COMPLEXITIES OF HEDGING MORTGAGES

DOUGLAS T. BREEDEN

The complexities of hedging mortgages have become clear in the tumultuous 1992-1994 period. During that period, we had steadily falling interest rates in the U.S., followed by sharply rising rates. There were four clearly defined major surges in prepayments, followed by a massive plunge. Additionally, the slope of the yield curve moved dramatically steeper in 1992, followed by a steady flattening in 1993-1994. With these dramatic changes, major mortgage securities losses of investment banks, commercial banks, and other corporations have frequently been in the headlines.

While bedeviling to traders, these volatile interest rate and mortgage refinancing conditions provide an ideal laboratory for statistically oriented financial economists. When statisticians seek to model behavior of consumers with respect to some economic variable (e.g., refinancings as a function of interest rates), it is very difficult to develop a statistically significant and powerful model if one has little data under widely varying economic conditions. The more data the statistician has under a wide variety of circumstances, the more powerful and robust the modeling results. For example, to estimate consumers' responses statistically to different yield curve shapes, it helps a lot to have data for years when the yield curve slope was quite volatile.

Perhaps the best that can be said about 1992-1994 is that it was a great "learning experience." As a result of the data gathered under a variety of interest rate circumstances, virtually every major mortgage trading firm in the world is updating its prepayment, pricing, and hedging models. The new models are more interesting, realistic, and complex than the models they replace. This issue of the *Journal of Fixed Income*

DOUGLAS T. BREEDEN is chairman of the board of Smith Breeden Associates, Inc., in Chapel Hill, North Carolina, and research professor of finance at the Fuqua School of Business of Duke University in Chapel Hill.

presents several of those new models for prepayments.

The research in this article gains strength from the interplay of two data sets for FNMA fixed-rate mortgage-backed securities. First, we have the relatively standard empirical data on interest rates, prepayments, and mortgage prices, for which the primary data sources are Telerate and Bloomberg, Salomon Brothers and Goldman Sachs.

The second data set, which was developed in this research and is substantially provided in exhibits here, is a survey of major brokers' published forecasts of 1) mortgage risks (price elasticities or option-adjusted durations), 2) mortgage returns as measured by option-adjusted spreads, 3) prepayment rates, and 4) prepayment option costs, i.e., whipsaw costs. In both the empirical analysis and the analysis of brokers' forecasts, we examine both standard fixed-rate mortgages and "high-risk mortgage derivatives" (interest-only and principal-only strips).

Modern option-based analyses of mortgage securities began in approximately 1984-1986, and major investment banks began to publish those analyses in 1987 and 1988. Thus, our broker forecast data begin in 1987, and the number of brokers in the series grows from one in 1987 to eight by 1994. In most cases, this analysis was extremely helpful to investors in ascertaining the risks of their investments. Of concern is that, with the current difficult times on Wall Street and with the litigious nature of losing investors, some brokerage firms have reduced their mortgage research and no longer publish option-based risk analyses. Investors are the losers in this reduced information dissemination.

My general strategy is first to present and analyze the empirical data, then to look at how brokers did in handling these turbulent times. As mortgage markets are very large and are traded by sophisticated investors, they are likely to be relatively "efficient," so one would not expect the average brokerage advice to produce superior or inferior profits (although some individual firms should do well and others poorly). What we wish to examine is whether brokerage firms present a fair picture of the risks of mortgage investments, given the difficulties in estimating those risks for the different investments.

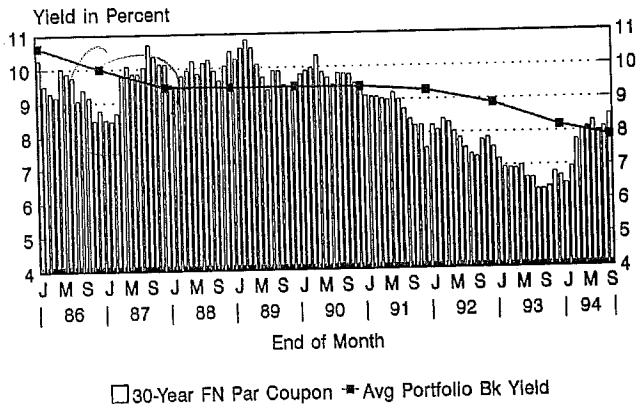
Section I presents and analyzes the major fluctuations in interest rates and prepayments between 1986 and 1994. Section II analyzes the changing empirical duration risks (one factor) in various mortgage coupons, using quarterly regressions of daily data from 1987 to 1994. Section III describes the non-parallel interest rate shifts that occurred, two-factor risk estimates, and the importance of slope sensitivity in hedging. Section IV introduces the broker forecast data and analyzes risk estimates, prepayments, option-adjusted spreads, and whipsaw costs for the "median broker" in each forecast. Section V examines interest-only (IO) and principal-only (PO) strips risks and estimated returns. Section VI analyzes the ranges of broker survey data for the information they give about the diversity of brokers' opinions. Section VII presents unhedged and hedged returns on standard fixed-rate mortgages and on IOs and POs, and examines their correlations with projected option-adjusted spreads.

I. INTEREST RATES, PREPAYMENTS, AND MORTGAGE PRICES

Exhibit 1 shows for 1986-1994 the ups and downs of interest rates on thirty-year fixed-rate mortgages guaranteed by FNMA. For any date, this is the coupon rate on the thirty-year FNMA mortgage-backed security (MBS) that would be selling for par ($100) at the time. We will also call it the current refinancing rate, although the actual refinancing rate for borrowers is this FNMA par rate plus a servicing and guarantee spread of about 50 to 75 basis points.

Noteworthy are two periods of large interest rate declines. The first major decline in rates was in 1985-1986, when the FNMA par yield dropped almost 400 basis points, from 12.8% on December 31, 1984, to 8.8% on December 31, 1986. This rate drop created in

EXHIBIT 1 ■ Current Thirty-Year FNMA Par Yield ■ 1986-1994 versus Portfolio's Book Yield Average



1986-1987 the largest refinancing boom in our history to that time. The second major decline in long-term mortgage rates was more gradual, as rates took four years again to drop 400 basis points from 10.5% in early 1989 to 6.3% in September 1993. This rate decline created an even larger refinancing boom in 1992-1993.

In the past ten years, there have been only two periods of significant increases in mortgage rates, and both have been quite sharp. First, in 1987 prior to the October 1987 stock market crash, rates increased by 200 basis points in the six months from 8.7% on March 31 to 10.8% on September 30. Second, an even larger increase in rates is the one taking place at the time of this writing. In the twelve months from September 1993 to September 1994, the FNMA par yield increased 220 basis points from 6.3% to 8.5%.

Exhibit 1 also plots the average thirty-year mortgage portfolio's accounting book yield. As time passed from 1985 to 1994, older, higher-rate mortgages were repaid, or prepaid and refinanced into lower-coupon mortgages, which reduced the average bank's MBS portfolio yield from 10.6% in 1985 to 7.8% on September 30, 1994. Thus, while the par mortgage rate in September 1994 (8.5%) was 160 basis points lower than in December 1985 (10.1%), the typical bank or thrift's portfolio of fixed-rate mortgages was more "under water" (market less than book) in 1994 with rates at 8.5%.

Many financial institutions' managers and boards (as well as the regulatory agencies) are just realizing that they have these embedded losses, despite their general view that current interest rates are still not high. The refinancing boom of 1992-1994 has substantially reduced bank and thrift portfolio yields, so a new perspective on what are "high rates" is needed to understand their gains and losses.

EXHIBIT 2 ■ FNMA 7.5% and 9.0% Mortgage Prices 1993-1994

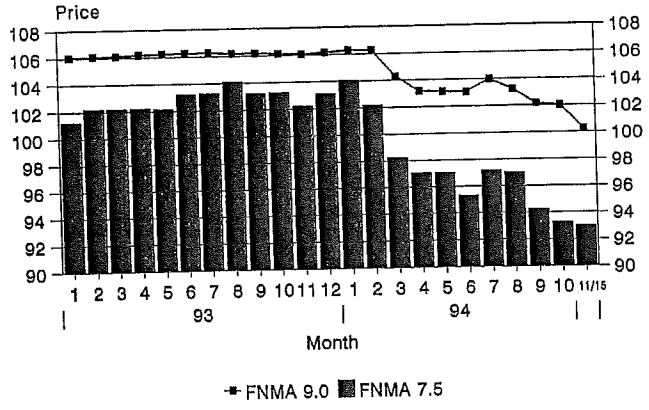
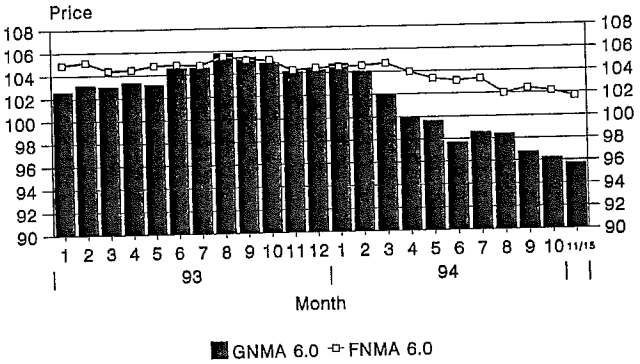


EXHIBIT 3 ■ GNMA and FNMA 6% ARM Prices 1993-1994



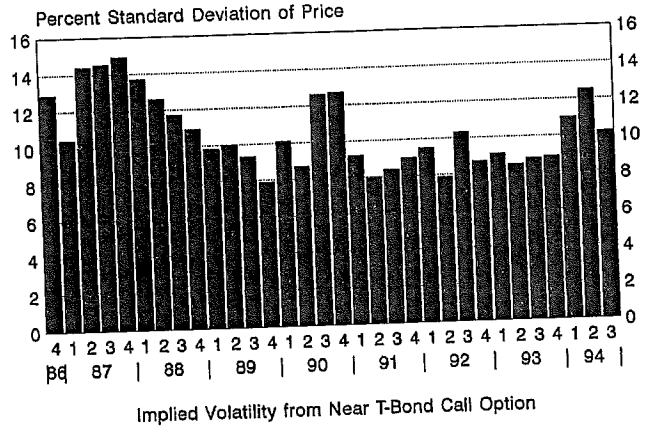
Notes: FNMA 6% = Pool #111672, Coupon = 6.36%; Margin = 2.26 Net; Life Cap = 15.02.
GNMA Caps: Annual = 1%, Lifetime = 11%.
FNMA Caps: Annual = 2%, Lifetime = 6%.

Exhibit 2 shows the price histories of FNMA 7.5% and 9.0% fixed-rate mortgages during the recent sharp surge in rates in 1993-1994. The FNMA 7.5% coupon, which is now close to the weighted-average coupon in the market portfolio, has dropped by 11 points from a high price of over $104 in August 1993 to just $93 at November 15, 1994. Thus, a $100 million portfolio of these has dropped in value by $11 million in just over a year, which is quite damaging to an unhedged bank or thrift with capital of 6% to 8%.

Perhaps more surprising to many managements, boards, and regulators is that the tight 1% annual caps on the rate adjustments of GNMA ARMs have caused them to have significant durations and price volatility. Exhibit 3 shows that the price of a GNMA 6% ARM has dropped from a high of over $105 to below $96 — a 9-point move that rivals that of the FNMA fixed-rate mortgages. In contrast, the price moves on a FNMA ARM with a wider adjustment band (2%) have not been nearly as volatile, dropping only 3 points, as their rates are more freely floating. Not surprising is the fact that these ARMs are now a focus of banking regulators, given their demonstrated price volatility.

Exhibit 4 shows the implied volatility percentage for long-term Treasury bond prices. This shows that

EXHIBIT 4 ■ Twenty-Year Treasury Bond Price Volatility



bond prices were most volatile in the large rate increases of 1987 and 1993-1994, as well as in the recession of 1990-1991. Otherwise, volatility of long-term bond prices and interest rates in the past ten years has been significantly lower than the norm for the prior ten years.

Exhibits 5 and 6 display the tumultuous moves in mortgage refinancings in the past three years. Exhibit 5 shows four distinct surges during 1992-1993 in the Mortgage Bankers Association's "Refinancing Index," with each peak setting a new record. The index, which had a base level of 100 in 1990, finally peaked at 1,700 at the trough in rates in September 1993. From 1,700 in September 1993, it plunged to under 100 in September 1994.

EXHIBIT 5 ■ Four Refinancing Waves and a Plunge

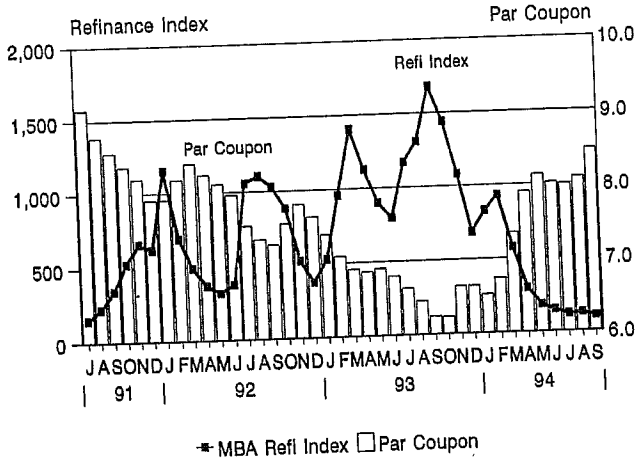
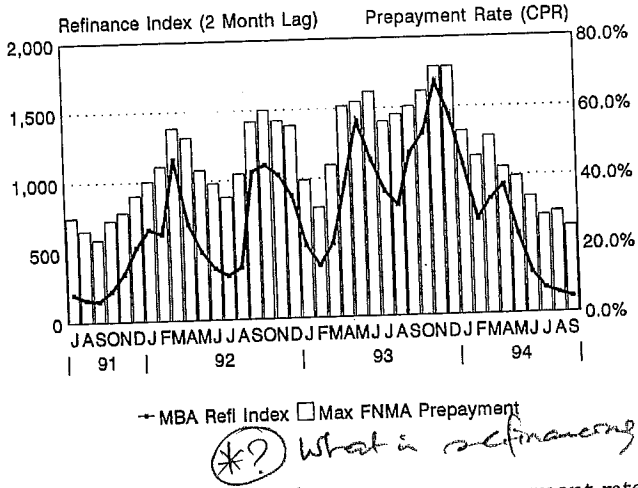


EXHIBIT 6 ■ Refi Index Predicts Peak Prepayments



(*?) What is refinancing Index

Exhibit 6 shows that mortgage prepayment rates track the refi index closely, but with approximately a two-month lag. The annualized conditional prepayment rate (CPR) on FNMA 8.5 coupons reached a peak of 72% in November 1993, two months after the refi index's September peak. With the subsequent sharp increase in rates and plunge in the refi index, the prepayment rate on FNMA 8.5s dropped from that 72% to 12% in September 1994.

Exhibit 7 shows the data on prepayment rates for seasoned FNMAs between 1983 and 1994. In these data, the surge of 1986-1987 is apparent in coupons 11% and higher, which prepaid at a very rapid 40% to 50% annual rate (averaged over twelve months). Comparing (as researchers and traders did) the 1992-1993 surge with the 1986-1987 surge, two more features are of interest.

First, despite the par mortgage rate being 225 basis points lower in 1992-1993 (7.25% versus 9.5% in 1986-1987), very high-coupon MBS actually prepaid less in the 1992-1993 surge. This is due to "burnout" of these pools, as the faster prepaying mortgage holders in the pool have refinanced and gone from the pool, leaving a slower prepaying pool population.

Second, in the 1986-1987 surge, 8% to 10% MBS coupons prepaid at only a 10% to 16% annual rate, as they had much less to gain than did those refinancing MBS with 12% to 13% coupons. Indeed, with the refi rate averaging about 9.5% in 1986-1987, coupons 8% to 10% really had no incentive to refinance. When refinancing rates dropped to the 6% to 7% range in 1992-1993, the 8.5% to 9.5% coupons had significant incentives to refinance and prepay, and their

EXHIBIT 7 ■ Empirical Data for FNMA Prepayments by Coupon — Moderately Seasoned/Seasoned

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994*
	Average Daily FNMA Par Yield											
	13.05	13.60	11.78	9.39	9.68	9.92	10.00	9.76	8.80	7.82	6.73	7.71
Coupon												
7.0										15.0	15.5	9.4
7.5										15.8	26.3	14.8
8.0	5.2	5.5	6.2	8.9	9.5	4.5	6.1	6.1	7.4	16.6	38.7	22.4
8.5	6.8	7.2	7.8	11.1	12.7	5.8	7.1	7.0	9.0	24.8	52.2	30.1
9.0	6.8	7.6	8.2	12.2	5.2	7.2	7.8	7.4	10.2	36.7	54.5	34.2
9.5	6.3	7.1	8.9	14.4	10.8	8.9	8.5	7.7	13.1	46.6	49.5	35.3
10.0	6.1	7.7	9.5	13.5	16.2	10.3	9.4	8.1	18.1	46.5	41.3	34.0
10.5	5.8	6.8	9.3	30.6	32.3	15.1	11.7	10.5	22.8	39.1	33.9	31.9
11.0	6.3	7.7	11.6	37.0	38.8	18.5	14.1	13.6	25.8	38.0	33.7	31.4
11.5	7.4	8.7	10.9	40.2	39.2	21.9	16.8	16.0	26.8	36.9	31.3	30.2
12.0	8.2	9.2	11.8	46.6	41.7	22.8	18.8	16.8	23.6	34.2	32.0	28.6
12.5	10.4	9.1	16.2	51.0	42.7	25.6	20.0	17.4	22.3	32.6	28.5	29.5
13.0	9.2	10.4	18.4	51.1	43.6	26.0	19.6	17.7	21.5	28.7	28.3	25.0
		Quiet			Surge			Quiet			Surge	Quiet

*1994 data through September 1994.

Source: Salomon Brothers Inc.

prepayment rates increased from the 10% range in 1986-1987 to the 50% range in 1992-1993.

It is broadly useful to view a 12% MBS in 1986-1987 as having a 2.5% refinancing incentive relative to the par coupon of 9.5% (ignoring transaction costs), and a 9.5% MBS as having a similar incentive relative to 7% par yield in 1993. To attempt to control for these effects of changes in the par yield through time, Exhibit 8 shows the coupon-by-coupon prepayments of Exhibit 7 sorted monthly by the size of the refinancing incentive (MBS coupon less refi rate, C – R).

Careful comparisons of Exhibit 8 with Exhibit 7 show that this transformation of prepayments as functions of "relative coupon" (C – R) gives evidence of a more stable relationship of prepayments to the refinancing incentive. As many of the duration risk, prepayment, and return measures examined in this article are related to the magnitude of the prepayments, many tables are sorted by C – R to develop more stable and robust functions.

Exhibit 9 is a particularly useful graph for understanding the challenges that faced researchers and traders during the 1992-1993 prepayment surge. It demonstrates the two most difficult aspects of mortgage analysis — non-linearity and non-stationarity. Curves for both surge periods, as well as the quiet prepayment time of 1988-1990, are non-linear S-curve shapes.

The general non-linear S-curve form is expected from the option insights of Black-Scholes [1973] applied to the mortgage prepayment option. Unfortunately, the Black-Scholes model doesn't help much in determining the exact inflection points and slope of the prepayment curve. Indeed, this curve appears quite non-stationary in this form, although omitted variables reflecting the health of the macroeconomy could help explain some of what appears to be non-stationarity.

Put yourself in a trader's or researcher's position in 1992-1993 when you look at Exhibit 9. Your most recent data are for the quiet period of very low prepayments from 1988-1991. As rates dropped and prepays surged in 1992, prepayment forecasts were revised dramatically upward, with "advanced researchers" being those who more quickly used the 1986-1987 experience as something of a guide to the very uncertain future for the coupons that were not burned out.

Then the 1992-1993 experience ultimately blew right through the 1986-1987 response curve for "cusp coupons," i.e., those coupons on the steep slope of the prepayment curve with refinancing incentives from 50

to 200 basis points. At a 150-bp refi incentive, the difference was in annual prepayments of 50% in 1992-1993 versus 40% in 1986-1987. Many premium MBS investments and IO strips that were winners at prepayment rates of 40% or less lost substantially at prepayment rates that averaged 50% for an entire year (with 60%-70% peak monthly rates).

The reasons for the shift leftward to a more optimal prepayment function are the subject of other articles, some in this issue. Generally, the focus is on 1) the reduced costs of refinancing during the 1992-1993 period, with many low down payment or low documentation loans available, 2) "media effects," as each new low in mortgage rates seemed to generate headlines that increased prepayments, and 3) increased borrower sophistication and familiarity with the refinancing process and costs and benefits.

This article focuses on FNMAs somewhat arbitrarily, although virtually all the results are expected to apply to GNMAs, FHLMCs, and whole loans. Yet it is worthy of note that GNMAs had added "non-stationarities" in 1992-1993 that shifted their prepayment curve (Exhibit 10) even farther leftward to a more optimal borrower response. Prior to 1993, GNMAs had always prepaid significantly more slowly than comparable FNMAs. Dominant reasons given for that historic pattern are the higher incomes and greater mobilities of FNMA borrowers.

During 1993 the FHA waived charges for refinancings on GNMAs, and sent letters to many high-

EXHIBIT 8 ■ Empirical Data for FNMA Prepayments Sorted by Refinancing Incentive (C – R)

		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994*
FNMA Par Yield Average		13.05	13.60	11.78	9.39	9.68	9.92	10.00	9.76	8.80	7.82	6.73	7.71
Refi Incentive Range (C – R)													
–5.5	–5.0	5.2	6.8										
–5.0	–4.5	5.8	7.2										
–4.5	–4.0	6.6	7.3	7.1									
–4.0	–3.5	6.8	7.6	7.7									
–3.5	–3.0	6.1	7.3	8.0									
–3.0	–2.5	5.9	7.8	9.0									
–2.5	–2.0	6.3	8.7	8.7		8.6		6.5					
–2.0	–1.5	7.0	8.7	10.2	8.4	9.2	5.1	6.7	6.5				
–1.5	–1.0	7.9	9.2	10.1	10.9	9.0	6.2	7.5	6.8	6.9			
–1.0	–0.5	9.2	9.8	11.5	11.9	8.6	7.6	8.2	7.3	8.2		10.8	
–0.5	0.0	9.7	10.2	12.4	13.4	11.7	9.3	9.1	7.7	9.2	13.4	15.9	15.5
0.0	0.5	10.8		13.6	18.5	11.8	12.1	10.2	8.0	10.6	18.4	17.4	21.9
0.5	1.0			20.3	24.9	17.4	16.0	12.9	9.9	14.7	27.7	26.5	27.2
1.0	1.5			26.1	35.4	24.1	20.0	15.8	12.9	21.6	41.4	40.2	32.3
1.5	2.0				43.1	33.8	21.7	18.6	15.3	26.4	48.3	52.5	35.5
2.0	2.5				48.9	40.9	24.0	19.0	17.0	27.5	45.3	54.1	35.7
2.5	3.0				51.9	43.6	26.5	20.8	17.4	24.1	40.6	48.4	35.1
3.0	3.5				52.3	44.7	27.0	21.2	17.4	23.7	37.5	41.7	33.3
3.5	4.0				52.0	45.0			18.3	22.2	35.4	35.7	29.9
4.0	4.5					44.4				24.2	33.7	33.0	30.9
4.5	5.0										30.9	31.1	27.4
		Quiet			Surge		Quiet				Surge		Quiet

*1994 data through September 1994.
**"Geometrically annualized" conditional prepayment rates (CPR), in percent.
***Data are for moderately seasoned and seasoned issues, sorted monthly by C – R, then averaged.

EXHIBIT 9 ■ Empirical Data for FNMA Prepayments Sorted by Refinancing Incentive (C – R)

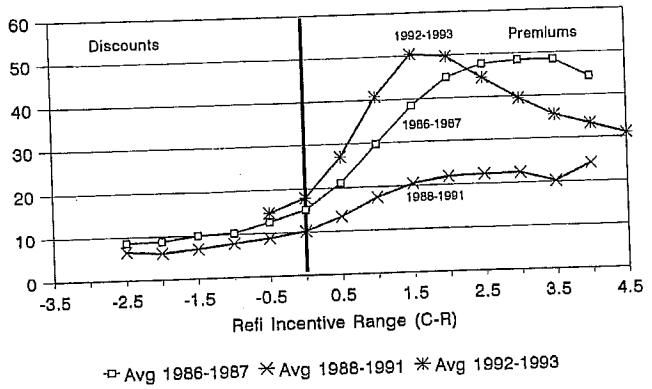
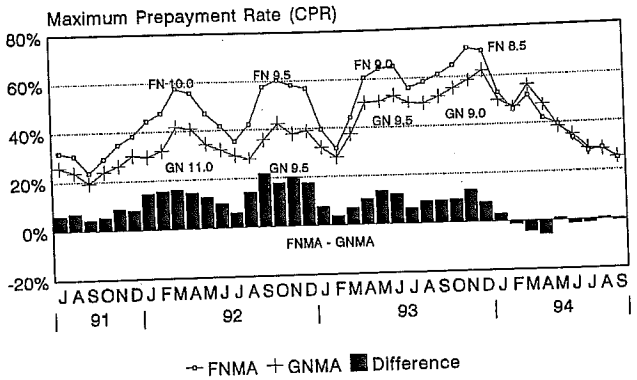


EXHIBIT 11 ■ FNMA/GNMA Gap Narrows and Reverses ■ Effect of FHA Fee Waiver and Cumulative Burnout



coupon borrowers encouraging them to refinance. This had a dramatic effect on GNMA prepayments, as their peak level closed (and occasionally reversed) their gap with FNMA prepayments, as shown by Exhibit 11.

GNMAs actually refinanced faster than FNMAs and FHLMCs for several coupons in 1993. As this had not been anticipated in 1992 by many market participants, this was another of the 1992-1993 challenges for traders. Many investors lost money investing in premium GNMAs (9%+ coupons) as a result of this change in the GNMA prepayment function.

As interest-only and principal-only stripped securities are much more levered than whole MBS in their dependence of risk and return on prepayments, holders of those securities have often made the headlines as winners or losers. Exhibit 12 shows the recent price movements of a FNMA 9% interest-only strip. Its price dropped by half (from $33 to $15) in the twenty-one-month period from January 1992 to September 1993, and the total return losses were actually greater than this due to the huge paydowns experienced on IOs during that time.

Losses experienced by several firms on IOs in 1992-1993 were in many newspaper headlines, but few newspapers have picked up on the huge gains racked up by IOs in the recent surge in rates. As advertised, IOs are hedging instruments in a mortgage portfolio, and Exhibit 12 shows that the FNMA 9 IO's price more than doubled from $15 in September 1993 to over $34 in September 1994.

During the recent rate surge, the media instead centered on the sharp decline in principal-only strip prices, as illustrated in Exhibit 13. FNMA 9% POs

EXHIBIT 10 ■ Enhanced GNMA Refinancing Efficiency

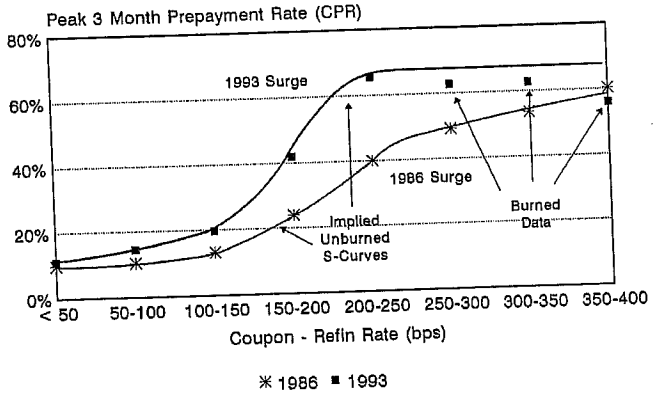
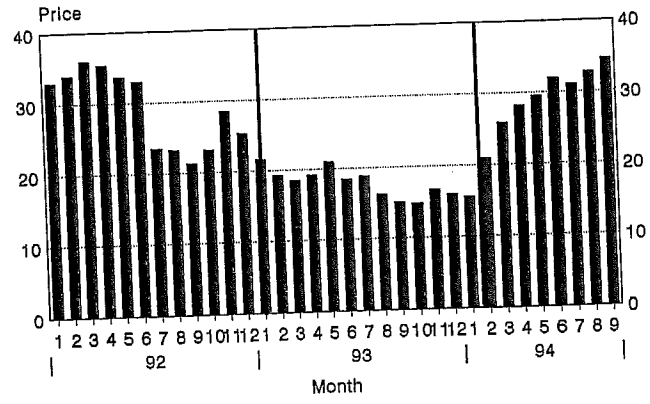
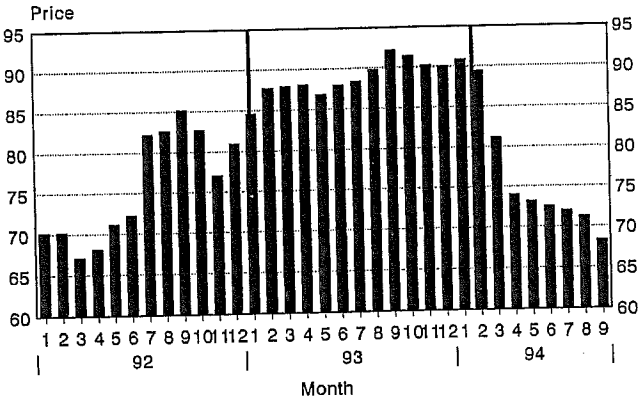


EXHIBIT 12 ■ FNMA 9% Interest-Only Prices 1992-1994



(*?) Why IO price ↑ when rates rise & more rarely
why PO price ↓ when rates rise & vice versa

EXHIBIT 13 ■ FNMA 9% Principal-Only Prices 1992-1994



dropped in price from over $90 in January 1994 to $68 only eight months later in September 1994. As will be shown in Section VI, brokers' risk estimates showed that POs were extremely bullish instruments that should and did fall very sharply in an increasing rate environment.

Exhibit 13 shows that the less recognized story is that POs had been star performers in 1992 and 1993, as rates dropped and prepayments surged, both of which helped POs increase from a price of $70 in January 1992 to over $90 in August 1993. Mortgage investors undoubtedly feel a negative media bias, as stories of the losers dominate the press. In virtually all derivatives, for every loser there is a winner of a very similar magnitude.

As both the risks and returns of standard fixed-rate mortgage securities are significantly dependent upon interest rates and the level of prepayments, this roller coaster ride of 1992-1994 has severely challenged researchers and traders. Indeed, many have lost their jobs in this extraordinary environment. It seems very safe to say that mortgage prepayments, pricing, and hedging were extremely complex in this period.

II. EMPIRICAL DURATIONS FROM DAILY DATA 1987-1994

Comprehensive, high-quality mortgage-backed securities price data are surprisingly hard to find. There are several reasons for this problem. First, there are many "vintages" of every mortgage security's coupon; i.e., there are FNMA 8.5s originally issued in 1974, in 1986, and in 1994. With thirty-year original maturities, these would now have remaining maturities of ten, twenty-two, and thirty years, respectively. Traded prices of these vintages differ, as they have different durations and prepayment behavior (reflecting seasoning and burnout), and offer different risks and returns.

In this research, the data analyzed are for "TBA prices," or brokers' prices for pools "to be announced" and chosen by the broker for delivery. Typically, brokers' inventories are made up of the most recent coupon issuance, as those are the pools that trade most often and in the largest magnitudes. For some coupons such as FNMA 7s, however, there were no issuances from the 1980s, as the thirty-year rate never got as low as 7% during the 1980s. Thus, prior to 1991, even TBA trading in FNMA 7s caused delivery of very old pools originated in the 1970s, which now have short durations.

In 1991-1993, FNMA 7s were again issued and in very large magnitudes, as rates had dropped to where investors rushed to refinance to these lower coupons. Thus, today we trade 1993 FNMA 7s with very long durations, as well as FNMA 7s with short durations from the 1970s.

Again, in the sample here we use TBAs, so FNMA 7 durations lengthened substantially after 1991, due to the switch of the TBA coupon's maturity from the 1970s to the 1990s. This is the most extreme example of the data problems we face in estimating a set of price elasticities or, interchangeably, empirical durations for mortgage securities.

Additional price quality problems occur with very high-coupon securities such as FNMA 11% to 13% coupons. After the huge refinancing surges in 1986-1987 and in 1992-1993, there just aren't many of them left. As a result, trading is sporadic and relatively illiquid in these coupons, and similar pools can trade at significantly different prices on the same day.

Many of these pools now have very low factors, as pools with $1 million original balances have paid down to only $50,000-$100,000 remaining balances. At those small pool sizes, transaction costs of receiving and accounting for principal and interest, which are normally very small in basis points, can become significant. This gives rise to different prices for small pools versus large pools. For these reasons, very high coupons' and very low coupons' price data are of distinctly lower quality than for middle coupons and coupons near the current par rate.

Despite these problems, there is much to be learned from market prices. Since late 1986, Smith Breeden Associates has used multiple sources (Telerate,

EXHIBIT 14 ■ Empirical Data for FNMA Daily Price Elasticities (option-adjusted durations)

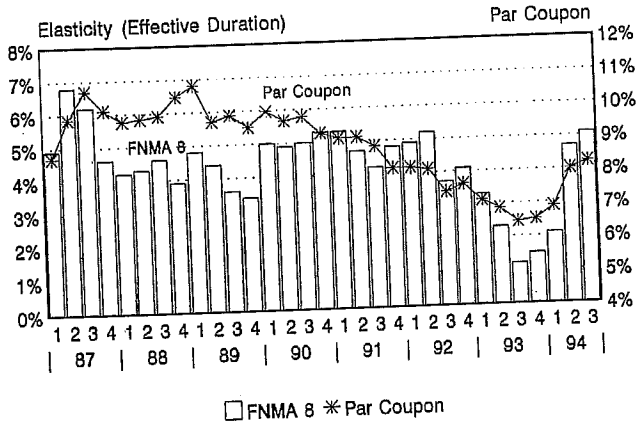
End of Quarter	Par Yield FNMA	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
86Q4	8.82			2.4	2.3	2.3	2.1	2.8	2.7	1.7	1.0	0.0	0.2	0.2
87Q1	8.69			3.8	4.8	4.9	4.8	3.4	2.7	1.7	1.3	0.5	0.4	0.5
87Q2	9.85			6.7	6.7	6.8	6.2	6.0	5.7	4.9	4.1	1.8	1.3	1.1
87Q3	10.70			4.5	6.4	6.2	5.7	5.1	5.0	4.6	3.6	3.0	2.4	1.7
87Q4	10.11			4.0	5.3	4.6	4.3	4.1	3.6	3.4	3.0	4.8	1.8	1.6
88Q1	9.76			3.7	4.2	4.2	4.5	3.8	3.5	3.1	2.4	1.5	0.9	0.7
88Q2	9.83			3.0	4.0	4.3	4.2	4.2	3.8	3.4	2.8	2.4	1.5	1.2
88Q3	9.91			4.6	4.8	4.6	4.5	4.3	4.1	3.6	3.1	2.0	2.0	1.0
88Q4	10.48			4.1	4.1	3.9	3.8	4.3	4.9	3.0	3.0	2.1	0.0	0.0
89Q1	10.81			4.3	4.9	4.8	4.7	4.6	5.6	4.3	3.8	3.0	0.5	0.4
89Q2	9.70			4.8	4.6	4.4	4.3	3.8	3.6	3.4	3.1	2.4	2.4	2.3
89Q3	9.88			3.8	3.7	3.6	3.8	3.5	3.1	2.9	2.3	2.0	1.7	1.7
89Q4	9.50			3.6	3.4	3.4	3.6	3.3	3.1	2.9	2.4	2.1	1.6	1.3
90Q1	9.97			4.8	4.9	5.0	4.7	4.8	4.3	3.6	3.0	2.6	1.9	1.7
90Q2	9.67			4.9	4.8	4.9	4.6	4.2	4.0	3.5	2.9	2.2	1.6	1.4
90Q3	9.78			5.0	5.0	5.0	4.9	4.7	4.2	3.8	3.0	2.4	1.9	1.2
90Q4	9.27			5.3	5.4	5.3	5.2	4.9	4.7	4.0	3.2	2.5	1.9	1.2
91Q1	9.10			5.2	5.4	5.3	5.1	4.8	4.2	3.2	2.8	2.2	1.7	1.3
91Q2	9.12				4.7	4.7	4.6	4.5	4.0	3.4	3.0	2.0	1.7	1.3
91Q3	8.83				4.1	4.2	4.2	4.0	3.6	3.0	2.4	1.8	1.4	1.1
91Q4	8.16			5.3	4.8	4.8	4.3	3.5	2.8	2.1	1.8	1.4	1.2	1.4
92Q1	8.17			4.7	5.1	4.9	4.1	3.3	2.6	2.0	1.4	0.7	0.7	0.5
92Q2	8.10			3.9	5.0	5.2	4.7	3.9	3.3	2.5	1.8	1.1	0.9	0.1
92Q3	7.40			4.6	4.2	3.7	3.1	2.3	1.6	1.1	0.8	0.6	0.6	0.7
92Q4	7.62			5.2	5.0	4.1	3.5	2.6	1.9	1.4	1.1	0.6	0.7	0.2
93Q1	7.12			4.8	4.3	3.3	2.4	1.7	1.1	0.8	0.7	0.3	0.0	0.2
93Q2	6.86			4.2	3.3	2.3	1.7	1.4	0.9	0.7	0.9	0.8	1.3	1.3
93Q3	6.44	5.1	4.6	3.4	2.0	1.2	0.8	0.6	0.5	0.4	0.5	0.2	−0.1	−0.2
93Q4	6.51	5.1	4.7	3.0	2.2	1.5	1.2	0.6	0.5	0.4	0.1	0.1	−0.1	−0.2
94Q1	6.89	5.1	4.9	4.3	3.2	2.1	1.7	1.2	0.8	0.7	0.0	0.0	0.3	0.3
94Q2	8.02	6.7	6.4	6.0	5.4	4.7	3.7	2.7	1.9	1.3	1.3	1.0	0.9	0.8
94Q3	8.23	6.9	6.6	6.2	5.6	5.1	4.4	3.3	2.7	1.8	1.4	1.4	1.4	1.6

Bloomberg, Knight Ridder, and Salomon Brothers) to compile daily price quotes for TBA FNMA, GNMA, and FHLMC fixed-rate MBS coupons from 6%-7% to 12%-13%. Generally, the wire services are used for the active coupons, while broker quotes and actual trade price data are used for the less liquid (high) coupons that are not quoted on the screens.

The resulting composite price data inevitably involve a lot of judgment calls about what are the most realistic prices. Still, the hedging incentive to minimize variance by finding the most sensible estimates of price elasticities keeps the firm focused on getting accurate and comparable price data.

Exhibit 14 presents our estimates of "empirical price elasticities" or "empirical durations" obtained from quarterly regressions of daily percentage changes (sixty to sixty-three observations each) in mortgage prices on changes in seven-year Treasury rates. The seven-year rate is chosen for the single factor, as it has had the highest correlation with mortgage returns for many years. (Its MBS correlation is only marginally higher than with the ten-year Treasury, though, so the results likely would not change in any significant way if the ten-year Treasury's rate change were used.) Also, the FNMA par mortgage yield's spread to the seven-year Treasury has been very stable for several years (at

EXHIBIT 15 ■ Empirical Elasticity (Option-Adjusted Duration) Rises and Falls with Rates



100 bp-120 bp), so price elasticities estimated in terms of the par mortgage yield likely would also be similar.

In virtually all regressions with elasticities estimated to be 1.0 or greater, t-statistics range from at least 4.0 to about 20.0, with t = 8 to 12 most common. These high t-statistics and high R-squared values (40%-90%) give some confidence that the quarterly fluctuations in the estimates are significant and useful. Even for high coupons (11%-12%), where durations are typically estimated to be between zero and two years, t-statistics often are in the 2.0 to 4.0 range.

Due to the poor quality of price data on super-premiums (10.5% and higher coupons since 1993), alternative elasticity estimates are calculated with one-day percentage changes, with five-day percentage changes, and with regressions of price levels versus rate levels. Exhibit 14 shows the coefficients estimated with the five-day rate and price change regressions for those high coupons, which we believe are their best empirical duration estimates. Results for one-day changes and for level regressions give coefficients of similar magnitude, but with more volatile estimates.

Exhibit 15 shows the time series of empirical durations for FNMA 8s between 1986 and 1994. The main point is that the interest rate risks of MBS can change dramatically through time as rates change. The lower rates of 1992-1993 increased prepayments dramatically, thereby shortening durations and reducing price volatility. As rates have surged up in 1994, the actual durations of FNMA 8s have stretched back out from 1.2-1.5 years in mid-1993 to five years in the third quarter of 1994.

Thus, investors should know that if they buy and hold MBS, their interest rate risks change continually and systematically with the level of interest rates. From Exhibit 14, one sees that this is true for all coupon levels, but that the changes are greatest for cusp coupons, as peak prepayment variability leads to the largest duration variability.

Exhibit 16 shows the cross-section of interest rate risk by mortgage coupon. Generally, higher-coupon mortgages have small price elasticities, but the price elasticities of all coupons have increased dramatically with the recent surge in rates. The patterns of all of these empirical results are entirely sensible from applying option and bond duration insights to understanding fixed-rate mortgages and the prepayment option (as in Breeden [1991]).

While the empirical duration of a given coupon changes dramatically through time, the changes are largely based upon prepayments, which we have shown are largely related to the refinancing incentive (C – R). Thus, it is plausible that a stabilizing transformation of the analysis would be to look at the time series of empirical durations for a strategy of holding the coupon at a constant spread to the par coupon.

For example, one dynamic portfolio strategy is always to hold the coupon that is 0 to 50 basis points over the current FNMA par. Another is to hold premiums with coupons 200 bp-250 bp over par, and yet another might be to roll coupons always to be under par by 100 bp to 150 bp.

Exhibit 17 provides the time series of empirical durations for these three strategies. It is seen that those

EXHIBIT 16 ■ Empirical Elasticity (Option-Adjusted Duration) Increases with Rates/ Decreases with Coupon

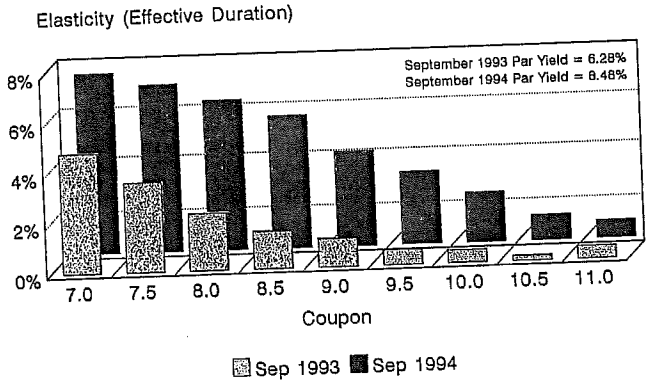


EXHIBIT 17 ■ Empirical Data for FNMA ■ FNMA Elasticities Sorted by Refi Incentive (C – R)

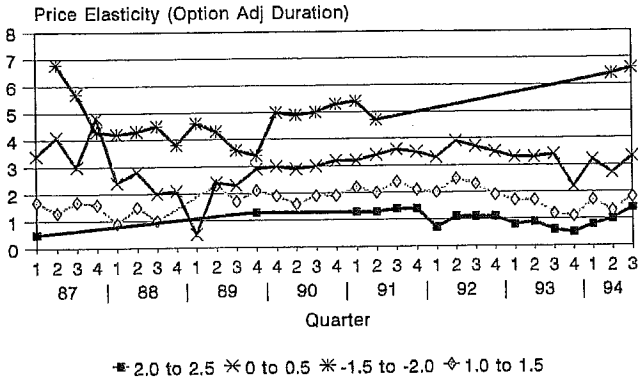
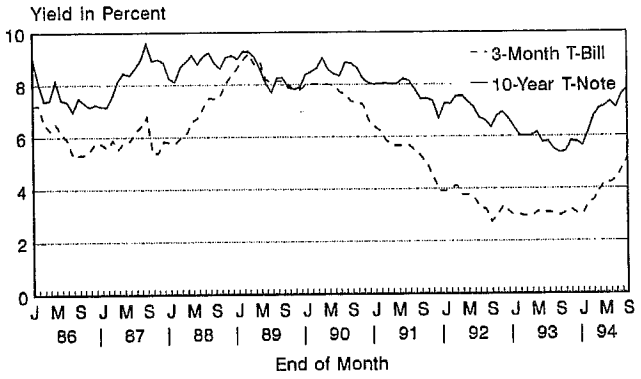


EXHIBIT 19 ■ Treasury Rates 1986-1994 ■ Three-Month T-Bill and Ten-Year T-Note



dynamic strategies' durations are much more stable in their risk characteristics than are the buy-and-hold portfolios' risks (Exhibit 14).

The time series stability of these dynamic strategies' empirical risks makes it reasonable to look at Exhibit 18's presentation of the average risks for the various strategies over the entire 1987-1994 period. The results are intuitive, as deep discounts have the lowest prepayment rates and the longest empirical durations, averaging a 5% price loss for a 100-basis point increase in rates. In contrast, the superpremiums have higher prepayment rates and shorter durations, with empirical price losses often only 1% or less for a 100 bp rate increase. The FNMA par coupon's empirical elasticity was near 4%, which corresponds roughly to the rate risk of a six- to seven-year Treasury note.

While these interest rate risk estimates are for a single factor, reflecting parallel rate shifts, the world is clearly more complex than that.

III. NON-PARALLEL INTEREST RATE SHIFTS

Our analysis of non-parallel rate shifts and some estimates of two-factor price elasticities for a short rate and a long rate follows on Waldman [1992]. In 1991-1992, non-parallel interest rate shifts and two-factor models were one of the biggest concerns in hedging mortgage and bond portfolios. To show why, Exhibit 19 presents the paths of short-term (three-month) and long-term (ten-year) interest rates from 1986-1994. Exhibit 20 shows their difference, which is the slope of the term structure.

The slope of the term structure moved from a

EXHIBIT 18 ■ Empirical Data for FNMA 1987-1994 ■ Empirical Elasticities Sorted by Refi Incentive

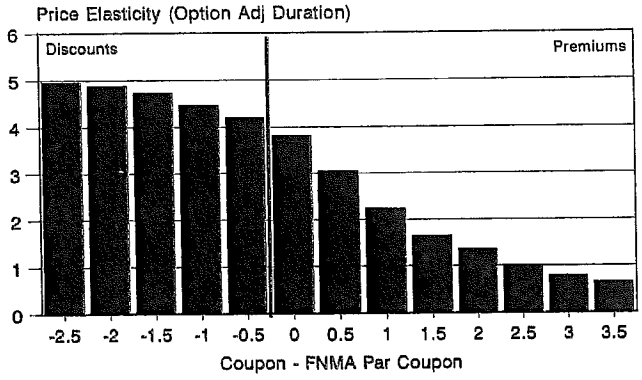


EXHIBIT 20 ■ Steepness of the Yield Curve 1986-1994 ■ Ten-Year Treasury Rate Less Three-Month T-Bill Yield

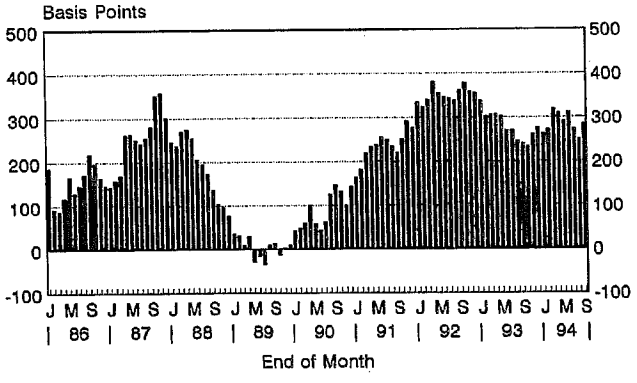


EXHIBIT 21 ■ Unit Duration Futures Hedge Returns ■ Gain in Return in Basis Points for Short Hedge of Unit Duration

Year	Euro Near	Euro Ct 2	Euro Ct 3	Euro Ct 4	Euro Ct 8	T-Bond Near	T-Bond Ct 4	T-Bond Ct 8	Trs. Yields (EOM) 3-Mo.	10-Yr.	Slope	Near T-Bond
1978	167	192	194	172	74	86	80	73	9.60	9.12	−0.48	90.34
1979	247	156	22	−36	−36	125	104	103	12.53	10.31	−2.22	82.19
1980	264	300	305	239	200	225	219	194	15.02	12.43	−2.59	71.38
1981	249	177	118	151	166	294	264	243	11.54	13.93	2.39	61.91
1982	−786	−567	−461	−469	−493	−248	−200	−170	8.13	10.31	2.18	76.63
1983	−57	−19	−5	16	22	86	99	118	9.26	11.76	2.50	70.03
1984	−396	−255	−177	−139	−82	−51	−22	−11	8.08	11.45	3.37	71.06
1985	−348	−390	−406	−403	−392	−256	−224	−191	7.24	8.98	1.74	85.22
1986	−141	−208	−265	−303	−276	−157	−151	−128	5.79	7.25	1.46	98.19
1987	35	70	98	121	104	82	87	86	5.84	8.86	3.02	87.97
1988	84	108	60	48	0	−38	−56	−74	8.36	9.13	0.77	89.13
1989	−48	−123	−159	−175	−119	−99	−110	−106	7.82	7.91	0.09	98.66
1990	−27	−84	−114	−128	−57	29	35	43	6.63	8.06	1.43	95.72
1991	−337	−372	−397	−420	−290	−119	−97	−75	3.93	6.70	2.77	104.8
1992	−101	−154	−142	−149	−122	−39	−29	−15	3.14	6.70	3.56	104.7
1993	−88	−125	−129	−170	−172	−125	−120	−125	3.04	5.79	2.75	114.5
1994*	74	131	161	170	186	68	107	89	4.77	7.61	2.84	98.9
'78-'94	−1,209	−1,163	−1,297	−1,475	−1,287	−137	−15	53				

*Through September 1994.

steep slope of over 300 basis points in 1987 to an inverted yield curve (negative slope) just two years later in 1989, and then back up to a very steep yield curve again in 1992 with a slope of 350 basis points. These movements in the slope are almost as large as the movements in the levels of rates.

In the recent surge in rates from September 1993, the yield curve has moved in a relatively parallel fashion, with both short and long rates up about 200 basis points. Thus, slope exposure hasn't been so much of an issue for the last couple of years, as the stories in the marketplace have been more on parallel shift exposure and prepayments.

To illustrate what has happened on slope exposure, look at 1991 yields. During 1991, the three-month Treasury bill rate dropped 270 basis points from 6.63% to 3.93%, while the ten-year Treasury note rate dropped only 136 basis points (8.06% to 6.70%). If one had hedged by shorting Eurodollar futures (tied to three-month LIBOR), one would have lost on the hedge much more than with a hedge in long-term Treasuries.

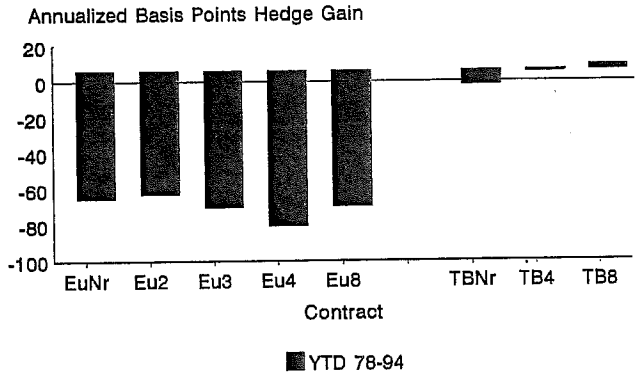
Alternatively, if a bond portfolio held short-duration assets in 1991, the significant drop in rates would have produced larger gains per unit duration than in long-duration assets. Thus, yield curve slope exposure affects portfolios both in gains and losses on various hedges, as well as gains and losses on various asset durations.

Exhibit 21 is a useful and dramatic comparison of the gains and losses on different interest rate futures hedges. It shows the gain or loss in basis points of a hedge of a unit duration of interest rate risk by using alternative maturities of Eurodollar futures contracts and Treasury bond futures.

For example, as Eurodollar futures have durations of about 0.25 years (three months), and a twenty-year Treasury bond futures contract has a duration of about ten years, the table shows the gain to four Eurodollar contracts short, but for only one-tenth of a Treasury bond contract short.

From Exhibit 21, as rates fell in 1991, hedging a 1.0 duration with the near Eurodollar future would have reduced the asset's total return by 3.37%, while hedging that same asset with the near T-bond contract would have reduced the asset's return only by 1.19%.

EXHIBIT 22 ■ Hedge Gains on Eurodollar and Treasury Bond Futures 1978-1994 ■ Annual Hedge Gain for Unit Duration of Risk



Comparing a mortgage hedge for a par coupon FNMA that had a duration of four years, those numbers are multiplied by four, giving a 13.48% hedge loss on the near Euro versus a 4.76% hedge loss on the near T-bond hedge.

Traders know that the short end of the yield curve is highly volatile, and hedging with the first Eurodollar contract can give much different results from hedging with the fourth contract (one year away) or the eighth contract (two years away). This is illustrated in many years in the table, including 1994's January-September results.

For that period, hedging with the near Euro contract produces only a 74-basis point gain, while hedging with the fourth contract produces more than double that gain, i.e., 170 basis points. In futures parlance, a stack of futures contracts all in the most liquid, near contract produced much inferior hedge returns in 1994 when compared to a strip of Euro futures that equally weighted a variety of maturities.

A priori, one might think that over a long period of time the unit duration futures gains would be similar for different interest rate futures contracts. This would be very incorrect for the seventeen-year period since Treasury bond futures were introduced in August 1977.

As Exhibits 21 and 22 show, rolling over unit duration short positions in the near T-bond would have lost an aggregate of only 1.37%, or about 8 basis points a year. In contrast, rolling over unit duration shorts in Eurodollar futures lost 12.09% in the near contract (70 bp/year), while the fourth and eighth contracts lost 14.75% and 12.87%, or 85 bp/year and 75 bp/year, respectively.

Thus, it mattered greatly whether one hedged with Eurodollars or with Treasury bonds. Throughout much of the seventeen-year period, the steep upward slope of the yield curve built into Eurodollar futures the implicit forecast that significantly higher rates were coming soon, and those higher rates rarely came. Exhibit 23 presents an example that shows that the placement of the hedge along the term structure can easily mean the difference between a net hedged profit and a net hedged loss on the same investment.

Litterman, Scheinkman, and Weiss [1991] have shown both a theoretical model for three factors in the term structure, as well as empirical evidence of the existence of three factors — level, slope, and curvature.

EXHIBIT 23 ■ Effects of Non-Parallel Interest Rate Shifts ■ Unit Duration Futures Hedges: January-August 1993

Near T-Bond Futures Hedge = 1.55
Near Eurodollar Futures Hedge Return = –0.72
Eighth Eurodollar Contract Hedge Return = –2.00

			Hedge Gains		Net Profit	
FNMA Coupon	MBS Return	Average Elasticity	Near Eucd Contract	Eighth Eucd Contract	Near Eucd Contract	Eighth Eucd Contract
9.0	3.75	2.72	–1.96	–5.44	1.79	–1.69
9.5	4.14	2.15	–1.55	–4.30	2.59	–0.16
10.0	5.08	1.65	–1.19	–3.30	3.89	1.78
11.0	5.43	1.57	–1.13	–3.14	4.30	2.29

All returns in percentages.

EXHIBIT 24 ■ FNMA Two-Factor Price Elasticities ■ Annual Averages of Quarterly Regression Coefficients

													Factor Models	
	1-Yr.	1991 10-Yr.	1991 Total	1991 1-Yr.	1992 10-Yr.	1992 Total	1992 1-Yr.	1993 10-Yr.	1993 Total	1993 1-Yr.	1994 10-Yr.	1994 Total	1994 $F = 1$	R^2 $F = 2$
Treas. Yld.	5.83	7.85		3.86	7.00		3.38	5.80		4.85	6.81		Data: 1994Q3	
6.0										0.5	6.9	7.4	0.90	0.96
6.5										0.6	6.4	7.0	0.91	0.96
7.0	0.9	4.4	5.3	0.7	4.6	5.3	0.3	4.2	4.5	0.4	5.7	6.1	0.90	0.95
7.5	0.4	4.6	5.0	1.2	4.4	5.6	0.5	3.1	3.5	0.3	4.9	5.2	0.89	0.94
8.0	0.2	4.7	4.9	1.1	4.1	5.2	0.7	1.9	2.7	0.4	4.0	4.4	0.89	0.94
8.5	0.2	4.5	4.6	0.9	3.6	4.5	0.4	1.4	1.8	0.4	3.2	3.6	0.88	0.93
9.0	0.0	4.3	4.3	0.9	2.7	3.5	0.6	0.8	1.4	0.4	2.2	2.6	0.79	0.92
9.5	0.0	3.8	3.8	0.9	1.9	2.8	0.3	0.6	0.9	0.4	1.6	2.0	0.75	0.80
10.0	0.1	3.0	3.0	0.7	1.4	2.1	0.5	0.5	1.0	0.2	1.2	1.3	0.62	0.77
10.5	−0.1	2.6	2.5	0.4	1.1	1.5	0.1	0.5	0.6	0.1	0.9	1.0	0.25	0.67
11.0	−0.1	1.9	1.9	0.5	0.5	1.0	0.2	0.4	0.6	0.4	0.2	0.7	0.27	0.40
11.5	0.1	1.6	1.6	0.3	0.6	0.9	0.3	0.2	0.4	0.2	0.8	1.0	0.30	0.36
12.0	0.1	1.2	1.3	0.5	0.6	1.1	0.3	0.3	0.6				0.24	0.42
Average	0.2	3.3	3.5	0.7	2.3	3.0	0.4	1.3	1.6	0.3	2.5	2.8	0.62	0.74

Waldman [1992] illustrates two interest rate factors for mortgage securities, a short-rate duration and a long-rate duration. There is not general agreement on what different MBS exposures are to short and long rates, and investment bankers do not generally publish two-factor risk estimates (except for Goldman, Sachs since 1993), much less three-factor estimates. As the best hedges are the most robust and simple ones that track important risk changes, it would seem that one next frontier focus should be on developing agreement on two-factor risk exposures for different fixed-rate MBS coupons, ARMs, and derivatives.

In a preliminary analysis, Exhibit 24 presents two-factor risk exposures for FNMA coupons, using daily percentage price changes regressed on changes in one-year and ten-year interest rates. From the improved R-squared values and the significant t-statistics, the second rate factor (or the slope) is statistically significant, in addition to the usual duration factor. Furthermore, my concerns about the stability of coefficients through time are somewhat alleviated, as it seems that the coefficients of the one-year rate are mostly between 0.0 and 1.0, and are reasonably stable through time and across coupons.

Changing MBS elasticities (as discussed in the prior section) are primarily reflected in exposures to the long-term rate, which makes economic sense. The sums of the coefficients give estimated sensitivities to parallel shifts in rates, and they are similar in magnitude to the one-factor empirical elasticities in Exhibit 14.

The two-factor coefficients found suggest hedging much of the "first year of duration" with a one-year strip of Eurodollars (which would track the one-year rate), and hedging the fluctuating "balance of duration" in longer-term futures. Of course, with interest rate swaps and five-year futures, one could be yet more refined in managing yield curve exposure, and most market participants do more precise duration matching.

This is appropriate, as the data in this section show very significant potential slope exposures.

IV. MEDIAN BROKER FORECASTS

One of the major goals of this research is to collect and analyze the major option-based risk and return analysis that brokers (investment banks) provide their clients in their published research. For several years now (for some, back to 1987-1988), brokers have provided coupon-by-coupon estimates of 1) option-adjusted durations or price elasticities, 2) prepayment rates, 3) option-adjusted spreads, and 4) option costs required to hedge the negative convexity of the prepayment option. These somewhat standardized (but continually evolving) analyses, plus periodic research pieces, have been extremely helpful in educating many investors on risks and returns in mortgages.

Still, these have been extremely difficult times in

the mortgage market, and surely no broker or researcher is content with the outcomes of every recommendation. Some critics are much more cynical than this, and believe that broker research is designed just to sell a product, and includes little of really rigorous educational content.

Before I looked at the outcomes of the research, my expectations were that:

- Brokers do a relatively good job at estimating risks in different mortgages.

- Brokers spend a lot of resources in modeling prepayments, and their prepayment forecasts are generally quite rational, although almost nobody has forecasted prepayments really well in the past three years.

- Brokers all give option costs as functions of mortgage coupons that are rational, in that they have reasonable shapes that are as anticipated from option pricing theory, but the sizes of the option costs vary significantly, partly due to definitional differences and partly due to different modeling skills.

- So much time and effort has been spent on option-adjusted spread (OAS) analysis that, paradoxically, brokers' forecasts are not very useful in identifying undervalued or overvalued securities, as the large, liquid parts of the mortgage market are probably relatively efficient.

Let's examine the data and see how these hypotheses turn out.

First, the goal was to compile a quarterly series of these forecasts covering several years, back to the origins of published option-based analysis of mortgages. A significant problem, which surely makes the diversity of opinion appear greater than it really is, is that some brokers publish reports weekly, some monthly, and some quarterly. Many have changed their publication habits in the last several years, with some becoming more detailed in their forecasts, and others limiting the scope of their published forecasts.

As far as timing is concerned, it is often the case that December 31 data contain several forecasts as of December 15, and some as of January 15. As rates have moved significantly during those holiday periods in the past few years, this is a problem with comparing individual forecasts (helping some and harming others).

Fortunately, I don't think mistiming is a serious problem in this section's examination of median broker forecasts, which were compiled as the medians of the individual broker forecasts, coupon-by-coupon. It is more of a problem in discussion of diversity of forecasts.

Exhibit 25 presents the quarterly data series for option-adjusted durations for FNMAs, with the number of brokers growing from one in 1987 to eight in 1994. A simple but revealing first test is to compare broker risk forecasts at the end of the quarter with the empirically measured risk that actually occurs the following quarter (as given in Exhibit 14).

The scatterplots and regression statistics are presented for two subsamples, 1987-1990 and 1991-1994, in Exhibits 26A and 26B, respectively. For the first half of the data, 1987-1990, the regression of next quarter's actual risk on the last quarter's forecast produces a slope of 0.87 and a regression R-squared of 0.73.

This is quite a strong relationship, although care should be taken in interpreting the slope's standard error, as the errors are highly correlated across coupons for the same quarter. The slope is less than 1.0, because when relatively high forecasts of elasticities were made during that subsample, they tended to end up being too high.

In the more recent years, the regression results were even stronger, as the slope is 1.04 in the 1991-1994 regression of actual risk on predicted risk, and the R-squared increases to 0.88. Both the larger sample of brokers' forecasts and improved modeling techniques are candidates for explaining the improvement in forecasting ability.

Regressions were also run quarterly, with just the seven to eleven cross-coupon observations of forecasts versus resulting empirical durations. The results of these regressions are also shown in Exhibit 25.

They show a very strong relationship, with twenty-five of thirty cross-sectional R-squareds in excess of 0.90, and many slope coefficients on both sides of 1.0, with the average near 1.0. Thus, certainly from a broad perspective it seems that brokers' risk estimates do a very good job at informing investors of the risks in FNMA fixed-rate mortgages.

Next, let's put those same risk estimates under a stronger microscope to look for historical errors and potential improvements. Exhibits 27A through 27D show the time series of results for FNMA 8s, 9s, 10s, and 11.5s, comparing the median broker forecasts of elasticities to the subsequent quarter's empirical elasticities.

Consistent with the regression statistics, the time

series patterns of forecasts and actual risks are quite similar. However, both in 1987-1989 and in 1992-1993, brokers' estimates of risks appeared to be consistently a bit too high, although the trends are correct.

Of course, this could be because brokers' forecasts relate to one issue year for the coupon, while the empirical price data refer to a shorter-duration vintage. Alternatively, it is entirely plausible that in 1992-1993 brokers underestimated the elasticity of prepayments with respect to interest rates (as prepayment behavior became more optimal), which would tend to lead to overestimates of empirical durations.

Exhibit 28 shows the results of transforming the broker forecasts of durations for coupons (Exhibit 25) into forecasts sorted by refinancing incentive, C – R, then averaging the time series estimates. Exhibit 28 shows that the brokers' risk forecasts form a sensible option delta-like S-curve, with higher relative coupons having higher prepayments and lower durations. It is very clear from this graph that brokers' forecasts on average overestimated risks of the FNMA fixed-rate MBS, particularly on the very high coupons.

While the brokers' forecasts generally did well in ranking risks, one might ask if other models might do just as well. To check that, Exhibit 29 shows the root mean squared forecast errors for all coupons with more

EXHIBIT 25 ■ Median Broker Forecasts ■ FNMA Price Elasticities (option-adjusted durations)

End of Quarter	Par Yield FNMA	Number of Brokers	Slope	R-Squared	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
87Q1	8.69	2							5.6	5.4	5.2	5.4	3.5	1.8	1.4		
87Q2	9.85	2	0.86	0.86					5.0	5.8	5.4	5.2	4.2	2.9	2.0		
87Q3	10.70	2	0.73	0.83					5.4	5.8	5.6	5.6	5.0	4.4	3.4	2.7	2.0
87Q4	10.11	2	0.58	0.50					6.1	5.8	5.6	5.2	5.0	4.0	2.8	2.2	1.6
88Q1	9.76	3	0.84	0.98				5.2	5.4	5.1	4.9	4.5	3.9	3.4	2.7	1.9	1.9
88Q2	9.83	4	0.87	0.98				5.2	5.5	5.2	5.0	4.6	4.0	3.5	2.8	2.1	1.0
88Q3	9.91	2	0.84	0.98				4.8	5.2	5.0	4.6	4.4	3.8	3.0	2.4	1.0	1.0
88Q4	10.48	4	1.03	0.88				5.8	5.4	5.1	4.7	4.2	4.0	3.2	2.8	2.3	1.8
89Q1	10.81	5	1.15	0.74				5.3	5.4	5.0	4.6	4.3	4.0	3.4	2.9	2.4	2.2
89Q2	9.70	5	0.73	0.97				5.1	5.2	4.6	4.1	3.9	3.5	2.9	2.2	2.0	1.6
89Q3	9.88	4	0.63	0.95				5.0	4.8	4.6	4.3	4.0	3.4	2.9	2.2	1.8	1.7
89Q4	9.50	5	0.63	0.95				5.0	5.1	4.7	4.0	3.7	3.3	2.4	1.8	1.7	1.6
90Q1	9.97	5	0.89	0.94				5.2	5.1	4.8	4.7	4.4	3.8	3.1	2.3	2.0	2.0
90Q2	9.67	4	1.01	0.99				5.2	5.4	5.1	4.8	4.4	3.8	3.2	2.6	2.3	2.4
90Q3	9.78	5	1.12	0.95				5.6	5.5	5.3	5.1	4.8	4.3	3.5	2.7	2.3	2.3
90Q4	9.27	5	1.14	0.98				5.2	5.3	5.2	4.8	4.3	3.6	2.7	2.7	2.8	2.7
91Q1	9.08	6	1.31	0.93				5.3	5.3	5.0	4.8	4.3	3.5	2.6	2.2	2.4	2.2
91Q2	9.19	5	0.96	0.93				5.2	5.2	5.2	5.0	4.4	3.8	3.0	2.4	2.2	2.5
91Q3	8.41	6	0.95	0.96				5.0	5.1	5.0	4.5	3.6	2.6	2.5	2.5	2.6	2.6
91Q4	7.55	8	1.20	0.95				5.6	5.0	4.8	3.9	2.8	2.0	1.8	1.9	1.6	2.4
92Q1	8.40	7	1.10	0.90					6.1	5.5	5.0	4.2	3.5	2.5	2.1	2.1	2.1	2.6
92Q2	7.84	7	1.00	0.93			6.2	6.2	5.7	4.8	3.6	2.7	1.9	1.8	1.4	1.9	2.6
92Q3	7.27	6	0.81	0.97			6.1	5.6	5.0	3.6	2.6	2.2	2.0	1.5	1.6	1.4	
92Q4	7.55	8	1.00	0.93			6.0	5.8	5.0	3.9	3.0	2.2	2.0	1.8	1.5	1.0	
93Q1	6.92	8	0.92	0.99		6.8	6.0	5.4	4.4	2.8	2.0	1.6	1.8	1.6	1.6	1.8	
93Q2	6.63	8	0.67	0.95		6.4	5.8	4.7	3.4	2.4	1.6	1.4	1.5	1.5	1.6	1.8	
93Q3	6.28	7	0.76	0.92	6.8	5.9	5.0	3.7	2.8	2.0	1.9	1.8	1.7	1.3	1.1	1.8	
93Q4	6.67	8	0.92	0.97	6.8	6.2	5.3	4.0	2.8	2.4	2.0	1.7	1.6	1.4	1.4	1.3	
94Q1	7.74	6	0.94	0.98	6.6	6.4	5.9	5.2	4.4	3.0	2.6	2.4	2.3	1.8	1.9	2.1	
94Q2	8.29	7	1.18	0.95	6.5	6.4	5.9	5.6	5.1	4.4	3.6	3.2	3.0	2.2	2.2		
94Q3	8.48	7	1.40	0.97	6.3	6.1	5.9	5.7	5.2	4.6	4.0	3.4	2.8	2.4	2.4		

EXHIBIT 26A ■ Broker Risk Estimates versus Empirical Risk ■ 1987-1990 Quarterly Data, Coupons 7%-12%

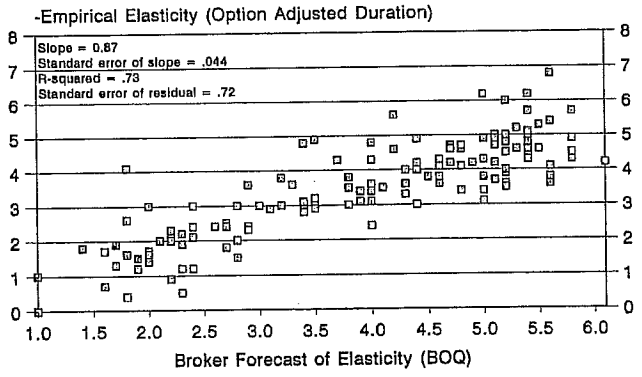
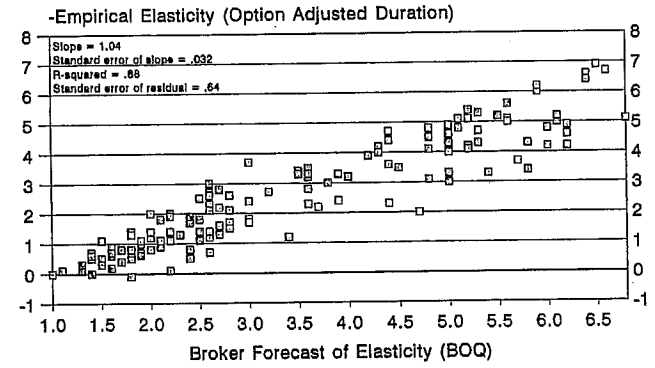


EXHIBIT 26B ■ Broker Risk Estimates versus Empirical Risk ■ 1991-1994 Quarterly Data, Coupons 7%-12%*



*Through 1994Q3.

EXHIBIT 27A ■ FNMA 8 Elasticity (Option-Adjusted Duration) ■ Empirical Elasticity versus Median Broker Forecast

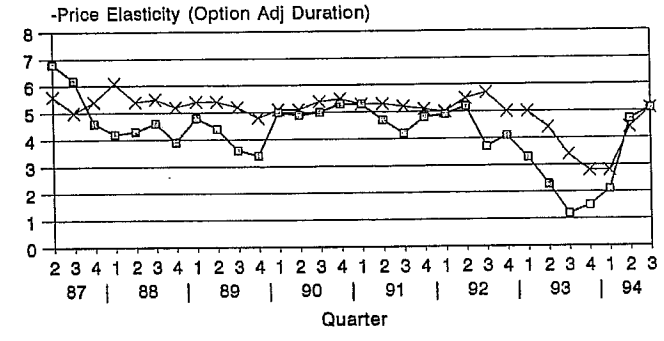


EXHIBIT 27B ■ FNMA 9 Elasticity (Option-Adjusted Duration) ■ Empirical Elasticity versus Median Broker Forecast

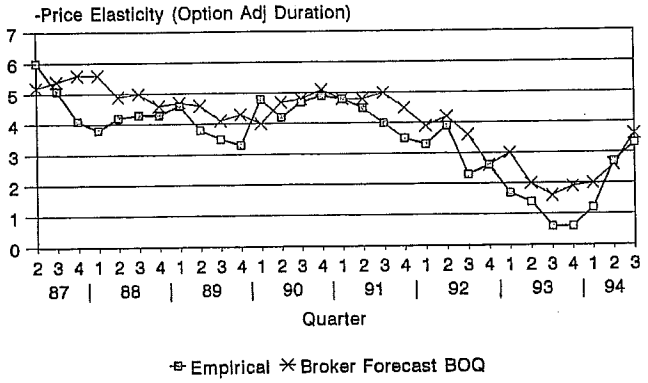


EXHIBIT 27C ■ FNMA 10 Elasticity (Option-Adjusted Duration) ■ Empirical Elasticity versus Median Broker Forecast

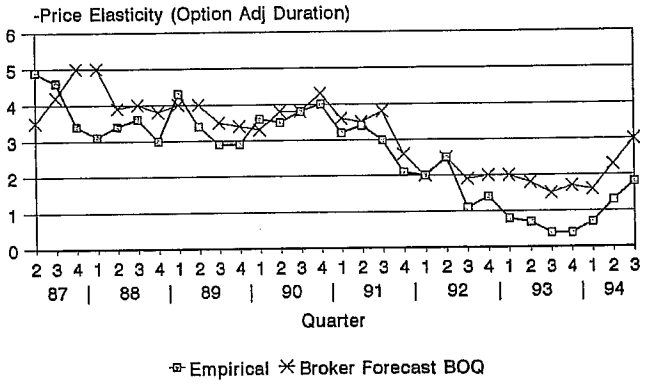


EXHIBIT 27D ■ FNMA 11.5 Elasticity (Option-Adjusted Duration) ■ Empirical Elasticity versus Median Broker Forecast

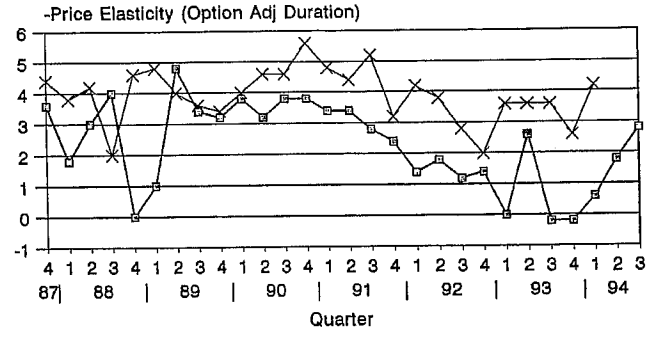
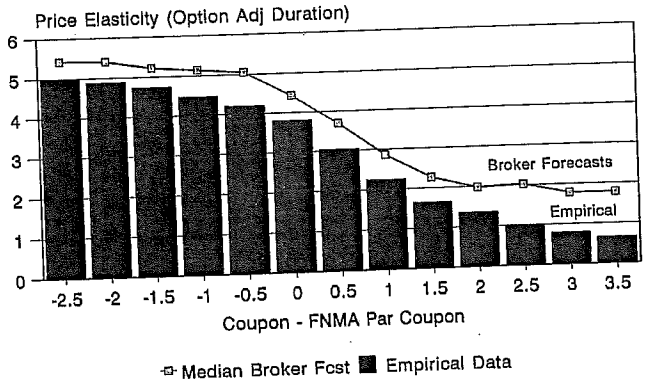


EXHIBIT 28 ■ Median Broker Forecasts ■ Broker versus Empirical Elasticities by C – R



than two years of data for three models: 1) median broker forecasts, 2) a random walk, no-change model for empirical durations, and 3) a roll-up/roll-down (RURD) model based on market prices by coupons as described in Breeden [1991], but just using the beginning of the quarter's price function, rather than averaging the last twelve months.

Generally, both the median broker forecasts and the random walk model did well, with the roll-up/roll-down doing less well. Among the two top contenders, the random walk model won more coupons than it lost to the median broker.

Thus, the brokers were edged out by the empirical data predicting their own risks next quarter. This surely is related to the brokers' persistent errors of overestimation of risk in 1992-1993, particularly for the higher coupons.

It is very interesting to see that a fifty-fifty combination of the median brokers forecasts with last quarter's empirical duration produces easily the lowest forecast errors of all. The optimal forecast weightings of the two (lagged empirical and broker) are typically 30%-50% weight on broker forecasts, and 50%-70% weight on the lagged empirical durations, with greater weight on the lagged empiricals for both deep discounts and superpremiums.

This shows that there is useful information in the brokers' forecasts that can be used to improve upon the "empirical no-change" model. Conversely, the lesson to brokers seems to be that their forecasts could be improved by combining their computer simulations of risks with the empirical durations of the past. Indeed, many brokers appear to be using that approach, as have we at least for the past two and one-half years.

Exhibit 30 presents the median broker forecasts of prepayment rates. An examination of their general levels and shape indicates rational properties. Unfortunately, however, there are some significant problems in evaluating these forecasts.

First, several brokers forecast only the next one-month or three-month prepays, plus a long-term PSA prepay percentage. As the analysis here is for an intermediate, twelve-month horizon, those too-short and too-long forecasts were weighted fifty-fifty to estimate

EXHIBIT 29 ■ Forecasting Empirical Durations for FNMAs ■ FNMA Root Mean Squared Forecast Errors (RMSE)

	Autoregressive				1/2 Broker 1/2 Empirical	Volatility of Forecasts		
Coupon	N	Broker Forecast	No-Change	Point RURD	No-Change	Broker	AR	RURD
7.00	9	1.45	0.87	1.01	0.89	0.37	0.88	1.27
7.50	26	1.12	0.81	0.97	0.81	0.53	1.03	1.30
8.00	30	1.12	0.92	0.91	0.87	0.75	1.23	1.16
8.50	30	0.87	0.79	0.51	0.74	1.03	1.25	1.26
9.00	30	0.82	0.83	1.07	0.73	1.15	1.34	1.21
9.50	30	0.83	0.93	1.27	0.75	1.19	1.45	1.09
10.00	30	0.85	0.83	1.36	0.72	1.01	1.28	0.93
10.50	30	0.85	0.73	1.34	0.71	0.81	1.11	0.94
11.00	30	0.91	0.89	0.99	0.79	0.55	1.07	0.80
11.50	27	1.00	0.76	1.21	0.71	0.45	0.71	0.69
12.00	20	1.03	0.82	1.37	0.76	0.50	0.65	0.66
Average		0.99	0.83	1.09	0.77	0.76	1.09	1.03

EXHIBIT 30 ■ Median Broker Forecasts ■ FNMA Twelve-Month Prepayment Rates

End of Quarter	Par Yield FNMA	Number of Brokers	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
86Q2	9.87	1					9.4	10.0	10.6	11.5	12.5	14.0	19.5	28.0	38.7	46.0	51.6
86Q3	9.38	1					10.3	10.8	11.4	12.2	13.0	17.0	29.2	37.0	46.9	54.0	61.4
86Q4	8.77	1					11.2	11.8	12.7	13.0	15.0	26.0	39.0	46.0	52.8		
87Q1	8.69	1					2.8	3.0	3.9	5.0	17.0	29.0	37.6	44.0	51.0		
87Q2	9.85	1					3.0	3.0	4.1	5.4	10.2	19.0	26.7	34.0	42.7		
87Q3	10.70	1					2.6	2.8	3.8	6.0	7.0	14.9	18.6	25.0	33.3		
87Q4	10.11	1					3.5	3.5	5.5	8.0	6.3	15.6	21.8	29.0	36.7		
88Q1	9.76	2					4.5	5.2	5.6	5.3	7.9	13.1	18.9	24.8	28.5	32.5	33.7
88Q2	9.83	3				5.8	4.5	5.6	6.3	6.0	6.7	13.1	18.9	26.1	29.6	32.2	33.0
88Q3	9.91	2					5.5	6.1	7.1	7.2	7.7	12.5	15.5	22.5	27.6		
88Q4	10.48	4				5.1	6.4	6.3	5.2	5.8	7.6	13.0	13.6	19.0	22.3	24.5	
89Q1	10.81	4				4.8	5.4	6.1	5.7	5.4	5.3	8.7	13.0	17.0	17.1	22.8	
89Q2	9.70	4				5.1	5.7	6.5	5.2	5.3	6.0	7.8	13.5	18.3	20.5	23.5	
89Q3	9.88	3				5.9	8.0	7.9	6.1	5.7	7.6	10.5	12.7	17.3	19.4	22.0	
89Q4	9.50	4				7.4	7.9	6.6	5.1	5.1	7.2	10.3	14.5	19.4	19.4	21.9	
90Q1	9.97	4				7.1	7.4	6.1	4.8	4.8	7.1	10.3	14.9	17.8	18.6	21.0	
90Q2	9.67	4				5.6	3.4	4.1	3.8	4.0	5.1	7.6	14.1	17.5	18.1	18.6	
90Q3	9.78	5				7.9	4.9	4.7	4.6	4.3	4.9	9.2	14.3	17.1	17.8	18.1	
90Q4	9.27	4				7.4	7.7	7.8	5.6	6.0	8.5	14.4	15.6	19.0	16.7		
91Q1	9.08	5				6.6	7.7	7.8	4.8	5.4	8.2	13.8	18.3	18.6	18.7	17.8	
91Q2	9.19	4				8.4	7.5	7.7	4.8	6.4	10.8	17.4	20.0	24.9	21.5		
91Q3	8.41	4				8.5	8.2	6.2	5.9	9.5	15.7	19.5	27.4	25.3	22.9		
91Q4	7.55	5				8.7	6.5	5.8	11.4	13.5	17.7	21.1	26.1	25.7	24.4	22.6	
92Q1	8.40	5				6.4	8.7	9.6	11.1	21.8	30.2	30.4	27.9	27.6	23.1		
92Q2	7.84	5				6.5	8.7	9.6	14.3	23.6	32.4	30.0	27.6	27.7	21.3		
92Q3	7.27	5			4.6	6.5	9.6	19.8	35.7	40.4	41.7	38.3	32.9	33.0	28.5		
92Q4	7.55	7			4.2	8.6	13.1	19.9	27.9	34.1	34.8	30.8	29.8	31.0	29.2		
93Q1	6.92	7		4.4	8.8	9.6	21.8	34.4	40.1	38.2	37.7	34.4	34.2	27.6	29.2		
93Q2	6.63	8		9.5	11.4	20.4	35.9	41.1	44.6	39.1	38.3	34.0	30.3	28.3	28.1		
93Q3	6.28	7	12.4	10.0	20.0	33.7	47.6	52.0	45.2	42.8	37.9	30.4	31.6				
93Q4	6.67	8		5.0	8.3	21.0	36.9	44.3	40.6	38.9	37.4	29.2	27.1				
94Q1	7.74	8		3.1	4.0	9.0	15.8	21.5	28.5	30.5	26.3	25.4	26.9				
94Q2	8.29	8	3.5	4.0	4.8	6.3	9.9	12.2	17.0	19.6	21.6	22.6	25.5				
94Q3	8.48	8	3.4	3.8	4.5	5.0	7.7	9.6	13.4	17.2	19.6	26.3	23.6				

the brokers' twelve-month prepay forecasts, if those were not directly available.

Second, as can be seen in Exhibit 30 for the 8s to 9.5s in early 1987, the prepayment forecasts dropped dramatically from 1986. The reason is not an increase in rates. Rather, it is simply the broker's shift to newly produced TBA mortgages, which start out prepaying slowly.

Finally, and much more interesting and complex, is the point that prepayment forecasts are made assuming no change in rates, or that rates move along the forward curve. In reality, rates may move substantially higher or lower over the next twelve months. If rates unexpectedly increase, it would almost automatically make the low forecaster in the group the winner of the forecasting contest. On the other hand, a sharp drop in rates would make the highest forecaster in the group the very likely winner.

Thus, a good evaluation of prepayment forecast performance deserves separate research, where the researcher carefully controls for the subsequent move-

ments in interest rates. In order to do that, the researcher will need to model forecasters' prepayment functions to estimate how their forecasts would be modified in light of what subsequently happens to interest rates.

Exhibit 31 shows the time series of estimated costs of purchasing options to hedge the risk of negative convexity generated by the prepayment option, i.e., estimated "whipsaw costs." In any given quarter, Exhibit 32 shows that the cross-section of these option costs has a rational shape, with cusp coupons just over par by 50-150 basis points having the greatest option risk.

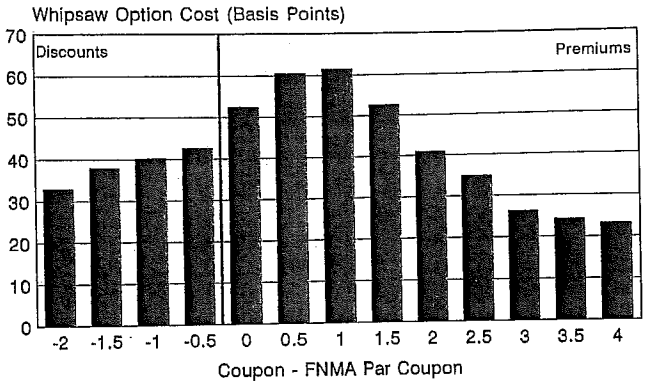
Exhibit 33 shows another check for sensible estimates, which is a comparison of prepayment option costs with bond market volatility. Higher bond market volatility leads to higher option costs. From Exhibit 33, it is seen that there generally is a positive relation from 1987-1994 between bond market volatility and the estimated option cost, but it is not as tight a fit as seems optimal. This suggests that brokers are not reflecting current prices for option volatility in their models as well as would be expected.

Exhibit 34 presents the median broker forecasts for option-adjusted spreads by coupon. These numbers

EXHIBIT 31 ■ Median Broker Forecasts ■ FNMA Option Cost (basis points)

End of Quarter	Par Yield FNMA	Number of Brokers	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
86Q4	8.77																
87Q1	8.69	1				57	62	60	60	65	73	79	85	70	56		
87Q2	9.85	1				62	67	65	65	70	74	75	90	91	92		
87Q3	10.70	1				57	62	61	61	66	72	82	92	88	83		
87Q4	10.11	1				24	30	38	51	58	82	93	86	71	41	38	
88Q1	9.76	3				34	43	53	59	68	78	88	98	93	88	43	
88Q2	9.83	3				33	28	34	50	61	74	85	93	84	75		
88Q3	9.91	2				36	45	50	58	68	82	91	78	56	38	33	
88Q4	10.48	3				32	42	46	57	67	88	91	99	108	116	69	
89Q1	10.81	3				44	48	53	66	79	94	105	112	101	84	70	
89Q2	9.70	3				8	20	23	33	44	56	68	48	45	47	49	
89Q3	9.88	2				19	20	28	34	42	53	62	55	43	39		
89Q4	9.50	2				22	23	25	32	39	49	56	52	40	36		
90Q1	9.97	2				22	23	27	32	40	48	57	50	41	35		
90Q2	9.67	2				22	22	26	30	35	43	52	50	46	40		
90Q3	9.78	2				23	21	27	38	45	50	49	33	31	25	12	
90Q4	9.27	3				16	22	25	36	46	54	54	33	13	24	14	
91Q1	9.08	3				12	16	21	29	39	45	44	32	18	10		
91Q2	9.19	2				14	9	21	35	40	38	23	12	10	7		
91Q3	8.41	3				4	11	32	37	34	30	28	17	3	1		
91Q4	7.55	4				14	20	41	43	42	31	13	4	−15	−24		
92Q1	8.40	3				2	42	43	42	26	11	73	−37	−49			
92Q2	7.84	3			25	4	14	20	36	32	39	31	50	46			
92Q3	7.27	3			9	29	40	54	67	63	59	54	72	75			
92Q4	7.55	4			19	31	44	66	56	58	61	41	49	51			
93Q1	6.92	4		14	20	31	47	50	42	37	34	34					
93Q2	6.63	4	17	20	29	42	50	30	25	15	19	36					
93Q3	6.28	4	10	18	41	50	52	55	49	33	34	50	56				
93Q4	6.67	5	13	24	36	50	64	73	71	56	40	52	52	48			
94Q1	7.74	5	15	22	29	39	53	61	69	63	57	64	58				
94Q2	8.29	5	17	19	23	28	39	50	47	49	41	23	31				
94Q3	8.48	5															

EXHIBIT 32 ■ Median Broker Forecasts 1987-1994 ■ FNMA Whipsaw Option Costs by C – R



have historically been used mostly to estimate prospective risk-adjusted returns, which are then used by investors to form optimal portfolios. Exhibit 35A shows that on average OAS estimated by brokers from 1987-1990 show higher spreads on deep discounts than on intermediate (near-par) or premium coupons. Estimated spreads range from about 85 basis points on the discounts to 65 basis points on the intermediates and premiums.

Exhibit 35B shows that in 1991-1994, on average, brokers' recommendations switch to a preference for premiums and superpremiums. OAS are estimated to be about 100 basis points on superpremiums, 70-80 basis points on premiums, and 60-65 basis points on intermediates and deep discounts.

Exhibit 36 shows the time series of OAS on the very liquid par coupon (C – R = 0 to 0.5). The range is from lows near 40 to highs of 90 basis points. (Evaluation of these OAS is deferred to Section VII when hedged returns on the various mortgage-backed securities are presented and related to these OAS.)

V. INTEREST-ONLY AND PRINCIPAL-ONLY STRIPS

Interest-only and principal-only stripped mortgage securities were often the story behind the headlines of losses in the 1992-1994 period. As Exhibit 12 shows, prices of IOs plunged in 1991, 1992, and 1993, and then soared, with over 100% gains in 1994. As Exhibit 13 shows, prices of principal-only strips rose in 1992 and 1993, as prepayment rates surged to their highest levels in history. As rates rose sharply in late 1993 and throughout 1994, however, prepayment rates plunged, and PO strips dropped in price by 25%, leading to major securities losses for some firms.

Of course, if we add a FNMA 9% IO and a FNMA 9% PO, we get the whole FNMA 9% MBS, which Exhibit 2 shows has a moderate price risk, similar to that of a five-year Treasury note. Thus, IOs and POs are not so mysterious; they are just the building blocks of a whole mortgage security.

As historical evidence illustrates, we can construct portfolios of IOs and POs to be no more risky (and even less risky) than standard FNMA MBS. IOs can be used as hedges for fixed-rate MBS or other bonds; indeed, they have performed extremely well as hedges in the current interest rate surge of 1993-1994. A significant virtue of IOs and POs is that they allow the portfolio manager to manage prepayment risk that is apart from pure interest rate risk (perhaps due to fluctuations in housing starts), as their values are even more closely tied to prepayments than to interest rates.

Forecasting the risks and returns of IOs and POs individually is a daunting task. As the strips have substantially offsetting prepayment risks, the prepayment risk of a whole mortgage is much lower than it is for either the IO or the PO.

In other words, the prepayment risks of the IO and PO pieces of an MBS are much higher than that of the mortgage they compose. Price elasticities, or effective durations, are much larger and more volatile on IOs and POs than for the whole mortgage.

For example, when rates were very low in 1993-1994, a 1.3-year option-adjusted duration of a FNMA 9% MBS might have been composed of a two-thirds

EXHIBIT 33 ■ Median Broker Forecasts ■ FNMA Whipsaw Option Cost versus Volatility

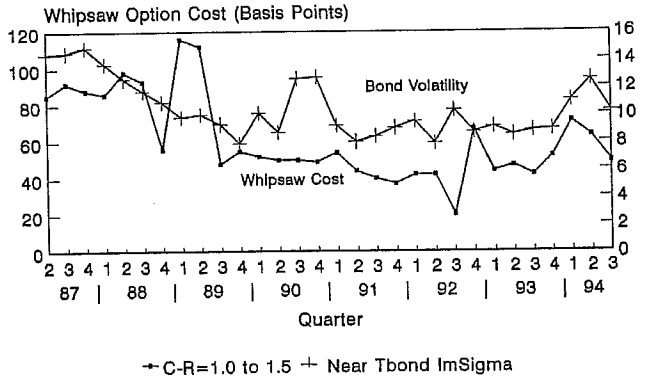


EXHIBIT 34 ■ Median Broker Forecasts ■ FNMA Option-Adjusted Spreads

End of Quarter	Par Yield FNMA	Number of Brokers	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
87Q4	10.11	2					112	106	103	102	93	89	85	78	70		
88Q1	9.76	4				99	95	84	75	71	49	36	28	11	32	11	
88Q2	9.83	5				78	74	72	63	54	44	38	32	20	9	9	−54
88Q3	9.91	3				82	86	81	70	60	46	41	29	32	29	68	
88Q4	10.48	4				95	84	88	84	82	74	92	60	79	54	62	
89Q1	10.81	5				97	97	103	102	91	91	64	59	76	71	76	10
89Q2	9.70	5				94	90	93	88	83	76	73	80	62	79	61	
89Q3	9.88	4				104	100	103	94	87	82	83	85	84	50	65	
89Q4	9.50	5				88	95	101	91	82	79	86	94	80	85	91	
90Q1	9.97	5				76	79	87	83	74	70	73	77	85	86	89	
90Q2	9.67	5				74	64	72	72	72	70	72	72	79	81	86	
90Q3	9.78	5				72	66	62	63	62	57	52	71	70	60	97	
90Q4	9.27	6				93	83	88	83	81	83	91	106	105	107	106	
91Q1	9.08	6				97	70	80	70	68	71	72	75	83	89	109	
91Q2	9.19	5				76	67	75	66	66	55	58	75	72	65		
91Q3	8.41	6			74	78	70	68	66	65	61	80	112	121			
91Q4	7.55	8					69	77	75	83	87	88	76	88	105	114	120
92Q1	8.40	7			76	67	64	61	61	69	73	70	46	85	106		
92Q2	7.84	7			79	66	65	61	58	65	72	70	71	104	131		
92Q3	7.27	6			86	85	92	90	82	97	96	96	99	122	179		
92Q4	7.55	7			65	64	68	69	69	70	69	53	60	67			
93Q1	6.92	7			67	77	93	100	80	80	80	80	105	79			
93Q2	6.63	7		58	63	71	85	83	83	85	85	56	77	43			
93Q3	6.28	7	58	72	98	115	126	135	96	102	108	87	121	125			
93Q4	6.67	7	66	68	70	73	68	77	79	71	69	68	106	124			
94Q1	7.74	7	69	69	65	59	57	52	60	59	44	41	52	115			
94Q2	8.29	6	55	54	54	54	56	55	45	42	42	3	23				
94Q3	8.48	6	51	48	52	52	54	52	58	49	42	23	50				

value weight in the PO part, which has a plus-twelve-year duration, plus a one-third value weight in the IO part, which has a duration of negative twenty years (2/3 × 12 + 1/3 × (−20) = 1.3). Thus, IOs and POs often have very large durations (in absolute value), which indicates that their returns will be highly volatile. Furthermore, those durations change significantly as rates and prepayments change, so IOs and POs have significant option-like payoffs that need to be carefully considered by investors.

In this section, first we discuss what patterns of risk are expected from theory, such as duration and option characteristics. The theory of what to expect for risk and return on IOs and POs was nicely developed in a pioneering work by Roll [1986] before there were any data to examine. Additional insights have come from Asay and Sears [1988] and several other authors. Next, we estimate empirical durations, and examine their changes with rates to see if the empirical results conform to the theory. Finally, we present the median brokers' forecasts and examine them to see how well they comply with the theory and the data.

Exhibit 37 illustrates for a GNMA 11% mortgage the potential prepayment rates and values of the IO and PO components under interest rate scenarios from 5% to 13% par yields. Exhibit 38 graphs those prices, and indicates the option-like payoffs that these investments have at different interest rate levels.

For example, at very low interest rates, when prepayments are near their peak level on their S-curve, an IO sells for a very low price, but has a favorable asymmetric return pattern (positive convexity). At that

EXHIBIT 35A ■ Median Broker Forecasts ■ FNMA Option-Adjusted Spreads 1987-1990

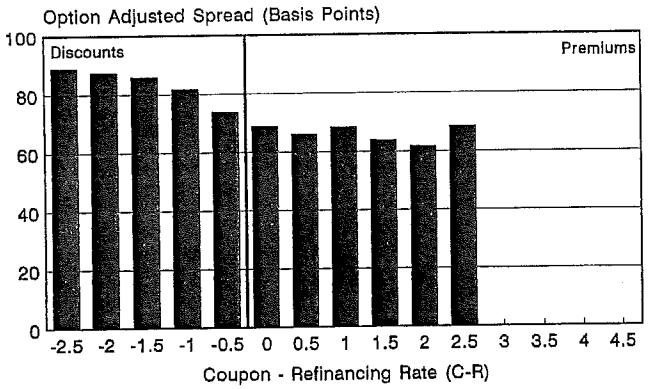
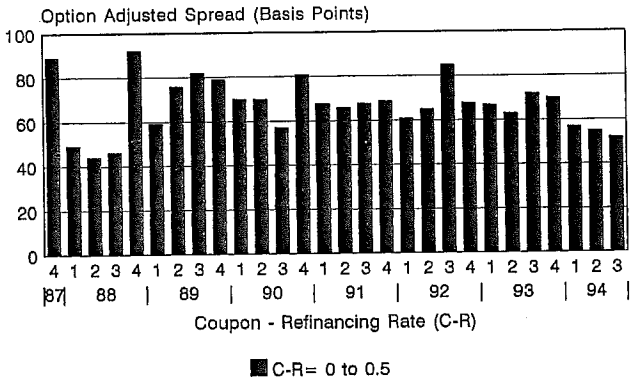


EXHIBIT 36 ■ Median Broker Forecasts ■ FNMA Par Coupon OAS 1987-1994



low price, the IO has little to lose (as prepays are near their peak and unlikely to increase much more with lower rates), but much to gain (as prepays will fall dramatically if rates increase).

Thus, at very low interest rates the IO has a limited downside in price, but a substantial potential upside if rates increase, very much like a put option on bond prices. Corresponding to this, at low rates the IO has a substantial option benefit of positive convexity, rather than an option cost of negative convexity, as a normal MBS has.

At very high interest rates, the situation is reversed for the IO, in that prepayment rates are then extremely low (near their minimum on their S-curve). IO prices are then quite high, but have limited upside for rate increases, and a very substantial downside if rates drop. At high rates, the payoff pattern for the IO is like having written a call option on bond prices, in that if rates increase and bond prices decline, the position has small gains; but if rates decline and bond prices increase, the position has large losses (as the call is in-the-money). Thus, at high rates the IO has negative convexity and a substantial whipsaw option cost.

It is interesting and important to note that the effective duration of an IO can actually change signs (to be positive, i.e., bond-like) both at very high and very low interest rates. At very low rates, as prepayments peak very quickly, additional drops in rates might not accelerate prepayments, but will benefit the IO by a lower discount rate for its cash flows (a standard positive duration effect). Similarly, at very high rates, when prepayment rates near minimum levels, additional rate increases will not benefit the IO much with lower prepays, but will decrease the value of the IO as its cash

EXHIBIT 35B ■ Median Broker Forecasts ■ FNMA Option-Adjusted Spreads 1991-1994

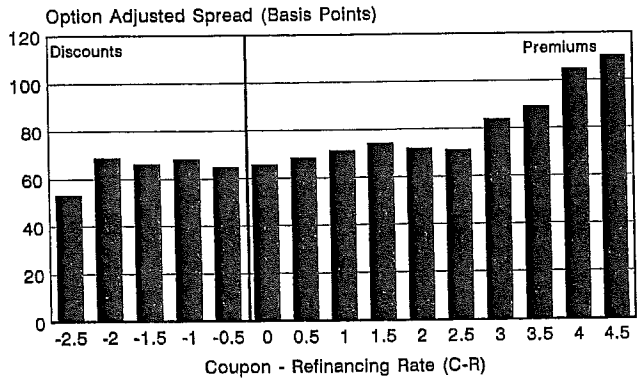
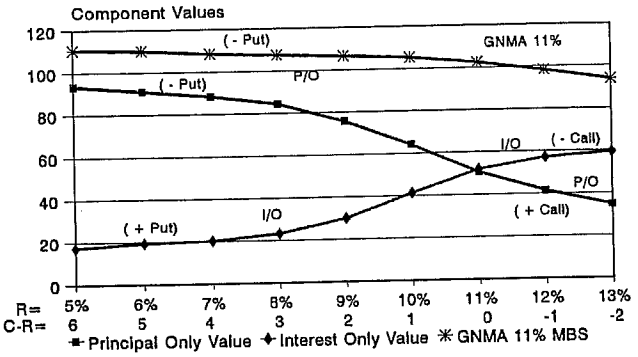


EXHIBIT 37 ■ GNMA 11% Illustration ■ Interest-Only and Principal-Only Strip Values

Current Coupon Mortgage Rate (%)	Coupon – Refi Rate (%)	Assumed Prepayment Rate (%)	Principal-Only Value	Interest-Only Value	GNMA 11% MBS
5.00	6	49.0	93.49	17.19	110.68
6.00	5	46.0	90.95	19.29	110.24
7.00	4	44.0	88.35	20.17	108.52
8.00	3	42.9	84.36	23.17	107.53
9.00	2	34.5	75.62	29.97	106.59
10.00	1	20.3	64.02	41.20	105.22
11.00	0	9.5	50.52	51.84	102.36
12.00	–1	7.0	41.21	56.93	98.14
13.00	–2	6.2	34.36	59.12	93.48

EXHIBIT 38 ■ GNMA 11% MBS Illustration
■ Prices of Interest-Only and Principal-Only Strips



flows are discounted at higher rates. Thus, while IOs usually have a large negative duration, their durations can become small (but negative) and even positive at rates that are both very high and very low (as measured by C – R for the IO coupon).

For principal-only strips, the world is a bit simpler. Interest rate effects on PO values both through prepayments and through cash flow discounting go in the same direction, which leads to a uniformly positive (and very long) effective duration for POs. With POs, the investor pays a discounted price, say, $75, and receives the principal of $100 as the pool's principal pays down. The PO earns no interest, but instead a fraction of the pool's principal repaid monthly, each dollar of which has a capital gain of 33%. Thus, if the pool pays down 20% in a year, and each dollar paid down has a capital gain of 33%, the PO's cash flow return is approximately 6.6% (20% × 33%).

For POs, consider that as interest rates go up, prepayments decline, and the PO loses value (less capital gains from paydowns). The PO's value is reduced again by the market's effect of discounting all cash flows at the new higher rates. For lower rates, both effects again go in the same bond-like direction, as the lower rates increase values from higher prepayments and from lower discount rates. Thus, POs are somewhat like buying a mortgage with leverage.

The option-like features of a typical PO are seen in Exhibit 38. At very low interest rates, PO prices are quite high, and the risk is like being short a put option. At very high rates, PO prices are very low, and the risk is akin to that of a long call option.

Exhibit 39 illustrates the anticipated relationships between the current par mortgage rate and IO, PO, and whole MBS effective durations. Exhibit 40 illustrates the expected option costs and benefits of these instruments for different mortgage refinancing rates. Note that both POs and IOs have ranges where they are positively convex (have option-like benefits), as well as ranges where they are negatively convex (option costs).

Data for POs were obtained from the Goldman, Sachs weekly "Mortgage Market Comment," which started publishing strip prices at the beginning of 1992. Data for IOs were obtained weekly from the same source until July 1992, when Smith Breeden began to record IO prices daily from Telerate screens and from broker quotes and trades executed. Many IOs and POs have markets with relatively wide bid-ask spreads and low liquidity, so the quality of the price data is not good, and some of the fluctuations in empirical durations might be the result of poor data.

Empirical durations for IOs were estimated with quarterly regressions and appear in Exhibit 41. IOs dis-

EXHIBIT 39 ■ GNMA 11% MBS Illustration
■ Option-Adjusted Durations for IO and PO Strips

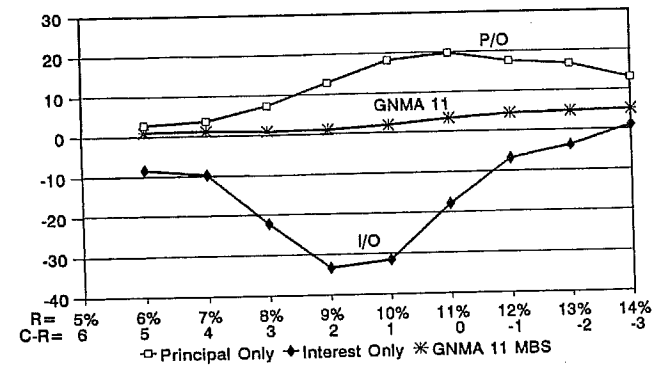


EXHIBIT 40 ■ GNMA 11% MBS Illustration
■ Whipsaw Option Costs for IO and PO Strips

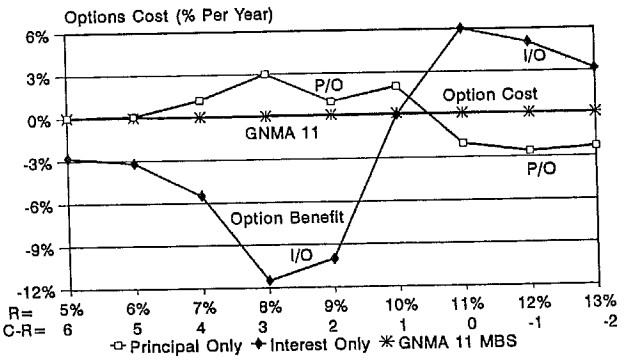


EXHIBIT 41 ■ Interest-Only Strips: Empirical Durations

End of Quarter	Par Yield FNMA	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
92Q1	8.40				−8.6	−14.2	−10.7	−25.3	−18.9	
92Q2	7.84				−39.2	−5.5	−12.8	−17.3	−15.0	
92Q3	7.27				−30.0	−37.4	−48.2	−47.9	−49.1	
92Q4	7.55				−10.9	−24.0	−26.8	−26.3	−18.7	−13.0
93Q1	6.92				−38.2	−25.0	−23.3	−27.1	−22.8	−29.4
93Q2	6.63				−41.0	−20.1	−19.9	−11.7	−9.0	−5.0
93Q3	6.28				−32.6	−17.9	−14.8	−16.0	−9.6	−6.8
93Q4	6.67		−32.5	−39.7	−34.8	−24.8	−22.0	−15.6	−10.6	−8.4
94Q1	7.74		−32.7	−44.2	−60.5	−44.6	−37.1	−28.3	−21.5	−13.2
94Q2	8.29		−8.0	−11.4	−14.6	−21.6	−19.8	−30.2	−26.2	−14.5
94Q3	8.48	−7.0	−10.1	−10.4	−14.0	−16.3	−15.5	−17.2	−15.2	−15.4

played large negative durations throughout the 1992-1994 period, with many especially large negative empirical durations (−30 to −40) during much of the low-rate, very high prepayment period experienced in late 1992 and 1993.

Much of the substantial drop in the prices of a typical IO happened as theory would predict with a substantial rate drop and its concomitant prepayment surge. Yet Exhibit 42 shows that median broker forecasts of IOs' durations frequently were much smaller (in absolute value) than the actual empirical durations experienced. For example, there was only one median broker forecasted duration in excess of −30 (8s in December 1993 at −31.8), but there are seventeen coefficients over −30 in the empirical measurements of Exhibit 41.

Exhibit 43 shows graphically for FNMA IOs with coupons between 8% and 10% (the large market) that brokers tended to underestimate IO empirical durations throughout the 1992-1994 period. Individual coupon graphs all look very much like Exhibit 43, as IO elasticities moved up and down together for the various coupons.

Consistent with these results, Exhibit 44 shows that brokers' estimated option-adjusted spreads for IOs expanded and contracted dramatically from 1992-1994.

EXHIBIT 42 ■ Median Broker Forecasts ■ Interest-Only Strips: Option-Adjusted Durations

End of Quarter	Par Yield FNMA	Number of Brokers	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
90Q4	9.27	1				−1.3	−2.7	−5.7	−8.1	−11.7	−15.9
91Q1	9.08	1				−1.0	−2.5	−5.7	−8.2	−11.7	−14.1
91Q2	9.19	1				1.4	0.0	−2.9	−4.9	−7.3	−9.9
91Q3	8.41	2				−1.2	−3.0	−6.7	−9.6	−11.7	−10.4
91Q4	7.55	3				−6.1	−8.6	−16.8	−16.9	−12.1	−7.7
92Q1	8.40	3				−1.8	−3.8	−9.2	−13.3	−16.4	−12.0
92Q2	7.84	3				−3.3	−6.0	−12.0	−16.9	−16.0	−7.1
92Q3	7.27	3				−10.4	−16.0	−17.0	−15.3	−15.0	−7.6
92Q4	7.55	4				−8.1	−9.9	−16.0	−14.7	−11.0	−8.0
93Q1	6.92	5				−19.4	−18.4	−16.1	−11.4	−10.9	−2.7
93Q2	6.63	5		−12.2	−20.1	−24.2	−20.5	−15.4	−11.4	−10.4	−4.6
93Q3	6.28	5		−20.2	−27.5	−29.1	−9.1	−9.3	−5.6	−3.0	−3.6
93Q4	6.67	5		−16.7	−27.3	−31.8	−14.4	−10.0	−8.3	−5.1	−4.6
94Q1	7.74	5	−4.3	−6.8	−11.4	−20.2	−22.3	−18.7	−13.6	−11.7	−13.0
94Q2	8.29	4	−2.1	−2.6	−4.6	−7.6	−9.4	−11.6	−8.9	−11.0	−15.2
94Q3	8.48	4	2.2	0.2	−2.5	−4.1	−2.8	−5.0	−7.9	−10.5	−12.8

EXHIBIT 43 ■ FNMA Interest-Only Strips: Average 8%–10% ■ Empirical Durations versus Median Broker Forecasts

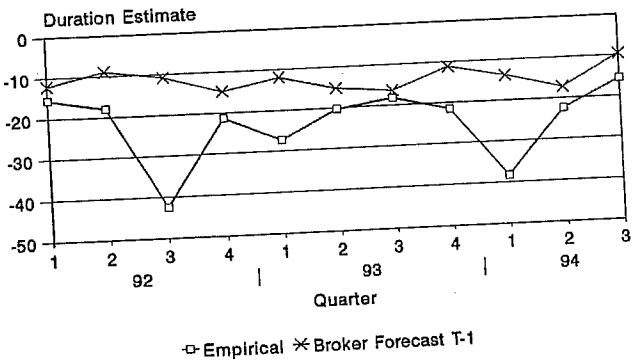
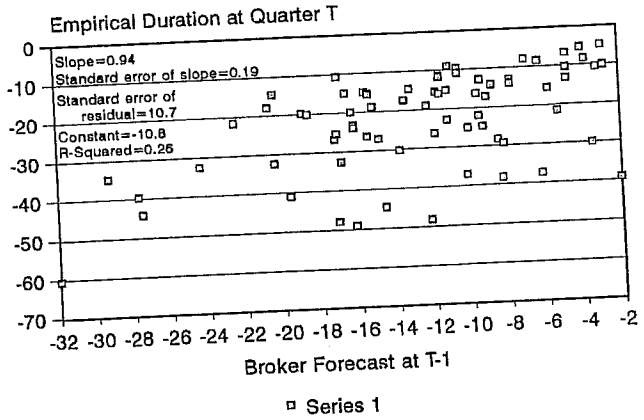


EXHIBIT 45 ■ FNMA Interest-Only Strips ■ Empirical Durations versus Median Broker Forecasts



Prices fell more sharply than anticipated when rates declined, and OAS expanded dramatically. For example, the median broker OAS for FNMA 8s increased from 110 in December 1991 to 1,779 at the trough in rates in September 1993.

IO prices also rose more sharply than anticipated when rates increased in 1994, as empirical elasticities remained higher than brokers' forecasts, and OAS contracted sharply. FNMA 8 OAS contracted from 1,779 to 238 between September 1993 and September 1994.

Given the difficulty that brokers had in forecasting the volatile IO empirical durations, it is surprising to find that the two tests we use for the evaluation of forecasts show that the brokers did reasonably well in these IO forecasts. First, Exhibit 45 shows that the pooled time series and cross-sectional estimates of IO risks by brokers were significantly and positively related to the risks that empirically occurred, and with a slope coefficient near 1. While the durations estimated were on average too low for IOs, when the brokers said that the risk of a certain IO at a certain time was five years more than before, that was on average correct.

Another surprising result for the IO forecasts is shown in Exhibit 46, which gives the root mean

EXHIBIT 44 ■ Median Broker Forecasts ■ Interest-Only Strips: Option-Adjusted Durations

End of Quarter	Par Yield FNMA	Number of Brokers	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
90Q4	9.27	1				−27	−1	−61	−27	−103	−178
91Q1	9.08	1				−63	−89	−77	−26	2	151
91Q2	9.19	1				3	17	−13	75	5	171
91Q3	8.41	2				84	88	184	186	137	193
91Q4	7.55	3				110	365	496	634	661	615
92Q1	8.40	3				69	170	244	396	430	205
92Q2	7.84	3				144	427	494	662	641	589
92Q3	7.27	3				645	919	1,480	1,488	928	998
92Q4	7.55	4				179	512	576	520	520	543
93Q1	6.92	5				808	1,441	1,398	1,240	1,109	973
93Q2	6.63	5		340	576	1,054	958	733	725	430	606
93Q3	6.28	5		1,146	1,559	1,779	1,467	1,312	1,089	1,127	620
93Q4	6.67	5		647	918	1,477	1,845	1,482	1,388	1,286	
94Q1	7.74	5	329	318	330	280	427	551	512	557	
94Q2	8.29	4	236	263	323	325	350	442	509	600	
94Q3	8.48	4	151	147	193	238	231	283	304	414	

EXHIBIT 46 ■ Forecasting IO and PO Empirical Elasticities ■ Root Mean Squared Errors

		Interest-Only Strips		Principal-Only Strips	
		Random Walk		Random Walk	
Coupon	N	No-Change	Broker Forecasts	No-Change	Broker Forecasts
7.00	3	14.3	10.2	3.1	2.1
7.50	3	19.1	10.3	4.5	3.4
8.00	10	22.3	21.2	8.1	6.3
8.50	10	15.2	15.8	5.6	4.3
9.00	10	15.4	15.5	5.7	4.4
9.50	10	14.3	14.6	3.9	3.8
10.00	10	16.0	13.5	4.0	3.3
10.50	7	11.3	9.0	--	--
Averages		16.0	13.8	5.0	3.9

squared forecast errors of the brokers and of the random walk model. On standard FNMA fixed-rates, the random walk model did the best, by itself, but the brokers' forecasts included with the lagged empirical data gave even better forecasts.

For IOs, brokers' forecasts were less volatile than the empirical elasticities, and had lower forecast errors than the no-change random walk model, despite being biased too low on the levels of IO elasticities. The reason this occurred is that when IO empirical elasticities bounced out to very large risks in 1992Q3 and 1994Q1, they bounced back to normal the next quarter. Therefore, the no-change forecast made very large errors in quarters after the large blips; these forecasts were substantially beaten by the lower forecast errors of the more stable broker forecasts.

For PO risk forecasts, the results were better. Empirical PO durations are in Exhibit 47, broker forecasts are in Exhibit 48, and Exhibit 49 graphs the typical time series of brokers' PO forecasts versus actual empirical risks. On average and for each coupon, the brokers' forecasts are of the correct general scale (usually around ten-year durations for most POs).

Exhibit 50 shows that brokers' forecasts of PO elasticities were more accurate than for IOs (R-squared = 0.35 versus 0.26). Exhibit 46 shows that again the root mean squared forecast errors of the brokers are consistently lower than for the lagged empirical results. Thus, the brokers generally did well in forecasting POs' empirical durations.

Brokers' estimates of option-adjusted spreads for POs are in Exhibit 51. They show PO OAS that were not nearly as volatile as OAS for IOs. Generally, when IO OAS were tight, those for POs were relatively wide, and vice versa. This provides fairly clear advice on optimal portfolio shifts between IOs and POs, using the OAS data. In Section VII, we'll see if the portfolio advice turned out very well.

VI. DIVERSITY OF BROKERS' FORECASTS

Investment bankers compete to have the best models for valuing and estimating the risks of mortgage-backed securities and their derivatives. It should be no surprise that, at any given time, there are substantial differences of opinion. Differences of opinion are likely to be greatest at the times of greatest change and volatility, as these are probably the times when

EXHIBIT 47 ■ Principal-Only Strips: Empirical Durations

End of Quarter	Par Yield FNMA	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
92Q1	8.40				14.8	14.4	10.6	13.9	10.9
92Q2	7.84				12.1	11.6	12.8	13.1	9.9
92Q3	7.27				22.5	20.5	19.3	16.2	14.3
92Q4	7.55				9.0	11.2	5.4	7.8	5.2
93Q1	6.92				19.0	12.4	9.7	7.7	7.7
93Q2	6.63				10.5	5.6	3.4	2.6	3.1
93Q3	6.28				1.7	6.7	4.6	3.3	1.6
93Q4	6.67		20.9	14.3	6.8	2.2	5.6	2.5	3.8
94Q1	7.74		16.9	20.0	16.1	10.1	9.5	8.1	5.4
94Q2	8.29	11.3	13.4	15.1	15.3	12.9	13.2	9.6	9.6
94Q3	8.48	11.4	12.8	13.0	13.7	11.8	12.9	12.7	7.7

EXHIBIT 48 ■ Median Broker Forecasts ■ Principal-Only Strips: Option-Adjusted Durations

End of Quarter	Par Yield FNMA	Number of Brokers	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
90Q4	9.27	1				9.5	10.0	11.2	12.0	13.1	15.0
91Q1	9.08	1				9.3	9.9	11.2	11.9	12.6	12.9
91Q2	9.19	1				7.8	8.6	10.1	10.6	10.9	11.1
91Q3	8.41	1				8.9	9.6	10.7	11.2	11.0	9.6
91Q4	7.55	2				10.2	10.4	10.8	10.5	9.3	6.4
92Q1	8.40	3				9.1	9.8	11.3	11.9	12.2	9.3
92Q2	7.84	3				9.9	10.3	10.0	9.4	8.3	6.2
92Q3	7.27	3				11.0	10.0	8.5	7.6	7.4	5.4
92Q4	7.55	3				10.6	10.7	10.0	10.0	8.0	6.6
93Q1	6.92	3				11.9	10.2	9.0	8.1	7.0	4.7
93Q2	6.63	4		15.6	16.2	12.9	9.9	9.2	8.6	7.8	
93Q3	6.28	4		14.4	13.4	10.7	6.8	6.3	6.0	5.4	
93Q4	6.67	4		14.1	14.6	13.0	7.1	7.2	7.0	6.0	
94Q1	7.74	4	12.2	12.3	13.2	14.1	10.6	9.0	8.0	7.8	
94Q2	8.29	4	10.2	10.8	11.3	12.0	8.8	9.0	8.4	8.3	
94Q3	8.48	3		9.1	9.8	10.3	9.3	10.0	10.5	10.0	

modelers are learning the most and updating their models most. The changes in broker ranges of opinion reflect changing degrees of uncertainty both through time and across coupons of the mortgage spectrum.

Exhibit 52 illustrates this diversity of opinion. It shows seven different brokers' forecasts of FNMA option-adjusted durations as of December 1992, both for whole MBS and for IO strips. There are economically significant differences in these risk estimates at all coupon levels.

FNMA 7s have an effective duration of either 5.1 years or 7.0 years, while FNMA 9.5s have durations of either 1.2 years or 3.0 years, according to different forecasters. As we have seen that empirical durations are quite volatile and mortgage risk analysis quite complex, this diversity should not be surprising. Given this diversity, investors should bear in mind that there is a band of possibilities around any researcher's estimates of mortgage risks and returns.

For IO strips, the diversity is especially large, as the risk on a FNMA 9.5 IO was estimated to be as small as –8.8 and as large as –22.7. With this difficulty, it's no wonder that some brokers lost significant amounts of money, while others did not.

Exhibit 53 presents individual brokers' estimates of option-adjusted spreads, also as of December 1992.

EXHIBIT 49 ■ FNMA Principal-Only Strips: Average 8%-10% ■ Empirical Durations versus Median Broker Forecasts

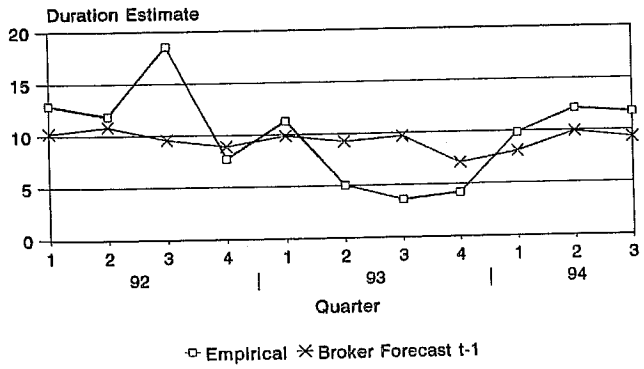


EXHIBIT 50 ■ FNMA Principal-Only Strips ■ Empirical Durations versus Median Broker Forecasts

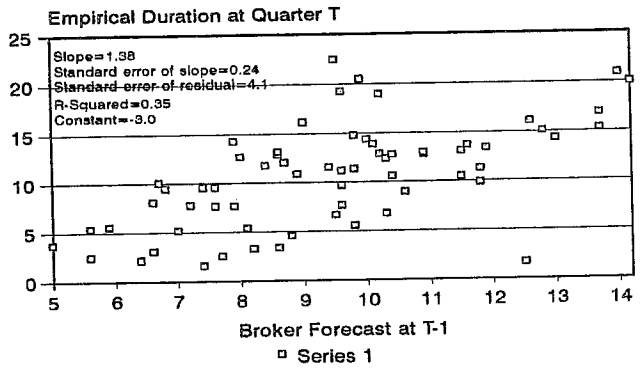


EXHIBIT 51 ■ Median Broker Forecasts ■ Principal-Only Strips: Option-Adjusted Spreads

End of Quarter	Par Yield FNMA	Number of Brokers	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
90Q4	9.27	1				171	165	197	162	213	294
91Q1	9.08	1				196	216	190	142	119	51
91Q2	9.19	1				158	154	161	132	88	10
91Q3	8.41	2				150	156	116	70	60	−31
91Q4	7.55	3				83	−40	−81	−103	−162	−64
92Q1	8.40	3				101	18	−41	−115	−114	16
92Q2	7.84	3				22	−139	−171	−227	−189	−86
92Q3	7.27	3				−73	−191	−286	−275	−168	−106
92Q4	7.55	4				56	−99	−152	−143	−70	−54
93Q1	6.92	5				−174	−305	−264	−243	−174	−25
93Q2	6.63	5		−37	−109	−245	−188	−150	−106	−52	
93Q3	6.28	5		−263	−291	−254	−198	−217	−122	−146	
93Q4	6.67	5		−145	−183	−255	−265	−283	−238	−236	
94Q1	7.74	5	−95	−69	−86	−101	−84	−130	−143	−178	
94Q2	8.29	4		−15	−67	−130	−66	−130	−166	−261	
94Q3	8.48	4	−5	12	−1	−75	−15	−69	−89	−186	

EXHIBIT 52 ■ Forecasts of FNMA Option-Adjusted Durations ■ December 1992 Forecasts

		Fixed-Rate Mortgages							IO Strips				
Coupon	12/31/92 Price	Salomon	Goldman Sachs	First Boston	Morgan Stanley	Bear Stearns	J.P. Morgan	Merrill Lynch	Brokers' Average	Goldman Sachs	J.P. Morgan	Bear Stearns	Brokers' Average
7.0	96.84	6.7	5.5	7.0	5.7		5.1	6.0	6.0				
7.5	99.75	6.2	5.4	6.7	5.4	6.1	4.8	5.6	5.7				
8.0	102.25	4.8	5.0	6.0	5.0	5.5	4.3	5.0	5.1	−3.6	8.5		2.5
8.5	104.25	3.8	4.5	3.8	4.1	3.8	3.8	4.2	4.0	−6.9	−14.5	−7.3	−9.6
9.0	105.63	2.4	3.0	3.0	3.3	2.1	3.1	2.4	2.8	−16.7	−17.6	−7.6	−14.0
9.5	106.69	1.2	1.9	3.0	2.7	1.7	2.7	1.9	2.2	−22.7	−17.5	−8.8	−16.3
10.0	108	0.3	1.1	2.6	2.5	2.4	2.6	1.5	1.9	−28.3	−13.5	−9.0	−16.9
10.5	109.94		0.2	1.9	2.0	2.1	2.6		1.8		−8.8	−12.4	−10.6
11.0	110.72		0.0	1.5	2.7	2.1	1.6						
11.5	111.28		−0.3		2.6		1.2						
12.0	112.38				2.6								

EXHIBIT 53 ■ Estimates of FNMA and IO Option-Adjusted Spreads to Treasury ■ December 1992 Forecasts

		Fixed-Rate Mortgages							IO Strips				
Coupon	12/31/92 Price	Salomon	Goldman Sachs	First Boston	Morgan Stanley	Bear Stearns	J.P. Morgan	Merrill Lynch	Brokers' Average	Goldman Sachs	J.P. Morgan	Bear Stearns	Brokers' Average
7.0	96.84	63.0	65.0	69.0	81.0		94.0	67.0	73.0				
7.5	99.75	66.0	64.0	75.0	80.0	57.0	86.0	66.0	71.0				
8.0	102.25	85.0	66.0	80.0	80.0	66.0	80.0	63.0	74.0	510.0	−55.0		228.0
8.5	104.25	82.0	73.0	77.0	83.0	66.0	75.0	70.0	75.0	748.0	493.0	473.0	571.0
9.0	105.63	72.0	66.0	84.0	85.0	40.0	75.0	57.0	68.0	712.0	647.0	659.0	673.0
9.5	106.69	54.0	62.0	99.0	96.0	32.0	76.0	57.0	68.0	714.0	742.0	741.0	732.0
10.0	108	18.0	59.0	98.0	101.0	97.0	68.0	46.0	70.0	522.0	456.0	771.0	583.0
10.5	109.94		23.0	50.0	57.0	87.0	33.0		50.0		146.0	711.0	429.0
11.0	110.72		32.0	60.0	130.0	115.0			84.0				
11.5	111.28		47.0		150.0				99.0				
12.0	112.38				173.0								

EXHIBIT 54 ■ Estimates of FNMA Lifetime PSA Prepayment Rates ■ November 30, 1992

Coupon	12/31/92 Issue	Median	Kidder Peabody	Shearson Lehman	Salomon	Goldman Sachs	First Boston	Merrill Lynch	Prudential	Morgan Stanley	Paine Webber	DLJ	J.P. Morgan	Citicorp	Smith Barney
7.5	1975	176	240	150	195	161	216	250	165	159	176	175	180	144	
8.0	1976	190	255	160	205	168	231	280	179	265	161	183	216	190	165
8.5	1976	273	295	180	215	212	284	340	221	325	171	273	286	305	194
9.0	1977	310	325	245	240	290	338	430	297	310	221	360	363	335	256
9.5	1986	390	440	360	495	389	334	550	350	430	375	483	479	390	340
10.0	1988	450	505	440	680	442	375	670	363	450	440	533	524	405	478
10.5	1989	491	560	465	830	491	416	720	367	470	472	561	515	420	579
11.0	1985	475	525	305	840	536	471	535	350	475	388	503	499	410	464
11.5	1985	470	545	260	940	549	470	515	348	475	369	459	482	410	455
12.0	1983	439	580	285	990	559	439	490	338	475	329	430	452	380	437

Some brokers thought that the low coupons offered better risk-adjusted spreads, while others thought that the high coupons were better. This is not much of a surprise, as when many talented investors play in the market, it becomes quite efficient and difficult to spot value. There are buyers and sellers in every transaction.

Exhibit 54 illustrates the range of opinion on lifetime prepayment rates, presented as a percentage of the Public Securities Association's (PSA) standard prepayment aging curve. For fully seasoned securities, the annualized conditional prepayment rate may be found by multiplying these PSA percentages by 0.06. Thus, the median broker's lifetime prepayment forecast on FNMA 10s was (450 × 0.05) = 27.0%, according to Telerate. A good look at Exhibit 54 shows substantial differences of opinion, particularly for the prepayment rates of the highest coupons, where the forecasts range from 285% PSA to 990% PSA.

Exhibits 55 and 56 show the time series of the ranges of forecasts for the option-adjusted durations of FNMA 8s and 10s. In both coupons, uncertainty was greatest in 1992 and 1993, as the forecasted durations of both dropped sharply with the surge in prepayments.

Averaging over all coupons (6%-12%) the ranges of forecasts produce the graph in Exhibit 57 of quarterly duration estimation risk. This shows that the degree of uncertainty increased quite significantly in 1992-1993. Exhibits 58 and 59 show very similar patterns for the ranges of duration estimates for IO and PO strips, with the IO risk estimation ranges five times as large as the PO ranges.

Prepayment uncertainty is displayed in Exhibit 60, which shows that the degree of uncertainty surged and plunged in 1992-1994 with the level of aggregate prepayments. It is interesting that Exhibit 61 shows that in 1992-1994 differences of opinion about relative OAS values were not significantly higher than before. That is, while risk management was very difficult in 1992-1994, and there were historic highs in diversity of opinion, disagreements about richness/cheapness were not particularly wide. As over this time period, OAS estimates were probably the statistics most widely used by traders,

EXHIBIT 55 ■ Diversity of Opinion ■ FNMA 8 Forecasts: High, Low, Range 1988-1994

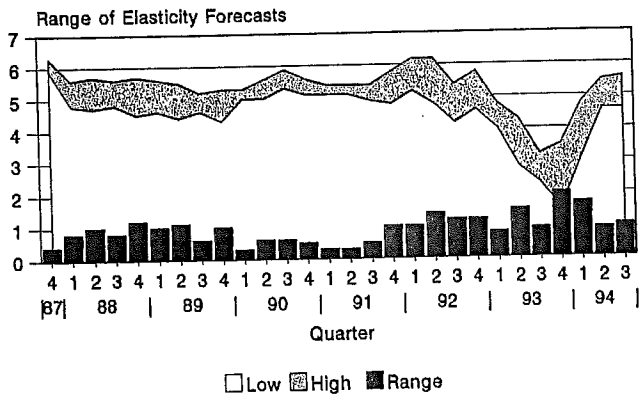


EXHIBIT 56 ■ Diversity of Opinion ■ FNMA 10 Forecasts: High, Low, Range 1988-1994

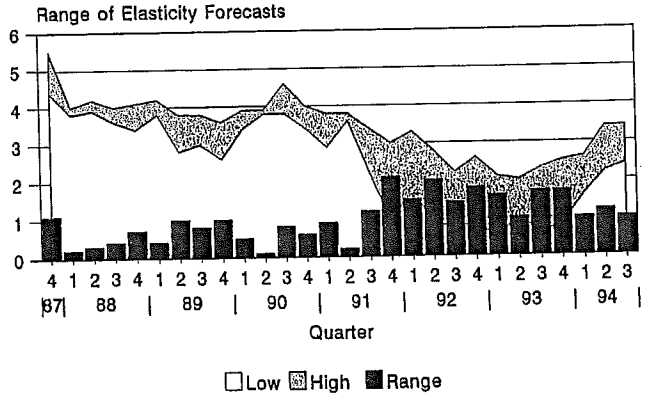
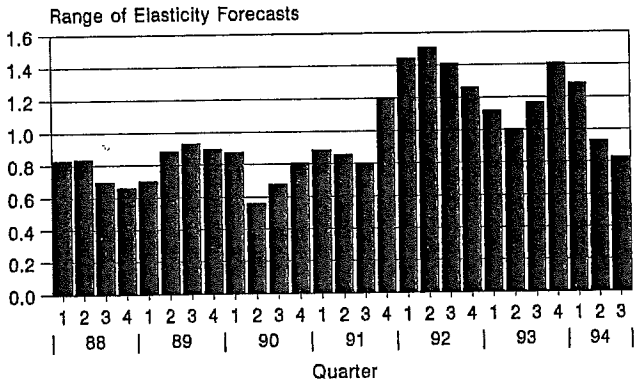


EXHIBIT 57 ■ Diversity of Opinion ■ Quarterly Duration Estimation Risk



Two-quarter moving average of ranges of brokers' forecasts.

EXHIBIT 58 ■ Diversity of Brokers' Opinions ■ Ranges of Interest-Only Strip Durations

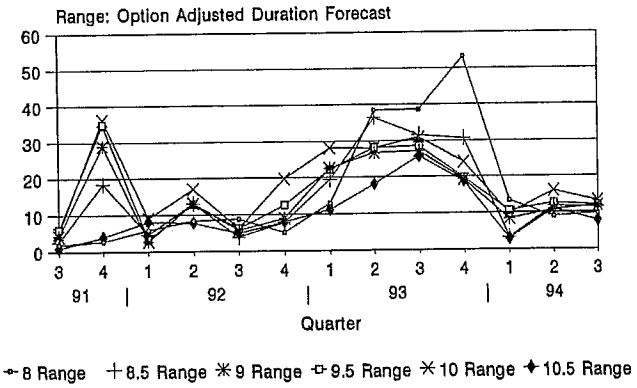


EXHIBIT 59 ■ Diversity of Brokers' Opinions ■ Ranges of Principal-Only Strip Durations

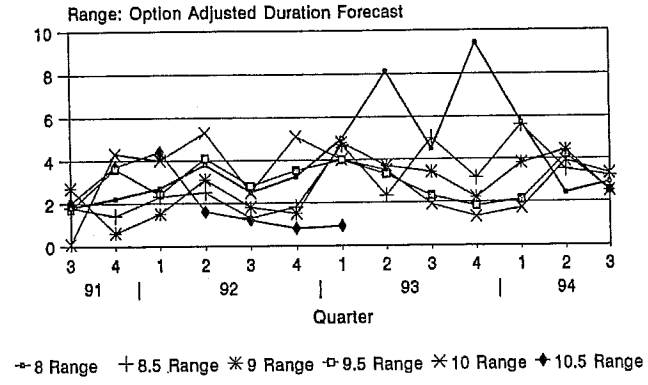


EXHIBIT 60 ■ Range of Brokers' Prepayment Forecasts ■ Average of FNMA 6%-12% Coupons 1988-1994

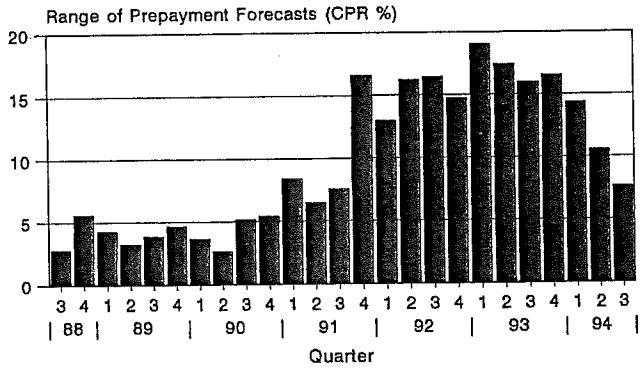


Exhibit 62 shows the patterns of OAS by coupon.

Degree of forecast risk varies by coupon, with basis risks due to forecast errors usually higher on higher coupons. This is shown in Exhibit 63 for duration estimates, in Exhibit 64 for OAS differences, in Exhibit 65 for prepayments, and in Exhibit 66 for whipsaws. By far the most significant practical differences across coupons are the disagreements in estimates of OAS and empirical durations, which determine what many investors buy and sell and how they hedge them.

VII. HEDGED RETURNS AND OAS

We conclude the study by examining the two main "bottom line" issues — risk and return. For evaluating risk control, hedge performance is examined

EXHIBIT 61 ■ Range of Brokers' OAS Forecasts ■ Average of FNMA 6%-12% Coupons 1988-1994

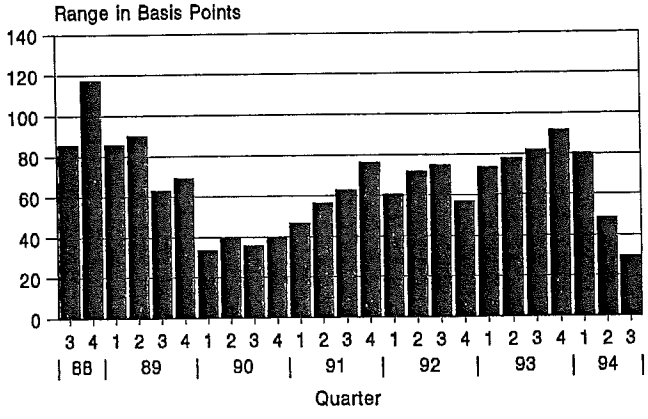


EXHIBIT 62 ■ Range of Brokers' OAS Forecasts ■ FNMA 8%-12% Coupons 1988-1994

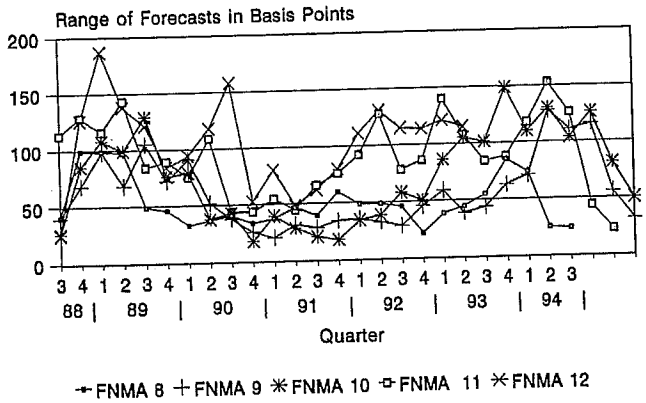


EXHIBIT 63 ■ Diversity of Opinion ■ Duration Estimation Risk by Coupon

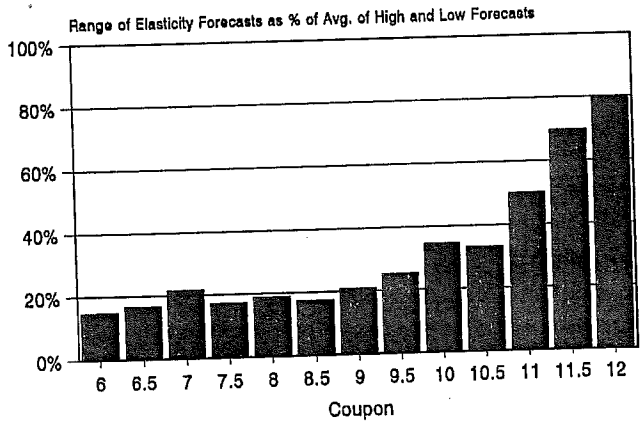


EXHIBIT 64 ■ Range of Brokers' OAS Forecasts by Coupon ■ FNMA 6%-12% Coupons 1988-1994

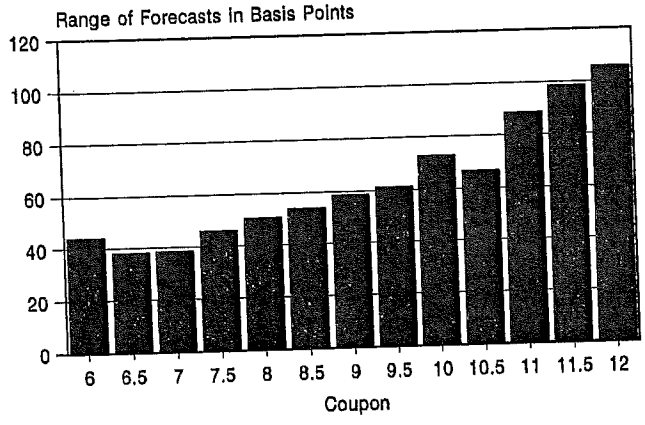


EXHIBIT 65 ■ Range of Brokers' Prepayment Forecasts ■ FNMA 6%-12% Coupons 1988-1994

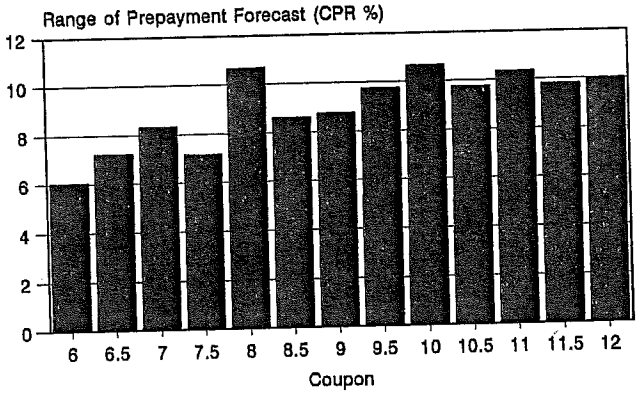
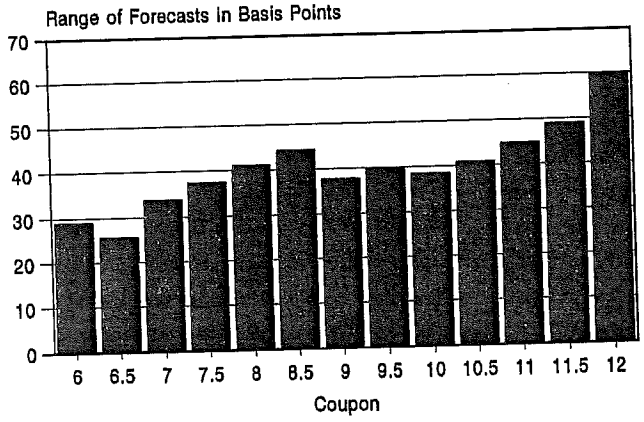


EXHIBIT 66 ■ Range of Brokers' Whipsaw Forecasts ■ FNMA 6%-12% Coupons 1988-1994



using broker forecasts, lagged empirical elasticities (random walk), and roll-up/roll-down (RURD) elasticities. For returns, the relationship of option-adjusted spreads to subsequent hedged returns is examined.

Exhibit 67 shows the hedge performance for FNMA regular fixed-rate mortgages, as well as for interest-only and principal-only strips. For each hedged return calculation, the beginning-of-quarter elasticity estimate is then multiplied by the Treasury bond futures unit duration hedge return (from Exhibit 21) to get the quarter's hedge gain or loss.

For regular FNMA fixed-rate mortgages, Exhibit 67 shows that empirical, broker, and RURD hedges are all quite successful at reducing risk. The average MBS standard deviation is reduced by 40%, from 2.1% quarterly to about 1.2%.

EXHIBIT 67 ■ Standard Deviations of Hedged FNMA Returns ■ Empirical, Broker, and RURD Elasticities 1987-1994

	Regular FNMA MBS				Interest-Only Strips			Principal-Only Strips		
Coupon	Unhedged	Empirical	Broker	RURD	Unhedged	Empirical	Broker	Unhedged	Empirical	Broker
7.0	2.5	1.5	1.6	1.7						
7.5	2.9	1.6	1.4	1.4						
8.0	2.9	1.5	1.4	1.3						
8.5	2.7	1.4	1.4	1.4	30.1	20.5	23.9	7.6	5.4	4.5
9.0	2.5	1.3	1.2	1.2	32.9	28.2	29.8	9.5	7.4	7.1
9.5	2.2	1.2	1.1	1.2	21.2	17.3	17.3	8.0	5.9	5.8
10.0	2.0	1.1	1.1	1.1	17.3	15.2	14.7	4.5	5.3	5.3
10.5	1.7	1.1	1.0	1.1	15.3	15.4	14.6			
11.0	1.3	0.9	1.0	1.0						
11.5	1.2	1.1	1.0	1.0						
12.0	1.1	1.1	1.2	1.2						
Average	2.09	1.26	1.20	1.26	23.4	19.3	20.1	7.4	6.0	5.7

Interestingly, the hedge using broker forecasts of elasticities is most effective, followed by a tie of RURD and lagged empirical elasticities. Consistent with Breeden's [1991] results, the hedges' risk reductions are most effective on the lower coupons, as the higher coupons have a preponderance of basis risk that is more difficult to hedge.

To illustrate the results for a typical hedge, Exhibit 68 graphs for FNMA 9s the futures hedge gains and losses versus the gains and losses on the "cash investment." The dynamic hedge (as durations change quarterly) leads to a good, linear relationship, with an R-squared of 0.78 (correlation = 0.88). The slope coefficient of −0.91 (insignificantly different from −1.0) indicates that the futures gains and losses are nearly "equal but opposite" the cash gains and losses. Exhibit 69 graphs the hedged and unhedged returns, and shows that the hedged returns are much more stable, as the statistics of Exhibit 67 indicate.

In summary, despite all the complexities of hedging mortgages, it remains true that effective mortgage hedges for standard MBS can be constructed from any of these three forecasts — 1) brokers' option-adjusted durations, 2) empirical durations from the previous quarter, or 3) roll-up/roll-down market price elasticities.

For IO and PO strips, Exhibit 67 shows that the hedges also reduce risk, but not as dramatically as for whole mortgages, as strips are more difficult to hedge. The IO strip hedges reduce risk by about 15% on average, with the empirical elasticities edging out the broker

EXHIBIT 68 ■ Median Broker Forecasts ■ FNMA 9: Cash Gain versus Futures Hedge

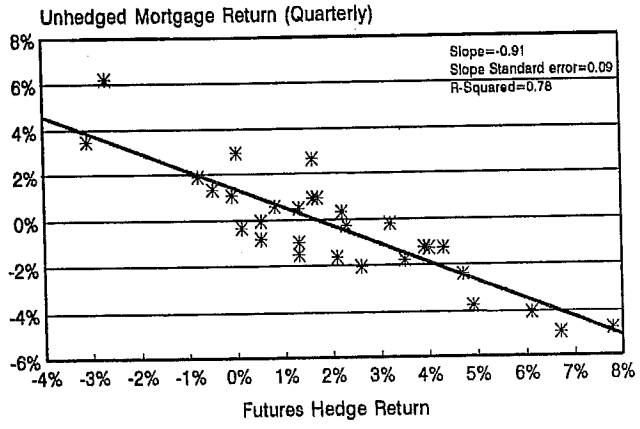


EXHIBIT 69 ■ Median Broker Forecasts ■ FNMA 9: Hedged versus Unhedged Returns

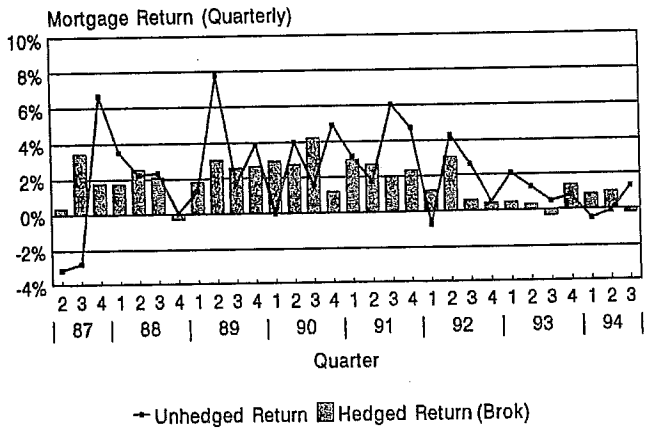


EXHIBIT 70 ■ Median Broker Forecasts ■ FNMA 9 IO: Hedged versus Unhedged Returns

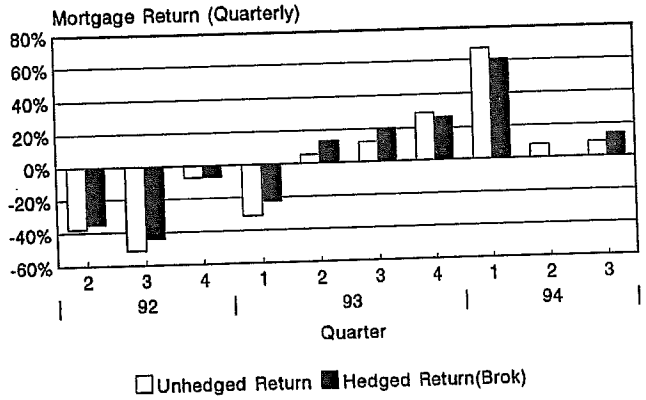
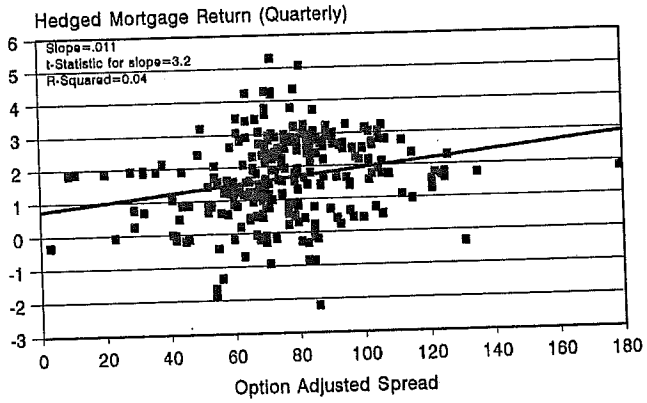


EXHIBIT 72 ■ Median Broker Forecasts ■ FNMA Broker OAS versus Hedged Returns

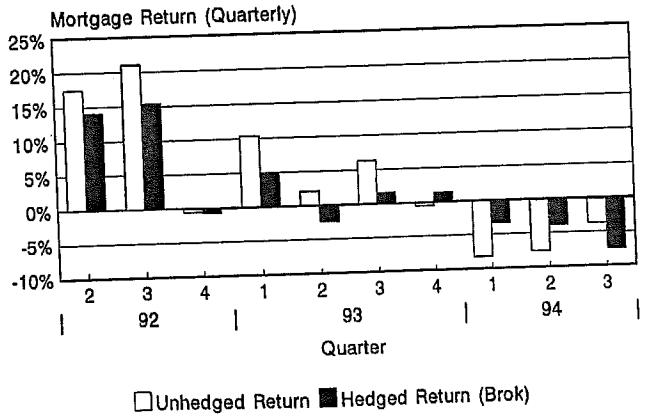


forecasts in risk reduction. The PO strip hedges reduce risk by about 25%, with the broker risk forecasts edging out the empirical elasticities in hedge performance.

Exhibits 70 and 71 show for IOs and POs, respectively, the hedged and unhedged returns. The graphs are revealing, in that the hedged returns are very similar in fluctuations to the unhedged returns, but are slightly less volatile. This indicates that while the hedges reduce risk, the reduction was not as large as would have been optimal, as seen with 20-20 hindsight. This is consistent with our general findings that brokers' risk estimates for IO strips were lower than the actual risks.

In fact, regressing IOs' ex post returns on unit duration T-bond futures returns indicates that for FNMA 9 IOs a duration of −53.5 would have given the lowest-risk hedged returns. In actuality, nobody estimated durations consistently that high, and the median broker's FNMA 9 IO duration averaged −13.5. This shows that duration estimation is a key to having low-risk hedged returns.

EXHIBIT 71 ■ Median Broker Forecasts ■ FNMA 9 PO: Hedged versus Unhedged Returns



For POs, the ex post optimal duration to use for hedging was 15.2 for FNMA 9s; the actual average of ex ante median broker estimates was 9.0. This explains why the PO returns in Exhibit 71 would also have had less risk with larger hedges. In contrast, the ex post optimal hedge for whole FNMA 9 MBS was 3.9, which is very close to the actual median broker hedges employed, which averaged 4.1 years of duration.

This is why Exhibits 68 and 69 show that the FNMA 9 hedges were quite effective, i.e., brokers estimated the risks of FNMA 9s quite well through time. Indeed, it is interesting that the "ex post optimal" static hedges produce returns with a standard deviation of 1.4%, while the dynamic broker hedges for FNMA 9s produce a lower hedge risk of 1.2%.

In the final set of tests, quarterly hedged returns on regular FNMAs, IOs, and POs are regressed on the brokers' estimates of OAS at the beginning of the quarter. The results for regular FNMAs are better than expected, as Exhibit 72 shows. Under the hypothesis that the coupons' results are independent, the t-statistic for the slope is 3.2, which indicates a significant, positive relationship for OAS to subsequent hedged returns on FNMAs during the 1988-1994 period. The individual coupon results are not reported, but the slope coefficient for each coupon's regression is positive.

For stripped securities, the OAS are also found to be useful in predicting hedged returns over this period (1992-1994 for strips). The results for POs in

EXHIBIT 73 ■ Median Broker Forecasts ■ POs: Broker OAS versus Hedged Returns

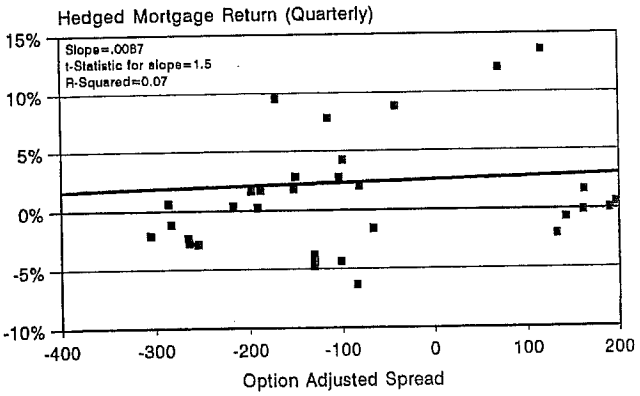


Exhibit 73 give a positive slope coefficient, with a t-statistic of 1.5, assuming independence. This is a bit weaker result than anticipated.

Finally, for IO strips, for which hedges were not very successful, the results of using OAS to predict hedged returns are most successful. As the graph and statistics in Exhibit 74 indicate, the slope is positive, with a t-statistic of 4.0. The R-squared for the aggregated IO OAS versus hedged return regression is 0.21, which is significantly better than for POs (0.07) and for standard fixed-rate FNMAs (0.04).

Thus, one might characterize the IO OAS as having a strong relationship with subsequent hedged IO returns, while the relationships for POs and for regular FNMA fixed-rates with their median broker OAS are considerably weaker, but of the right sign and marginally significant.

VIII. CONCLUSION

This has been a comprehensive study of the complexities of hedging mortgages, with a focus on the recent turmoil during 1992-1994. The sharp decline in interest rates in 1992-1993 set off an unprecedented surge in prepayment rates, followed by a plunge in 1994. Risks of mortgage securities changed dramatically during that period, in non-linear relation to interest rates (as option-pricing theory would predict). Yet the prepayment and effective duration functions behaved in ways that were not stationary through time, which made this an extraordinarily difficult environment for risk management.

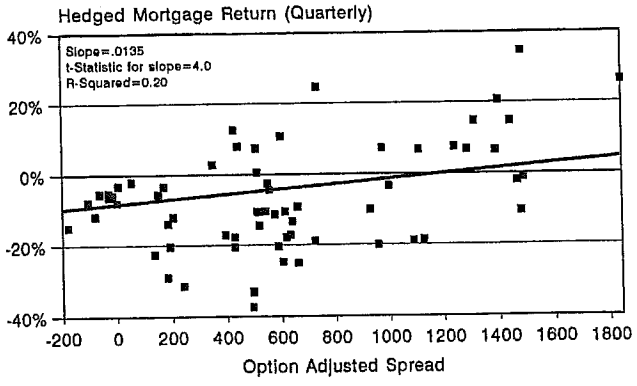
A major focus of the study is on examining brokers' forecasts of risks and returns for standard FNMA mortgage-backed securities, as well as for their major risky derivatives — IO and PO strips. Brokers' risk estimates are found to have been very helpful in hedging risks of regular FNMAs. Risk estimates could be improved by combining brokers' risk estimates with empirically measured risks. Risks are reduced by about 40% on average by hedging with the risk estimates from the median broker.

For IO strips, risk measurement is not as successful, as the risk reduction was only about 15%, and started from a very large risk amount. Although the hedges do reduce risk, the reductions in risk with hedging still leave very large risks. Hedging of PO strips is more successful, as risks are reduced by about 25% by hedging. As their unhedged risks are smaller than IOs and their hedges are more successful, the resulting risks of hedged returns on POs are substantially smaller than the risks of hedged returns for IOs.

Somewhat surprisingly for such a large market as MBS, brokers' estimates of option-adjusted spreads were significantly related to subsequent hedged returns on FNMA fixed-rate MBS, on POs, and (especially) on IO strips. Thus, it seems that regular MBS and POs are easier to hedge and to price, and there is less predictability to the mean of the (lower-risk) hedged return. In contrast, it is very difficult to hedge IOs, but option-adjusted spreads are useful in predicting their risky mean returns.

There is great diversity in brokers' risk and return estimates. The median broker's risk and return estimates, however, are generally sensible estimates in difficult markets, both in relation to the theory and the data.

EXHIBIT 74 ■ Median Broker Forecasts ■ IOs: Broker OAS versus Hedged Returns



ENDNOTE

The author gratefully acknowledges the help of colleagues Carl Bell, Sue Brickhouse, John Kerschner, Heidi Parker, and especially Kerrie Hillman and Dan Adler.

REFERENCES

Asay, Michael R., and Timothy D. Sears. "Stripped Mortgage-Backed Securities, Part I: Basic Concepts and Pricing Theory; Part II: Trading Strategies and Portfolio Applications." Goldman, Sachs & Company, Inc., January 1988.

Black, Fischer, and Myron S. Scholes. "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy*, 81 (May-June 1973), pp. 637-659.

Breeden, Douglas T. "Risk, Return, and Hedging of Fixed-Rate Mortgages." *Journal of Fixed Income*, 1 (September 1991), pp. 85-107.

Litterman, Robert, José Scheinkman, and Laurence Weiss. "Volatility and the Yield Curve." *Journal of Fixed Income*, 1 (June 1991), pp. 49-53.

Roll, Richard. "Stripped Mortgage-Backed Securities." Goldman, Sachs & Company, Inc., October 1986.

Waldman, Michael. "Beyond Duration: Risk Dimensions of Mortgage Securities." *Journal of Fixed Income*, 2 (December 1992), pp. 5-15.