Measuring the Mortgage Market's Convexity Needs

LAURIE S. GOODMAN AND JEFFREY HO

LAURIE S. GOODMAN
is a managing director and co-head of Global Fixed Income Research at UBS in New York City.
laurie.goodman@ubs.com

JEFFREY HO
is an executive director at UBS in New York City.
jeffrey.ho@ubs.com

In the last few years, fixed-income market participants have become quite aware that certain activities of mortgage market participants amplify movements in Treasury rates. That is, there are fundamental factors that move interest rates (i.e., economic data, monetary policy, Fed activity). Interest rate movements, in turn, are exacerbated in both directions by mortgage hedging activity. As rates are *falling*, mortgage hedgers are forced to buy bonds, which then drives rates down more than otherwise would have been the case. Similarly, as rates *rise*, mortgage hedgers are forced to sell bonds, thus driving rates up more than if hedgers had been absent from the market. The importance of mortgage convexity hedgers became particularly clear when interest rates rose 150 basis points during an eight-week period in the summer of 2003.

The extent to which mortgage hedging has amplified movements in Treasury rates has been investigated by Perli and Sack [2003]. They find that mortgage hedging activity amplifies rate moves by 16%-30%. Goodman and Ho [2003], using a simpler methodology, found that rate moves were amplified 10%-16% due to the participation of mortgage convexity hedgers. Whether by research or market experience, the point is very clear—mortgage market participants do have a major impact on interest rates.

We believe the behavior of mortgage market convexity hedgers can be anticipated only if fixed-income market participants understand *who they are* and *what motivates them*. We first show that there has been more convexity hedging over time, due to both structural changes in the composition of the fixed-income markets (mortgages constitute a greater share of the fixed-income markets than has been the case historically) and the greater concentration and greater efficiency of mortgage market participants.

We then identify three distinct groups of convexity hedgers—mortgage investors, mortgage servicers, and mortgage originators. We measure the convexity needs of each investor group separately, and then sum them to produce a "mortgage misery index"—that is, the total convexity needs of mortgage market participants for any given 50 basis point change in rates. We track the mortgage misery index over time, and discuss its implications. Finally, we look at the total convexity hedging needs of the market over time, with special emphasis on the events during the summer of 2003, and discuss the implications for a higher rate environment.

I. CHANGES IN THE MARKET

Convexity hedging has clearly become more important over the past few years. There are a number of reasons for this:

- The mortgage market is larger now, as a proportion of the overall fixed-income market.
- Originator and servicer activity has become more concentrated.

EXHIBIT 1
Growing Importance of Mortgage Market

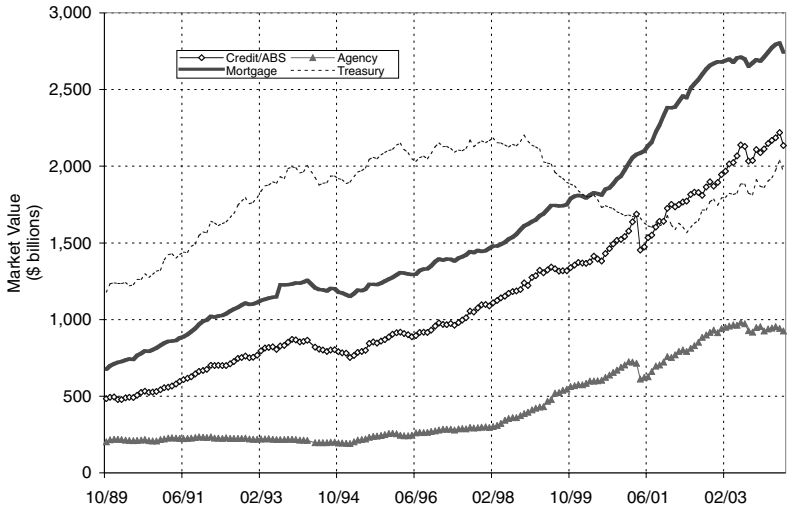


EXHIBIT 2
Mortgage Sector—% of BIG Index

- Mortgage borrowers are becoming more efficient in exercising their refinancing options.
- There has been a shift in the fixed-income investor base, from investors who don't hedge their convexity needs toward those who do.

Exhibits 1 and 2 demonstrate growth in the mortgage market. Exhibit 1 shows the relative size and growth of each of the four major components of Citigroup's BIG (Broad Investment Grade) Index.[1] The sectors depicted consist of the market capitalization of all relevant fixed-rate outstandings with a remaining maturity longer than one year; a BBB–/Baa3 quality minimum; and a minimum issue size (over $1 billion for Treasuries, over $200 million for agencies, corporate (credit), and asset-backed securities, and over $5 billion in a mortgage coupon). Mortgages actually became the largest component of the BIG Index in 1999, when they overtook Treasuries. Over the past few years, the mortgage share has hovered between 35% and 37%, as shown in Exhibit 2.

Not only is the mortgage market larger, but the originator and servicer community is far more concentrated, as shown in Exhibit 3. In 1989, the top ten mortgage originators generated 15.3% of all originations; by Q1 2004, that share had expanded to 58.7%. Over the same period, the top 25 mortgage originators moved from a 25.6% market share to a 78.0% market share.

Servicing shows a similar pattern of increasing concentration. It is undoubtedly the case that the amount of convexity hedging by these parties is much higher than a decade ago. As the larger originators and servicers have grown, this part of their business has become more important, and they have become more sophisticated.

Borrowers are becoming much more efficient in exercising their prepayment option. This reflects dramatic drops in both costs and transaction difficulties on the mortgage origination side, including streamlined underwriting standards, increasingly automated back-office processing, more competitive origination channels (brokers, retailers, correspondents), declining closing costs, and the rise of automated underwriting. On the borrower side, there is easier access to information on refinancing rates and product alternatives, as well as multiple competing opportunities with regard to refinancing process on-line, especially when one is awake late at night.

If homeowners are exercising their refinancing option more efficiently, we would then expect refinancing thresholds to drop and refinancing amplitudes to widen. The refi threshold can be defined as the midpoint of the refi response curve. That is, if deep-in-the-money mortgages experience prepayments of 60%, and turnover is 4%, then the refi threshold is the point at which borrowers prepay at 32% CPR (as [4 + ([60 – 4]/2)] = 32% CPR).

To show how those thresholds decline over time, Boyd [2001] took one-month CPRs from pools issued the

EXHIBIT 3

Top Mortgage Originators (% market share)

Year	Top 10	Top 25
Q1 2004	58.7	78.0
2003	61.0	76.5
2002	60.7	78.5
2001	50.6	69.4
2000	41.0	60.7
1999	39.0	57.4
1998	38.2	54.6
1997	30.8	45.0
1996	28.1	40.3
1995	25.9	39.0
1994	22.2	33.0
1993	23.1	36.8
1992	18.7	30.6
1991	16.0	26.8
1990	17.4	28.4
1989	15.3	25.6

Source: Inside Mortgage Finance.

prior year, subtracted out the turnover component, then fitted the remaining refi component with an S-curve to extract the refi threshold (the midpoint of the curve) and the amplitude (speeds on deep-in-the money mortgages).[2]

Exhibit 4 is developed using this methodology to depict refi thresholds for new production, which show a dramatic drop over time. In 1998, the refi threshold was about 85 basis points; this is significantly lower than in 1991, when it was 65 bp. Our most recent data, from early 2004, show a continuing decline, to 40 basis points.

Finally, there has been a shift within the mortgage community, away from investors who don't hedge their convexity and toward those who do. Exhibit 5 breaks out ownership patterns of mortgage-backed securities at the end of several individual years, ranging from 1992 through 2003. Note that there has been a dramatic change in relative ownership, away from financial institutions and insurance companies (which do not generally hedge their convexity) to the Fannie Mae and Freddie Mac portfolios (government-sponsored entities, GSEs, which do hedge most of their convexity needs up-front).

Exhibit 5 shows that at the end of 1992, depository institutions owned 36.7% of the mortgage-related securities market (agency MBS + non-agency CMOs). By the end of 2003, depository institutions held only 24.0%. Similarly, over the 1992-2003 period, the insurance company share of the market has dropped from 17.6% to 10.1%. Freddie Mac's and Fannie Mae's portfolios have expanded from 1.5% to 29.3%.

This means that not only is the mortgage market larger in relation to other portions of the fixed-income market—but also a higher proportion of mortgage security investors need to hedge.

II. AND THE CONVEXITY HEDGERS ARE . . . ?

Our discussion suggests there are three distinct groups of convexity hedgers—investors, servicers, and mortgage

EXHIBIT 4

Refi Thresholds on New Production Decline with Time

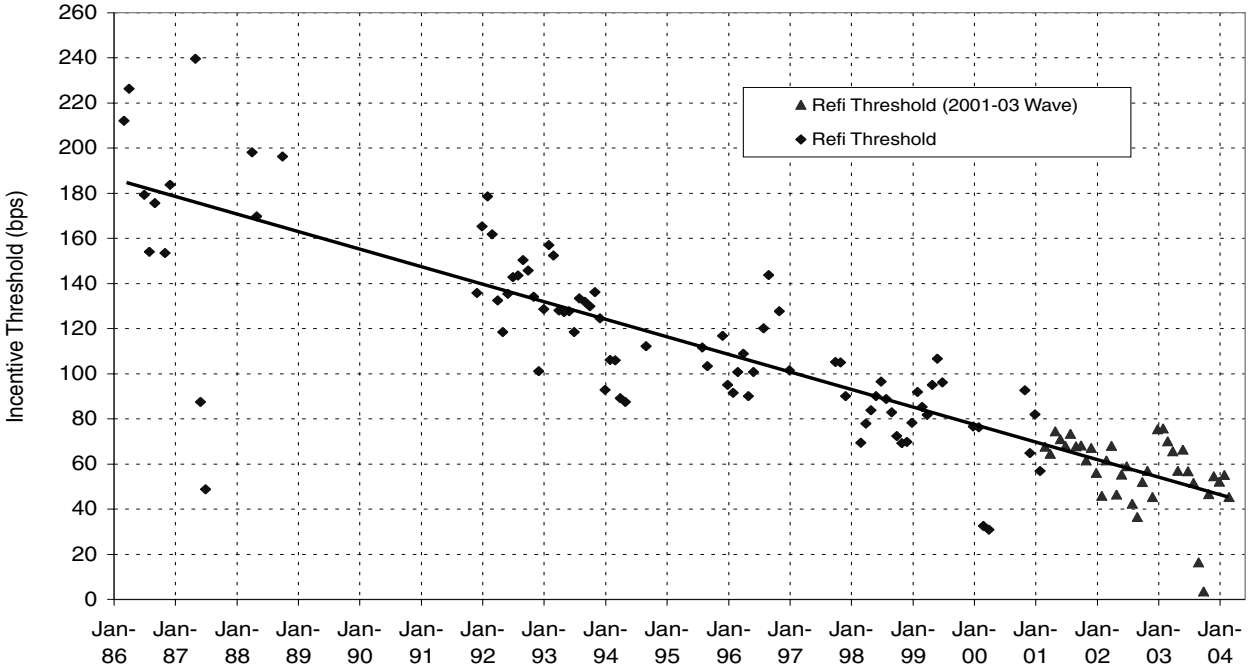


EXHIBIT 5

Mortgage-Related Security Holdings by Investor Type ($ billions)

	Year-End							
	1992		2000		2002		2003	
Investor Type	Amount	% of Tot	Amount	% of Tot	Amount	% of Tot	Amount	% of Tot
FDIC Insured Banks	$337.5	24.30%	$470.5	16.01%	$702.1	18.57%	$775.6	18.44%
All Thrifts	155.6	11.20	212.7	7.24	209.7	5.55	206.4	4.91
Federal Credit Unions	17.0	1.22	10.4	0.35	25.3	0.67	28.9	0.69
TOTAL DEPOSITORY	$510.1	36.72%	$693.6	23.60%	$937.1	24.78%	$1,010.9	24.03%
Finance Companies			$52.9	1.80%	$65.0	1.72%	$75.0	1.78%
FHLBanks	22.8	1.64%	81.2	2.76	96.4	2.55	98.9	2.35
Public Pension Funds	115.0	8.28	196.2	6.68	235.0	6.22	250.5	5.95
Priv. Pension Funds	58.0	4.18	112.5	3.83	121.0	3.20	118.5	2.82
Life Insurance Cos.	244.1	17.57	353.2	12.02	401.5	10.62	425.5	10.11
Mutual Funds	104.6	7.53	182.0	6.19	275.0	7.27	295.0	7.01
Private Individuals	32.0	2.30	174.0	5.92	47.7	1.26	135.0	3.21
REITs	16.9	1.22	10.7	0.36	17.0	0.45	30.0	0.71
Foreign Investors	130.0	9.36	164.0	5.58	207.0	5.47	223.0	5.30
MBS Dealer Inventory	70.7	5.09	37.3	1.27	35.0	0.93	32.0	0.76
FNMA/FHLMC Portfolio	20.6	1.48	783.8	26.67	1,109.4	29.34	1,232.5	29.30
DEPOSITORY & MAJOR INVESTORS	$1,324.8	95.37%	$2,841.4	96.69%	$3,547.1	93.81%	$3,926.8	93.34%
All Other Investors	$64.3	4.63%	$97.4	3.31%	$234.0	6.19%	$280.0	6.66%
TOTAL OUTSTANDING	$1,389.1	100.00%	$2,938.8	100.00%	$3,781.1	100.00%	$4,206.8	100.00%

Source: Mortgage Market Statistical Annual for 2002 and Inside MBS and ABS.

originators. We look at the motivations of each of these distinct groups of investors, and calculate their convexity needs at each time. We then sum up the needs of the three groups of participants, to explain the events of the summer of 2003.

Let's start with investors (it's relatively easy to figure out the duration and convexity of the mortgage market, but it requires more judgment to figure out what percent of this is hedged). We then assess the needs of servicers, and finally move on to originators.

Investors

The dollar convexity of the mortgage market is easily measured via aggregate indexes. Assume that on a particular day the mortgage market showed a duration of 3.05 years and a convexity of –1.91 (we select January 14, 2004). We then determine the price change for each interest rate change scenario as a function of the current price, the duration, and the convexity. We display this in the middle, boxed section of Exhibit 6, where we calculate duration and convexity of the mortgage market in +/– 50 basis point scenarios. We then translate this into ten-year equivalents, shown at the end of the table.

Thus, as of the January 14, 2004, date we selected, the mortgage index as a whole had a duration of 1,057 ten-year equivalents. If the market rallied 50 basis points at that point, it would drop $337 billion of ten-year equivalents, to reach a duration of $720 billion ten-year equivalents. If the market sold off 50 basis points, mortgage market duration would expand to $1,399 billion ten-year equivalents, for an increase of $342 billion ten-year equivalents. The bottom line of Exhibit 6 shows that the average change in ten-year equivalents for a 50 basis point shift in rates is $340 billion.

The raw duration and convexity numbers we use for this analysis are taken from the mortgage component of Citigroup's BIG (Broad Investment Grade) Index.[1] As we looked at our convexity numbers, we observed large changes resulting from 1) changes in the prepayment and term structure model used to compute the duration and convexity, and 2) changes in the volatility surface, which may or may not be hedged out and which are distracting to the analysis. Consequently, we smoothed the convexity relationship.

We do this by taking the average dollar price in the fixed rate agency MBS market from the mortgage component of Citigroup's BIG Index and, using the relationship between the dollar price of the mortgage market and historic convexity numbers, fitting a convexity relationship, as shown in Exhibit 7. The horizontal axis in the figure is the premium—that is, the differential between the average price of the mortgage market and par. Thus, if the market is at a 104 price, the premium is 4; if the price is 98, then the premium is –2. This smoothing makes the convexity numbers much more easy to understand.

Exhibits 8 and 9 show the duration and dollar con-

EXHIBIT 6

Calculating 10-Year Equivalents and Changes (50 basis point shift)

Index Characteristics on Particular Day

Face	Flat Px	Full Px	Dur	Cx	Date
2,668	102.34	103.27	3.05	-1.91	1/14/04

10yr Swap Yield	3.58	4.08	4.58	5.08	5.58
Yield shift	-1.00	-0.50	0.00	0.50	1.00
Start Px	102.34	102.34	102.34	102.34	102.34
Duration	3.12	1.56	0.00	-1.56	-3.12
Convexity	-0.98	-0.24	0.00	-0.24	-0.98
Term Px	104.48	103.65	102.34	100.53	98.24

		Mtg Px			Mtg			10yr Swap				
Center	Price Type	+50	base	-50	dur	cx	$dur	$dur	yld	HR	10yr Eq	Chg in 10yr Eq
-50	flat	104.48	103.65	102.34	2.07	-1.89	2.16	8.01	4.08	0.27	720	337
	full		104.59									
0	flat	103.65	102.34	100.53	3.05	-1.91	3.15	7.95	5.08	0.40	**1,057**	
	full		103.27									
+50	flat	102.34	100.53	98.24	4.08	-1.95	4.14	7.89	4.58	0.52	1,399	342
	full		101.47									
Average Change in 10-year Equivalents for 50 bps Shift >>>>>>>>>												340

vexity over time for the investor community, using weekly data beginning in March 2002. The duration numbers, shown in Exhibit 8, are expressed in ten-year equivalents, and the convexity numbers in Exhibit 9 are expressed in ten-year equivalents for a 50 basis point change in rates.

Let's focus on the experience during the summer of 2003. Note that in early June 2003 the duration of the mortgage market was less than $500 billion ten-year equivalents. By August 2003, it had risen to over $1300 billion ten-year equivalents.

Note also that in June 2003 at the lows in Treasury rates, the mortgage market showed a convexity measure of $174 billion ten-year equivalents for a 50 basis point change in rates. By July 2003, that number had doubled, to $340 billion. This makes perfect sense, as is reinforced by Exhibit 7. This exhibit confirms the generally known fact that the most negatively convex security in the mortgage market is the one priced just over 102. In June 2003, the average dollar price of the mortgage market was over 103.5. Just one month later, in July 2003, it was at 102.5.

What Percentage of Convexity is Hedged?

Obviously, not all changes in mortgage market duration need to be hedged. Financial institutions, which owned 24% of the mortgage market as of year-end 2003, do not generally hedge their portfolio purchases (although they do hedge their servicing). Total return mortgage investors benchmarked against the mortgage index need to hedge only their overweighted or underweighted portion, as the index itself shortens (or lengthens) as the market rallies (or sells off).

The investors most active in convexity hedging are the dealer community, the hedge funds, and the Freddie and Fannie portfolios. The dealer community, which delta-hedges (dynamically hedges) close to 100% of its purchases, represents quite a small group within this category, as it accounts for less than 1% of outstandings (although that relative share is not constant).

Exhibit 10 shows Federal Reserve data for net dealer positions in agency MBS. During the early part of summer 2003, the dealer community was as heavy as it had been at any time since 1998. Indeed, the shedding of long dealer positions in MBS that quickly unfolded during that summer clearly exacerbated the market's sell-off.

The Freddie and Fannie portfolios, which together account for 30% of mortgage market outstandings, do most of their hedging up-front, although they still need to do some delta hedging. Their financial statements indicate that the two agencies hedged 70%–75% of their fixed-rate outstandings with callable debt, swaptions, or options. Unfortunately, looking at the par amount of holdings tells us nothing about the amount of convexity that they have purchased through the callable debt, swaptions, or options markets versus the amount of convexity that they were short through their retained portfolio holdings. As a ballpark measure, it would be reasonable to assume that the agencies hedge 75% up-front, and 25% on a delta basis.

EXHIBIT 7
Investor % Convexity versus Premium

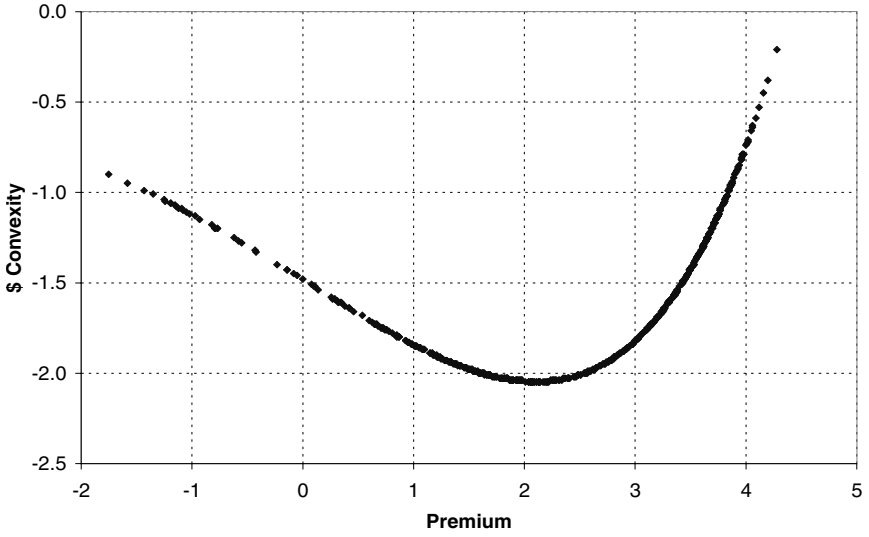
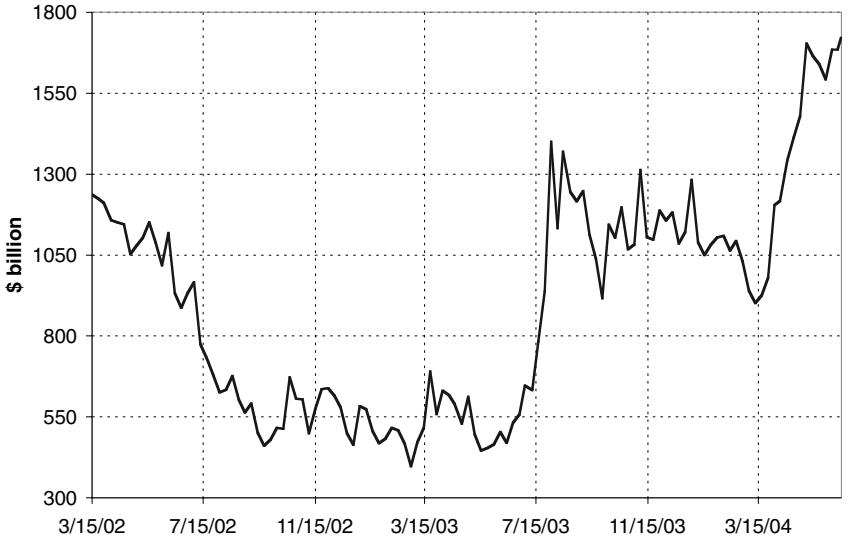


EXHIBIT 8
Investor Duration in 10-Year Equivalent (weekly)



For the purposes of our calculations, we assume that 15% of the convexity needs of mortgage investors are delta-hedged. This is based on the assumptions that dealer needs contributed 1%-2%, and the Fannie and Freddie portfolios combined contributed 7.5%, based on [30% share of the market) × (25% delta hedged)]. Other market participants may also have delta hedging needs. We assume that money managers are usually a bit overweighted, and may need to delta-hedge small amounts. Moreover, we have not taken into account the behavior of hedge funds, which generally do delta-hedge. In fact, assuming any constant number for delta hedging will be completely wrong.

It is quite clear that the amount of delta hedging changes over time, depending on the behavior of each of the participants and how active each is at any given time. Dealer and hedge fund activity is highly variable over time. GSE behavior can be as well; Fannie and Freddie are clearly willing to let their duration gaps swing within a range, but feel compelled to hedge outside that region. Money managers will be more overweighted when mortgages are cheap. For purposes of our analysis, we assume this delta hedging percentage is constant.

Servicers

To measure the hedging needs of servicers, we use the aggregate characteristics of the mortgage market, as shown in Exhibit 11. That is, we assume that the aggregate amount of servicing needing to be hedged is [aggregate WAC – aggregate CPN – 15 basis points]. That 15 basis points is a proxy for [guarantee fees + actual costs of servicing]. We then pick two interest-only instruments that could be combined to mirror the aggregate characteristics of the mortgage universe, and use them to calculate the duration and convexity of the servicing universe. The choice of IOs will change over time as the average coupon of the mortgage universe drops.

Let's walk through an example of our methodology. On December 31, 2003, the gross WAC of the mortgage market was 6.40, and the aggregate coupon was 5.88%—thus the amount of servicing was 37 basis points [6.40 – 5.88 – 0.15]. This servicing amount gets collected against an almost $2 billion balance. We then combine [(23% of a 5.5% Trust, FNS 329) + (77% of a 6% Trust, FNS 332)]. That combination provides a coupon of exactly 5.88% and a weighted average loan age of 21, which effectively mirrors the marketplace.

The duration and convexity of those two trusts, along with the weighted duration and convexity, are

EXHIBIT 9

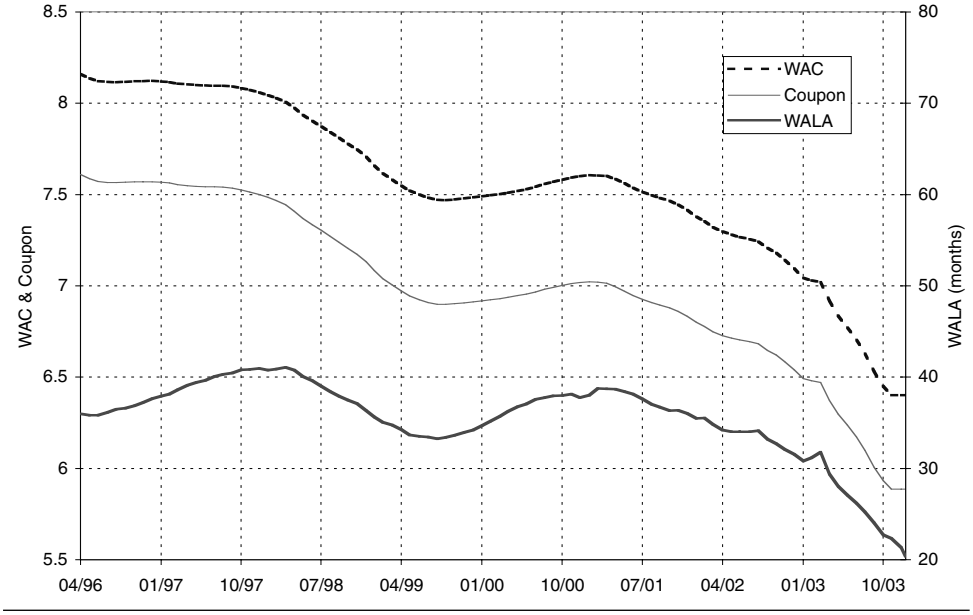
Investor 50bp $ Convexity in 10-Year (weekly)

EXHIBIT 10

Net Dealer Positions—Agency MBS

Source: The Federal Reserve.

EXHIBIT 11
Aggregate Characteristics—30-Year Fixed-Rate Agencies



shown in Exhibit 12. The price of each of the trusts, the multiplier (price/coupon), and the weighted multiple are also shown. The price of the servicing is [(37 basis points) × (weighted multiple)].

Measuring Servicer Convexity Needs

Exhibit 13 shows the duration of aggregate servicers' portfolios over time, and Exhibit 14 displays the percent convexity of aggregate servicing. The percent convexity is graphed against the average premium in the mortgage market.

Note that the convexity of the servicing portfolio is generally negative. Servicing reaches its most negatively convex point when the average premium in the mortgage market is around 102. When the servicing portfolio is very deep in the money, the dollar price of the servicing is very low, and cannot really drop more in value; it can only rise. In such circumstances, the convexity of the servicing will be positive. (It is clear from Exhibit 14 that at very high premiums, servicing will have positive convexity.) That was definitely the case in May and early June of 2003.

Obviously, approximating the duration and convexity of the servicing market by using only two IOs at any time is a computational simplification. The more accurate way would be to approximate each 15- and 30-year coupon cohort with an IO, and then to calculate the duration and convexity of each of those IOs. The problem is that a lot of IOs will not be priced. Our approach, while oversimplified, captures the highlights of the convexity needs of mortgage servicers.

One drawback is that, even at very low rate levels, servicers are not likely to actually behave as if they had positive convexity. Given the amount of new production that had been locked in (and not picked up via our methodology) plus the value of that servicing relative to outstandings, there will always be some servicing hedges in place. Thus, we placed a floor (> zero) on the convexity needs of mortgage servicers.

Exhibit 15 shows the convexity impact of servicers for a 50 basis point change in rates. Again, note that in May and early June of 2003, when interest rates were very low, the convexity needs of this group were light. Servicers' convexity needs expanded sharply when interest rates rose in July and August of 2003.

Thus far we have assumed that servicers are hedging 100% of their convexity needs. This overestimates what really happens, for three reasons: 1) Some excess servicing has been securitized, thus removing it from the servicer's books; 2) not all servicing that is on a servicer's books will be hedged; and 3) OAS durations may overstate the negative duration of the mortgage market.

Consequently, we arbitrarily use 60% of the convexity needs of servicers as a proxy in calculating the servicer contribution to the aggregate convexity needs of convexity hedgers.

Originator Behavior

The third and final group of market participants consists of originators. During the summer of 2003, there was no question that this particular group was the most instrumental in moving the mortgage market. Mortgage applications were high to begin with, necessitating a considerable amount of selling. As the Treasury, mortgage, and swap markets sold off, the percent of applications expected to close shot sky high, necessitating considerably greater selling, and driving the market far lower than otherwise might have been the case.

EXHIBIT 12

Composite Servicing—Estimating Attributes

Aggregate Balance ($ billions)				1,919
Price of Servicing [(6.40-5.88-15bp)*3.30]				1.21
Value of Servicing ($ billions)				23.17
	Agg #	FNS329	FNS322	WtgAvg
Weight		23%	77%	
Coupon	5.88	5.50	6.00	5.88
WAC	6.40	6.01	6.55	6.43
WALA	21	14	23	21
Price		23-06	18-05	
Multiplier*		4.22	3.03	3.30
Duration		-37.03	-49.31	-46.48
Cx		-35.87	-31.14	-32.23

Note: As of 12/31/03. # 30yr FN/FH/G1/G2. * Price/Coupon

EXHIBIT 13

Servicer Duration in 10-Year Equivalents (weekly)

EXHIBIT 14

Servicer % Convexity versus Premium

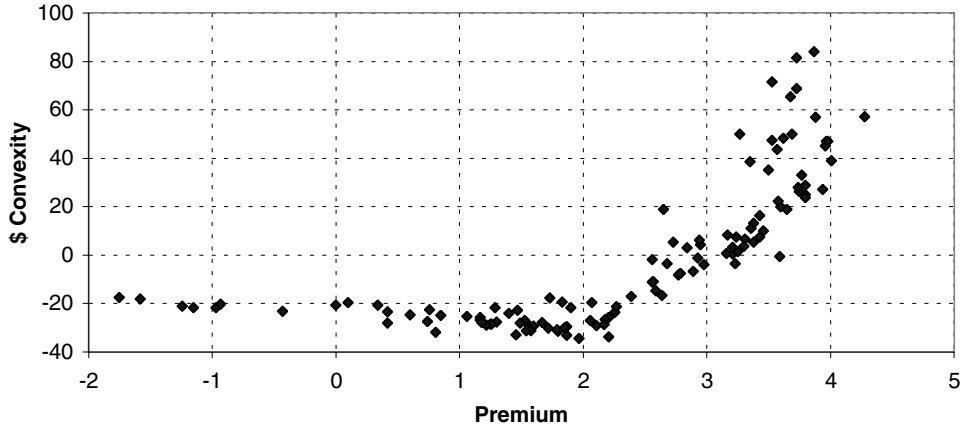


EXHIBIT 15

Servicer 50bp $ Convexity in 10-Year (weekly)

But in order to model the behavior of originators, we must first model fallout. That is, as the market rallies, applications in the queue are less apt to close, as borrowers can find more favorable rates away from the mortgage source they are dealing with at one time. And, as the market sells off, applications in the queue are more likely to close, as the rates locked in are far more favorable than what would then be obtainable from other lenders.

To model fallout, we use data provided by Countrywide, one of the largest mortgage originators. On a monthly basis, Countrywide releases information on the dollar volume of applications submitted and the dollar volume that has closed. Note in Exhibit 16 that in December 2003, $29.48 billion of mortgage applications were submitted (equivalent to $1.34 billion per business day), while $25.15 billion were funded, for an 85% funding rate (ergo 15% fallout).

We also show the monthly average Freddie Mac survey rate and the three-month moving average survey rate. The difference between the three-month average survey rate and the one-month average survey rate generates a short-term rate attractiveness variable. This rate attractiveness is used to measure fallout. The fit of the regression that measures the percentage of mortgage applications that will eventually be funded is shown in Exhibit 17 (the fitted values are shown in the last column of Exhibit 16).

Note that the regression has a reasonable 55% R-squared. And even more important, the numbers are intuitive. For each application submitted (given zero rate attractiveness of rates on top of three-month averages), the likelihood of closing is 78%. If rates rally and hence rate attractiveness rises to +20 basis points, the likelihood of closing declines to 63%. If rates rise and rate attractiveness falls to –20 basis points, the likelihood of closing rises to 94%.

To model the hedging needs of mortgage originators, we begin by looking at the MBA fixed-rate composite [refis + purchase] index. We scale this to actual fixed-rate agency securities production, on the assumption that if rate attractiveness is zero, then 78% of applications will close. Thus, Exhibit 18 shows our estimate of the number of fixed-rate agency applications. We also show the amount that must be hedged, depending on expected fallout.

Fixed-rate agency securities, from which we have benchmarked production, constitute roughly half of the mortgage market. The other half consists of unsecuritized agency fixed-rate paper, conforming-sized hybrids, jumbo mortgages (both fixed and hybrids), and subprime mortgages. Thus, we multiply the hedging needs of mortgage originators for their agency origination, as derived from the estimation procedure in Exhibit 18, by two, in order to obtain the aggregate hedging needs of mortgage originators.

III. LESSON—FROM THE SUMMER OF 2003

Exhibit 19 shows the needs of each group of market participants, scaled to reflect our estimation of the amount of duration to be made up by each group as the market moves. (That is, [15% of the convexity needs of investors + 60% of our servicer estimate + 200% of our grossly understated originator estimate].)

Note that in June and July 2003, servicers had very light hedging requirements. In early June, the needs of the investor community were also fairly light. It is quite clear it is the originator group that was driving the original leg of the sell-off. By August 2003, however, investors were by far the most significant force; they were far more important than originators, as the refi index was fairly low.

Exhibit 20 shows the aggregate ex ante convexity needs of the market as a whole, which we compile by adding the convexity needs of each of the three market participants we have identified. It is clear that mortgage market convexity needs were relatively high last July (2003), much higher than in mid-2004 at the time of this writing. We refer to the aggregate ex ante convexity needs of the market as a whole as the *mortgage misery index*.

Exhibit 21 summarizes the convexity needs of our three convexity hedging groups separately, as well as adding them up to show the total ex ante convexity needs of the

EXHIBIT 16

Countrywide's Experience with Loan Applications and Fundings

Date	Days	Avg App	Apps	Funded	Survey	3moAvg	RA**	% *	Fit
08/01	23	0.753	17.319	11.717	6.97				
09/01	19	0.888	16.872	10.385	6.82				
10/01	23	1.144	26.312	14.837	6.62	6.80	-0.18	56%	65%
11/01	21	1.232	25.872	17.054	6.66	6.70	-0.04	66%	75%
12/01	20	0.797	15.940	17.550	7.07	6.78	0.28	110%	100%
01/02	21	0.947	19.887	14.838	7.00	6.91	0.09	75%	85%
02/02	19	1.053	20.007	13.991	6.90	6.99	-0.09	70%	72%
03/02	21	0.851	17.871	15.204	7.00	6.97	0.04	85%	81%
04/02	22	0.845	18.590	14.111	6.99	6.96	0.02	76%	80%
05/02	22	0.878	19.316	13.661	6.82	6.94	-0.11	71%	70%
06/02	20	1.070	21.400	14.358	6.65	6.82	-0.17	67%	66%
07/02	22	1.366	30.052	17.124	6.49	6.65	-0.17	57%	66%
08/02	22	1.695	37.290	21.190	6.29	6.48	-0.19	57%	64%
09/02	20	2.060	41.200	25.320	6.09	6.29	-0.20	61%	64%
10/02	23	1.960	45.080	34.660	6.11	6.17	-0.05	77%	75%
11/02	20	2.200	44.000	32.210	6.07	6.09	-0.02	73%	77%
12/02	21	1.870	39.270	35.200	6.05	6.08	-0.03	90%	76%
01/03	21	2.000	42.000	33.700	5.92	6.01	-0.09	80%	71%
02/03	19	2.190	41.610	30.900	5.84	5.94	-0.09	74%	71%
03/03	21	2.690	56.490	37.900	5.75	5.83	-0.09	67%	72%
04/03	22	2.290	50.380	42.250	5.81	5.80	0.01	84%	79%
05/03	21	3.190	66.990	39.500	5.48	5.68	-0.20	59%	64%
06/03	21	3.240	68.040	48.440	5.23	5.51	-0.28	71%	57%
07/03	22	2.530	55.660	51.840	5.63	5.45	0.18	93%	93%
08/03	21	1.810	38.010	40.980	6.26	5.71	0.56	108%	110%
09/03	21	1.860	39.060	33.100	6.15	6.01	0.13	85%	89%
10/03	23	1.560	35.880	28.970	5.95	6.12	-0.17	81%	66%
11/03	19	1.480	28.120	22.200	5.93	6.01	-0.08	79%	73%
12/03	22	1.340	**29.480**	25.150	5.88	5.92	-0.04	85%	75%

* % of Apps Funded (Funded/Apps).

** Rate Attractiveness.

market. The exhibit also displays the yield on the ten-year note, and the average premium prevailing in the mortgage market. Note that the convexity needs are expressed in billions of ten-year equivalents. The weekly table starts in April 2003, allowing us to focus on the events during summer 2003.

Note that in late May 2003, the convexity needs of originators dominated all other transactors. Specifically, on May 30, 2003 (marked by an arrow in Exhibit 21), the mortgage misery index was at 106, with 70 of that attributed to originators. (That is, for a 50 bp change in rates, all convexity hedgers together would need to make up (buy or sell) $106 billion ten-year equivalents; originators alone would need to "make-up" $70 billion of that.) This is not surprising; mortgage rates were near generational lows, and this was fully reflected in mortgage activity. The MBA Refi Index was close to a record high of 10,000, and the MBA composite index also close to a record high.

At that point, with the ten-year note at 3.35% and the average price of MBS at 103.69, the needs of investors and servicers were modest. When prices in the Treasury market began to back up in mid-June 2003, however (from Fed statements indicating that the market had misinterpreted the Fed's intent), the originators' hedging needs rose dramatically. This low in rates was reached on June 13. By June 20 (marked by another arrow in Exhibit 21), with the ten-year note hovering at the 3.40 level and the MBA Index down to the 9000 area, borrowers were quickly locking in their mortgages. With the rate backup, the percentage of applications that was expected to close was very high (Exhibit 17), and hence originators were forced to sell forward a considerably higher percentage of applications than they otherwise would have. Thus, our mortgage misery index reached 115, and the originator component rose to 77.

As the market continued to back up, the convexity needs of originators tapered off. By late July, most borrowers who were able to lock had done so, and new application volume was lighter at higher rates. Thus, by the time the ten-year note hit 4.18 on July 25, 2003 (another arrow in Exhibit 21), originators' convexity needs contracted from $77 billion ten-year equivalents for each 50 basis point change in rates to $47 billion.

Meanwhile, between June 20, 2003, and July 25, 2003, the convexity needs of investors and servicers had

EXHIBIT 17
Percent Funded as a Function of Rate Attractiveness

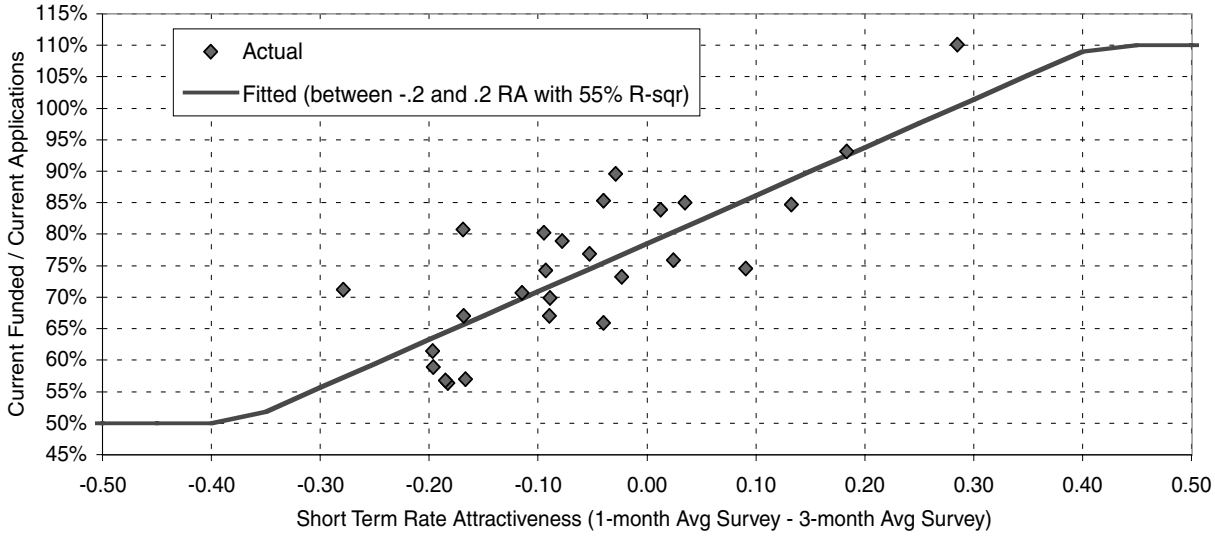
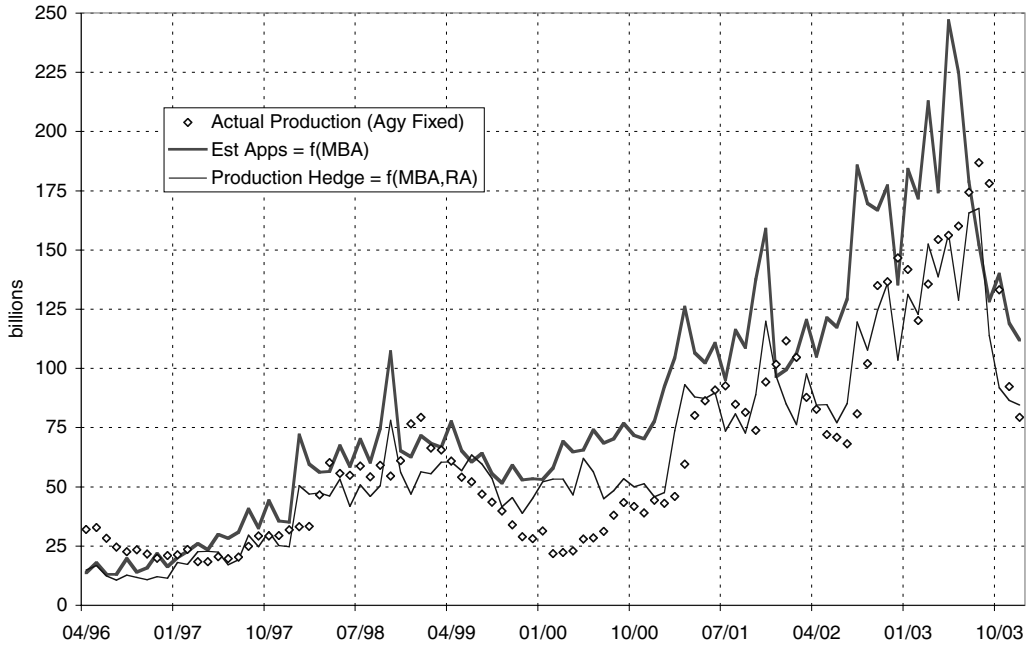


EXHIBIT 18
Applications as a Function of MBA Index



grown dramatically—by $25 billion ten-year equivalents. This reflected the increased negative convexity of the market, with the average dollar price of MBS moving from 103.62 to 102.56. And rates were really rising rapidly, necessitating quick action. Thus, by late July, it was the investors and servicers who were selling heavily (in an attempt to rebalance duration), thus driving Treasury and swap rates higher.

At this point, the convexity needs of investors (52) were greater than those of the originators (47). In mid-August (August 14 in Exhibit 21, marked by an arrow) the ten-year, at 4.58%, had way overshot, and rates started to decline. And those rates dropped quickly, necessitating heavy investor buying. That wave of buying was finished by September 2003, when the ten-year note hit 4.02%.

EXHIBIT 19
Component Convexity Needs (weekly)

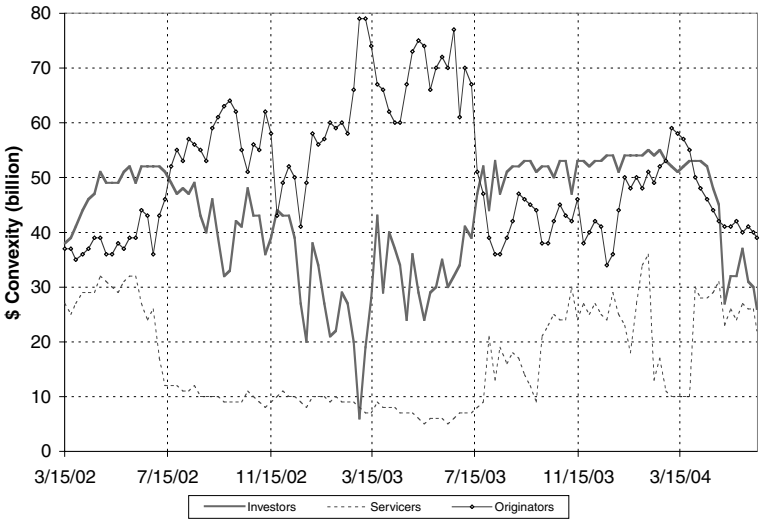
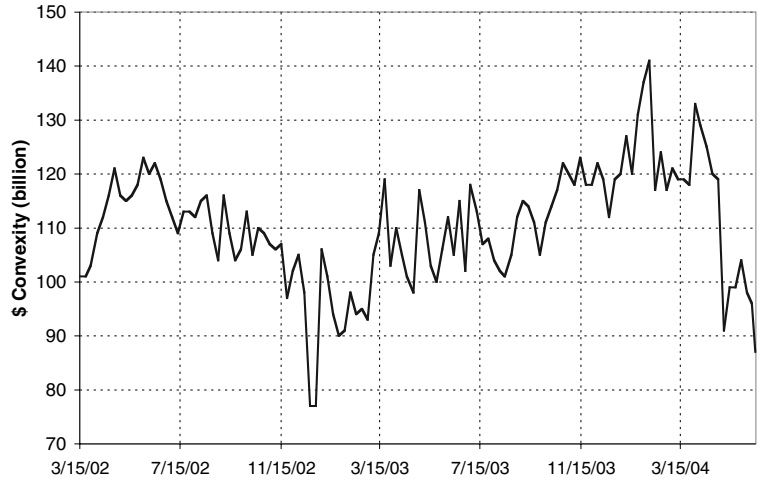


EXHIBIT 20
Mortgage Misery Index (weekly)



IV. BOTTOM LINE

During the summer of 2003, it was the originators who experienced the first bout of convexity needs, and this group was responsible for moving the market from 3.10% to 4.00% far more quickly than would have otherwise been the case. As the market sold off, originators' needs slackened, but the convexity requirements of mortgage investors and servicers expanded. Thus, it was these latter participants who were largely responsible for taking the ten-year from around 4.00% up to 4.60%. When the market reversed, they had to buy, thus aiding and abetting the rally.

Let us look at the implications of this analysis in a higher rate environment. Exhibit 21 shows that as rates rose dramatically in the April-June 2004 period, the convexity needs of mortgage market participants dropped off dramatically. This reflects the fact that the hedging needs of servicers and investors are highest when the market is at its most negatively convex point—that is, when the average dollar price in the market is at the 102.0-102.5 level. By mid-June 2004, the average dollar price (the premium in Exhibit 21 less par) in the market had fallen to $98.25. The rise in rates clearly curbs the hedging activity of investors and servicers. Meanwhile, originator hedging is also very subdued, as mortgage applications plummeted. As interest rates continue to rise, we should see convexity needs taper off even more.

V. CAVEATS

Do realize that: Ex ante needs are unequal to ex post needs. Convexity needs ex ante will not necessarily coincide with the actual impact of convexity hedgers. Those ex ante levels theoretically measure how much convexity hedging will be needed for a 50 basis point change in rates. If the market does not move, however, a high mortgage misery index may not have any implications for the market. If the market moves considerably within a short period of time, then even a lower mortgage misery index may have quite a large impact.

To make this point more concretely, note that by our measurements, July 2003 was not the peak in ex ante convexity needs. Such needs were considerably higher in January 2004 than in July 2003. This reflects the fact that convexity needs from investors were extraordinarily high in January 2004, as the average dollar price of the mortgage market hovered just over 102. Yet the market did not move to any considerable degree during this period, so the high ex ante convexity needs of the market were never realized.

VI. SUMMARY

One of the major benefits of our analysis is that it gives market participants an idea of who the actual convexity hedgers are at each time, and what their ex ante convexity hedging needs will be. While some of the underlying assumptions are arbitrary (i.e., that 15% of the

EXHIBIT 21

Component Convexity Needs (weekly)

Date	Misery	Inv	Serv	Orig	T10	Premium
6/14/04	87	26	22	39	4.87	-1.75
6/10/04	96	30	26	40	4.79	-1.24
6/4/04	98	31	26	41	4.78	-1.15
5/28/04	104	37	27	40	4.65	-0.43
5/21/04	99	32	24	42	4.76	-0.93
5/14/04	99	32	26	41	4.79	-0.97
5/7/04	91	27	23	41	4.77	-1.58
4/30/04	119	45	31	42	4.50	0.42
4/23/04	120	48	29	44	4.45	0.74
4/16/04	124	52	28	44	4.35	1.18
4/8/04	129	53	28	48	4.20	1.54
4/2/04	133	53	30	50	4.14	1.46
3/26/04	118	53	10	55	3.84	2.56
3/19/04	119	52	10	57	3.79	2.68
3/12/04	119	51	10	58	3.76	2.73
3/5/04	121	52	10	59	3.83	2.65
2/27/04	117	53	11	53	3.98	2.59
2/20/04	124	55	17	52	4.10	2.27
2/13/04	117	54	13	49	4.05	2.39
2/6/04	141	55	36	51	4.09	1.98
1/30/04	137	54	34	48	4.14	2.14
1/23/04	131	54	27	50	4.07	2.21
1/16/04	120	54	18	48	4.01	2.26
1/9/04	127	54	23	50	4.09	2.17
1/2/04	120	51	25	44	4.37	1.17
12/26/03	119	54	29	36	4.15	1.97
12/19/03	112	54	24	34	4.13	2.11
12/12/03	119	53	25	41	4.25	1.67
12/5/03	122	53	27	42	4.21	1.58
11/28/03	118	52	25	40	4.33	1.49
11/21/03	118	53	27	38	4.14	1.87
11/14/03	123	53	24	46	4.23	1.85
11/7/03	118	47	30	42	4.45	0.81
10/31/03	120	53	24	43	4.30	1.79
10/24/03	122	53	24	45	4.21	1.80
10/17/03	117	50	25	42	4.39	1.22
10/10/03	114	52	23	38	4.25	1.72
10/3/03	111	52	21	38	4.19	1.53
9/26/03	**105**	**51**	**9**	**44**	**4.02**	**2.64**
9/19/03	111	53	12	45	4.16	2.07
9/12/03	114	53	14	46	4.27	1.90
9/5/03	115	52	17	47	4.35	1.40
8/29/03	112	52	18	42	4.45	1.47
8/22/03	105	51	16	39	4.47	1.29
8/14/03	**101**	**47**	**19**	**36**	**4.58**	**0.76**
8/8/03	102	53	13	36	4.29	1.83
8/1/03	104	44	21	39	4.42	0.42
7/25/03	**108**	**52**	**9**	**47**	**4.18**	**2.56**
7/18/03	107	47	8	51	3.97	2.94
7/11/03	113	39	7	67	3.64	3.35
7/3/03	118	41	7	70	3.65	3.27
6/27/03	102	34	7	61	3.56	3.57
6/20/03	**115**	**32**	**6**	**77**	**3.40**	**3.62**
6/13/03	105	30	5	70	3.10	3.68
6/6/03	112	35	6	72	3.35	3.53
5/30/03	**106**	**30**	**6**	**70**	**3.35**	**3.69**
5/23/03	100	29	6	66	3.33	3.73
5/16/03	103	24	5	74	3.46	3.87
5/9/03	111	29	6	75	3.69	3.73
5/2/03	117	36	7	73	3.91	3.53
4/25/03	98	24	7	67	3.89	3.88
4/17/03	101	34	7	60	3.96	3.58

negative convexity of the mortgage is actually made up by investors), we believe the methodology is robust and has a considerable amount of explanatory power.

Clearly, the realized ex post convexity needs (which will be the actual impact of convexity hedgers) will depend on ex ante convexity needs and how quickly the market moves. Once interest rates begin to move quickly, a high mortgage misery index (or, equivalently, high convexity hedging need) means that interest rates will move further, faster, and sooner than would otherwise be the case. And that's clearly of interest to the overall fixed-income market.

ENDNOTES

[1]Originated in the 1980s as the Salomon Brothers Broad Investment Grade Bond Index.

[2]A display of the percent of a cohort refinancing (on an annualized basis) versus the incentive to refinance. The S-shape reflects the fact that when there is no incentive or a negative incentive to refinance, refinancing activity is extremely light. For positive incentives, refinancing activity ramps up quickly. At some (high) positive incentive, refinancing activity is so high that it does not go considerably higher as the incentive increases.

REFERENCES

Boyd, Glenn. "The Next RefinancingWave—To Infinity & Beyond?" UBS *Mortgage Strategist*, October 14, 2001, pp. 4-12.

Goodman, Laurie S., and Jeffrey Ho. "Mortgage Hedging & Volatility—The Fed Study Demystified." UBS *Mortgage Strategist*, October 7, 2003, pp. 11-20.

Perli, Roberto, and Brian Sack. "Does Mortgage Hedging Amplify Movements in Long-Term Interest Rates?" *The Journal of Fixed Income*, December 2003, pp. 7-17.

To order reprints of this article, please contact Ajani Malik at amalik@iijournals.com or 212-224-3205.