Risk and Return in the Mortgage Market: Review and Outlook

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The mortgage sector continues to present many challenges to active fixed-income portfolio managers. Mortgage prepayment models and option-based valuation tools have been widely used by portfolio managers for over a decade, yet many important questions remain unanswered.

Is option-adjusted spread (OAS) a reliable measure of expected excess return? How do mortgages interact with the other fixed-income markets? What do these linkages imply about the key drivers of mortgage excess returns? And, finally, how should mortgages be deployed in an actively managed fixed-income portfolio; in particular, when should mortgages be overweighted, and how should they be hedged?

This article addresses these questions by analyzing the performance of mortgages over the last eleven years. We first review the historical excess returns of mortgages and other investment-grade spread sectors over the 1989-1999 period. The Lehman Brothers Mortgage Index had an average annual excess return of 28 basis points over this period, significantly below the average index OAS of 77 bp. We attribute the discrepancy to steady improvement in refinancing efficiency over the past decade, which has caused prepayment models to consistently understate mortgage callability. This model bias has resulted in lower measured excess returns for at least two reasons: 1) underestimation of the impact of refinancing on both prices and paydowns, and 2) assignment of too great a duration to mortgages during a period of generally declining rates.

We then examine the correlation between mortgages and other fixed-income securities to assess mortgages in a portfolio context. Mortgage excess returns exhibit strong positive correlation with investment-grade corporate excess returns. The mortgage-corporate correlation is highest when prepayment risk is low or when liquidity events dominate the market.

Mortgages also have linkages to Treasuries beyond the traditional measures of duration and convexity. We show that when aggregate prepayment risk is high, as indicated by a high average price of the MBS index, mortgage spreads tend to widen in Treasury rallies and tighten in backups. With this conditional directionality, investors should hedge mortgages at approximately 80% of their model-implied durations when the index price is above $102.

We propose a five-factor empirical model to explain the historical variation in mortgage excess returns. Three of the five risk factors — convexity, vega, and prepayments — are familiar to investors. The other two risk factors — credit spread changes and spread directionality — follow from our analysis.

The five-factor model explains 40%-59% of the variation in mortgage excess returns. The most important risk factors are volatility, both realized and implied, and movements in credit spreads. Risk sensitivities esti-

mated empirically correspond closely to those implied by our valuation model.

Our analysis has implications for relative value and hedging. First, investors should include the impact of further reduction in origination and refinancing costs in their expectations of excess returns. Preliminary analysis suggests that using a forward-looking prepayment model would lower the current OAS for thirty-year par coupon pass-throughs by 7 bp and for premium coupons by as much as 16 bp.

Second, investors should consider the effects of a forward-looking prepayment model and spread directionality in determining appropriate hedge ratios. The combined impact could be quite substantial. Using a forward-looking prepayment model would currently lower par coupon duration by 0.2 to 0.3 years, while spread directionality would reduce duration by an additional 0.6 to 0.8 years if the index price is above $102.

I. MORTGAGE PERFORMANCE SINCE 1989

An analysis of mortgage excess returns from January 1989 through December 1999 provides some historical perspective. Our analysis demonstrates the following:

1. Mortgage excess returns are similar to agency debenture excess returns, implying that investors were not compensated for taking prepayment risk over this period.
2. The average 28-basis point per year excess return for the mortgage index is significantly lower than the average 77 bp OAS of the index. The observed shortfall is greater for higher dollar-price securities in the index.
3. We attribute this 49 bp discrepancy largely to the steady improvement in refinancing efficiency over the past decade, which has caused prepayment models to consistently understate mortgage callability. For thirty-year mortgages, this model bias has resulted in lower measured excess returns because of 1) underestimation of the impact of refinancing on both prices and paydowns (32 bp), and 2) assignment of too great a duration to mortgages during a period of declining interest rates (15 bp — leaving 2 bp unexplained).

Mortgages Have Fallen Short of Expectations

Mortgage performance has been lackluster over the January 1989-December 1999 study period (Exhibit 1). The Lehman Brothers Mortgage Index had an average

EXHIBIT 1
Excess Returns of Lehman Brothers Mortgage Index — 1989-1999
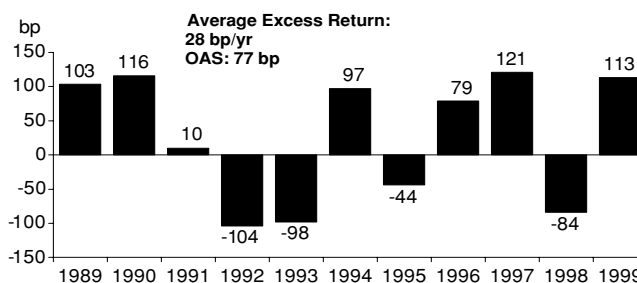
excess return of 28 bp per year over the past eleven years, while the average index OAS was 77 bp over the same period. Since OAS is a measure of expected annual excess return, it appears that realized excess returns of mortgages fell 49 bp per year short of their target.[1]

The underperformance of mortgages in the period is consistent across price sectors and maturities. To illustrate, we subdivide the thirty-year and fifteen-year mortgage indexes into four price buckets: *discount* (price < = $98), *current* (98 < price < = 100), *cusp* (100 < price < = 102), and *premium* (price > 102).[2] Historical average performance for these subindexes is shown in Exhibit 2.[3]

In the thirty-year sector, excess returns are distinctly declining in dollar price despite the higher OAS of higher-priced mortgages. For example, discounts outperform premiums by an average 48 bp per year over the 1989-1999 period, even though discount OAS is an average 10 bp *lower* than premium OAS over this period. In the fifteen-year sector, current-coupon mortgages have historically posted the highest excess returns. Comparing maturities, the fifteen-year mortgage sector has offered a better risk-return trade-off than the thirty-year sector in non-discount price buckets, with 1 bp-8 bp higher average excess returns and lower risk.

We report the performance of corporates, agencies, and asset-backed securities (ABS) in Exhibit 2 for comparison. Corporate index returns are also lower than their average OAS over the study period. We attribute the discrepancy to 1) the spread widening over 1998-1999; 2) the impact of defaults, estimated at 5 bp per year; and 3) the mark-to-market impact of both downgrades and upgrades, estimated at roughly 35 bp per year.

Agencies, on the other hand, produce excess returns roughly commensurate with their OAS. This is not sur-

E X H I B I T 2

**Historical Performance of Mortgages versus
Other Fixed-Income Sectors — 1989-1999**

	1989-1997			1989-1999		
	Excess Returns(bp/yr)		**Average OAS**	**Excess Returns**(bp/yr)		**Average OAS**
	Average	**S.D.**	(bp)	**Average**	**S.D.**	(bp)
30-Year Mortgages						
Discount (< $98)	62	124	75	59	146	74
Current ($98-100)	44	121	79	37	138	77
Cusp ($100-102)	37	129	77	32	134	75
Premium (> $102)	18	148	85	11	141	84
15-Year Mortgages						
Discounts (< $98)	45	114	64	38	121	65
Current Coupon ($98-100)	52	112	65	40	119	65
Cusp Coupon ($100-102)	47	116	67	33	118	67
Premiums (> $102)	24	113	73	19	113	74
MBS Index	**31**	**133**	**78**	**28**	**133**	**77**
A Corporates						
Long (> 7.5 years)	58	178	86	32	244	91
Intermediate (4-7.5 years)	44	136	85	37	165	87
Short (< 4 years)	57	69	75	54	79	76
BBB Corporates						
Long (> 7.5 years)	47	235	134	21	325	139
Intermediate (4-7.5 years)	37	260	133	25	277	138
Short (< 4 years)	98	117	121	92	121	122
Corporate Index	**50**	**101**	**77**	**36**	**147**	**85**
Agencies						
Intermediate (4-7.5 years)	24	40	29	18	64	30
Short (< 4 years)	24	21	19	21	25	22
Agency Index	**32**	**33**	**20**	**26**	**41**	**23**
ABS Index*	**57**	**43**	**59**	**49**	**77**	**62**

*Returns since January 1992.

prising, since agencies can be modeled much more accurately than corporates or mortgages, due to their minimal credit risk and relatively straightforward optionality.

In cross-sector comparisons, mortgages show mixed performance versus similar-duration corporates and poor performance versus agencies. Versus corporates, discount mortgages outperform long and intermediate corporates, while current-coupon mortgages outperform intermediate corporates. Cusp coupon and premium mortgages, however, generally underperform intermediate and short corporates. Versus agencies, the average mortgage excess returns closely match agency excess returns, despite the much higher OAS for mortgages. The riskiness of mortgages, however, as measured by the standard deviation of excess returns, is much higher than that of agencies. This suggests that mortgage investors were not compensated for bearing prepayment risk over the past eleven years.

Why Have Mortgages Underperformed?

The past underperformance of mortgages relative to their OAS is attributable largely to changing prepay-

ment expectations. Prevailing prepayment models, calibrated to past prepayment data, did not anticipate the steady improvements in refinancing efficiency realized over the past fifteen years. As a result, these models understated callability during the three major refinancing waves of 1986, 1993, and 1998.

An examination of peak refinancing rates during past refinancing episodes illustrates the dramatic impact of technological innovation on refinancing behavior (Exhibit 3). Over the 1986 to 1993 period, the refinancing threshold declined by 35 bp, while the slope of the refinancing curve increased by 30%. Similarly, between 1993 and 1998, the refinancing threshold declined by another 20 bp, while the slope stayed largely unchanged.[4]

The increase in prepayment efficiency has negatively affected mortgage excess returns, both directly and indirectly. The direct effect, or the *price/paydown effect*, is obvious: Faster-than-expected prepayments have resulted in price declines and negative paydown returns.

The indirect effect, which we call *duration bias*, is more subtle. Mortgage investors immediately update their prepayment assumptions with the arrival of new information; this information is aggregated in an unobservable market prepayment model. Meanwhile, changes to proprietary models occur less frequently, and therefore with a lag. Since mortgage callability steadily increased over the study period, the market prepayment model was often more callable than proprietary models. As a result, model estimates of mortgage durations were generally greater than their true values, causing estimated excess returns to be overstated in rate backups and understated in rallies. Since interest rates declined over

E X H I B I T 3

**Increases in Mortgage Callability
Estimated Refinancing Functions for Thirty-Year
Unseasoned Conventional Mortgages**
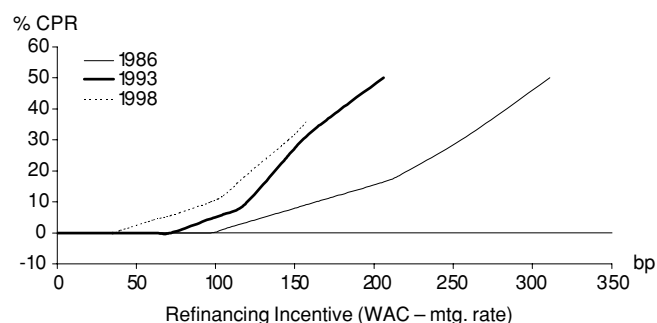
the study period, the duration bias has had a net negative effect on excess returns.[5]

Measuring the Impact of Increasing Mortgage Callability

We examine the hypothetical effect of increasing callability on excess returns using a simulation approach. First, we estimate the price impact and duration bias as follows:

1. We simulate the 1986 prepayment model by adjusting the current prepayment model to reflect the prevailing refinancing environment in 1986. The simulated "1986 prepayment model" combines the yield curve and volatility structure of December 29, 1999, with the refinancing sensitivity of 1986.
2. Using the "1986 prepayment model" and the yield curve of December 29, 1999, we determine the coupons and durations corresponding to mortgages with dollar prices of $96, $99, $101, and $104. These hypothetical securities represent the discount, current, cusp, and premium sectors of the mortgage market in 1986. All calculations assume an OAS of 55 bp.
3. We recalibrate the prepayment model to mimic the refinancing sensitivity in 1993. The "1993 prepayment model" is used to reestimate the dollar price and duration of the four hypothetical mortgage securities. We attribute the change in dollar price and duration to the increase in refinancing efficiency over the 1986 to 1993 period.
4. The procedure is repeated to determine the effect of improvement in refinancing technology between 1993 and 1998.

The results of this analysis are shown in Exhibit 4, which highlights the significant price impact of the changing callability on cusp and premium collateral. The price of the hypothetical premium coupon dropped from $104-00 to $103-02 as a result of the refinancing efficiency achieved between 1986 and 1993. This sector lost a smaller, but still significant 13/32nds from 1993 to 1998.

Exhibit 4 also highlights the duration bias, the difference in duration between a forward-looking model and a model benchmarked to the previous refinancing wave. The duration bias is also greatest for the premium coupon, with a bias of 0.61 during the first episode and a bias of 0.27 during the second.

We use this procedure to estimate the resulting impact on mortgage excess returns. The price, pay-

EXHIBIT 4
Price Impact and Duration Bias of Enhanced Refinancing Efficiency 1986 versus 1993 and 1993 versus 1998[*]

Enhanced Refinancing Efficiency from 1986 to 1993						
		Calibrated to 1986		Calibrated to 1993		
Price Bucket	Coupon (%)	Price	Duration (yrs)	Price	Duration (yrs)	Price Impact	Duration Bias (yrs)
Discount	6.78	96-00	5.05	95-17	4.87	0-15	0.18
Current	7.42	99-00	4.57	98-13	4.40	0-19	0 27
Cusp	7.85	101-00	4.23	100-10	3.93	0-22	0.30
Premium	8.52	104-00	3.51	103-02	2.90	0-30	0.61

Enhanced Refinancing Efficiency from 1993 to 1998						
		Calibrated to 1993		Calibrated to 1998		
Discount	6.89	96-00	4.86	95-28	4.80	0-04	0.06
Current	7.56	99-00	4.27	98-27	4.18	0-05	0.09
Cusp	8.0	101-00	3.73	100-25	3.51	0-07	0.22
Premium	8.69	104-00	2.77	103-19	2.50	0-13	0.27

[*]All computations at 55 OAS. Yield curve and volatility structure as of December 29, 1999.

down, and duration effects are computed each month for each price bucket, assuming that refinancing efficiency increased uniformly between prepayment waves. The *price effect* is the negative valuation impact, at constant OAS, of the monthly improvement in refinancing efficiency. The *paydown effect* is calculated using the difference between market and production model prepayment forecasts and the price of the representative security. The *duration effect* (the impact of the duration bias) is assumed to increase linearly between prepayment waves and depends on the interest rate movement in a given month. Duration bias affects excess returns negatively in months when rates rally and positively in months when rates back up.

The three effects are aggregated across the price buckets by market weight to compute the summary impact on index excess returns. As shown in Exhibit 5A, the price/paydown effect explains most of the discrepancy between OAS and average excess returns for the premium and cusp buckets. Duration bias also has a significant effect, explaining 18 basis points of the underperformance of premiums. For the thirty-year fixed-rate MBS index, we attribute 32 bp of the 51 bp underperformance to the price/paydown effect and 15 bp to duration bias, leaving 4 bp unexplained.

What would have happened if interest rates had

E X H I B I T 5 A
Why Realized Excess Returns Were Lower Than OAS: An Approximate Attribution of the Slippage for Thirty-Year Mortgages — 1989–1999…

	bp/yr				
Source of Underperformance	Discount	Current	Cusp	Premium	30-Year Index
Price Return	6	8	12	19	16
Paydown Return	0	0	2	21	16
Duration Bias	8	16	16	18	15
Total	**14**	**24**	**30**	**58**	**47**
Average Index Price					**$101-07**
OAS — Excess Return	15	40	43	73	51

E X H I B I T 5 B
…and What Would Have Happened If Rates Had Increased

	(bp/yr)				
Source of Underperformance	Discount	Current	Cusp	Premium	30-Year Index
Price Return	6	8	12	19	7
Paydown Return	0	0	2	21	2
Duration Bias	-10	-19	-30	-20	-16
Total	**-4**	**-11**	**-16**	**20**	**-7**
Average Index Price					**$97-10**

increased, rather than decreased, over the study period? The measured excess returns were lower by 15 bp because of incorrect durations and the decline in rates over the measurement period. If the market had backed up, the duration bias would have increased measured excess returns. We attempt to quantify this in Exhibit 5B. We alter the realized interest rate path from 1989-1999 so that rates are 278 bp higher at the end of the period, rather than lower as actually happened. A small upward drift is added to rates every month to accomplish this.

The changed rate path improves the index excess returns in two ways. First, the duration bias improves measured excess returns, as discussed earlier. Second, in this rate evolution, the index is more concentrated in discounts and par coupon buckets — the average index price is $97-10, instead of $101-07. These buckets have smaller price and paydown effects than cusp and premium securities. In fact, Exhibit 5B indicates that had rates backed up instead of rallying, index excess returns would have exceeded OAS by 7 bp, on average.

II. HISTORICAL LINKAGES BETWEEN MORTGAGES AND OTHER FIXED-INCOME SECTORS

The mortgage market is tightly linked with other fixed-income markets, as clearly demonstrated during the recent financial crisis of late 1998. Our examination of mortgage linkages with corporates and with Treasury rates suggests conclusions as follows:

1. Mortgage excess returns exhibit a strong correlation with corporate excess returns, ranging from 14% to 56%, depending on the duration/price bucket. Linkages between corporates and mortgages are strongest for discount mortgages and weakest for premium mortgages.
2. Despite the significant correlation over the eleven-year period, across shorter time horizons, the correlation varies considerably, due to the shifting relative importance of common versus sector-specific risk factors. In general, the correlation increases when there are large positive or negative returns to either sector.
3. The systematic variation in mortgage-corporate correlation implies that traditional mean-variance analysis is inappropriate for asset allocation decisions. We propose an alternative asset allocation framework that incorporates the current spread information, as well as the historical comovement of asset returns.
4. Treasury rate movements and mortgage spread changes exhibit a strong negative correlation when the aggregate level of prepayment risk is high, as indicated by a high average price of the securities in the mortgage index. This causes mortgages to trade much shorter than model-implied durations when the index price is above $102.

Linkages Between Mortgages and Corporates

Mortgage and corporate excess returns are driven by both common and sector-specific factors. Large variations in common factors will cause mortgage and corporate excess returns to move in sync. For instance, if the expected inflation rate increases, the required nominal excess return for all sectors will also likely increase. Similarly, an increase in the premium for liquidity is likely to cheapen all spread sectors relative to Treasuries.

Large variations in sector-specific factors, on the other hand, will result in independent movements in mortgage and corporate returns. For example, corporate

spreads move in response to the market's changing perception of economic conditions, with effects magnified for creditors with high financial and/or operating leverage. Meanwhile, mortgage excess returns vary with changes in the value of the embedded prepayment option, which in turn varies with changes in interest rate volatility and prepayment expectations. In addition, supply or demand shocks in a given sector, such as a large issuance of corporate debt or the entrance of a large new buyer for mortgages, will cause unique variation in returns to that sector. The realized correlation between the two sectors will depend on the relative strength of the common versus sector-specific factors.

In Exhibit 6, we examine the correlation structure of monthly excess returns of mortgages and corporates over the 1989-1999 period. For all corporate classes, the mortgage-corporate correlation decreases with increases in the dollar price of mortgage securities. For instance, the correlation between intermediate A-rated corporate excess returns and mortgage excess returns declines from 0.42 for discount mortgages to 0.28 for premiums.

This is easy to interpret. Spread duration is lower for premium mortgages than for discounts, which means that systematic spread movements explain a smaller fraction of the variation of premium excess returns. At the same time, refinancing shocks are more significant for premium mortgages. Overall, excess returns for premiums are driven more by mortgage-specific factors than excess returns for discounts, accounting for the lower correlation with corporates.

Changes in Mortgage-Corporate Linkages Over Time

There is considerable time variation in the average correlation numbers reported in Exhibit 6. To illustrate, we examine the correlation between A-rated intermediate corporates and current-coupon mortgages, computed over rolling twenty-four-month windows (Exhibit 7). This correlation fell steadily through the 1990s and was close to zero for much of the 1996-1997 period. Yet during the two recent credit shocks — the Asian crisis of late 1997 and the global contagion fears of late 1998 — all spread sectors moved together, causing the intersector correlation to spike to 0.8 in the second instance. This indicates that the use of historical correlations in a mean-variance asset allocation framework can often be misleading, especially if correlation is high in periods of large negative excess returns.

EXHIBIT 6
Correlation of Monthly Excess Returns of Thirty-Year Mortgages and Selected Corporate Sectors January 1989-December 1999

| Sector | Mortgages | | | | |
	Index	Discount	Current	Cusp	Premium
Corporate Index	**0.51**	**0.56**	**0.60**	**0.56**	**0.39**
A-Short	**0.38**	0.49	0.49	0.40	0.22
A-Intermediate	**0.42**	0.52	0.52	0.46	0.28
BBB-Short	**0.30**	0.47	0.44	0.31	0.14
BBB-Intermediate	**0.33**	0.46	0.46	0.36	0.20

EXHIBIT 7
Time Variation in Correlation of Excess Returns of Mortgages and Corporates January 1991-December 1999*
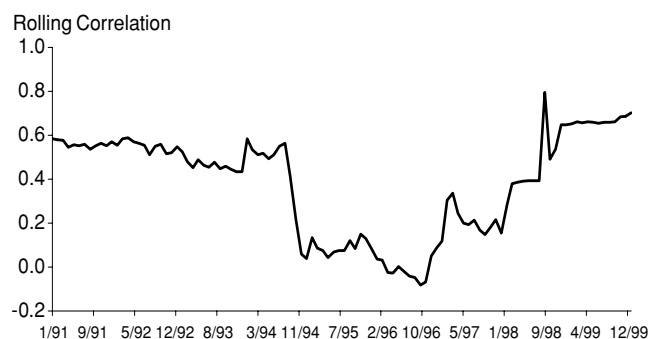
*Correlations estimated using monthly data over twenty-four-month window for thirty-year par coupon mortgages and non-callable A-rated securities in Lehman Brothers Corporate Index with five to ten years to maturity.

Finally, we examine mortgage excess returns conditional on large negative and positive excess returns to A-rated intermediate corporates (Exhibit 8). Mortgages and corporates tend to move together when corporate excess returns are either strongly positive or strongly negative. When corporate excess returns are in the bottom quartile of their historical distribution, the mortgage-corporate correlation is 56%. Similarly, when corporate excess returns are in the top quartile, the correlation is 39%. Yet when corporate excess returns are in the second or third quartile, the correlation is only 3%.

The high mortgage-corporate correlation during periods of large positive and negative corporate excess returns is driven by the relatively strong influence of com-

E X H I B I T 8

Conditional Correlation between Mortgages and Corporate Excess Returns
January 1989-December 1999*

Quartile of Corporate Excess Returns	Correlation of Excess Returns to Mortgages and Corporates	Number of Observations
First	0.56	33
Second and Third	0.03	65
Fourth	0.39	33

*Thirty-year par coupon mortgages and non-callable A-rated securities in the Lehman Brothers Corporate Index with five to ten years to maturity.

mon versus sector-specific factors during periods of financial crisis. Similar results are observed when correlations are calculated conditional on mortgage excess returns.

Integrating Historical Performance and Current Spreads in an Asset Allocation Framework

The systematic variation in mortgage-corporate correlation implies that traditional mean-variance analysis is inappropriate for asset allocation decisions.[6] We develop an alternative asset allocation framework based on the historical variability of returns and current spreads. Four asset classes are considered: the ABS, agency, corporate and mortgage indexes. We begin by noting that, for a default-free, non-callable security, the current spread is a fair indication of the expected excess return over Treasuries. The spreads on credit-sensitive corporate debt must be reduced to account for expected losses, as well as the price impact of net downgrades. For a callable security, the default-adjusted OAS is the expected return.

Investment decisions cannot be based on expected returns alone; the distribution of returns about the mean is also important. This distribution of returns is largely a function of the terminal spread of the security; a widening causes realized returns to fall below expected returns. Since there are no liquid instruments from which to deduce the terminal distribution of spreads, we develop a methodology to simulate the return distribution. This methodology is based on the assumption that the variability of returns over the investment horizon will be similar to that observed in the past. We illustrate this methodology using spread information as of December 29, 1999.

Specifying Expected Excess Returns. Agencies can

be considered default-free, and we set the expected return equal to the current spread. For mortgages, the current OAS on the index overstates expected returns and needs to be adjusted down. As we discuss later, our current prepayment model does not incorporate the expected increase in future callability due to enhanced refinancing efficiency. As a result, it overstates OAS on thirty-year MBS by 6 bp-15 bp, with the bias greater for premiums than for discounts. Since the mortgage market is currently dominated by discount loans (the weighted average price of the mortgage index is currently $96.40), we adjust the OAS on the mortgage index down by 6 bp to 58 bp.

Finally, expected returns on corporates are set equal to the OAS less adjustments for defaults and the mark-to-market impact of downgrades and upgrades. Given the current composition of the corporate index, historical default rates, and rating transition probabilities, we predict the average slippage due to defaults and rating changes to be 5 bp/year and 35 bp/year, respectively.

Simulation of Future Return Distribution. We simulate the distribution of annual excess returns for each sector using a methodology as follows:

1. The 132-month history (January 1989-December 1999) of excess returns is used to generate future returns. We randomly select twelve monthly excess returns from the historical series for each asset class. Combining these twelve random draws gives us one annual excess return observation. This process is repeated several thousand times to simulate the annual return distribution.
2. The distribution of each asset class is subsequently shifted so that the mean of the distribution is equal to the current expected excess return.

Exhibit 9 shows the distribution of annual returns for the MBS index; the negative excess return region represents underperformance relative to a Treasury benchmark. The probability of underperformance (29% in this case) is the area spanned by the probability bars in the underperformance region. This is a useful summary measure of risk for a portfolio manager and should be weighed against the expected return from the security.

Exhibit 10 summarizes this risk-return trade-off for the various asset classes considered. The ABS index offers the lowest probability of underperformance and the highest expected return. The estimates for this sector are less reliable than for others, however, because of a shorter history of excess return (only 108 months of data). Agencies

EXHIBIT 9
Simulated Distribution of Annual Returns on MBS Index — December 28, 1999
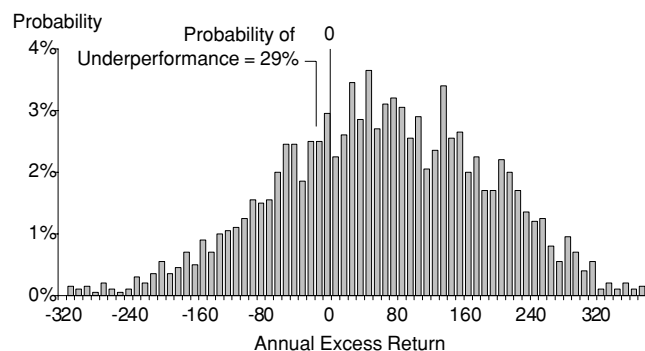
EXHIBIT 10
Distribution of One-Year Projected Excess Returns by Sector***

Sector	Excess Return		Probability of Underperforming Treasuries
	Mean	S.D.	
ABS Index	76	77	0.12
Agency Index	34	39	0.13
Corporate Index	72	143	0.30
Mortgage Index	58	129	0.29

*As of December 28, 1999.

offer the lowest expected returns, but also have the lowest risk of underperformance.

Portfolio managers can choose a combination of the four assets depending on their risk tolerance. For instance, an asset manager who wants to keep the probability of underperformance below 13% should restrict attention to agencies. Those willing to live with the higher risk of underperformance should selectively add mortgages and corporates.

Other Considerations. While this analysis does provide a concrete risk-reward trade-off, it does not account for the superior liquidity of mortgages over other fixed-income sectors. This makes mortgages an ideal instrument for a tactical underweight or overweight to the spread sectors. This is especially important at the current moment, since the mortgage index is weighted in discounts, which have a higher correlation with other spread sectors than premiums (see Exhibit 6). Finally, given their high liquidity, mortgages provide an effective way to express views about both implied and realized volatility in the Treasury/swap market.

Linkages Between Interest Rates and Mortgage Spreads

Mortgage excess returns have shown a strong positive correlation of 38% with interest rate changes over the past ten years. Part of this correlation is due to the duration bias we have identified. The more significant factor, however, is mortgage spread directionality; that is, mortgage spreads tend to widen in Treasury rallies and tighten in rate backups.

Why should par coupon OAS exhibit directionality?[7] A possible explanation is that the premium for bearing prepayment uncertainty is a function of the level of rates. When Treasury rates rally, the average dollar price of outstanding MBS increases, and so does the aggregate prepayment risk borne by mortgage investors.

If the current level of prepayment risk is sufficiently high, every marginal increase in risk requires additional yield compensation. If the current aggregate level of prepayment risk is relatively low, on the other hand, investors do not demand incremental yield to bear more prepayment risk. The average price of the Lehman Brothers Mortgage Index is a barometer of the aggregate level of prepayment risk in the economy; in particular, a high index price indicates a high level of prepayment risk.

Evidence of Directionality over the 1994–1999 Period. To examine this relationship, we compare weekly changes in par coupon thirty-year FNMA mortgage spreads with weekly changes in ten-year Treasury note yields. As shown in Exhibit 11A, there is a clear pattern between Treasury yield changes and changes in par coupon mortgage spreads when the index price is above $102.

We report statistical analysis of the mortgage-Treasury relationship for different levels of the mortgage index in Exhibits 11B and 11C. When the index is above $102, mortgage spreads are more than twice as likely to widen than tighten in a Treasury rally, and the two series have a large negative correlation of −0.51. Linear regression analysis shows that a 10 bp rally in the ten-year yield results in a 2 bp widening in par coupon OAS in this environment. When the index is trading in the $98-$102 price range, however, there is no evidence of a relationship between Treasury yields and mortgage spreads. There is weak support for a positive relation between mortgage spread changes and Treasury yield changes when the index is at a discount, but the sign tests are inconclusive for this range.

EXHIBIT 11A

Par Coupon OAS Changes versus Ten-Year Treasury Yield Changes When Index Price Above $102 Weekly Observations — January 1999-December 1999
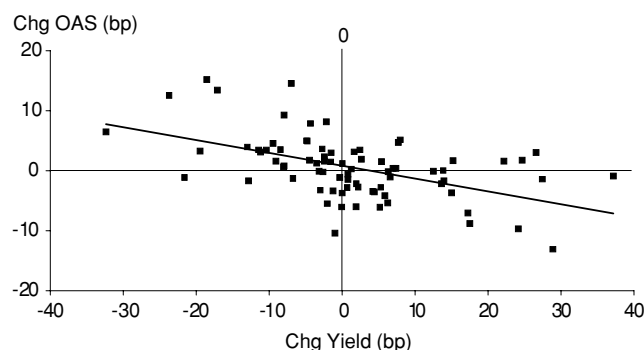
EXHIBIT 11B

Impact of Index Price on Spread Directionality January 1994-December 1999

MBS Index Price	# of Weekly Observations	Relationship between Ten-Year Yield Changes and Par Coupon OAS Changes		
		Same Sign	Opposite Sign	Correlation
< $98	60	58%	42%	0.29
$98 - $100	69	55	45	0.07
$100 - $102	103	39	61	-0.09
> $102	77	32	68	-0.51

EXHIBIT 11C

Changes in Par Coupon OAS versus Changes in Ten-Year Treasury Yield January 1994-December 1999

MBS Index Price	bp Change in OAS/ 10 bp Change in Tsy Yield	Standard Error	t-statistic	% of Variation Explained
< $98	1.3	0.06	2.3	0.08
$98 - $100	0.2	0.04	0.6	0.00
$100 - $102	-0.3	0.03	-0.9	0.01
> $102	-2.1	0.04	-5.2	0.26

Implications of Mortgage Spread Directionality. The directionality of mortgage spreads when the index price is high has several implications for portfolio managers. First, mortgage spreads and excess returns will be more volatile when the index is at a premium because of the systematic variation of OAS with Treasury rates in our sample. Over the 1994-1999 study period, monthly index excess returns were 40% more volatile when the index was trading above $102.

Second, empirical durations will be shorter than model durations when the index price is high, since spread changes will tend to dampen mortgage price movements. When the index price is above $102, spread directionality causes par coupon mortgages to trade at approximately 80% of their model-implied durations.

III. EMPIRICAL TESTING FOR RISK FACTORS IN MORTGAGES

Our analysis so far considers the past behavior of mortgage excess returns and their relationship with other fixed-income sectors. It suggests that spread changes in competing fixed-income products, as well as movements in Treasury rates, have a significant effect on mortgage excess returns. From our theoretical understanding of MBS as a short position in a prepayment option, we know that volatility and prepayment surprises are important determinants of mortgage performance. Our examination of the collective impact of these variables on mortgage excess returns indicates that:

1. Five key drivers of mortgage excess returns — realized volatility, implied volatility, aggregate prepayment surprises, common movements in fixed-income spread sectors, and OAS directionality — together explain between 40% and 59% of the variation in mortgage excess returns.
2. While all these risk factors are significant, the most important risk factors are realized and implied volatility, which combine to explain 18%-28% of the variation in excess returns, and credit spread movements, which explain 8%-39% of variation.

The Five Key Risk Factors in Mortgage Excess Returns

In seeking a simple empirical model, we propose five key drivers of mortgage excess returns. These five factors are suggested by our general understanding of the behavior of mortgage prices and supported by empirical evidence. Proxies for these variables are chosen both for their strong linkages with the mortgage market and for the quality of historical data. The five factors and their proxies are:

1. *Convexity* (realized interest rate volatility): Squared changes in the off-the-run ten-year par Treasury yield are used to capture the impact of convexity.
2. *Vega* (changes in the term structure of implied volatil-

ity): This variable is proxied using changes in the Black volatility of five-year maturity options on the ten-year swap rate.

3. *Prepayment Surprises:* The surprise in the MBA refinance index is used to measure the impact of unanticipated prepayments on mortgage returns.

4. *Spread Changes:* The impact of changes in the spread of competing fixed-income securities is captured through movements in five-year swap spreads.

5. *Directionality:* This variable refers to the mortgage-Treasury correlation when there is a high aggregate level of prepayment risk. It is proxied using changes in the off-the-run ten-year par Treasury yield when the index price is above $102.

A Simple Proxy for Marketwide Prepayment Surprises. Our variable for prepayment surprises requires some discussion. It would be naive to expect prepayment model forecast errors to be a surprise to the market. Changes in proprietary prepayment models typically lag updates to market prepayment expectations. Instead, we propose a proxy based on unanticipated changes in the MBA Refinance Application Index, a commonly tracked measure of refinancing activity. While this does not identify security-specific surprises, it does capture prepayment surprises in the aggregate.

The first step in the computation is to forecast the MBA Refinance Index as a function of the aggregate refinancing incentive.[8] The market-weighted sum of the refinancing incentive of all securities in the Lehman Brothers Mortgage Index is used as a proxy for the aggregate refinancing incentive. As shown in Exhibit 12, the MBA index closely tracks the aggregate refinancing incentive over the period of study, with significant deviations appearing only in 1998.

We estimate the sensitivity of the MBA index to changes in aggregate refinancing incentive using a linear regression over a thirty-six-month rolling window. This estimated sensitivity is used to generate a month-ahead estimate of the change in the level of the MBA index conditional on the next month's change in the aggregate refinancing incentive. The surprise in the MBA index, measured as the difference between the actual and predicted MBA index, is used as a proxy for marketwide revisions in prepayment views (Exhibit 13). The variable clearly identifies the sharp and unexpected spikes in the refinance index in January and October 1998.

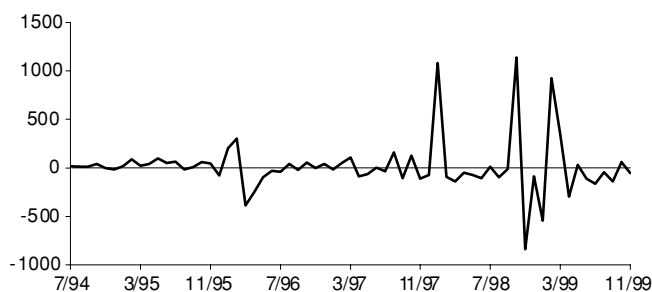***Model Estimates of Risk Sensitivities.*** A linear multiple regression is a robust way to quantify the col-

E X H I B I T   1 2
MBA Refinance Index versus Aggregate Refinancing Incentive — January 1994–December 1999
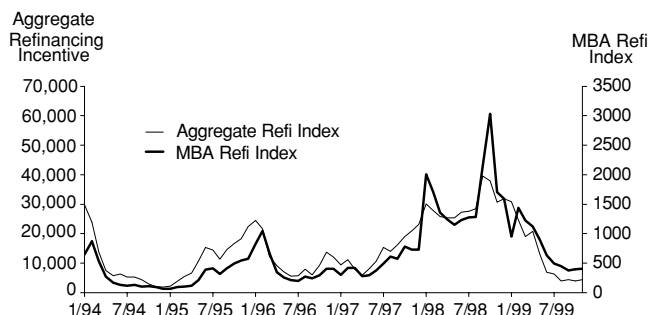
E X H I B I T   1 3
Innovation (actual minus projected) in the MBA Refinance Index — January 1994–December 1999

lective impact of the various drivers of mortgage excess returns. The coefficient estimates from the regression can be considered the empirical risk sensitivity of excess returns to the risk factors, and should be comparable to the theoretical estimates from our valuation models. Exhibit 14 lists selected model risk sensitivities for benchmark unseasoned mortgages as of November 30, 1999.

Convexity is analogous to the gamma of an option. Extending the options analogy, at-the-money options — the cusp coupon securities — have the highest negative convexity. Vega, the sensitivity of MBS prices to changes in the implied volatility of Treasury rates, declines as we go up in coupon.

To interpret this, it helps to think of an MBS as a long position in a Treasury and a short position in a portfolio of several call options. In this framework, a discount MBS is short out-of-the-money call options, while a premium MBS is short in-the-money call options. Since implied volatility has a greater impact on out-of-the-

E X H I B I T   1 4
Theoretical Risk Measure for Thirty-Year FNMA Pass-Throughs — November 30, 1999

Coupon	Price	Convexity	Vega (32nds)	Prepayment Duration (32nds)*	Spread Duration	ZV Spread	OAS
7.0	97-21	-0.9	-8	-2	4.8	96	50
7.5	99-23	-1.5	-8	-3	4.5	112	54
8.0	101-14	-2.2	-8	-4	4.1	132	60
8.5	103-04	-2.2	-6	-5	3.7	144	70

*For 10 bp shift in the refinancing elbow.

money than in-the-money options, discounts generally have a higher vega relative to premiums.

Prepayment duration, which measures the change in price due to a 10 bp decline in the refinancing threshold (elbow), increases with MBS price. Again using the option analogy, a decline in the refinancing threshold implies lowering the strike rate for all the embedded call options. The impact of this decline is greater for the in-the-money call options embedded in premiums rather than the out-of-the-money options embedded in discounts.

Finally, spread duration, which measures the percent change in price due to a 100 bp widening in Treasury spread, declines with price, a straightforward consequence of the longer average life of discounts.

Testing the Five-Factor Model

We test the five-factor representation of excess returns over the July 1994-December 1999 period.[9] The model is tested using monthly excess returns of four price-sorted (discount, current, cusp, and premium) portfolios of TBA thirty-year conventional mortgages. To determine the explanatory power of the five factors, alone and in combination with other factors, we regress excess returns on an intercept and:

1. Each individual risk factor.
2. The two volatility factors, vega and convexity.
3. All five risk factors together.

Exhibit 15 displays the coefficient estimates, or the empirical risk sensitivities, from the multiple regression, which can be compared to the model-determined sensitivities reported in Exhibit 14. The size of the coefficient is not an adequate measure, however, of the significance

E X H I B I T   1 5
Empirical Risk Measures for Thirty-Year Agency Fixed-Rate Mortgages — July 1994-December 1999

	Convexity	Vega*	Prepayment Surprise	Spread Duration	Directionality	ZV	% of Variation Explained
Discount Est.	-1.5	-4.7	0.0	-5.1	-0.1	130	52%
t-stat	(-1.8)	(-2.9)	(0.2)	(-6.1)	(-0.2)	(2.4)	
Current Est.	-2.7	-3.8	-0.4	-4.4	0.8	171	59%
t-stat	(-3.7)	(-2.6)	(-3.3)	(-5.4)	(2.6)	(3.4)	
Cusp Est.	-2.1	-4.2	-0.5	-3.6	0.1	150	59%
t-stat	(-3.6)	(-3.3)	(-4.4)	(-5.6)	(0.4)	(3.7)	
Premium Est.	-1.2	-2.5	-0.3	-1.8	-0.5	79	40%
t-stat	(-2.2)	(-2.1)	(-3.0)	(-2.9)	(-1.9)	(2.1)	

*In 32nds.

of the factor in determining mortgage returns; the variability of the factor is also an important consideration.

In Exhibit 16, we compute the partial contribution of each of the risk factors to the total excess return variability.

Empirical Estimates of Risk Sensitivities. Empirical convexities, ranging from −1.2 to −2.7, are roughly comparable to theoretical risk measures, while empirical vegas, ranging from −2.5 to −4.7/32nds, are less negative than theoretical vegas. At first blush, this difference suggests that mortgage prices are less sensitive to changes in implied volatility than our valuation model indicates. We suspect, however, that some econometric issues are biasing our coefficient estimates. For instance, if mortgage prices do not adjust instantaneously to changes in implied volatility, this would bias the coefficient estimates toward zero.

Swap spreads are significant for all price buckets, and the coefficient estimates are comparable to theoretical measures. Our estimate for the surprise in the MBA

E X H I B I T   1 6
Contribution of Risk Factors to Observed Mortgage Excess Returns — January 1994-December 1999 (%)

	% of Explained Variation			
	Discount	**Current**	**Cusp**	**Premium**
Risk Factors				
Convexity	5	22	20	14
Vega	15	7	8	4
Volatility Factors	**19**	**28**	**28**	**18**
Credit	39	24	22	8
Directionality	0	7	1	3
All Factors Except Prepayments	**52**	**51**	**45**	**29**
Prepayments	1	7	13	12
All Factors	**52**	**59**	**59**	**40**

refinancing index is significant for all non–discount price buckets and is most pronounced for current and cusp coupon mortgages. This pattern is not consistent with Exhibit 14, where premiums have the highest prepayment sensitivity, and underscores the inadequacy of our proxy as a measure for prepayment surprises.

Finally, the directionality of mortgage spreads is significant for current-coupon mortgages, which trade 0.8 years shorter than their theoretical duration. For other buckets, the effect of directionality is limited. The unexplained variation in excess returns ranges from 40% to 60%, which can be attributed largely to prepayment-related factors that are not easily captured through any measured variable.

How Well Does the Model Explain Variation in Excess Returns? The five-factor model does a good job of explaining variation in excess returns, as measured by the R^2 statistic from the regressions (Exhibit 16). The variation in the five risk factors explains 52%–59% of the variation in excess returns of non-premium mortgages and 40% of the variations in excess returns of premiums.

Realized volatility is the most important risk factor, explaining 5%–14% of the variation in excess returns. The two volatility risk factors, realized and implied volatility, together explain 18%–28% of the variation in excess returns of thirty-year mortgage returns.

Credit spreads have high explanatory power for lower-priced mortgages, reaching a maximum of 39% for discounts. The measured prepayment risk factor explains 7%–13% of the variation in the prepayment-sensitive current, cusp, and premium mortgages. Finally, spread directionality appears to be an important factor only for current-coupon mortgages.

IV. OUTLOOK

Our analysis has shed light on the historical behavior of mortgage returns: their past performance, their interrelationships with other fixed–income sectors, and their key drivers. This understanding of past return behavior provides a basis for insights into future mortgage performance. Looking forward, we expect the following:

1. Refinancing costs will decline significantly over the next three to five years, due to increased automation in mortgage underwriting, access to refinancing over the Internet, and technological improvements in the title search process.
2. Our production prepayment model, which does not

build in this increased efficiency, currently overstates durations by 0.1-0.3 years and overstates OAS by 6 bp –15 bp. Once the full improvements in efficiency are realized, par coupon duration will be 0.4 years lower, and option cost will be 15 bp higher.
3. In setting Treasury hedge ratios, investors should account for spread directionality when the mortgage index is at a premium.

Refinancing Efficiency Will Continue to Improve

Increasing refinancing efficiency has had a significant impact on past excess return performance. Our current prepayment model does not build in improvements in refinancing technology, so the reported OAS overstate expected excess returns. To gauge the impact of continuing technological innovation, we have attempted a preliminary assessment of the potential for future cost savings and its impact on MBS valuation.

Exhibit 17 reports the cost breakdown for refinancing a $130,000 loan in a typical state.[10] Brokerage represents the cost of soliciting customers. The under-writing/processing item includes all the costs incurred from the receipt of application to loan closing, including appraisal and closing.

Each of these cost items is under siege as a result of industry consolidation, automation, and Internet usage. With increasing Internet usage, we expect brokerage costs to decline from $395 to $200 for a refinancing transaction (originators currently pay $30-$50 to Internet portals for

E X H I B I T 1 7
Mortgage Origination — Current versus Projected Cost Structure for a $13,000 Loan

	Current (2000)	Forecast (2004)	Savings
Fixed Costs			
Brokerage	$ 395	$ 200	
Underwriting/Loan Processing	475	330	
Appraisal and Credit Check	470	200	
Legal	400	400	
Govt. Fees	170	170	
Total Fixed Costs	1,910	1,300	$610 (32%)
Variable Costs			
Title Insurance	0.6%	0.4%	
Govt. Taxes	0.3%	0.3%	
Total Variable Costs	0.9%	0.7%	0.2%

Sources: E-loan (online mortgage broker) and Lehman Brothers.

loan referrals). Industry sources indicate that processing costs will decline by 30% (from $475 to $330), due to automation, over the next three to four years. Furthermore, many mortgage companies are now using sophisticated statistical techniques to get reasonable estimates of home value without a detailed physical examination of the home, sharply reducing third-party costs.

We estimate accordingly that the fixed costs of refinancing a loan could decline by 32%. In our view, this is an optimistic scenario from the perspective of mortgage investors, and the potential exists for a significantly greater reduction in fixed costs associated with refinancing.

Finally, the increasing computerization of court records will reduce the cost of the title search and insurance. Our analysis suggests that a 30% reduction in title insurance costs is likely over the next three to five years, implying a 20 bp decline in the variable costs of refinancing.

While the implication of a decline in variable costs is a straightforward shift in the refinancing threshold, the impact of decreasing fixed costs is more complex. To simplify the analysis, we note that, from a callability perspective, a decline in fixed costs is equivalent to an increase in loan amount with unchanged fixed costs. Consequently, the 32% projected decline in fixed costs is equivalent to an increase in the loan balance of 47% (1/0.68).

Since the average jumbo loan size is about double that of agencies, the lower fixed costs should move agency mortgages about halfway along the current callability gradient from agencies to jumbos. This analysis implies a further 25 bp inward shift in the refinancing threshold (in addition to the 20 bp shift due to variable cost savings) and a 15% increase in the slope of the refinancing function.

Valuation Impact of Expected Technological Innovation

We assume that the reductions in refinancing costs would be achieved in four years. We simulate a gradual and uniform increase in callability over the next four years and show the current valuation impact on representative securities in Exhibit 18A. Naturally, the valuation impact will be greater once the efficiencies are fully realized, i.e., in January 2004. This is reported in Exhibit 18B, where we compute OAS and durations with the full increase in callability at today's prices, yield curve, and volatility environment.

Not surprisingly, the greatest impact is on premiums. The current OAS impact for TBAs varies from 6 bp for discounts to 15 bp for premiums (Exhibit 18A). After

E X H I B I T 1 8 A
Current Impact of Projected Improvements in Refinancing Efficiency on Valuation of Thirty-Year Conventional TBA Mortgages — December 29, 1999

Coupon	Price	No Improvement		Projected Improvement*		Change	
		OAS (bp)	OAD	OAS (bp)	OAD	OAS (bp)	OAD
7.0	96-25	45	4.7	36	4.6	9	0.1
7.5	98-31	47	4.2	36	3.9	11	0.3
8.0	100-27	53	3.6	40	3.1	13	0.5
8.5	102-23	53	2.7	31	1.9	22	0.8
9.0	104-19	77	2.6	53	1.9	24	0.7

*Due to a uniform increase in refinancing sensitivity over the next four years (refinancing threshold declines by 45 bp; the slope increases by 15%).

E X H I B I T 1 8 B
Future Impact of Projected Improvements in Refinancing Efficiency on Valuation of Thirty-Year Conventional TBA Mortgages — December 29, 1999

Coupon	Price	No Improvement		Projected Improvement*		Cha
		OAS (bp)	OAD	OAS (bp)	OAD	OAS (b
7.0	96-25	45	4.7	36	4.6	9
7.5	98-31	47	4.2	36	3.9	11
8.0	100-27	53	3.6	40	3.1	13
8.5	102-23	53	2.7	31	1.9	22
9.0	104-19	77	2.6	53	1.9	24

*Due to an instantaneous increase in refinancing sensitivity (the refinancing threshold declines by 45 bp and the slope increases by 15%).

the full increase in callability (Exhibit 18B), an unchanged prepayment model would understate OAS by 9 bp–24 bp and durations by 0.1–0.8 years. We expect the market to progressively price the increasing callability. Exhibit 18B indicates how much the value of an MBS will erode over time due to greater callability, even if the rate and volatility environment remains unchanged.

We emphasize that this analysis understates the true impact of the continuing transformation of the mortgage banking industry. For example, we do not forecast any change in refinancing sensitivity after four years. The industry will continue to evolve, and costs are likely to be squeezed relentlessly. This limited analysis nevertheless highlights the relative sensitivities of different securities to this source of risk.

How Should Mortgages Be Hedged?

Our analysis should provide some guidance on appropriate hedging techniques for mortgages. The

empirical model suggests that five factors drive most of the variation in excess returns. To be sure, the exposure to prepayment surprises is difficult to hedge, and investors should be compensated for prepayment exposure. Yet the other four factors are readily hedgeable.

Most investors already dynamically manage the duration of their mortgage positions. The evidence, however, shows that mortgages have a significant exposure to vega risk, which can be hedged using derivatives such as swaptions. The significant role of swap spread changes suggests that swaps are a better hedge for mortgages than Treasuries. The existence of spread directionality implies that managers must adjust their hedge ratios when the mortgage market trades at a premium, i.e., the mortgage index is priced above $102.

The adjustment of model hedge ratios is not a straightforward task; most mortgage investors have struggled to find the appropriate adjustment, particularly over the past year. Empirical durations have often deviated from model durations, and this relationship has varied considerably over time. Our analysis, coupled with our expectations about future refinancing efficiency gains, suggests a framework for hedging mortgages. As a first step to improve hedging precision, investors should use forward-looking prepayment models, as detailed in Exhibits 17 and 18. A further refinement would take into account the relationship between spread directionality and the level of the index.

A preliminary attempt to measure the combined impact of refinancing efficiency and spread directionality is shown in Exhibit 19. The duration of current-coupon mortgages (7.5s) should be adjusted downward from 4.2 to 3.4 if the index price is above $102, due to spread directionality. Incorporating future refinancing efficiencies will reduce this duration by an incremental 0.2 years, resulting in a combined impact of 1.0 years. Similarly, the duration of 8.5% mortgages should be adjusted downward by as much as 0.8 years.

E x h i b i t 1 9

Combined Impact of Refinancing Efficiency and Spread Directionality on Durations of Thirty-Year Conventional TBA Mortgages — December 29, 1999

Coupon	Index Price	Improvement in Refinancing	
		None	Projected
7.5%	< $102	4.2	4.0
7.5	> $102	3.4	3.2
8.5%	< $102	2.7	2.4
8.5	> $102	2.1	1.8

V. CONCLUDING COMMENT

We recognize that our research is only a first step in the empirical analysis of mortgage excess returns and the implications for hedging mortgages, as well as fixed-income asset allocation. Much work remains to be done in refining the analysis, as well as making concrete recommendations for portfolio managers. We look forward to continuing to build a better foundation for understanding mortgage returns.

ENDNOTES

The authors thank their colleagues — Jeffrey Biby, Lev Dynkin, Richard Kazarian, Prafulla Nabar, Andrew Sparks, and Prashant Vankudre — for their various suggestions and their patience in reading many drafts of this article. This study is made possible by the availability of reliable index data.

[1]Our analysis focuses on excess returns of securities in the Lehman Brothers Aggregate Index. We define excess return as the security's total return minus the total return of a duration-matched portfolio of Treasuries. The replicating duration-matched Treasury portfolio is rebalanced every month. The excess return of an index is the market-weighted average excess return of all securities in the index.

[2]We use these price bucket definitions throughout.

[3]We also report performance statistics for the 1989-1997 subperiod to isolate the impact of the 1998 credit/liquidity crisis.

[4]Refinancing threshold is the incentive required for refinancing to become economically attractive to some homeowners, which occurs at the "elbow" of the refinancing curve. Slope is the part of the curve to the right of the elbow.

[5]The ten-year Treasury yield, for instance, declined from 9.22% on January 3, 1989, to 6.44% on December 29, 1999.

[6]Another blow against mean–variance optimization is the considerable evidence that financial asset returns are fat-tailed, i.e., Z-scores underestimate the true likelihood of extreme negative or positive returns.

[7]This phenomenon is not attributable to the greater callability of the market prepayment model. While underestimating mortgage callability would make empirical durations shorter than model durations, it would not cause *par coupon* OAS to vary systematically with rates.

[8]The refinancing incentive for a pool is simply the weighted-average coupon (WAC) less the mortgage rate.

[9]The sample period is limited by the availability of price data on longer-maturity swaptions. TBA FNMAs are chosen for their high-quality return data, a result of their greater liquidity.

[10]Refinancing costs vary substantially across states due to differences in title insurance, legal requirements, and recording taxes.