INTEREST RATE OPTIONS DEALERS' HEDGING IN THE US DOLLAR FIXED INCOME MARKET

John Kambhu

Federal Reserve Bank of New York
Research Paper No. 9719

May 1997

Interest Rate Options Dealers' Hedging in the US Dollar Fixed Income Market

John Kambhu

Federal Reserve Bank of New York

May 22, 1997

Abstract

The potential for the dynamic hedging of written options to lead to positive feedback in asset price dynamics has received repeated attention in the literature on financial derivatives. Using data on OTC interest rate options from a recent survey of global derivatives markets, this paper addresses the question whether that potential for positive feedback is likely to be realized. With the possible exception of the medium term segment of the term structure, transaction volume in available hedging instruments is sufficiently large to absorb the demands resulting from the dynamic hedging of US dollar interest rate options even in response to large interest rate shocks.

I am grateful for helpful comments and suggestions of Young Ho Eom, James Mahoney, and participants in workshops at the Bank for International Settlements and the Federal Reserve Bank of New York. The views expressed in this paper are the authors' and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

May 22, 1997

Interest Rate Options Dealers' Hedging in the US Dollar Fixed Income Market

John Kambhu

With the growth of derivatives markets the scope of financial intermediation has gone beyond the traditional realm of credit intermediation. The instruments in these markets allow derivatives dealers to intermediate the risk management needs of their customers by unbundling customer risks and reallocating them through the derivatives markets. Thus a customer can trade or hedge away unwanted risks while retaining other exposures. Options are one example of such unbundling as they allow the buyer to acquire exposure to a change in asset prices in one direction without exposure to a move of asset prices in the opposite direction.

In addition to advances in technology, the growth of these markets have been driven by the two-sided nature of customer demands. Hence, dealers have been able to intermediate customer demands, passing exposures from some customers to others without themselves assuming all the risks shed by their customers.[1] Without such ability to lay off exposures, the markets' growth would be limited by dealers' ability to absorb the risks shed by their customers. Nevertheless, in the over-the-counter US dollar interest rate options market, some residual risks are concentrated among dealers. First, dealers have sold more options than they have purchased, and additionally, the bought and sold options may have different characteristics. Sold options exceed bought options by 30% in terms of notional amount (see Annex Table A2), and sold options also have lower degrees of moneyness. Hence, while the aggregate dealer portfolio has positive value (to dealers as a group), large changes in interest rates would cause the aggregated dealer portfolio value to turn negative.

1/ For additional discussion, see Kambhu, Keane, and Benadon (1996).

Dealers' hedging transactions in underlying fixed income markets required for the management of the price risks of their options' business raises two questions. First, might dealers' hedging demands be so large as to disrupt the markets in the available hedging products? Second, is the dynamic hedging of dealers' residual exposures sufficiently large to justify a concern about positive feedback in price dynamics in the fixed income market?

The potential for dynamic hedging of written options positions to introduce positive feedback in asset price dynamics has received repeated attention in the literature on financial derivatives. A short and incomplete list would include, Grossman (1988), Gennotte and Leland (1990), Fernald, Keane and Mosser (1994), Bank for International Settlements (1995), and Pritsker (1997). Using data on OTC US dollar interest rate options from a survey of global derivatives markets, this paper assesses the likelihood of such positive feedback caused by dynamic hedging of options.

The estimates in this paper suggest that, with the possible exception of the medium term segment of the term structure, transaction volume in available hedging instruments is large enough to absorb dealers' dynamic hedging of US dollar interest rate options. While a definitive answer to the positive feedback question would require data on investors' demands in addition to dealers' hedging demands (see Pritsker 1997), comparing potential hedging demand with transaction volume in typical hedging instruments might give a provisional assessment of the likelihood of positive feedback.

1. Introduction

The analysis in this paper is based on global market data for US Dollar OTC interest rate options from the April 1995 Central Bank Survey of Derivatives Markets (Bank for International Settlements, 1996). The options were option contracts on US dollar interest rates, most of which were probably LIBOR related rates.[2] Using data on the options' notional amounts and market

---

[2]/ The Survey also included data for over-the-counter options on traded interest rate securities (bond options). These options were not included in the analysis in this

values, strike prices of the options were estimated and used to analyze potential dynamic hedging volume in response to interest rate shocks. In particular, given notional amount and maturity data (from the Survey) and market growth data (from ISDA[3]), estimates were generated of the notional amount of options by maturity and origination date. Strike prices, based on historical interest rate data, were then assigned to the options originated at each point in time, such that the strike prices produced option values equal to those observed in the survey.

With the estimated strike prices and a postulated interest rate shock, we ask what would be the change in dealers' hedge positions that would restore the net delta of a hedged option portfolio to its initial level? This hedge adjustment is the estimated incremental net demand of dealers for hedge instruments, given the assumed interest rate shock. The estimated demand for hedge instruments might give some indication of the potential for positive feedback effects attributable to derivatives dealers' hedging of their OTC options portfolios.

2. Price Sensitivity of the Global Dealer Portfolio of US Dollar Interest Rate Options

Figure 1 shows the estimated price sensitivity of the global dealers' portfolio based on data at the end of March 1995. The value at the prevailing forward rates is the amount reported in the Survey, and the values at the indicated changes in interest rates are estimated values. While dealers have sold more options than they have purchased, at the prevailing forward rates the bought options had higher market values and the net value to dealers of the global portfolio was positive (see Annex Tables A1 and A2). This relationship between the notional amounts and market values of bought and sold options implies that the options sold to customers had a lower degree of "moneyness" than options purchased from customers. The estimated strike prices are consistent with this relationship, as relative to swap rates at origination, sold options were found to be out-of-the money while options purchased from customers were estimated to be in-the-money.

---

paper. They amounted to less than 8% of options related to interest rates.

3/ International Swaps and Derivatives Association.

Since dealers were net sellers of options, large interest rate shocks that drive the sold options into-the-money will cause the value of the sold options to exceed the bought options' value. Hence, the aggregate dealers' portfolio value becomes negative if interest rate rise by more than 100 basis points. Figure 1 shows, however, that if the portfolio is hedged (but the hedge not dynamically adjusted) the value of the hedged portfolio would turn negative only after an extremely large interest rate shock. A rise of interest rates of almost 200 basis points would be required before the hedged portfolio value turns negative. Dynamically adjusting the hedge position as interest rates change would make such an adverse outcome even less likely.

The curverture of the option value function implies that the hedge position must be adjusted after an interest rate shock because the option values decrease at an increasing rate as interest rates rise. Without the hedge adjustment, the gain in value of the initial hedge position would no longer be sufficient to compensate for the declining option values. This need to dynamically adjust the hedge position as interest rates change introduces a potential for positive feedback. Since the required hedge is a short position in fixed income securities, the hedge adjustment would introduce additional sales into the market on top of the initial selling pressure that accompanied the initial interest rate shock.

Another feature of the aggregate dealer position is its exposure to rising interest rates: the negative slope of the option value curve at the prevailing forward rates in Figure 1. The conventional view of financial institutions' interest rate risk profile holds that these firms have a structural long position in the fixed income market. Namely, exposure to rising rates. Thus figure 1 implies that, in the aggregate, dealers as a group can not hedge their net option exposures with offsetting structural exposures from other business lines. While some dealers may have offsetting exposures elsewhere in their firms that hedge their options position, Figure 1 suggests that not all dealers can fully hedge internally.

3. Dynamic Hedging Volume

The market for US dollar interest rate products is sufficiently large and diverse that options dealers can choose from a wide range of hedging instruments, such as futures contracts, FRAs, interest rate swaps, and Treasury securities. While these instruments are not perfect substitutes because of differences in credit risks, transactions costs, and liquidity, dealers intermediate risks and provide risk management services to the markets by taking on and managing these risks. If dealers have sufficient time to hedge a position or replace a hedge with a cheaper alternative, they are unlikely to encounter difficulty meeting their hedging needs. For immediate hedge adjustments in large volume, however, their alternatives may be be more limited. Across the range of maturities that need to be hedged, the most liquid instruments available are Eurodollar futures, Treasury securities, and Treasury futures.

Eurodollar futures:

The Eurodollar futures market appears to have transaction volume sufficiently large to accommodate the estimated hedge adjustments for small interest rate shocks. At shorter maturities, the Eurodollar futures market is more than large enough to accommodate dealers' hedging demands, even for large interest rate shocks. For hedging of longer maturity exposures, however, the Eurodollar futures market appears to be able to accommodate only the hedging of residual exposures (after the use of other hedging instruments) and marginal adjustments to hedge positions.

The largest daily turnover volume of Eurodollar futures contracts exceeds the estimated hedge adjustments: out to 10 year maturities, for a 10 basis point change in forward rates; out to 4 to 5 years, and also between 8 and 10 year maturities for a 25 basis point change in forward rates (Table 1); and, out to only 2 year maturities, for a 75 bp change in forward rates (Table 2). To put these figures in perspective, a 25 basis point change is slightly less than the largest daily change, and a 75 basis point change is slightly less than the largest two-week change, in forward rates in the 4 to 7 year segment of the yield curve (during the period 1991 to 1995).

The estimated hedge adjustments are smaller than the stock of outstanding futures contracts. Even in the case of hedge adjustments to a 75 basis point change in forward rates, the estimated hedge adjustment in most cases is much less than half of outstanding futures contracts (Table 3.)

With respect to the estimated hedge position, rather than adjustments to the hedge position, for longer maturity exposures the Eurodollar futures market is not large enough to accommodate the entire hedge demands that would be generated by a fully delta neutral hedging strategy, especially for exposures beyond 4 or 5 years (Table 3.)

Treasury securities:

To hedge exposures to forward rates between 5 and 10 years maturity, a possible hedge position in Treasury securities consists of a short position (sale of a borrowed security) in the 10 year note, and a long position in the 5 year note. With this hedging method, dealers' estimated hedge adjustments would be less than the daily turnover volume of on-the-run securities (Table 4, Panel A). For an extremely large shock to forward interest rates, however, such as a 75 basis point shock to forward rates beyond 5 years out, the estimated hedge adjustment in the 5 and 10 year note would be as large as half of average daily turnover.

With regard to the hedge position, the on-the-run issue volume appears to be too small to accommodate hedging demand if a fully delta neutral hedging strategy were attempted exclusively in the cash market in Treasury securities. For example, if dealers fully hedged their exposures beyond 5 years with 5 and 10 year on-the-run issues, the required hedge position would be approximately equal to the outstanding amount of the on-the-run 5 and 10 year notes (Table 4, Panel A).

Two means by which the Treasury market may accommodate this hedging demand exist. *First*, the existence of a large repo (collateralized security lending) market in Treasury securities allows a fixed stock of on-the-run Treasury securities to meet trading demands that exceed the size of the on-the-run issue. Through the repo market, a trader that establishes a short position enables another trader to establish a long position in the security. Hence, the size of market participants' long position in the security can be larger than the outstanding stock of the security. *Second*, off-the-run issues when available can also be used, further enlarging the pool of available hedging instruments. Fleming (1997) reports that off-the-run securities account for approximately 24% of daily turnover.

Futures on Treasury securities:

In addition to the cash market in Treasury securities, dealers can also hedge exposures between 5 and 10 year maturities with futures contracts on Treasuries. As seen in Panel B of Table 4, open interest and turnover volume in the Treasury futures market exceeds estimated dealers' hedging demand. Nevertheless, that demand could be significant relative to the size of the market. For example, the estimated hedge adjustment to a 75 basis point shock could be large as 25% of the combined average daily turnover in the Treasury cash and futures markets, while the estimated hedge position could be as large as a third of total outstandings in both markets (see Table 4, Panels A and B).

Interest rate term structure models and hedging:

If dealers are willing to accept model risk (correlation risk), they could also hedge exposures beyond 5 years by spreading their hedging demands across a wider maturity range of securities than only the 5 and 10 year notes. For example, with the use of a two (or more) factor interest rate term structure model, a dealer could construct a hedge of exposures between 5 and 10 years using a position in one year bills and 30 year bonds that replicate the exposure to the term structure factors that drive forward rates between 5 and 10 years. Such hedges, however, would be vulnerable to atypical price shocks that the term structure model does not account for.

Conclusions:

The estimated size of dealers' hedge positions of longer maturity exposures, suggests that dealers' hedges, especially of exposures beyond 4 years maturity, are distributed over a range of fixed income instruments. While outstanding Eurodollar futures contract volume is smaller than the estimated size of the hedge position beyond 5 years, the large size of the US dollar fixed income market suggests that the hedge positions can still be absorbed by the markets in other fixed income instruments. With regard to an immediate dynamic hedge adjustments to an interest rate shock, however, the ideal hedging instrument is one that is liquid and has low transactions costs, such as Eurodollar futures, on-the-run Treasury securities, or Treasury futures.

Impact on transaction volume.

The Eurodollar futures, on-the-run Treasury securities, and Treasury futures markets together can easily absorb hedge adjustments to shocks to the forward curve as large as 25 basis points along the entire term structure (Tables 1 and 4). For example, the estimated hedge adjustment for 5 to 10 year exposures to a 25 basis point shock is approximately 10% of the combined turnover in the Treasury on-the-run cash and futures markets.

For an extremely large interest rate shock, however, such as a 75 basis point shock to forward rates, dealers' dynamic hedge adjustments would generate significant demand relative to turnover in these hedging instruments: on the order of 25% of combined turnover (see Tables 2 and 4). In this case, by bearing the price risk of a partially hedged position and spreading the hedge adjustment over more than one day, the hedge adjustment could be broken into pieces that would be small relative to daily turnover. The terms of this tradeoff between price risk and the cost of immediacy or liquidity of course would depend on the volatility of interest rates, and volatility may rise at the same time that liquidity is most impaired.

These results suggest that dealers' intermediation of price risks through market making in interest rate options is supported by liquidity in underlying markets that allow them to manage their residual price risks. Transaction volume in the standard hedging instruments appear to be large enough to accommodate dealers' dynamic hedging in all but the most extreme periods of interest rate volatility.

Price impact.

With regard to the price impact of dynamic hedging our results are less clear. For a definite answer an analysis of demands of other market participants would be required (see Pritsker, 1997). For example, investors whose demands are driven by "fundamentals" could be expected to undertake transactions in the opposite direction of dealer's dynamic hedging flows if those transactions drove interest rates to levels that appeared unreasonable. If these investors constitute a sufficiently large part of the market, then their transactions would stabilize prices and keep positive feedback dynamics in check. However, such stabilizing investors are not the only other market participants. Other participants include traders who follow short term market trends either because of "technical trading" strategies or because they interpret short term changes to be driven by transactions of better informed investors. These traders could amplify the price impact of dealers dynamic hedging. Thus, the ultimate impact of dealers' dynamic hedging would depend on the relative sizes of these types of market participants, as described in Pritsker (1997).

At shorter maturities, transaction volume and open interest of the most liquid trading instruments are so much larger than dealers' dynamic hedging flows that positive feedback driven by dealers' dynamic hedging seems unlikely, even with very large interest rate shocks. However, at longer maturities, around 5 to 10 years, dynamic hedging in response to an extremely large interest rate shock could be of significant volume relative to total transaction volume and open interest in the most liquid trading instruments. Hence, at this segment of the yield curve, the positive feedback hypotheses in the case of a very large interest rate shock can not be dismissed. The dynamic hedging volume in response to an unusually large interest rate shock could be large enough to have a significant impact on order flows. Such order flows might have a transitory impact on this medium term segment of the yield curve.

4. Volatility Shocks

The results in Section 3 were estimated under the assumption that the volatility of interest rates remained constant while interest rates changed. However, large changes in interest rates are typically associated with higher implied volatilities in options prices. For this reason, hedge adjustments were also estimated assuming simultaneous volatility and interest rate shocks (Table 5). Forward rates were assumed to increase by 75 basis points, while interest rate volatility was assumed to increase by 25% relative to initial volatility levels at the shortest maturity and by 8% at 10-years (one-third of the change at the short end). While the estimated hedge adjustment is larger, the difference does not appreciably change the conclusions in Section 3.

While exposure of interest rate option values to interest rate changes can be hedged with a wide range of instruments, exposure to changes in the volatility of interest rates is not easily hedged. Given that dealers as a group are net writers of options, their exposure to volatility probably remains largely unhedged as the volatility risk of an option can be fully hedged only with another option. Figure 2 shows the estimated volatility risk of the global dealer portfolio. An increase in volatility of approximately 40% would cause the portfolio value to turn negative.

Since most customer options in the over-the-counter market are probably held to maturity, changes in volatility would affect dealers through changes in their hedging costs and the mismatches between the option and hedge positions over the life of an option. A rise in volatility would raise these hedging costs, as it amplifies the costs of adjusting hedge ratios. The increase in these costs over the life of an option equals the change in the option's value. Figure 2 shows an estimate of these costs.

5. The Data and Estimation

Options market data:

The data are from the 1995 Central Bank Survey of Derivatives Markets (Bank for International Settlements, 1996). This data, reported by derivatives dealers world wide, are global market totals of outstanding derivatives contracts at end of March 1995. The options data in the survey included notional amounts, market values, and maturity data, broken down by bought and sold options, as shown in Annex Tables A1, A2, and A3. The options data had three counterparty types: interdealer options, options bought from customers, and options sold to customers. Since reporters in the Survey were derivatives dealers, interdealer transactions appear as both bought and sold options because an option bought by one dealer would also be reported as an option sold by another dealer. The discrepancy between interdealer amounts in the bought and sold columns is reporting error in the survey.

Maturity distribution:

The maturity data in Table A3 and market growth rates from ISDA's surveys were used to estimate a more refined maturity distribution. This distribution was based on an assumption that the options had maturities up to 10 years, with origination dates up to 10 years earlier, both in 6 month increments. The maturity distribution of options originated at any date is described by a quadratic function, and the notional amount of options with t periods remaining maturity, originated p periods in the past is

$$n(t,p) = \left(\prod_{j=0}^{p} g_j\right)\left(a + b(t+p) + c(t+p)^2\right) \qquad (1)$$

and, $n(t,p) = 0$, for $t+p < 1$ year,

where t is remaining maturity, $t < 10$ years; p is the origination date (periods earlier), $p < 10$ years; $t+p$ is the original maturity, $t+p < 10$ years; g_j is the market growth term at period j. The restriction in (1) forces caps and floors to have maturities of at least one-year when originated. (Regardless of this restriction, the first caplet (option) in any cap or floor has a maturity of 3 months (the midpoint of the first 6-month time band). Estimates without this restriction are shown in Section 6.

The maturity distribution is found by solving for the parameters (a,b,c) of the quadratic function (1) in the following system of equations,

$$\sum_{t \le 1yr} \sum_{p} n(t,p) = N_1 \qquad (2a)$$

$$\sum_{1yr < t \le 5yrs} \sum_{p} n(t,p) = N_5 \qquad (2b)$$

$$\sum_{5yr < t \le 10yrs} \sum_{p} n(t,p) = N_{10} \qquad (2c)$$

where N_m are notional amounts in the survey's three maturity categories (see Annex Table A3).

Separate maturity distributions were estimated for interdealer options, options purchased from customers, and options sold to customers. The maturity data, however, were available only for all sold options and all bought options, where interdealer options were included in the maturity data of both bought and sold options. The maturity distribution of interdealer options was assumed to be the average of the bought and sold options' maturity distributions.

Figures A1 and A2 show the estimated distribution of outstanding contracts over remaining maturity and origination dates. In these charts, contracts along the diagonal from left to right are contracts that were ten-year contracts at origination, where the left most point is a 10-year contract originated within 6-months of the survey date. The growth of the market is apparent along this diagonal. Most outstanding contracts were of less than five years remaining maturity and were originated within three years of the survey date. The estimated distribution has a trough along the diagonal for caps of greater than 5 and less than 10 years maturity (at origination). This feature of the distribution suggests that long maturity caps are clustered at discrete maturities, and at the 10 year maturity in particular.

Option price function:

All options are assumed to be caps and floors on 6-month interest rates, whose values are estimated using Black's forward contract option model (see Hull, 1993). The value of the period t payoff of a cap and floor with strike rate x and notional amount n is

$$C(n,t,x) = e^{-r_t t}[f_t\, N(D1(t,x)) - x\, N(D2(t,x))]\frac{\lambda}{1 + \lambda f_t}\, n$$

$$F(n,t,x) = e^{-r_t t}[x\, N(-D2(t,x)) - f_t\, N(-D1(t,x))]\frac{\lambda}{1 + \lambda f_t}\, n$$

where, $$D1(t,x) = \frac{\ln(\frac{f_t}{x}) + \frac{\sigma_t^2\, t}{2}}{\sigma_t \sqrt{t}}, \qquad D2(t,x) = D1(t,x) - \sigma_t \sqrt{t},$$

and λ is the length of the period for which the reference interest rate applies (6-months), f_t is the period t interest rate, σ_t is its volatility, and $N(.)$ is the standard normal distribution function. The value of a cap (floor) with maturity m is,

$$v^c(n,m,x) \quad = \quad \sum_{t<m} C(n,t,x),$$

$$v^f(n,m,x) \quad = \quad \sum_{t<m} F(n,t,x).$$

The valuation used the term structure of forward rates and the term structure of implied volatilities coinciding with the option value data (end-of-March 1995).[4] Section 6 presents estimates using alternative implied volatility structures.

Strike prices:

Strike prices were derived from historical yield curves. Because separate market values were not available for caps and floors, a relationship between the strikes of caps and floors was required in the estimation. The structure was chosen on the assumption that buyers (sellers) of caps and floors had similar preferences regarding their options' moneyness. Thus, if buyers of caps desired out-of-the money options because of their cheaper premia, then buyers of floors would also. This structure regarding the options' moneyness was implemented in three different ways. These implementations gave similar results as shown in Table 6.

First, a proportional displacement of the strike price from the swap rate. The strikes of caps and floors are,

$$x^{cap}(t,p,A) \quad = \quad h(t+p,p)\,A \tag{3.1a}$$

4/ The data are from Derivatives Week (1996). The Derivatives Week data on forward rates and implied volatility data are consistent with those implied by Eurodollar futures prices and Eurodollar futures options prices.

$$x^{flr}(t,p,A) \quad = \quad \frac{h(t+p,p)}{A} \tag{3.1b}$$

where, t is the remaining maturity of the cap, p is the origination period (periods earlier), $t+p$ is the cap's original maturity, $h(m,p)$ is the historical swap rate of p periods earlier for a m period maturity swap, and A is a scaling factor.[5]

Second, a cap and floor are assumed to have equal premia at origination,

$$v^{cap}(n,\ t,\ h(t,p)A^{cap}) \quad = \quad v^{flr}(n,\ t,\ h(t,p)A^{flr}), \tag{3.2a}$$

where the option values are evaluated at the term structures prevailing at origination, the strikes are defined as,

$$x^{cap}(t,p,A) = h(t,p)A^{cap}, \quad \text{and,} \quad x^{flr}(t,p,A) = h(t,p)A^{flr}, \tag{3.2b}$$

and A^{cap} and A^{flr} are separate scaling factors for caps and floors.

Third, a cap and floor are assumed to have equal deltas at origination,

$$\Delta\, v^{cap}(n,\ t,\ h(t,p)A^{cap}) \quad = \quad |\ \Delta\, v^{flr}(n,\ t,\ h(t,p)A^{flr})\ |, \tag{3.3}$$

where $\Delta\, v^{cap}$ and $\Delta\, v^{flr}$ are the deltas of a cap and floor (evaluated at the term structures prevailing at origination), and the strikes are defined as in (3.2b).

The scaling factors (A) are chosen so that the option values at the resulting strike prices

---

5/ A complete 10 year time series for swap rates could not be found (data were available only from 1988). To complete the time series, the missing values were assumed to equal the corresponding Treasury rate plus the last available swap spread.

equal the observed market values in the Survey. In each of the above specifications, the restrictions are applied to bought and sold options separately, with different scaling factors (A) for bought and sold options. In these strike price specifications, a cap will be out-of-the-money when a floor is out-of-the-money. These specifications produced similar results, as seen in Table 6. Other strike price specifications are presented in Section 6.

Estimated strike prices and option values:

Given the strike prices defined in (3), total values for bought and sold customer options, and interdealer options can be defined as functions of the scaling factors (A),

$$V_b(A^b) = \sum_t \sum_p v^c(B^c(t,p),t,x^c(t,p,A^b)) + \sum_t \sum_p v^f(B^f(t,p),t,x^f(t,p,A^b)) \quad (4a)$$

$$V_s(A^s) = \sum_t \sum_p v^c(S^c(t,p),t,x^c(t,p,A^s)) + \sum_t \sum_p v^f(S^f(t,p),t,x^f(t,p,A^s)) \quad (4b)$$

$$V_D(A^D) = \sum_t \sum_p v^c(D^c(t,p),t,x^c(t,p,A^D)) + \sum_t \sum_p v^f(D^f(t,p),t,x^f(t,p,A^D)) \quad (4c)$$

where B and S are notional amounts for bought and sold customer options, D is notional amount of interdealer options; and $v(n,t,x)$ is the value of a cap (floor) with notional amount n, maturity t, and strike price x. The index t represents remaining maturity, the index p is the origination date, where $t+p < 10$ years, and the superscripts c and f denote caps and floors.

On the basis of ISDA data we assume that caps amount to 73% of the options with the remainder being floors. A small proportion of interest rate options are swaptions (19% at year-end 1994 in the ISDA data). However, for simplicity, we treat all options as either caps or floors.[6]

6/ This assumption is not likely to alter the paper's conclusions. For example, if a one year option on a five year swap were reported as a one year option, then the swaptions would appear as shorter maturity options in the data. Hence, the true exposures of shorter maturity would be less than assumed in the estimation, with the result that hedging demand for shorter maturity instruments would be smaller

The value of each group of options in (4) is determined by the scaling factors in the strike rates -- the parameter A in the strike price equations (3) and the value equations (4). The estimation is to find values of A^b, A^s, and A^D, such that:

$$V_b(A^b) + V_D(A^D) = v_b \tag{5a}$$

$$V_s(A^s) + V_D(A^D) = v_s \tag{5b}$$

subject to the restriction in (3.1, 3.2, or 3.3), where v_b (and v_s) is the observed market value of US dollar options bought (and sold) by dealers including interdealer options.

Given the value of interdealer options (see below), in the case of the strike price structure (3.1), the estimation for bought options consists of solving for the single parameter A^b in equation (5a). In the strike price structure (3.2), however, the estimation for bought options consists of solving for the two parameters A^{cap}, A^{flr} in the two equations (3.2a) and (5a).

Interdealer options:

Separate market values of interdealer US dollar options were not collected in the Survey. (The interdealer market values was available only in aggregate across all currencies, see Annex Table A1). For that reason, the solution to the equations in (5) is calculated using four alternative assumptions: (1) inter-dealer options have strikes equal to the reference rate, A^D=1, in (3.1), (at-the-money strikes, relative to the swap term structure); (2) inter-dealer options have the same

---

than estimated. This effect would only strengthen the conclusion that shorter maturity hedging volumes are small relative to transaction volume in Eurodollar futures. On the other hand, however, the swaptions would add to the estimated hedging demand at longer maturities. Nevertheless, since swaptions are only 19% of the market, the net increment to estimated hedging demand would not significantly change the conclusions. The effect would be to strengthen the conclusion that longer maturity hedging demand could be significant relative to order flows in longer maturity hedge instruments, but not so much larger as to overwhelm the market.

strikes as options bought from customers, $A^D = A^b$; (3) inter-dealer options have the same strikes as options sold to customers, $A^D = A^s$, and; (4) estimate the value of US Dollar interdealer options from the data in Annex Tables A1 and A2. The last estimation method (4) distributes the market value of interdealer options in Annex Table A1 between US dollar and other currencies so as to minimize the error in the ratios of market value to notional amounts relative to the margin ratios of the totals in Annex Tables A1 and A2.

The first and last alternatives produce comparable values for interdealer options. The at-the-money assumption (1) produces a value of interdealer options of $11.3 billion, while the estimation in (4) results in a value of interdealer options of $10.9 billion. Table 8 shows the comparability of the hedge estimates with assumptions (1) and (4). Results using the other assumptions (2 and 3) were also similar to those in (1) and (4). The results reported in Sections 2 3, and 4 were derived using assumption (4).

An implication of the comparability of methods (1) and (4) is that interdealer options have strikes closer to at-the-money than customer options. This result is plausible, since dealers who use the interdealer market to hedge their short volatility and negative gamma position would obtain more hedging benefit from at-the-money options since such options have larger gamma and provide the most hedging benefit relative to their premia.

Customer options:

For options sold to customers, estimated strikes consistent with observed market values were predominantly deep out-of-the money (relative to swap rates of comparable maturity) at origination. This result is plausible, as customers buying options to hedge could acquire cheap protection against large interest rate shocks with deep out-of-the money options. For caps sold to customers, the estimated strike rates were 18% higher than swap rates of the same maturity at origination. The figure of 18% is comparable to the standard deviation of annual changes in interest rates, or two standard deviations of quarterly interest rate changes (6-month LIBOR rates during the period 1991 to 1995).

For options bought from customers, strike prices consistent with the observed market values were predominantly in-the-money (relative to swap rates of comparable maturity) at origination. This relationship is the opposite of the relationship found for options sold to customers. While this result might appear counterintuitive and could point to a problem in the estimation, it is consistent with market commentary in the early 1990s. Customers looking for "yield-enhancement" during the low-interest rate regime of the early '90s, acquired higher premia by selling interest rate caps with a higher degree of moneyness. While this "higher yield" is the market price or compensation for the expected payout of the option, investors speculating on the path of interest rates would obtain higher investment returns (or losses) per option by selling in-the-money options. In addition, investors who believed that the forward curve was an overestimate of the future path of spot rates would sell options that were in-the-money relative to the forward curve. In retrospect, for positions that were not leveraged, the risks appear to have been moderate.

Assumptions regarding hedging:

The analysis of dealers' hedging behavior relies on the following assumptions.

(a1) Customers do not hedge their options positions.

Customers who have sold or bought options are assumed not to hedge, because doing so would negate what ever hedging or investment objective the options were used for. Customers who have sold options to dealers presumably did so for speculative "yield enhancement" or intertemporal income shifting. In which case, the costs of delta hedging the options would negate that investment objective. On the other hand, customers who have bought options from dealers for hedging purposes would not hedge the option since doing so would expose the underlying position the option was hedging.

If customers were to hedge their options, perhaps due to a reassessment of risks, then the market impact of dealers hedge adjustments would be smaller because they would be offset by customers' hedging. Since the predominance of our results support the claim that the market impact of dealers' hedging is small relative to the size of the market, dropping assumption (a1) would only strengthen the results.

(a2) Dealers restore the net delta of their position after an interest rate shock to its initial level.

Regardless of whatever hedge ratio they had initially, subsequent to an interest rate shock dealers are assumed to adjust their hedge position to bring the net delta of the portfolio back to its initial level. Dealers may or may not fully hedge the initial delta of the options book, and whatever hedging is initially done may be accomplished either internally with offsetting positions in the firm or with external hedging transactions. These initial offsetting positions, either internal or external, are assumed to have small gamma so that a change in the options' delta requires additional hedging transactions to return the portfolio's net delta to its original level.

(a3) An option exposure to a period t interest rate is hedged with an instrument that also has exposure to the period t interest rate -- no basis risk in hedged positions.

With this assumption, a separate hedge ratio was calculated for each maturity's exposure.

Estimated hedge:

The delta and the change in delta of the global dealers' portfolio was calculated given the notional amounts (from equation (2)) and estimated strike prices (from equation (5)). The estimated delta is the hedge position of all dealers' (if they fully hedged) and the change in delta given an assumed interest rate shock is the change in the dealers' hedge position. In response to an interest rate shock, if dealers are assumed to restore the net delta of their portfolios to their initial levels, then the change in delta of the global portfolio is the incremental dealer demand for hedge instruments. If hedging is executed with futures contracts, the estimated hedge adjustments are shown in Tables 1 and 2, and the hedge position (assuming complete hedging) is shown in Table 3. Table 4 shows the hedge adjustment and hedge position, if hedging of 5 to 10 year exposures is done with Treasury securities and futures on treasuries. These results are described in Section 3.

6. How robust are the results?

The results shown in Tables 1 to 4 are the results with the basic assumptions described above with the strike price specification (3.1). To explore whether these results were sensitive to the assumptions, estimates were also performed using a variety of assumptions regarding the structure of strike prices, implied volatility, and other restrictions. The estimated hedge position and its change due to interest rate shocks were comparable across these different specifications and do not alter the conclusions. The results with these alternative assumptions are shown in Tables 6 through 8. The first column in these tables is the result under the basic assumptions, and the other columns are the results with the alternative assumptions.

Strike price variations:

Distribution of strike prices. Options uniformly distributed over two different strike prices, with the larger strike 22% higher than the smaller (10% above and below the reference rate).

Maturity variation in strike prices. For options bought from customers, the options' "moneyness" was assumed to vary with original maturity. In the first variation, the deviation of the strike from the swap reference rate decreased with maturity, and in the second the deviation increased with maturity.

Identical strike prices for caps and floors. Estimation of the value of bought options with the restriction that caps and floors have identical strikes. This estimation produced in-the-money caps and out-of-the money floors. Applying a similar restriction for sold options was not meaningful, as it produced estimated option values that exceeded the observed values. This result supports the use of equation (3) for sold options.

Implied volatility variations:

Cap and floor implied volatilities. Option values estimated with different volatilities for caps and floors. Caps were estimated using the Derivatives Week implied volatility data as in the base case, but volatilities for floors were adjustment upwards to conform with the difference between cap and floor implied volatility in DRI data. (The DRI implied volatility data are available only from January, 1996; while the Derivatives Week implied volatility data are derived from caps).

Volatility smile. As an alternative to a common implied volatility across all degrees of "moneyness," results were also estimated using a volatility smile. A volatility smile over degrees of moneyness consistent with Eurodollar futures options prices was constructed, and extrapolated across all maturities using the base volatility term structure as the at-the-money volatility.

Other variations:

Options on 3-month interest rates. Instead of assuming that all options were on the 6-month interest rate, results were derived on the assumption that the options were 3-month interest rate options.

Growth rate assumption in maturity distribution. The ISDA market size data for interest rate options contained a number of anomalous growth rates between certain dates. On the possibility that these growth rates were due to survey problems at those dates, alternative smoothed growth rates were derived by ignoring the anomalous market volumes. The notional amounts from the Central Bank Survey were then distributed across maturities and origination dates using these alternative growth rates in equations (1) and (2).

Unrestricted maturity distribution. The distribution of notional amounts across maturities and origination dates in (1) and (2) was estimated without the restriction that all caps (floors) have a maturity of at least one year when originated.

References

Bank for International Settlements. Issues of Measurement Related to Market Size and Macroprudential Risks in Derivatives Markets. February, 1995.

______. Central Bank Survey of Foreign Exchange and Derivatives Market Activity. May, 1996.

Derivatives Week. April 1, 1996.

Fernald, Julia, Frank Keane, and Patricia Mosser. "Mortgage Security Hedging and the Yield Curve." Federal Reserve Bank of New York Quarterly Review, 19, #2, 1994.

Fleming, Michael. "The Round-the-Clock Market for U.S. Treasury Securities." Federal Reserve Bank of New York Economic Policy Review, Forthcoming, 1997.

Gennotte, Gerard, and Hayne Leland. "Market Liquidity, Hedging, and Crashes." American Economic Review, 80, #5, 1990.

Grossman, Sanford. "An Analysis of the Implications for Stock and Futures Price Volatility of Program Hedging and Dynamic Hedging Strategies." Journal of Business, 61, 1988.

Hull, John. Options, Futures, and other Derivative Securities, 2nd edition. Prentice Hall, Englewood Cliffs, NJ, 1993.

Kambhu, John, Frank Keane, and Catherine Benadon. "Price Risk Intermediation in the Over-the-Counter Derivatives Markets: Interpretation of a Global Survey." Federal Reserve Bank of New York Economic Policy Review, 2, #2, 1996.

Pritsker, Matt. "Liquidity Risk and Positive Feedback." Working Paper, Federal Reserve Board, March, 1997.

Annex: Data

Table A1
Market Values of OTC Interest Rate Options
Billions of USD

	Bought			Sold		
	USD	Other	Total	USD	Other	Total
Dealer			22.4			21.6
Customer			15.2			14.6
Total	20.9	16.7	37.6	19.4	16.8	36.2

Table A2
Notional Amounts of OTC Interest Rate Options
Billions of USD

	Bought			Sold		
	USD	Other	Total	USD	Other	Total
Dealer	529.4	726.5	1255.9	576.1	681.9	1258.1
Customer	432.7	340.6	772.2	690.4	398.1	1088.4
Total	961.1	1067.1	2028.1	1266.5	1080.0	2346.5

Table A3
Maturity Distribution of USD Interest Rate Options

	Bought Options		Sold Options	
Up to one year	295	(30%)	357	(28%)
Over one and up to five years	573	(58%)	697	(56%)
Over five years	116	(12%)	189	(15%)
Total	984		1,243	

Note: With adjustment for reporting error in interdealer bought and sold options.

Figure A1
Bought Options

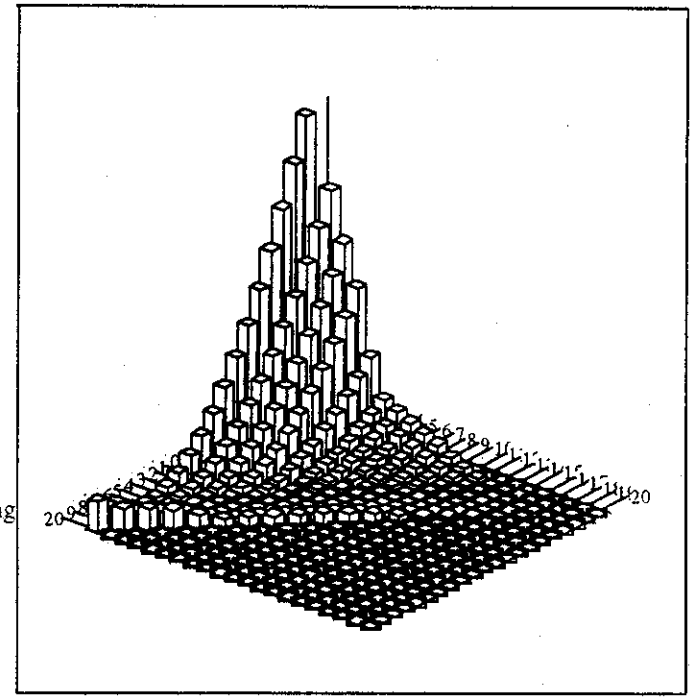
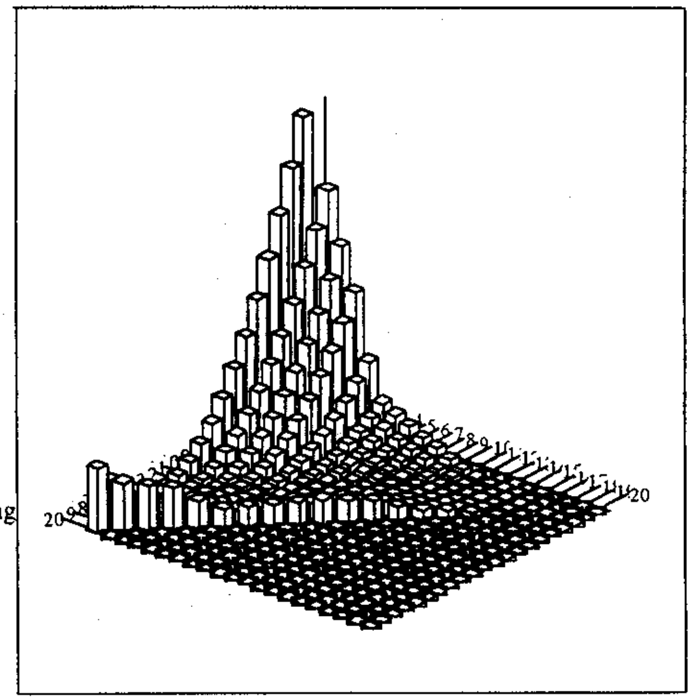
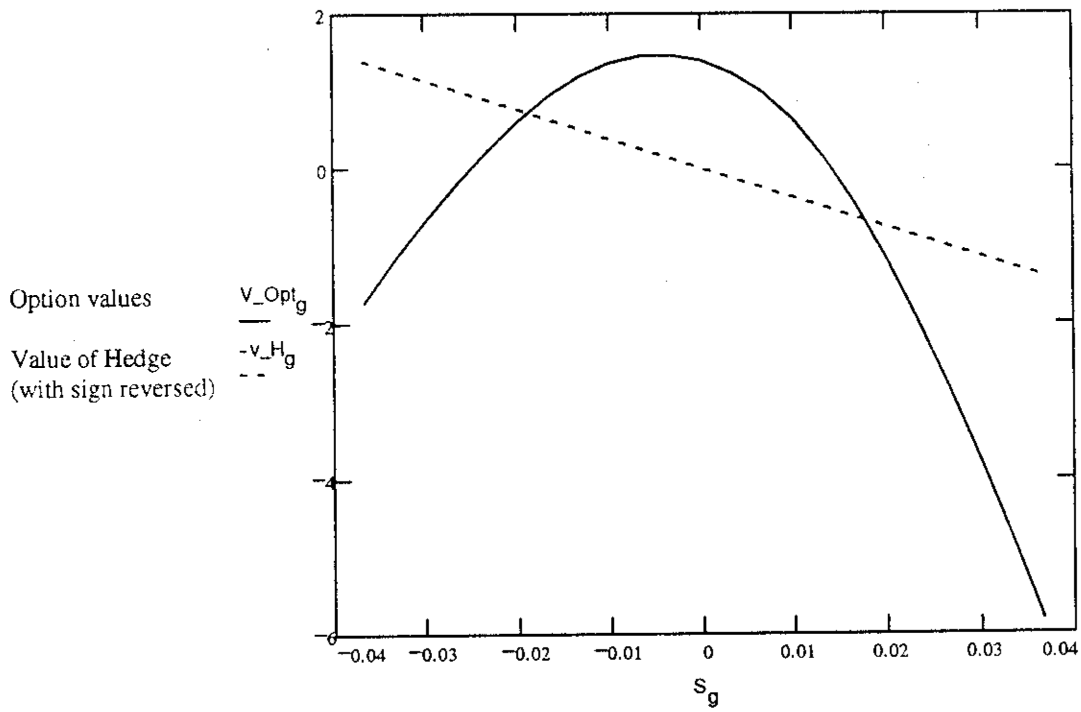


Figure A2
Sold options



Note: The period numbers on the axis are in six month increments (20 periods = 10 years), and the origination date is the number of periods ealier.

Figure 1
Net Options and Hedge Values (-)

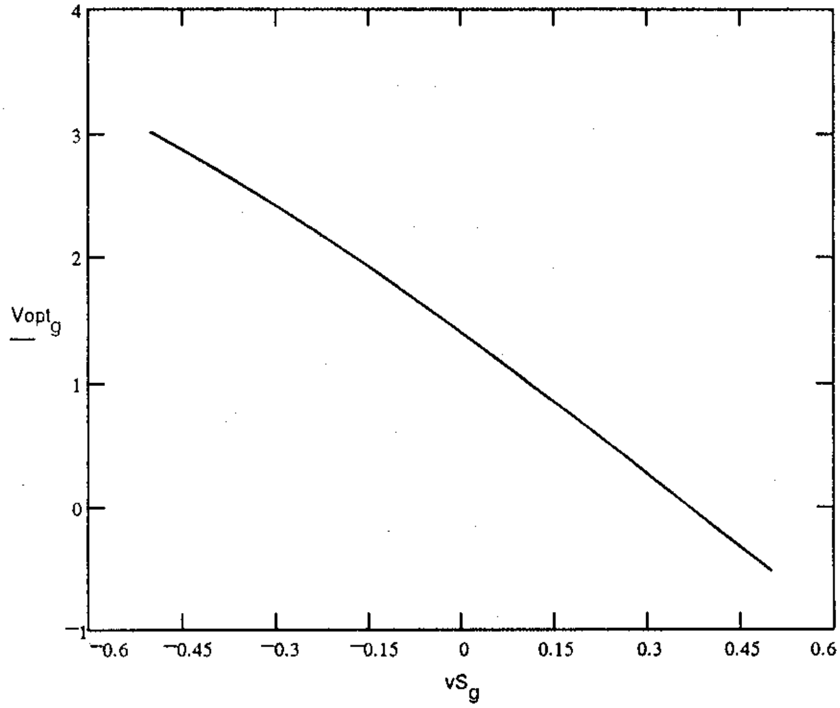


Notes:

(1) Vertical axis is market value in billions, and horizontal axis is interest rate change in percentage points (0.01 is 100 bp).

(2) The solid curve is the options value, and the dotted line is the mirror image of a hedge portfolio that delta hedges the options at the initial interest rate. The hedged portfolio has positive value when the solid curve (the options value) is above the dotted line (the hedge).

Figure 2
Option Values As a Function of Changes in Volatility



Note:
Vertical axis is market value in billions, and horizontal axis is volatility change in percentage points (0.5 is a 50 percent increase in volatility).

Table 1

Change in required hedge position compared to daily volume of Eurodollar futures 25 BP change in forward curve

Mtrty (yrs)	Change in Hdg Pstn	Largest volume vol of 1st contr	Largest volume vol of 2nd contr	Average volume vol of 1st contr	Average volume vol of 2nd contr
0.5	-6.3	**374.0**	**334.1**	**115.73**	**148.36**
1	-9.2	**260.9**	**135.2**	**92.05**	**35.81**
1.5	-7.7	**55.1**	**39.7**	**19.99**	**14.00**
2	-5.7	**26.9**	**18.9**	**9.40**	**5.96**
2.5	-4.6	**9.2**	**7.5**	4.02	3.26
3	-3.7	**7.3**	**4.5**	2.69	1.94
3.5	-3.1	**3.9**	2.6	1.52	1.32
4	-2.6	**2.7**	**3.3**	1.20	1.09
4.5	-2.1	2.4	2.3	0.89	0.79
5	-1.9	**2.0**	1.4	0.75	0.46
5.5	-1.6	1.3	**2.4**	0.20	0.23
6	-1.4	1.3	1.3	0.22	0.20
6.5	-1.2	1.0	1.2	0.17	0.15
7	-1.0	**3.3**	0.7	0.20	0.12
7.5	-0.9	0.6	**1.2**	0.07	0.09
8	-0.6	**0.8**	**3.7**	0.07	0.11
8.5	-0.4	**1.2**	**1.2**	0.11	0.09
9	-0.3	**1.2**	**1.7**	0.08	0.08
9.5	-0.1	**1.0**	**0.7**	0.07	0.06
10		1.2	1.0	0.06	0.04

Notes:

(1) Billions of USD. Hedge estimates based on data at end of March 1995.
(2) The second coluumn is the change in hedged position by maturity of exposure.
(3) The middle columns are the largest daily volumn of futures contracts (by maturity of contract) in the first half of 1995.
(4) The right most columns are the average daily volume (by maturity) in the first half of 1995.
(5) The first and second futures contracts in the futures volumn columns represent the two back to back contracts on 3-month interest rates required to hedge a six month exposure.
(6) Bold indicates contract volume in excess of change in hedge position.
(7) Negative values indicate an increase in a short position.

Table 2

Change in required hedge position
compared to daily volume of Eurodollar futures
75 BP change in forward curve

		Largest volume		Average volume	
	Change in	vol of	vol of	vol of	vol of
Mtrty (yrs)	Hdg Pstn	1st contr	2nd contr	1st contr	2nd contr
0.5	-31.9	**374.0**	**334.1**	**115.73**	**148.36**
1	-31.2	**260.9**	**135.2**	**92.05**	**35.81**
1.5	-23.7	**55.1**	**39.7**	19.99	14.00
2	-17.2	**26.9**	**18.9**	9.40	5.96
2.5	-13.6	9.2	7.5	4.02	3.26
3	-11.0	7.3	4.5	2.69	1.94
3.5	-9.0	3.9	2.6	1.52	1.32
4	-7.6	2.7	3.3	1.20	1.09
4.5	-6.2	2.4	2.3	0.89	0.79
5	-5.5	2.0	1.4	0.75	0.46
5.5	-4.7	1.3	2.4	0.20	0.23
6	-4.1	1.3	1.3	0.22	0.20
6.5	-3.5	1.0	1.2	0.17	0.15
7	-3.0	**3.3**	0.7	0.20	0.12
7.5	-2.4	0.6	1.2	0.07	0.09
8	-1.9	0.8	**3.7**	0.07	0.11
8.5	-1.3	1.2	1.2	0.11	0.09
9	-0.7	**1.2**	**1.7**	0.08	0.08
9.5	-0.3	**1.0**	**0.7**	0.07	0.06
10		1.2	1.0	0.06	0.04

Notes:

(1) Billions of USD. Hedge estimates based on data at end of March 1995.
(2) The second coluumn is the change in hedged position by maturity of exposure.
(3) The middle columns are the largest daily volumn of futures contracts (by maturity of contract) in the first half of 1995.
(4) The right most columns are the average daily volume (by maturity) in the first half of 1995.
(5) The first and second futures contracts in the futures volumn columns represent the two back to back contracts on 3-month interest rates required to hedge a six month exposure.
(6) Bold indicates contract volume in excess of change in hedge position.
(7) Negative values indicate an increase in a short position.

Table 3

Required hedge position in eurodollar futures contracts
Compared to contracts outstanding

Mtrty (yrs)	Hdg Pstn	Open Int 1st contr	Open Int 2nd contr	Chg in Hdg (75 BP Chg)
0.5	38.3	**561.9**	**366.4**	-31.9
1	23.9	**279.7**	**222.0**	-31.2
1.5	2.8	**174.0**	**145.4**	-23.7
2	-4.0	**114.2**	**96.3**	-17.2
2.5	-9.8	**84.9**	**68.6**	-13.6
3	-13.4	**60.3**	**54.8**	-11.0
3.5	-16.4	**49.5**	**38.8**	-9.0
4	-17.9	**34.4**	**27.2**	-7.6
4.5	-20.2	**22.6**	14.5	-6.2
5	-18.9	12.9	9.5	-5.5
5.5	-18.8	7.5	7.7	-4.7
6	-18.4	6.2	5.9	-4.1
6.5	-17.5	6.7	6.8	-3.5
7	-15.1	6.8	4.5	-3.0
7.5	-12.6	3.8	2.5	-2.4
8	-9.6	1.6	2.2	-1.9
8.5	-6.2	1.8	1.8	-1.3
9	-3.4	1.7	2.0	-0.7
9.5	-1.4	0.8	0.9	-0.3
10		0.8	0.0	

Notes:

(1) Billions of USD. Hedge estimates and open interest at end of March 1995.
(2) The second coluumn is the hedge position by maturity of exposure.
(3) The middle columns are the outstanding volumn of futures contracts at end of March 1995.
(4) The first and second futures contracts in the futures volumn columns represent the two back to back contracts on 3-month interest rates required to hedge a six month exposure.
(5) Bold indicates contract volume in excess of hedge position.
(6) Negative values indicate a short position or an increase in a short position.

Table 4

Hedge Position in Bonds
Using 5 and 10 Year Securities

Panel A: Treasury Securities

	Hedge Position	Chg Hdg (10 BP)	Chg Hdg (25 BP)	Chg Hdg (75 BP)	On-the-run Treasury Outstnd	Daily Vol.
5 year	13.0	0.4	1.0	2.9	13.2	6.0
10 year	-13.0	-0.4	-1.1	-3.3	13.8	4.0

Panel B: Treasury Futures

	Hedge Position	Chg Hdg (10 BP)	Chg Hdg (25 BP)	Chg Hdg (75 BP)	Treasury Futures Open Intr	Lrg Dly Vol	Av Dly Vol
5 year	13.0	0.4	1.0	2.9	19.7	12.3	5.1
10 year	-13.0	-0.4	-1.1	-3.3	25.8	24.4	9.2

Notes:

(1) Billions of USD. Hedge estimates based on data at end of March 1995.
(2) Treasuries outstanding at end of March 1995; daily volume is from GovPX only (Fleming, 1997).
(3) Treasury futures are the 5 and 10 year note contracts. Open interest at of end of March 1995, and volume is over first half of 1995.
(4) Negative values indicate a short position or an increase in a short position.

Table 5

Change in required hedge position due to simultaneous volatility and forward rate shocks

Mtrty (yrs)	I.R. Shock Only	Volt. Shock Only	I.R. and Volt. Shock
Change in futures hedge			
0.5	-31.9	-6.0	-40.7
1	-31.2	-9.7	-38.7
1.5	-23.7	-8.7	-29.4
2	-17.2	-7.7	-22.6
2.5	-13.6	-6.2	-17.9
3	-11.0	-4.9	-14.4
3.5	-9.0	-3.9	-11.6
4	-7.6	-3.0	-9.5
4.5	-6.2	-2.2	-7.5
Change in Bond hedge			
5 year	2.9	0.8	3.4
10 year	-3.3	-0.8	-3.8

Notes:

(1) Billions of USD. Hedge estimates based on data at end of March 1995.

(2) Forward rates increase by 75 basis points, and volatility increases by 25% relative to initial volatility levels at short maturities, and by 8% at 10 years.

(3) Negative values indicate an increase in a short position.

Table 6
Strike Price Variations
Change in required hedge position
due to 75 bp change in forward curve

Mtrty (yrs)	Base	Equal Premia	Equal Delta	Strike Distr.	Maturity Vrtn 1	Maturity Vrtn 2	Identical Caps/floors
Change in futures hedge							
0.5	-31.9	-38.3	-33.3	-34.9	-38.5	-24.8	-55.8
1	-31.2	-32.9	-30.5	-27.1	-33.3	-29.6	-42.2
1.5	-23.7	-24.2	-22.8	-21.3	-24.3	-23.4	-29.3
2	-17.2	-17.3	-16.6	-15.9	-17.4	-17.2	-20.1
2.5	-13.6	-13.6	-13.2	-12.7	-13.6	-13.7	-15.4
3	-11.0	-10.9	-10.7	-10.4	-10.9	-11.1	-12.1
3.5	-9.0	-8.9	-8.8	-8.6	-8.9	-9.2	-9.8
4	-7.6	-7.5	-7.4	-7.2	-7.5	-7.7	-8.1
4.5	-6.2	-6.2	-6.1	-6.0	-6.2	-6.4	-6.6
Change in Bond hedge							
5 year	2.9	2.9	2.9	2.8	2.9	3.0	3.1
10 year	-3.3	-3.2	-3.2	-3.2	-3.2	-3.3	-3.4

Notes:

(1) Billions of USD. Hedge estimates based on data at end of March 1995.
(2) Column headings indicate the assumption as described in the text.
(3) Negative values indicate an increase in a short position.

Table 7
Volatility Variations
Change in required hedge position
due to 75 bp change in forward curve

Mtrty (yrs)	Base	Cap/Floor Volatility	Volatility Smile	Cap/Floor and Smile
Change in futures hedge				
0.5	-31.9	-31.5	-27.2	-26.8
1	-31.2	-31.2	-27.8	-27.7
1.5	-23.7	-23.7	-21.1	-21.0
2	-17.2	-17.2	-14.6	-14.5
2.5	-13.6	-13.6	-11.4	-11.3
3	-11.0	-10.9	-9.1	-9.0
3.5	-9.0	-9.0	-7.4	-7.4
4	-7.6	-7.5	-6.2	-6.2
4.5	-6.2	-6.2	-5.3	-5.3
Change in Bond hedge				
5 year	2.9	2.9	2.6	2.6
10 year	-3.3	-3.3	-2.9	-2.9

Notes:

(1) Billions of USD. Hedge estimates based on data at end of March 1995.
(2) Column headings indicate the assumption as described in the text.
(3) Negative values indicate an increase in a short position.

Table 8
Other Variations
Change in required hedge position
due to 75 bp change in forward curve

Mtrty (yrs)	Base	Dlr optn at-the-m	Options on 3-mth rate	Growth Rate	Unrestr Mtry Dstr
Change in futures hedge					
0.5	-31.9	-25.2	-32.5	-38.6	-35.9
1	-31.2	-28.6	-30.4	-32.2	-30.9
1.5	-23.7	-22.6	-23.4	-25.5	-24.4
2	-17.2	-16.6	-17.0	-19.2	-18.1
2.5	-13.6	-13.2	-13.5	-15.4	-14.5
3	-11.0	-10.7	-10.9	-12.5	-11.7
3.5	-9.0	-8.9	-9.0	-10.2	-9.6
4	-7.6	-7.5	-7.5	-8.3	-7.9
4.5	-6.2	-6.2	-6.2	-6.6	-6.4
Change in Bond hedge					
5 year	2.9	2.9	2.9	2.4	2.8
10 year	-3.3	-3.3	-3.3	-2.7	-3.1

Notes

(1) Billions of USD. Hedge estimates based on data at end of March 1995.
(2) Column headings indicate the assumption as described in the text.
(3) Negative values indicate an increase in a short position.

FEDERAL RESERVE BANK OF NEW YORK
RESEARCH PAPERS
1997

The following papers were written by economists at the Federal Reserve Bank of New York either alone or in collaboration with outside economists. Single copies of up to six papers are available upon request from the Public Information Department, Federal Reserve Bank of New York, 33 Liberty Street, New York, NY 10045-0001 (212) 720-6134.

9701. Chakravarty, Sugato, and Asani Sarkar. "Traders' Broker Choice, Market Liquidity, and Market Structure." January 1997.

9702. Park, Sangkyun. "Option Value of Credit Lines as an Explanation of High Credit Card Rates." February 1997.

9703. Antzoulatos, Angelos. "On the Determinants and Resilience of Bond Flows to LDCs, 1990 - 1995: Evidence from Argentina, Brazil, and Mexico." February 1997.

9704. Higgins, Matthew, and Carol Osler. "Asset Market Hangovers and Economic Growth." February 1997.

9705. Chakravarty, Sugato, and Asani Sarkar. "Can Competition between Brokers Mitigate Agency Conflicts with Their Customers?" February 1997.

9706. Fleming, Michael, and Eli Remolona. "What Moves the Bond Market?" February 1997.

9707. Laubach, Thomas, and Adam Posen. "Disciplined Discretion: The German and Swiss Monetary Targeting Frameworks in Operation." March 1997.

9708. Bram, Jason, and Sydney Ludvigson. "Does Consumer Confidence Forecast Household Expenditure: A Sentiment Index Horse Race." March 1997.

9709. Demsetz, Rebecca, Marc Saidenberg, and Philip Strahan. "Agency Problems and Risk Taking at Banks." March 1997.

9710. Lopez, Jose. "Regulatory Evaluation of Value-at-Risk Models." March 1997.

9711. Cantor, Richard, Frank Packer, and Kevin Cole. "Split Ratings and the Pricing of Credit Risk." March 1997.

9712. Ludvigson, Sydney, and Christina Paxson. "Approximation Bias in Linearized Euler Equations." March 1997.

9713. Chakravarty, Sugato, Sarkar, Asani, and Lifan Wu. "Estimating the Adverse Selection Cost in Markets with Multiple Informed Traders." April 1997.

9714. Laubach, Thomas, and Adam Posen. "Some Comparative Evidence on the Effectiveness of Inflation Targeting." April 1997.

9715. Chakravarty, Sugato, and Asani Sarkar. "A General Model of Brokers' Trading, with Applications to Order Flow Internalization, Insider Trading and Off-Exchange Block Sales." May 1997.

9716. Estrella, Arturo. "A New Measure of Fit for Equations with Dichotomous Dependent Variables." May 1997.

9717. Estrella, Arturo. "Why Do Interest Rates Predict Macro Outcomes? A Unified Theory of Inflation, Output, Interest and Policy." May 1997.

9718. Ishii Jun, and Kei-Mu Yi. "The Growth of World Trade." May 1997.

To obtain more information about the Bank's *Research Papers* series and other publications and papers, visit our site on the World Wide Web (http://www.ny.frb.org). From the research publications page, you can view abstracts for *Research Papers* and *Staff Reports* and order the full-length, hard copy versions of them electronically. Interested readers can also view, download, and print any edition in the *Current Issues in Economics and Finance* series, as well as articles from the *Economic Policy Review.*