BEYOND DURATION: RISK DIMENSIONS OF MORTGAGE SECURITIES

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As perhaps their primary responsibility, fixed-income managers control the durations of their portfolios. In doing so, they govern the portfolio's exposure to interest rate movements, relative to the applicable liabilities or performance benchmarks. Option-adjusted spread (OAS) models measure this exposure, called the effective duration, for securities with embedded options, such as callable corporate bonds and mortgage securities.

Investors also face the daunting task of managing the vulnerability of their portfolios to several other major risks, including potential shifts in credit quality, rate volatility, prepayment speed, yield curve shape, and yield spreads. Quantitative tools for measuring these other risks are not as well developed or commonly applied as the effective duration.

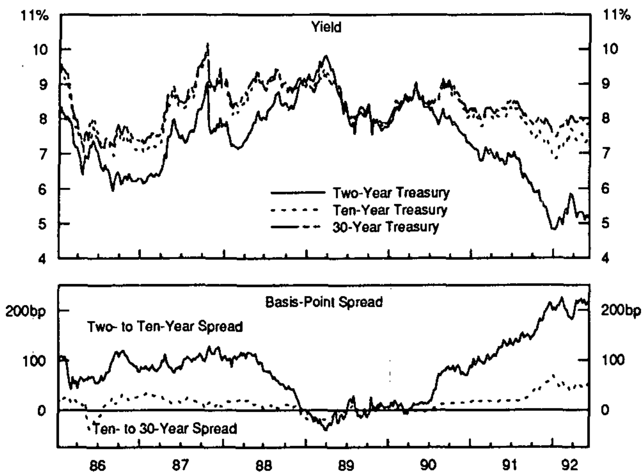
In this article we describe techniques that can help investors to quantify and manage a portfolio's exposure on these other risk dimensions, with a particular emphasis on yield curve exposure. We illustrate these methods using mortgage securities, but for the most part they apply to any fixed-income security.

YIELD CURVE RISK

Over the past three years, thirty-year Treasury yields have been relatively unchanged, while ten- and two-year Treasury yields have fallen by about 100 basis points and 300 basis points, respectively (see Exhibit 1). This radical shift in the shape of the yield curve — from flat to unprecedentedly steep — has overshadowed the changes in intermediate- and long-term interest rates during the period.

Consequently, yield curve effects have had a critical impact on investment results. Bullet versus bar-

EXHIBIT 1 ■ Changes in the Treasury Yield Curve, January 1986-June 1992



bell strategies, yield curve rolldown, and inverse floater strategies all have posted substantial gains. Yield curve steepening also has aided mortgage investment strategies by contributing significantly to a tightening in mortgage/Treasury spreads.

The prospect for a reversal of the previous trend — with a sizable flattening of the yield curve over the next few years — suggests that yield curve reshaping tactics will remain critical.

In Exhibit 2, we show one-year rolling volatility for the two- to ten-year and ten- to thirty-year Treasury yield spreads. Since 1986, the volatility of the two- to ten-year spread has ranged from 43 basis points to 79 basis points; it currently stands at an appreciable 58 basis points. The ten- to thirty-year spread has been more stable, with a latest volatility value of 32 basis points.

EXHIBIT 2 ■ One-Year Volatility of Treasury Yield Curve Spreads, January 1986-June 1992

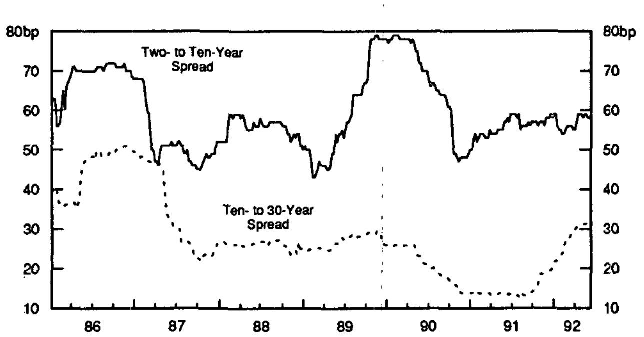
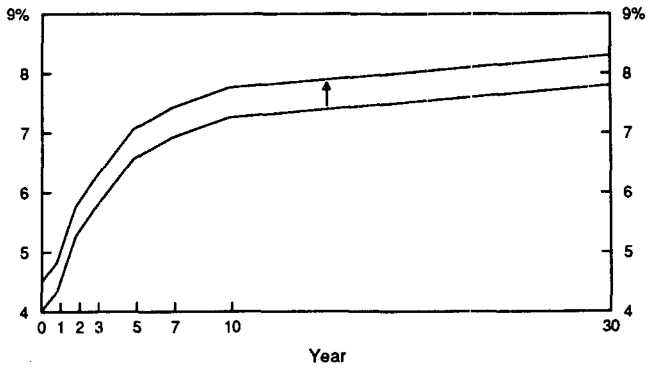


EXHIBIT 3 ■ Effective Duration — Percentage Price Change for Parallel Yield Curve Shifts



THE PARTIAL DURATION CONCEPT

When we introduced our OAS models for mortgage securities and corporate bonds in the mid-1980s, effective duration of a security was defined as its percentage price change per 100-basis point movement in interest rates.[1] The calculation is performed by computing the price change assuming a constant OAS for a small parallel shift of the Treasury yield curve (see Exhibit 3).

The effective duration as a measure of a security's sensitivity to changes in the overall level of rates has served well as a general portfolio management tool. It does not provide any information about a security's sensitivity to changes in the shape of the yield curve, however.

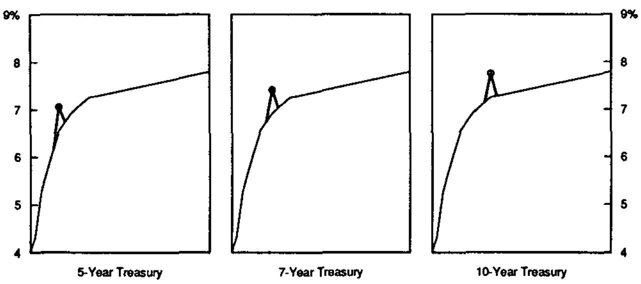
To address this issue, we can define a series of "partial durations" relative to specific yield curve points. The partial duration is the percentage price response per 100-basis point movement in a particular Treasury rate, while the rest of the yield curve remains fixed.

When applying this concept, we choose a particular set of key Treasury maturities, for example, the eight on-the-run issues shown in Exhibit 4. To calculate the partial duration relative to the five-year maturity, for instance, we move the five-year rate a small

EXHIBIT 4 ■ Key Treasury Maturities

• Three Months	• Five Years
• One Year	• Seven Years
• Two Years	• Ten Years
• Three Years	• Thirty Years

EXHIBIT 5 ■ Partial Duration — Percentage Price Change for Move in Specific Yield Curve Point



amount, while keeping the other key rates unchanged. The interest rates for maturities between the five-year point and the adjacent three- and seven-year key issues move by interpolated amounts (see Exhibit 5). Then, we recompute the price of the security given this revised yield curve. The percentage price change per 100-basis point movement in the five-year rate is its partial duration.

Under this approach, the rate movements that we use to calculate partial durations of the eight key points together form a parallel yield curve shift. Consequently, the eight partial durations will sum to a value that is close to the overall duration.

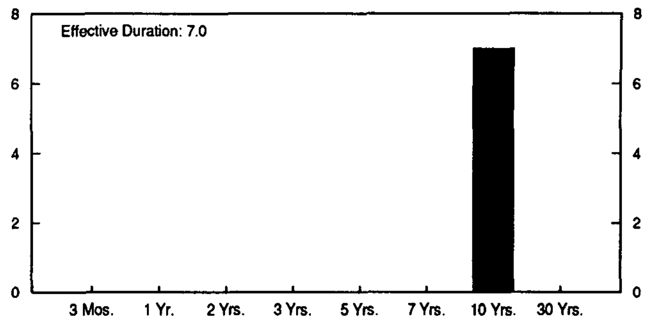
Although we have chosen eight key interest rates to partition shifts in the Treasury curve, the number selected is arbitrary. We could have chosen fewer or more points. We also should emphasize that we have chosen to measure price sensitivity relative to changes in current "par" Treasury rates.[2]

Just as for the overall duration, we can measure the partial durations on a "nominal" or "effective" basis. The former calculation assumes that the security's base case cash flows are fixed — that is, it ignores the impact of any option features. For the latter approach, we allow the full variability of cash flows and apply an OAS model. We describe these measures as the "nominal partial durations" and the "effective partial durations."

Ten-Year Non-Callable Bond

Exhibit 6 illustrates a simple case — a ten-year bullet bond priced at par. Because the bond is non-callable, its cash flows are fixed, and the nominal and effective durations are the same, 7.0 years. Furthermore, all of the rate sensitivity of the bond is concentrated at the ten-year point. Thus, the partial duration

EXHIBIT 6 ■ Partial Durations — Ten-Year Non-Callable Bond



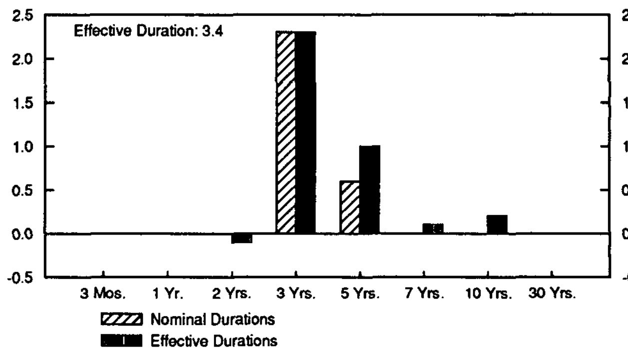
relative to the ten-year rate is 7.0 years, and all other partial durations are zero.

Three-Year PAC

The closest relative to the non-callable bond in the mortgage market is the Planned Amortization Class (PAC). An example is the three-year PAC whose risk profile is shown in Exhibit 7. The cash flows of a PAC are fixed if prepayment rates on the collateral fall within a certain range. Expected prepayment rates for this particular security are well within the PAC range so that the likelihood is high that the PAC schedule will be followed.

Exhibit 7 illustrates both the nominal and effective partial durations of the PAC. The nominal partial durations derive from the maturities of the PAC schedule. Because these occur within a three- to four-year window, the nominal partial durations are concentrated in the three- and five-year rates.

EXHIBIT 7 ■ Partial Durations — Three-Year PAC (FHLMC 1260C)



The impact of potential departures from the PAC schedule, loosely described as "option effects," is captured by the effective partial durations. They display modest additional exposure to the five-, seven-, and ten-year rates and small negative exposure to the two-year rate. This means that under constant OAS, a rise in the five- or seven-year rate, for instance, will produce a decrease in the price of the PAC, while a rise in the two-year rate will result in an increase in price.

We can understand these partial durations by realizing that the primary exposure for a short PAC, beyond that of the PAC schedule, is extension risk — that the bond will extend under slowing prepayment rates at the same time that interest rates rise. Under these circumstances, the price of the security will fall more than suggested by the PAC schedule.

Interest rate movements that mirror the partial duration pattern of Exhibit 7 will produce just this result. Within our OAS model, fixed mortgage rates are associated with the seven-year Treasury rate. Thus, rising seven-year rates will lead to higher mortgage rates and, consequently, slower prepayments. If, at the same time, short Treasury rates fall and ten-year rates rise, the steeper yield curve will imply higher forward seven-year rates. This results in higher forward mortgage rates and a slower average distribution of prepayment rates within the OAS model.

Pass-Through

The nominal partial durations of FHLMC Gold 7½s, shown in Exhibit 8, essentially line up with the pass-through's projected base case cash flows. As with the three-year PAC, the effective partial durations indicate a small additional exposure to yield curve steepening. Such steepening implies higher forward rates, slower prepayments, and, hence, a longer average life. Given a positively sloped yield curve, this leads to a small reduction in value.

Interest-Only STRIP

While the yield curve exposure of the short PAC and pass-through have some modest prepayment-related effects, these effects predominate for interest-only (IO) and principal-only (PO) STRIPs.

We show the partial durations of FNMA Trust 4 9½% IOs in Exhibit 9. This security has positive partial durations for Treasury rates of five years or less and strong negative partial durations for the longer-term rates. In other words, the IO STRIP has a substantial exposure to a flatter yield curve.

The positive partial durations from one to five years are consistent with the IO's relatively short base case cash flows. Given recent refinancing activity, we project a four-year average life for this security.

The leveraged effect of shifting prepayments, however, has the most significant impact on the IO's risk profile. The greatest risk for an IO investment is fast prepayments, which erode the interest payments from the collateral. If seven-year Treasury rates fall, the associated decline in mortgage rates will accelerate prepayments and, thus, reduce the value of the IO. If, in addition, ten-year rates fall while short-term rates rise, the flatter yield curve will imply lower forward seven-year rates. This, in turn, produces lower forward mortgage rates and a faster distribution of prepayment rates in our OAS model, again reducing the value of the IO.

EXHIBIT 8 ■ Partial Durations — Pass-Through (FHLMC Gold 7½s)

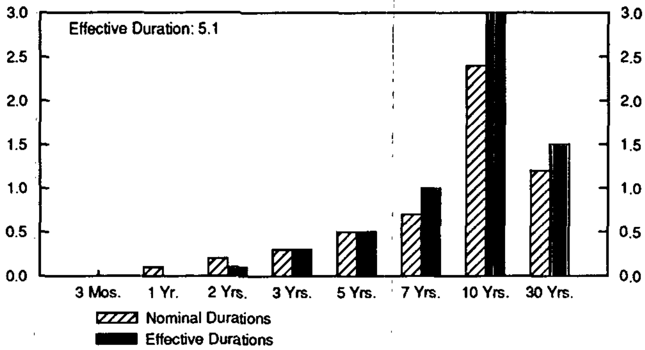


EXHIBIT 9 ■ Partial Durations — Interest-Only STRIP (FNMA Trust 4 IO)

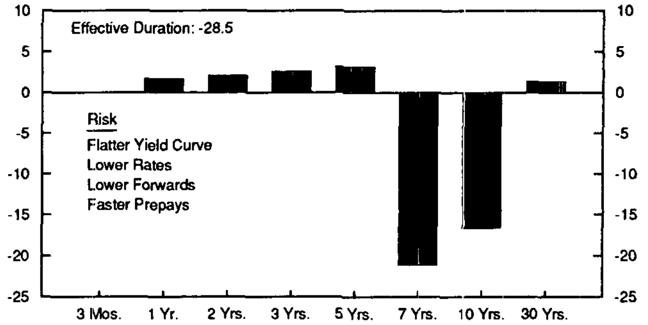


EXHIBIT 10 ■ Partial Durations — Principal-Only STRIP (FNMA Trust 4 PO)

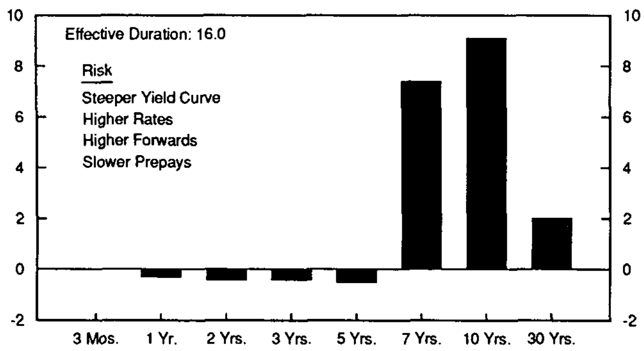
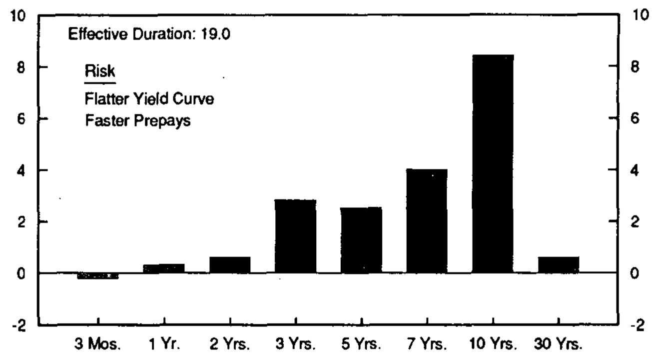


EXHIBIT 12 ■ Partial Durations — LIBOR Inverse Floater (FNMA 1992-32SA)



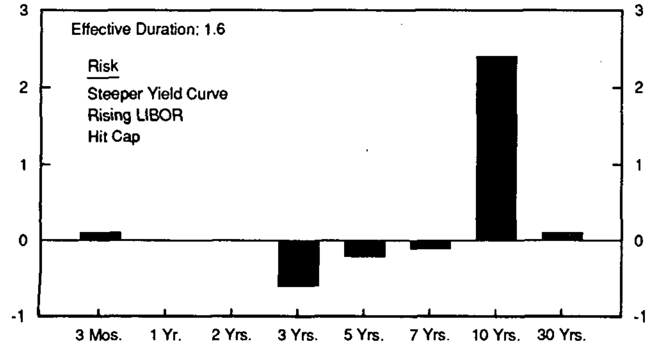
Principal-Only STRIP

The partial durations of POs display the opposite pattern from that of IOs — POs are exposed to a steepening yield curve. In particular, rising seven-year Treasury rates will imply higher mortgage rates and slower prepayments. Furthermore, a steeper curve produced by rising long-term rates and falling short-term rates will imply higher forward seven-year rates. This, in turn, produces higher forward mortgage rates and, hence, slower forward prepayments (see Exhibit 10).

LIBOR Floater and Inverse Floater

The primary market risk for a LIBOR floater comes from its rate ceiling. If LIBOR rises to levels high enough to reach the ceiling, the bond's coupon will be fixed, and the price of the bond will fall under subsequent rate increases like that of a fixed-rate mortgage security. Such a LIBOR rise can be associated with a steepening yield curve, as indicated by the partial duration pattern in Exhibit 11. A steeper curve implies higher forward LIBOR rates and, thus, a greater risk of reaching the ceiling.

EXHIBIT 11 ■ Partial Durations — LIBOR Floater (FNMA 1992-32FA)



While the floating-rate coupon of a floater minimizes its vulnerability to rate movements, the coupon adjustments on an inverse floater accentuate the effect of rate movements. As a result, the partial durations of the inverse floater form a pattern similar to that of a pass-through, with exposures all along the yield curve (see Exhibit 12).

YIELD CURVE RESHAPING DURATIONS

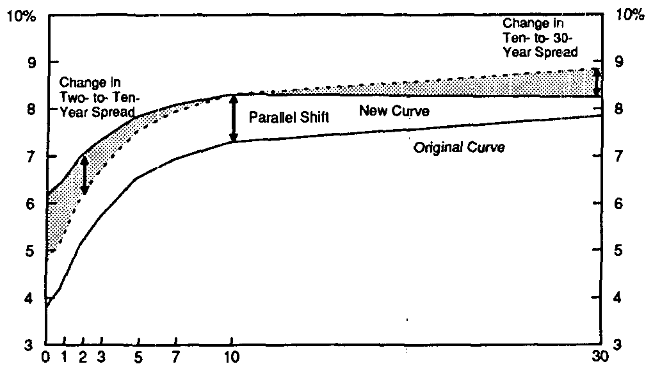
Under the partial duration approach, we determine a security's price sensitivity to interest rate movements at specific yield curve points. By combining the rate movements at individual points into broader patterns such as steepenings, flattenings, or other reshapings, we can express a security's yield curve sensitivity in a simpler way.

Klaffky, Ma, and Nozari [1992] reduce a yield curve change to three elements: 1) the change in the ten-year rate, which is applied to a parallel shift of the curve; 2) a short-end reshaping, represented by the change in the two- to ten-year spread; and 3) a long-end reshaping, represented by the change in the ten- to thirty-year spread (see Exhibit 13).

The changes in yield curve slope are applied to other maturities in proportion to their current spread. That is, if the two- to ten-year spread widens by 20%, the three-month to ten-year spread and the five- to ten-year spread also expand by 20%.

Then, we can compute the percentage price change of a given security per 100 basis points of each

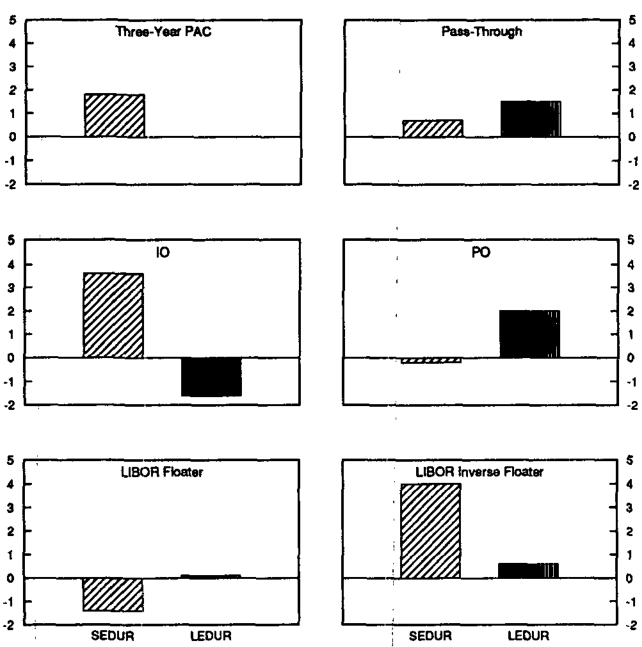
EXHIBIT 13 ■ Decomposing a Treasury Yield Curve Movement



of these three yield curve movements. With respect to the first — the parallel shift — the result is the overall effective duration. For the second and third, we find the sensitivity to changes in the short end of the curve (SEDUR) and the long end of the curve (LEDUR), respectively.[3] Along with the overall effective duration, these "yield curve reshaping durations" provide a simple way to summarize a security's yield curve risk.

In Exhibit 14, we indicate these results for the instruments previously discussed. The three-year PAC, IO, pass-through, and LIBOR inverse floater all are exposed to flattening at the short-end of the curve, while the LIBOR floater is vulnerable to steepening at the short end. The pass-through, PO, and LIBOR inverse are exposed to steepening at the long end of the yield curve, while the IO is susceptible to flattening at the long end.

EXHIBIT 14 ■ Yield Curve Reshaping Durations of Selected Securities



OTHER SOURCES OF RISK

Mortgage Spreads Over Treasuries

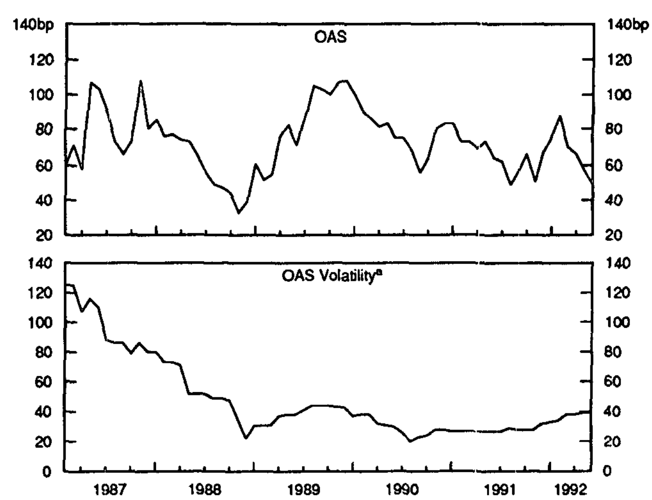
When we catalogue the sources of risk to a mortgage security portfolio, credit risk essentially does not apply unless non-agency securities are involved. However, the fluctuations in mortgage yield spreads over Treasuries — caused by a variety of factors — are a significant risk.

In the top panel of Exhibit 15, we show monthly since 1987 the average OAS of the securities that comprise the Salomon Brothers Mortgage Index. The mean OAS has varied from 108 basis points to 33 basis points, averaging 73 basis points.

In the bottom panel of the figure, we indicate the rolling one-year volatility for the OAS. Recently, this spread volatility has been 39 basis points per year, compared with more variable rates in earlier periods.

We call a security's percentage price change per 100-basis point change in OAS its spread duration (see Leibowitz, Krasker, and Nozari [1988]). The June

EXHIBIT 15 ■ OAS and OAS Volatility of the Salomon Brothers Mortgage Index, January 1987-June 1992



[a] Measured over one-year periods.

1992 overall spread duration of the Salomon Brothers Mortgage Index was 4.1. By multiplying the historical spread volatility by the spread duration, we can convert the spread volatility to an associated price volatility. Thus, an estimate for the one-year price risk in the mortgage index because of changes in OAS is 4.1 × 0.39 = 1.6%.

Rate Volatility

Changes in interest rate volatility also can affect mortgage security prices, because of the security's embedded prepayment option. Mortgage values are most influenced by expected interest rate volatility over a long-term period because homeowners can exercise their prepayment options at any time until maturity.

We have constructed an index that can serve as a proxy for long-term interest rate volatility. The index is based on the annualized volatility of ten-year Treasury yields and is calculated as the weighted average of this volatility measured for the past six months (60% weight) and the past five years (40% weight). The volatility index is shown in the top panel of Exhibit 16.

The annualized standard deviation of the changes in the volatility index is shown in the bottom panel. The June 1992 value for this volatility of volatility was 1.1%. We also can compute the percentage price change per 1% change in volatility, again keeping OAS constant. This volatility sensitivity for the Salomon Brothers Mortgage Index is 0.3. Thus, we can estimate the one-year price risk of the mortgage index relating to changes in volatility as 0.3 × 1.1 = 0.3%.

Prepayments

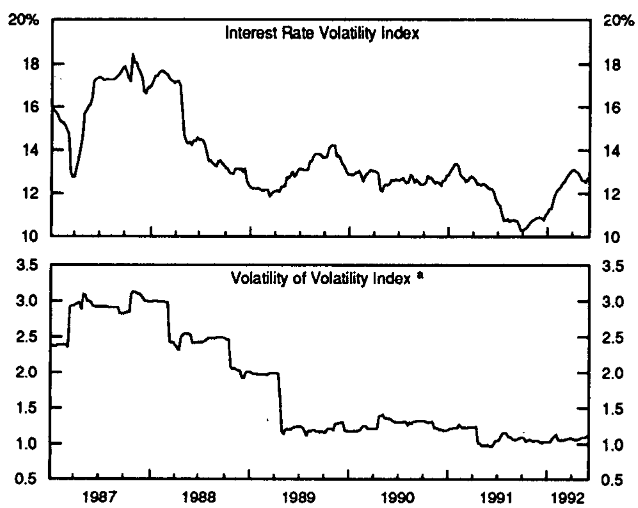
Prepayment risk can be defined as the risk of unforeseen changes in the market's assumed prepayment rates, beyond those projected to occur with movements in interest rates. These can be interpreted as errors in prepayment model forecasts, changes in housing or mortgage finance that modify prepayment prospects, or changes in market attitudes about prepayments. In any case, to the extent that market prices reflect such altered prepayment expectations, these shifts will have a direct impact on investment results.

We would like to see how variable the market's pricing prepayment assumptions have been historically, after adjusting for interest rate movements. It is difficult, however, to determine or even to define the market's prepayment assumption for any given security.

As an admittedly imperfect proxy, we can use the PSA median prepayment projections. Then, changes in the percentage of Salomon Brothers long-term projections represented by this PSA consensus forecast provide an indication of shifts in the market's prepayment expectations over time, adjusted for interest rate movements.

These data are plotted in Exhibit 17 for moder-

EXHIBIT 16 ■ Interest Rate Volatility Index and Volatility of Volatility Index, January 1987-June 1992



[a] Measured over one-year periods.

EXHIBIT 17 ■ PSA Median and Salomon Brothers Long-Term Prepayment Projections — January 1990-December 1991

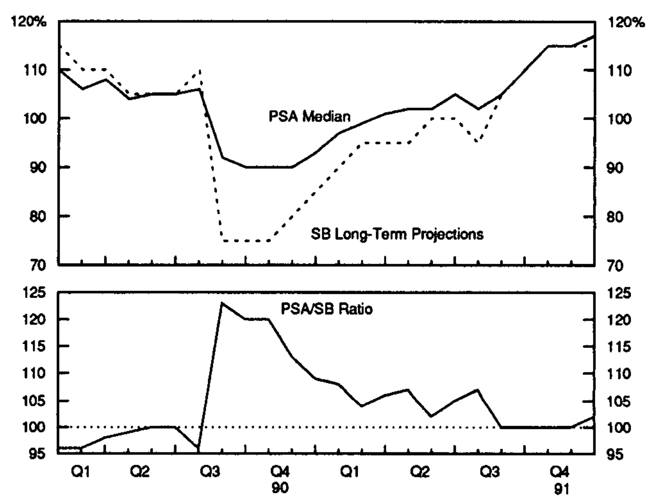


EXHIBIT 18 ■ Ratio of PSA Median to Salomon Brothers Long-Term Projection, January 1990-December 1991

Issue[a]	Low	High	Average	Volatility[b]
GNMA				
8%	96%	123%	104.6%	21.7%
9	100	120	106.4	12.4
10	84	142	120.6	28.2
Conventional				
8%	96%	115%	102.9%	14.4%
9	97	116	105.9	16.6
10	83	129	110.3	27.7
Total	93%	124%	108.5%	21.1%

[a]Moderately seasoned pass-throughs.
[b]Annualized standard deviation of monthly changes in the prepayment ratio.

ately seasoned GNMA 8s during January 1990-December 1991, a period during which the Salomon Brothers model was unaltered. The ratio of the PSA median to the Salomon Brothers projection varies from 96% to 123%, with an annualized volatility of 21.7%.

To assess prepayment volatility for a range of issues, we have computed this ratio of PSA median to projections during 1990-1991 for six securities: moderately seasoned GNMA 8s, 9s, and 10s, and moderately seasoned conventional 8s, 9s, and 10s. We summarize the results in Exhibit 18. The annualized volatility of the ratio across the six issues was 21.1%.

We define a security's sensitivity to prepayment shifts as its percentage price change assuming constant OAS under a 1% change in the prepayment projections from the Salomon Brothers model. The average prepayment sensitivity for the mortgage index is 0.015. Thus, we can estimate the one-year price risk because of shifts in prepayment expectations as $0.015 \times 21.1 = 0.3\%$.

SUMMARY OF RISK FACTORS: SALOMON BROTHERS MORTGAGE INDEX

In Exhibit 19, we summarize six primary risk factors for the Salomon Brothers Mortgage Index. The first row of the table shows the sensitivity of the market value of the mortgage index to variations in each of the factors. The second row indicates the annualized volatility of each factor during the recent past. The product of these two figures, shown in the final row, estimates the one-year market value risk of the mortgage index associated with each factor.

Shifts in interest rates, spreads, and the short end of the yield curve, in that order, produce the greatest prospective changes in the aggregate market value of the mortgage index. Variations in volatility, prepayments, and the long end of the curve result in smaller estimated changes.

These results provide investment managers with some perspective on the degree of effort to expend on each dimension. Of course, the relative scale of these factors will vary for specific issues. In particular, derivative structures can greatly magnify the risk/reward impact of any of the factors.

In Exhibit 20, we show the sensitivities to changes in OAS, rate volatility, and prepayment expectations for the mortgage securities discussed previously. The IO has a significant exposure to increases in rate volatility and prepayment expectations. In contrast, the three-year PAC, PO, and LIBOR inverse floater all are vulnerable to a decrease in prepayment speeds.

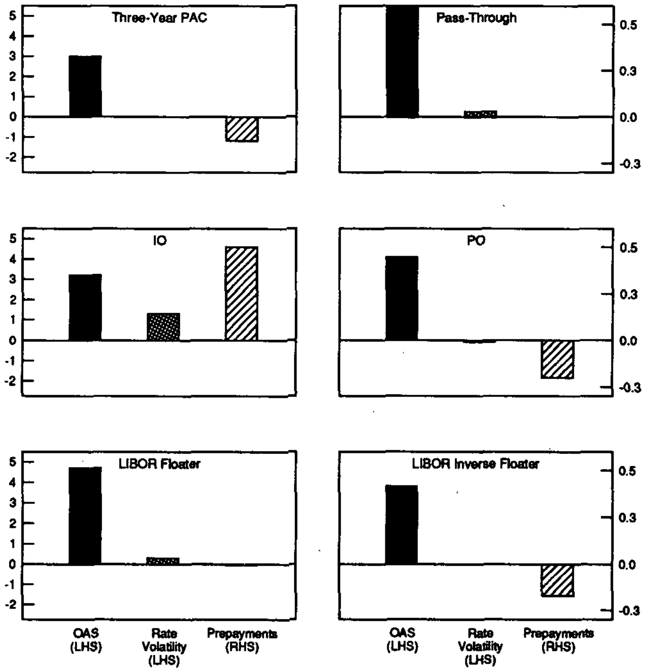
Finally, it should be noted that these risk factors are not independent and thus cannot be combined

EXHIBIT 19 ■ Risk Factors for the Salomon Brothers Mortgage Index, June 5, 1992

	Interest Rates	Yield Curve Short End	Yield Curve Long End	OAS	Rate Volatility	Prepayments
Sensitivity[a]	3.3	1.1	0.6	4.1	0.3	0.015
Historical Volatility — Annual[b]	0.84%	0.58%	0.32%	0.39%	1.12%	21.1%
Related Price Risk	2.8	0.6	0.9	1.6	0.3	0.3

[a]Percentage price change per 1% move in risk factor.
[b]Annualized standard deviation of absolute changes in risk factor, assuming zero mean. Volatility for interest rates, yield curve, and interest rate volatility are based on weekly data during the past year. OAS volatility is based on monthly data during the past year. Prepayment volatility is based on monthly data during the 1990-1991 period.

EXHIBIT 20 ■ Additional Sources of Risk — Price Sensitivities for Selected Securities



LHS Left-hand side. RHS Right-hand side.

simply to give the total risk of the index or of an individual security. Mortgage spread changes, for instance, clearly are affected by yield curve and volatility shifts.

A PORTFOLIO APPLICATION

In this final section, we illustrate how to apply the concepts that we have discussed to quantify and control these risks for a portfolio. We have taken the securities in our sample portfolio from the June 1 Salomon Brothers Model Portfolio, which is managed versus the Salomon Brothers Broad Investment-Grade (BIG) Index.[4] In Exhibit 21, we display these securities and compare the portfolio's characteristics with those of the Salomon Brothers Mortgage Index.

The portfolio consists of GNMA 9½%, FNMA 8½%, and fifteen-year FNMA 9% pass-throughs; PACs with average lives of five, seven, and ten years; and GNMA 10% IO STRIPs. In general, we chose these holdings because of their perceived relative value, without particular regard to matching the mortgage index's risk profile. Thus, the estimated OAS of the sample portfolio is 28 basis points greater than that of the mortgage index, while the FNMA 8½s provide additional return benefits from dollar rolls.

Differences in the risk characteristics of the sample portfolio and the mortgage index, however, could create performance problems. For example, the cash flows of the portfolio essentially are longer than those of the mortgage index, leading to a greater spread duration — 5.0 versus 4.1. In addition, the portfolio is more vulnerable than the mortgage index to an increase in prepayment rates. Furthermore, given the concentrated principal payments of the PACs, the portfolio is less exposed than the mortgage index to movements at both the short end and long end of the Treasury yield curve. Finally, the effective duration of the portfolio is modestly longer than that of the mortgage index.

EXHIBIT 21 ■ Sample Portfolio versus the Salomon Brothers Mortgage Index — Risk Profile, June 5, 1992

			Sensitivity					
				Yield Curve				
Issue	Market Weight	OAS	Interest Rates	Short End	Long End	OAS	Rate Volatility	Prepayments
Portfolio								
GNMA 9.5%	8.4%	44bp	3.3	1.0	0.9	4.5	0.4	0.023
FNMA 8.5	28.6	36	4.8	1.0	1.0	4.9	0.4	-0.007
15-Year FNMA 9	5.0	62	2.2	1.3	0.0	3.2	0.2	0.011
Five-Year PAC	14.2	59	3.4	1.5	0.0	3.6	0.1	0.003
Seven-Year PAC	17.2	63	4.4	0.5	0.0	4.8	0.3	-0.002
Ten-Year PAC	22.4	80	7.1	0.0	0.3	7.0	0.1	0.005
GNMA 10% IO	4.2	303	-25.7	4.7	-2.3	4.0	1.0	0.568
Total	100.0%	66bp	3.5	0.9	0.3	5.0	0.3	0.025
Index	100.0%	38bp	3.3	1.1	0.6	4.1	0.3	0.015
Difference		28bp	0.2	-0.2	-0.3	0.9	0.0	0.010

EXHIBIT 22 ▪ Sample Portfolio versus the Salomon Brothers Mortgage Index — Estimated One-Month Price Risk, June 5, 1992

	Risk Factor					
		Yield Curve				
	Rates	Short End	Long End	OAS	Volatility	Prepayments
Net Sensitivity (Port. vs. Index)	0.2	-0.2	-0.3	0.9	0.0	0.010
Historical Volatility — Monthly	0.24%	0.17%	0.09%	0.11%	0.32%	6.1%
Related Price Risk	-0.05	0.03	0.03	0.10	0.00	0.06

Exhibit 22 traces some of the potential implications of these differences. We assume that the sample portfolio's performance is measured monthly and therefore show historical volatility and the associated price risks on a monthly basis.

Thus, for instance, if mortgage OAS uniformly widen by 11 basis points (recent monthly volatility), the portfolio will lag the performance of the mortgage index by 10 basis points. Similarly, if the ten- to thirty-year Treasury spread steepens by 9 basis points, and all OAS are unchanged, the sample portfolio will lag the mortgage index by 3 basis points.

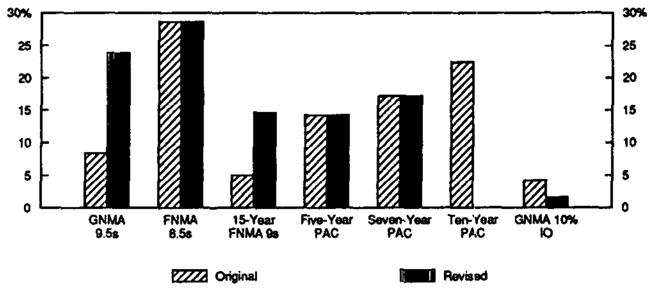
Some restructuring can be done to reduce these exposures. In particular, by using optimization techniques, one could require the sample portfolio's risk characteristics to match those of the mortgage index, while, for instance, maximizing the OAS or projected return or minimizing the transaction amount.

For our illustration, we have constrained the risk sensitivities to balance as closely as possible, while using only the issues currently held in the portfolio and maintaining the portfolio's basic pass-through – PAC – IO structure. This leads to the following transactions:

- Sell the ten-year PACs.
- Reduce the weighting of GNMA 10% IOs.
- Buy additional GNMA 9 1/2s and 15-year FNMA 9s.

The revised composition of the portfolio is shown in Exhibit 23. The new portfolio now more closely matches the mortgage index in risk profile (and still provides a significant — although smaller — 14-basis point OAS advantage) (see Exhibit 24). Thus, we largely have neutralized the portfolio's risks versus its benchmark, while continuing to emphasize the relative value of the holdings.

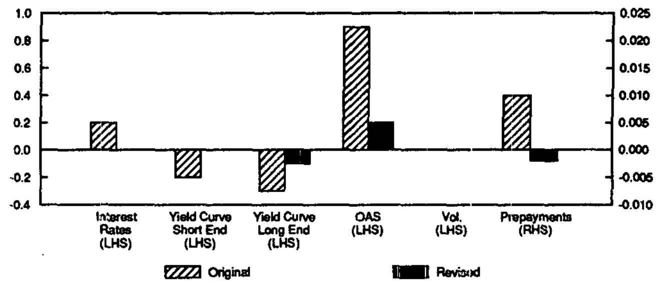
EXHIBIT 23 ▪ Portfolio Restructuring — Composition



In conclusion, mortgage securities are vulnerable to a variety of risk factors. Pass-throughs, on average, are most exposed to interest rate and spread changes. Certain derivative mortgage securities may be more sensitive to changes in the shape of the yield curve, prepayments, or volatility.

Portfolio managers need to monitor their positions on all of these risk fronts. The tools that we have discussed can help them to quantify and manage their exposure to each of these risks.

EXHIBIT 24 ▪ Portfolio Restructuring — Risk Sensitivities versus the Salomon Brothers Mortgage Index



LHS Left-hand side. RHS Right-hand side.

ENDNOTES

[1]See "A Framework for Evaluating ARMs" [1984]; "Evaluating the Option Features of Mortgage Securities" [1986]; and Boyce and Koenigsberg [1987].

[2]Other analysts explore similar themes. Johnson and Meyer [1989] discuss a "partial derivative approach" for measuring a fixed-income portfolio's exposure to changes in the yield curve, where the changes are expressed in terms of implied forward short-term rates. Ho [1990, 1992] describes the decomposition of returns into components associated with identifiable market factors. To analyze yield curve risk, he defines a set of "key rate durations" — a bond's price sensitivity to changes in key zero-coupon Treasury rates. He also discusses other risk factors, including volatility and OAS.

[3]The yield curve reshaping durations describe a security's exposure to rate increases in the short end and long end of the curve. When performing the calculation for the SEDUR, for example, we fix the ten-year rate and subtract the security's price assuming a small increase in the two-year rate (and other short-term rates) from its price assuming a small decrease in the two-year rate. The percentage price change per 100-basis point movement is the SEDUR. A similar calculation applies for the LEDUR.

[4]The weightings of the securities have been changed for purposes of illustration.

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