc.

\( \text{CORP}_j \)

The ten-year \( j \)-rated corporate bond yield on newly
issued noncallable ten-year corporate (coupon) bonds,
\( j = \text{AAA}, \text{AA}, \) and A. Corporate bond yields are from
the bond market research department of Salomon, Inc.

\( \text{IRVOL} \)

Implied standard deviation from the closest at-the-
money options on 30-year Treasury bond futures con-
tracts. Calculated using the Barone-Adesi and Whaley
(1987) model. Options and futures prices are from
various issues of the Wall Street Journal.
IPG_t Monthly growth rate in industrial production. Monthly industrial production data are from Citibase.

Appendix B

Swap rates derived from Eurodollar futures prices can be calculated using spot LIBOR quotes and Eurodollar futures prices. These rates are calculated as the semiannual bond-equivalent yield of a Eurodollar strip rate that covers the life of the swap. Swap rates and spreads derived from Eurodollar futures prices are also calculated as n-year LIBOR par bond yields. Means and variances of the two series are not statistically different from one another during the sample period. The empirical results reported are qualitatively similar when I use LIBOR par bond yields as proxies for swap rates derived from Eurodollar futures prices. To check for the robustness of the conclusions, I estimate LIBOR par bond yields derived from Eurodollar futures prices by using exponential interpolation of discount factors. The results are qualitatively the same whether discount factors are estimated using linear or exponential interpolation.

Step 1: Convert Eurodollar futures prices to rates for each contract date, n:

\[ R_{n,n+1} = \frac{100 - P_n}{100}. \]

Step 2: Calculate the implied effective annual LIBOR for the full period covered by the swap, R_p:

\[ R_p = \left[ \left( 1 + R_{0,1} \left( \frac{D(0)}{360} \right) \right) \prod_{t=1}^{n} \left( 1 + R_{t, t+1} \left( \frac{D(t)}{360} \right) \right) \right]^\tau - 1, \]

where \( R_{0,1} \) equals the spot LIBOR covering the period from the start date until the first contract date,

\[ \tau = \frac{360}{\sum_{t=0}^{n} D(t)}. \]

and \( D(t) \) denotes the actual number of days covered by the rth Eurodollar futures contract.

Step 3: Convert the full-period LIBOR, \( R_p \), from a money-market basis to its semiannual bond-equivalent basis (i.e., the same payment frequency as swap rate):

\[ \text{SABE Strip Rate}_p = \left[ \left( 1 + (R_p) \cdot \left( \frac{365}{360} \right) \right)^{1/2} - 1 \right] \times 2. \]
References


Minton, B.A., 1994. Interest rate derivative products and firms’ borrowing decisions: the case of interest rate swaps and interest rate futures. Working paper, Ohio State University, Columbus, OH.