THE EVOLUTION OF MORTGAGE YIELD CONCEPTS

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This paper traces the evolution of the concept of "mortgage yield", starting with the yield to prepayment which held sway until the mid-seventies, to the cash flow yield which dominated until the late eighties, to the option adjusted yield which is intellectually dominant today. It is argued that while each of these concepts represented an improvement over the one that preceded it, the cash flow yield should have given way to the holding period yield, and then to an option adjusted holding period yield of which the (currently fashionable) option adjusted yield is merely a special case. The holding period yield is the ideal tool for scenario analysis because of its sensitivity to the particular circumstances of the user, and the option adjusted variant provides better information about whether a security is correctly priced because it does not prejudge the market's consensus holding period.

The Evolution of Mortgage Yield Concepts

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This paper traces the evolution of the concept of "mortgage yield", starting with the yield to prepayment which held sway until the mid-seventies, to the cash flow yield which dominated until the late eighties, to the option adjusted yield which is the current favorite among market "intellectuals" although not necessarily among practitioners.

While each of these yield concepts represented an improvement over the one that preceded it, I will argue that the cash flow yield should have given way to the holding period yield, which is conceptually more powerful. A major purpose of the paper is to demonstrate the power of the holding period yield when it is used as a schedule, over every possible holding period. When the holding period yield is option adjusted, the (currently fashionable) option adjusted yield is seen for what it is: a special case. It is merely the one point on the holding period yield schedule that corresponds to the term of the security.

I Yield to Prepayment

A. The Concept

The yield to prepayment is the internal rate of return (IRR) on an individual mortgage. The cash flows consist of the scheduled monthly payments until the loan is prepaid in full, in

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[1]The author is indebted to Allan Redstone and Kenneth R. Scott for helpful suggestions.

which month the cash flow includes the remaining unpaid balance. If the investor pays an amount I, which is equal to the balance times the price expressed as a decimal, the yield to prepayment in month n is y in the equation below.

$$I = PMT_1/(1 + y) + PMT_2/(1 + y)^2 + \ldots (PMT_n + B_n)/(1 + y)^n.$$

In the United States, the convention is to calculate y as a monthly figure from monthly cash flows which is then multiplied by 12 to obtain the annual reported figure.[2] This convention holds for all the yield concepts discussed in this paper.

If the investor pays par for the security, the yield to prepayment is independent of the period to prepayment.[3] In any other case, one must specify the period to prepayment to determine the yield. For many years the standard prepayment assumption for 30-year loans was 12 years, and one still encounters this practice in the marketplace, but it has largely died out with the yield to prepayment itself.

B. Shortcomings

While the cash flow assumption underlying the yield to prepayment, that the investor receives an installment payment every month the loan is in force and the remaining balance in the month the loan is prepaid, may be a reasonable way to view an

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[2]Because this figure does not take account of monthly compounding, it is sometimes called the "nominal yield." It can be converted into an "effective" yield that does take account of monthly compounding using the formula $E = [1 + Y/12)^{12} - 1$.

[3]Par is 100 if the payment is received by the investor on the day it is due from the borrower. If there is a payment delay, which is customary on mortgage-backed securities, par is less than 100.

investment in a single security, it has very serious limitations as a measure of performance for investors who hold portfolios of securities. The individual loans in a portfolio, even when each loan is the same general type and has the same coupon, will not all prepay at one point in time. Rather, prepayments will occur over the entire life of the portfolio.

Furthermore, the use of a point prepayment assumption to characterize a portfolio, even if that point accurately reflects the average period to prepayment of all the loans in the portfolio, will not provide an accurate measure of the yield on the portfolio. This is illustrated in Table 1 which compares the yield to prepayment in 12 years on a 10%, 30-year mortgage, with the yield on a large portfolio of identical mortgages that has an average life of 12 years.[4] (It is assumed that the prepayment rate for this portfolio is constant). Because of the curvilinear relationship between yield to prepayment and prepayment period, the yield to prepayment has a downward bias on a discounted mortgage and an upward bias on a premium mortgage. [5]

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[4]This is identical to the "cash flow yield" defined below.

[5]For an early discussion of this point, see Guttentag and Beck [4].

Table 1

Bias in Yield to Prepayment Relative to a Portfolio Yield
(10.5% mortgage, .5% servicing fee, 30-year term)

	Price						
	85	90	95	100	105	110	115
Yield to PP	12.50	11.60	10.77	10.00	9.28	8.61	7.98
Cash Flow Yld	12.97	11.87	10.89	10.00	9.19	8.45	7.76
Bias	-.47	-.27	-.12	0.0	.09	.16	.18

Note: Yield to prepayment is calculated at 12 years. The portfolio yield assumes an annual prepayment rate of 5.613 which results in 50% of the mortgages in the pool surviving to the end of the 12th year.

The limitations of the yield to prepayment as a measure of performance on portfolios led to the widespread use of the cash flow yield, which is a portfolio concept. Since cash flow yield is generally more difficult to compute, the transition was facilitated by the increasing power of computer technology and the growing use of PCs.

II <u>Cash Flow Yield</u>

A. The Concept

The cash flow yield is the IRR on a hypothetical portfolio of securities that prepays according to a specified scenario over the life of the portfolio. The output is a single portfolio yield calculated from monthly cash flows. Except in the case where the prepayment scenario is one of zero prepayments, the monthly cash flows used to calculate the cash flow yield include prepayments in full of some mortgages in the hypothetical portfolio. These are usually referred to as "unscheduled" principal payments, as contrasted to the principal portion of the regular payment which are termed the "scheduled" payments.

Assume the scheduled payment is PMT; the number of loans in the portfolio at the outset is N_0, the number at the end of period 1 is N_1, and the number that go to term is N_t; the prepayment rates in period 1 and 2 are pp_1 and pp_2, and the balances after amortization but before prepayment are B_1 and B_2. Then y is the monthly cash flow yield in the equation below.

$$I = (PMTxN_0 + pp_1xB_1xN_0)/(1 + y) + (PMTxN_1 + pp_2xB_2xN_1)/(1+y)^2 + \ldots(PMTxN_t)/(1 + y)^t$$

B. Prepayment Scenarios

The counterpart of varying the period to prepayment when using the yield to prepayment is varying the prepayment rate when using cash flow yield. Several conventions have been adopted for defining prepayment rates, including the constant prepayment rate (CPR), which is the percent of loans outstanding at the beginning of a month that will be prepaid during the month, defined as an annual rate; and the single monthly mortality (SMM), which is a monthly equivalent where $SSM = 1 - (1 - CPR)^{1/12}$. The specified CPR or SMM can be kept constant over the life of the mortgage, or it can be changed, perhaps in line with some assumed change in market interest rates.[6]

[6]For this reason, the adjective "constant" in "constant prepayment rate" is a misnomer.

An alternative method of defining prepayment rates, the PSA convention, builds in an assumed rise in CPRs over the first 30 months of mortgage life. 100% of PSA means CPRs of .2% in month 1, .4% in month 2, .6% in month 3...to 6.0% in month 30 where they remain. 150% of PSA means CPRs of .3% in month 1, .6% in month 2 and so on to 9% in month 30 and thereafter. To use PSA it is necessary to know the age of the mortgage. [7]

C. Shortcomings

The cash flow yield has three major drawbacks. First, as with any IRR (including the yield to prepayment), it assumes that all cash flows are reinvested at the cash flow yield. This assumption makes the cash flow yield a poor tool for scenario analysis, where interest rates are assumed to follow alternative future patterns. Since the reinvestment rate used in the cash flow yield is fixed, the yield differences corresponding to the different scenarios will only reflect the effect of different prepayment rates on the cash flow. The differences will thus be understated.

The point is illustrated in Table 2 below which shows the cash flow yield and the "adjusted cash flow yield" on a GNMA 10 under 5 different future interest rate and prepayment rate

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[7] The rationale for the PSA convention is that prepayment rates tend to rise in the early years of a pool's life, perhaps for about 30 months. Prepayment experience used as the basis for projecting prepayment rates will underestimate future rates for a relatively new pool unless this tendency for rates to rise in the early months is taken into account. After 30 months, PSA and CPR/SMM are identical.

scenarios. The adjusted cash flow yield is the monthly yield that equates present value with future value, where the cash flows used to derive future value are reinvested at rates which are assumed to change in line with the yield scenarios.[8]

The variability in adjusted cash flow yields as between the different scenarios is much wider than the variability in cash flow yields. This indicates that changing reinvestment rates have a larger impact on yield than changing prepayment rates, and the failure of cash flow yield to capture the effect of changing reinvestment rates is a significant weakness.

Table 2

Cash Flow Yields and Adjusted Cash flow Yields on a GNMA 10 With 354 Months Remaining, Priced at 101-07

Future Yield Scenario	PSA	Cash Flow Yield	Adjusted Cash Flow Yield
No change	135	9.705	9.705
+ 1.5%	85	9.738	10.893
+ 3.0	70	9.748	12.073
- 1.5	235	9.641	8.443
- 3.0	300	9.602	7.147

Note: Changes in both prepayment rates and reinvestment rates are phased in smoothly over the first three years. The reinvestment rate used in calculating adjusted cash flow yield is 9.705% plus or minus the yield changes in the scenario. The PSA assumptions are from Morgan Stanley as of 10/24/90, extrapolated by the author.

[8]The adjusted cash flow yield is identical to the holding period yield defined below where the holding period is the term of the mortgage.

The second weakness of the cash flow yield concept (which is also shared with the yield to prepayment) is that it fails to capture the value of the option to prepay granted the borrower. Most mortgages allow borrowers to prepay the loan at any time without penalty. Since borrowers can elect to prepay when it is financially advantageous to them, the option to do so has value to the borrower and is a cost to the lender. This option cost varies from mortgage to mortgage, depending on mortgage characteristics, but the principal determinant of option cost is the coupon rate relative to the current market rate.

For example, a GNMA 10 selling at a small premium has a relatively large option cost to the lender because many borrowers are on the refinancing threshold. If market rates decline, the prepayment rate will rise sharply and the lender will lose them. If rates rise, on the other hand, the prepayment rate will fall but not by much because not many were being refinanced before. In contrast, the option cost to the holder of a GNMA 8 is smaller because prepayment rates on the GNMA 8 will be affected much less by moderate increases or decreases in market rates. A GNMA 12 also has a lower option cost than the GNMA 10. The prepayment rate on the GNMA 12 is already high and won't go much higher if market rates decline but it will decline markedly if rates rise. These points are illustrated in Table 3.

Table 3

Various Yield Comparisons Between GNMA 12s, 10s and 8s

	GNMA 12	GNMA 10	GNMA 8	10-8	10-12
Price 10/24/90	109-15	101-07	90-30		
Period remaining	24-06	29-07	26-06		
Projected PSA					
Stable Rates	250	135	80		
+ 1.5%	190	85	60		
+ 3.0	110	70	50		
- 1.5	310	235	120		
- 3.0	330	300	200		
Cash flow yield, stable rates	9.358	9.705	9.443	.262	.347
Average cash flow yield over 5 scenarios	9.413	9.687	9.530	.157	.274
Average adjusted cash flow yield over 5 scenarios	9.630	9.652	9.626	.026	.022

Note: See note to Table 2.

For this reason the cash flow yield is lower on both GNMA 8s and GNMA 12s than on GNMA 10s. In effect the investor in GNMA 10s is demanding a higher yield in a stable yield environment to compensate for unfavorable changes in prepayment rates that would occur in a fluctuating yield environment.

A simple way to capture differences in option cost is to average cash flow yields across a number of hypothetical interest rate scenarios. As shown in the 2 far right columns of Table 3, averaging reduces the difference in cash flow yield between the two securities, and averaging the adjusted cash flow yield virtually eliminates it. The latter can be viewed as a very crude option adjusted yield (OAY), the concept considered in Section III.

The OAY is responsive to both of the shortcomings of the cash flow yield described above. However, the cash flow yield has a third weakness which the OAY does not address, namely, that it assumes an investment horizon equal in all cases to the remaining life of the mortgage. We will return to this issue in Section IV.

III Option Adjusted Yield

A. The Concept

The OAY is a cash flow yield that uses current reinvestment rates and is net of option cost to the investor. The research underlying the concept has come largely out of Wall Street rather than academia, and it has been adopted in one form or another by all the major investment banking firms that are active in the mortgage backed securities market. The approach generally taken involves three major steps:

1. A large number of future interest rate paths are generated through a random selection process, the distribution of paths corresponding to prior assumptions about the volatility of rates and the shape of the distribution.

2. The cash flows corresponding to each path are calculated using a model that relates prepayment rates to the spread between the coupon rate and the current market rate, as well as to other factors that affect prepayments.

3. These cash flows are used to calculate either a cash flow yield net of option cost, or (more commonly) a spread above

Treasury securities of the same duration that is also net of option cost -- the "option adjusted spread".[9]

On Wall Street (although not on Main Street) option adjusted yields or spreads have become the key measure of investment performance. One suspects that in part the fondness of the Wall Street firms for the concept is due to the fact that with few exceptions only those firms have the computer facilities, prepayment forecasting models, and data banks required to produce the numbers.

B. Shortcomings

Unfortunately, the OASs provided by different firms for the same security may differ widely. In part, these differences reflect differences in the statistical procedures used and/or in the prepayment forecasting models, information about which the firms view as proprietary. To outside users, OAS estimates produced by Wall Street come out of a number of black boxes.

As a result, OAS estimates are not verifiable by anyone other than the firm that produces them. This is in contrast to yield to prepayment and cash flow yield, for which the calculation rules are standard so that two parties using the same assumptions will produce the same numbers. This problem inheres in the complexity of the OAS calculation; it will not go away unless a standard option adjustment procedure is adopted, with

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[9]For further background on OAS and detail about how the calculations are made, see Bartlett[1], Carron and Hogan[2], Davidson[3], Herskovitz[5], and Jacob and Toevs[6].

the implementing software required to make calculations available to everyone.

The major conceptual weakness of the OAS is that it assumes (as does the simple cash flow yield) an investment horizon equal to the term of the security. For many investors this assumption is invalid. A life insurance company using mortgage backed securities to fund a 5-year guaranteed investment certificate, for example, is concerned with the return over 5 years.[10] The holding period yield, which we turn to next, is a performance measure that is responsive to the great diversity of investment horizons on the part of different investors.

III The Holding Period Yield

A. The Concept

The holding period yield is a point-to-point return that measures the increase in the investor's wealth. If the investor begins with wealth of W1 and ends with W2, the return HPY over the period is (W2 - W1)/W1. The annual equivalent HPY over a period of n months is $[(1 + HPY)^{1/n}-1]12$.

To calculate the HPY on a mortgage requires three scenarios: a prepayment scenario similar to that used in calculating cash flow yield; a reinvestment rate scenario which governs how interim cash flows are invested; and either a scenario of prices at which the security will be sold, or a scenario of yields for

[10]It is somewhat paradoxical that the OAS is calculated on the assumption that all investors have a time horizon equal to the term of the security, but it is used mainly to identify undervalued and overvalued securities for trading purposes.

valuing the security at the end of every period.

The HPY is not unknown to Wall Street, but its use has been largely limited to historical measures of realized return, where actual closing prices, prepayment rates and reinvestment yields are known. On a prospective basis it is used for very short future horizons, where the output is a single HPY over one period - usually a year. The focus is on trading, not portfolio management.

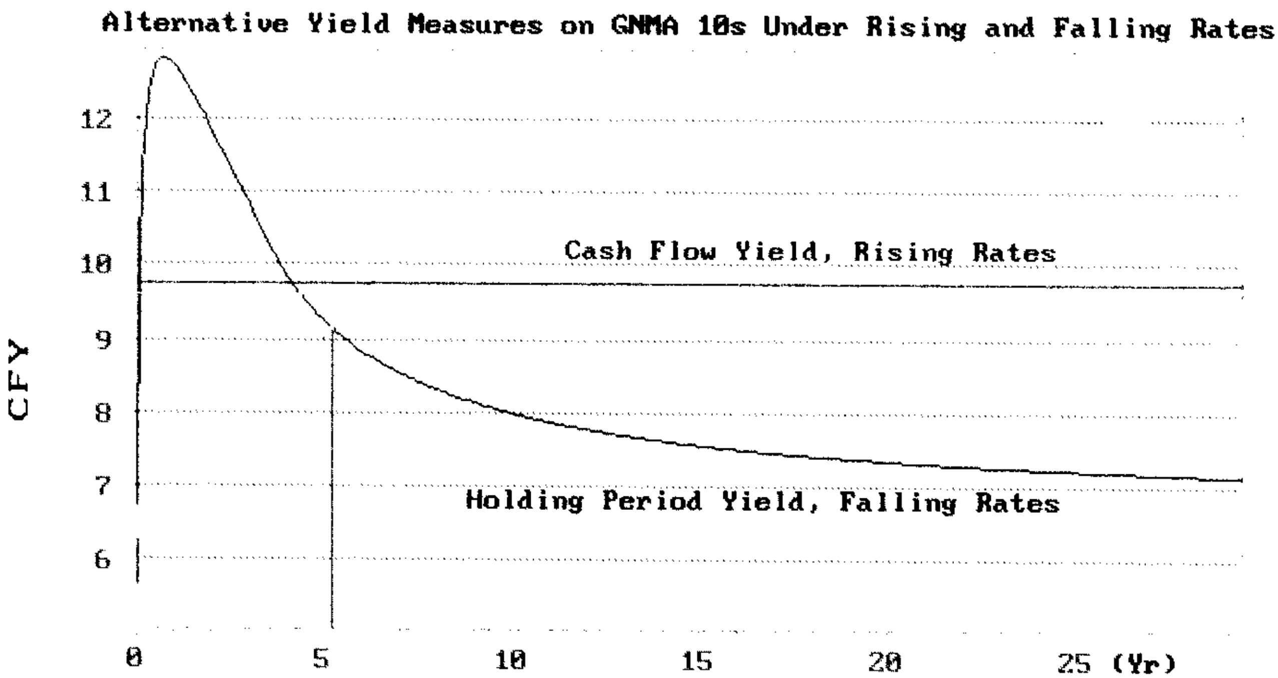
B. Use in Scenario Analysis

The major potential of the HPY as a measure of performance is realized only when the measure is calculated over every possible horizon. Scenario analysis, where the user tests performance over a range of possible futures, is far more insightful using complete HPY schedules than using cash flow yields. This is illustrated in Chart 1 covering the GNMA 10 referred to earlier. The difference between the HPY schedules under rising and falling interest rate scenarios (+3% and -3%) provides a unique measure of risk to the investor[11], and shows how that risk varies with the holding period. In the illustration, the risk is nil at a holding period of 63 months where the schedules intersect. The horizontal cash flow yield schedules, in contrast, reveal nothing of this, and an option adjusted yield would be just another horizontal line.

Chart 2 uses the same approach to compare the risks of GNMA

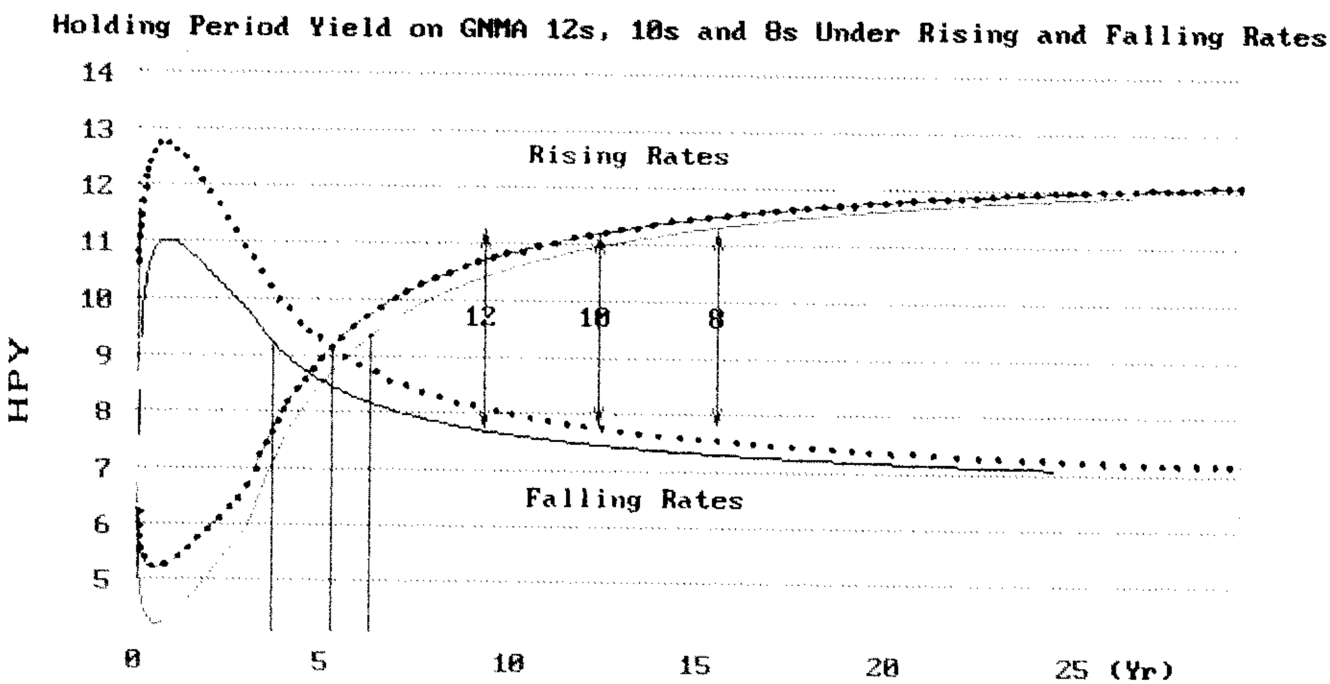
[11] Roll[7] used this measure to assess the relative riskiness of different CMO tranches but I know of no other references to it.

Chart 1



Alternative Yield Measures on GNMA 10s Under Rising and Falling Rates
CFY
12
11
10
9
8
7
6
Cash Flow Yield, Rising Rates
Holding Period Yield, Falling Rates
0
5
10
15
20
25 (Yr)

Chart 2


Holding Period Yield on GNMA 12s, 10s and 8s Under Rising and Falling Rates
HPY
14
13
12
11
10
9
8
7
6
5
Rising Rates
Falling Rates
12
10
8
0
5
10
15
20
25 (Yr)

12s, 10s and 8s. Over short holding periods the 12s have the lowest risk while over long holding periods the 8s have the lowest risk, with 10s in-between in both cases. The intersection points where risk is nil are 45, 62 and 74 months, respectively. Only the holding period return can provide the investor with this type of perspective.

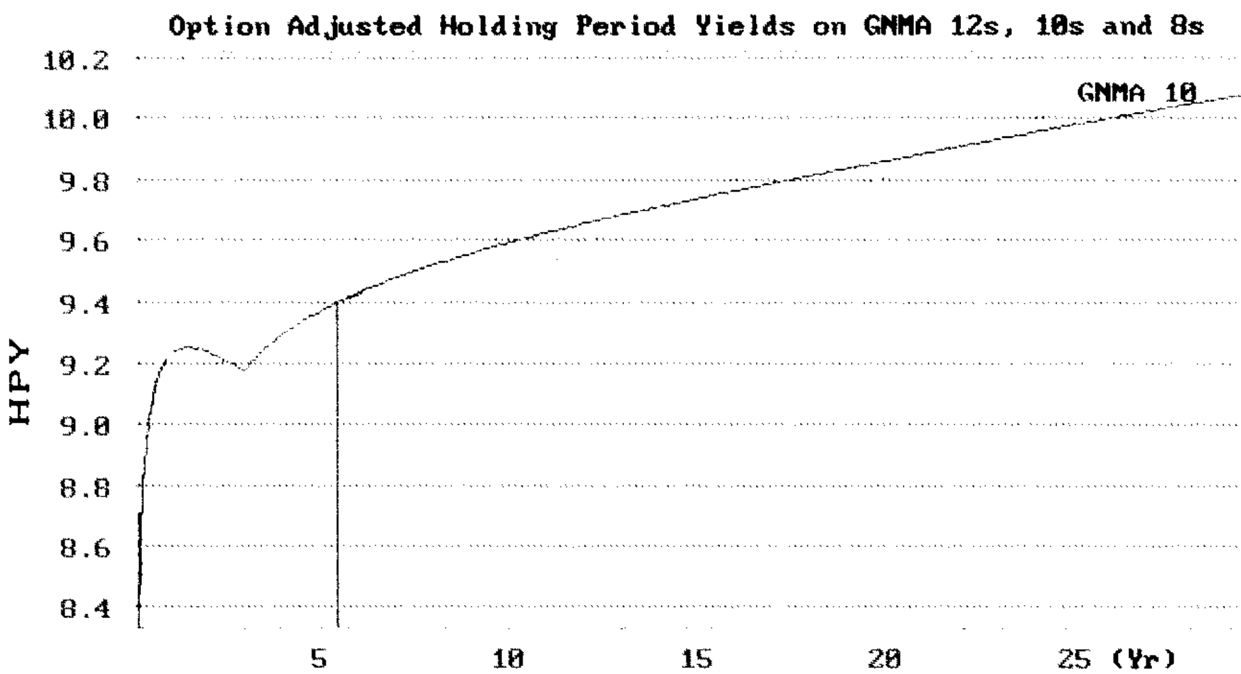
C. Adjusting for Option Cost

The holding period return can also be adjusted for option cost. A simple way to do this is to create hypothetical portfolios based on symmetrical rising and falling rate scenarios, and then compute the holding period return on the portfolios.[12] I have done this for the GNMA 12s, 10s and 8s using the scenarios shown in Table 3; the holding period return schedules are shown in Chart 3. Using this measure, the 8s provide the highest expected return over holding periods to 65 months, where the schedules intersect. The 12s provide the highest return beyond 65 months, and the 10s are generally in-between.

Chart 3 raises some interesting questions regarding what constitutes fair pricing of mortgage securities. The currently fashionable option adjusted yield purports to measure the fair price after allowing for the value of the prepayment option, but

[12]An advantage of this type of option adjustment is that it is easily replicable because the scenarios are explicitly defined. The more sophisticated methodology that has been developed on Wall Street to measure option cost can also be applied to the holding period return, and a project is now underway at the Wharton School to develop this methodology.

Chart 3


Option Adjusted Holding Period Yields on GNMA 12s, 10s and 8s
10.2
10.0
9.8
9.6
9.4
9.2
9.0
8.8
8.6
8.4
HPY
GNMA 10
5
10
15
20
25 (Yr)

it presupposes that the market's consensus holding period is the term of the security being assessed. Since terms vary for different securities, this is inherently contradictory. The option adjusted holding period yield, in contrast, does not prejudge the market's consensus holding period, but neither does it provide a clear cut criterion for determining whether a security is fairly priced.

One possible way of viewing the fair price problem in the context of varying holding periods is to postulate that an efficient market will cause the option adjusted holding period yields on different securities to converge at the market's consensus holding period. Using the information on Chart 3, for example, we might infer that the market is efficient, and that the consensus holding period is 65 months.

Of course, data on three securities for a single day using a single method of option adjustment are not sufficient evidence to support either claim. I am particularly doubtful that the market can be relied on to provide yield convergence when so many decisions are made using inappropriate yield concepts. My speculations are designed to stimulate the research that will be badly needed when the holding period return concept becomes pervasive in managing portfolios, as I believe it must.

D. Components of the Holding Period Return

Part of the power of the holding period return as measure of performance lies in the ability to decompose the return into meaningful components. Let:

Price at beginning = P_1
Price at end = P_2
Balance at beginning = B_1
Balance at end = B_2
Coupon payments received during period = C
Principal payments received during period = $(B_1 - B_2)$
Reinvestment earnings during period = R
Investor's wealth at beginning = W1
Investor's wealth at end = W2

(1) $W_1 = P_1B_1$
(2) $W_2 = P_2B_2 + (B_1 - B_2) + C + R$
(3) $W_2 - W_1 = (P_2B_2 - P_1B_1) + (B_1 - B_2) + C + R$

It is possible to reformulate the first two components of equation 3 to show the effect of price change and recovery of discount. P_2B_2 can be written $B_2P_1 + B_2(P_2 - P_1)$, where the second term shows the contribution of the price change during the period. And $B_2P_1 + (B_1 - B_2) - P_1B_1$ can be written $[(B_1 - B_2)/B_1](B_1 - B_1P_1)$. The term in the bracket is the percent of the initial balance that is paid off, the second term is the original discount, and their product is the recovery of the discount. Thus:

(4) $W_2 - W_1 = C + R + B_2(P_2 - P_1) + [(B_1 - B_2)/B1](B_1 - B_1P_1)$

The increase in wealth during the period is equal to the coupon payment received, reinvestment earnings, the change in the market value of the remaining balance, and the recovery of the initial discount. If the security was initially acquired at a premium, the last term is negative. As far as I know the components of HPY have never been broken down in this way.[13]

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[13] Wallace [8] refers to the four components of the wealth increase shown in equation 3 as the market value return, principal payment return, interest return and reinvestment return, respectively. The first two components of this breakdown, however, defy any analytically useful interpretation. The "market value

An example may be useful. Let:

P1 = .9
P2 = .9158
B1 = 100
B2 = 95
C = 10   R = 2

The investor buys a security with a face value of 100 for 90, so that his initial wealth is 90. His terminal wealth is equal to the value of the security at the end of the period (.9158 x 95 = 87) plus the coupon payment of 10, principal payment of 5 and reinvestment earnings of 2, or 104. The increase in wealth is thus 14. We now partition this return as follows:

Coupon payment = 10
Reinvested earnings = 2
Price change effect = 1.5
Recovery of discount = .5
Total increase in wealth = 14

The intuition behind the price change effect is that if prices had not changed, the security remaining at the end of the period would have had a value of 85.5 (.9 x 95). Since the value was in fact 87, a price increase contributed 1.5 to the increase in wealth.

The intuition behind the recovery of discount is simply that such recovery must be proportional to the repayment of the original balance. Since the original discount was 10 and 1/20 of

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return" component combines the change in price and the change in balance whereas we want to know the impact of the price change alone. Furthermore, showing the return of principal as a component of return is misleading because most of the principal repaid during any period was in fact part of the investor's wealth at the beginning of the period. The only part that was not is the recovery of the discount -- the difference between the market value of the security and its face value at the beginning of the period.

the balance was recovered, 1/20 of the discount, or .5, was also recovered.

Breaking the annual equivalent HP into components helps in understanding exactly why the return is changing.[14] In general, over short periods the return is dominated by coupon payments, and by price change to the degree that rising or declining valuation yields are used in the scenario. Reinvestment earnings are of little consequence in the short term but become the major component of the total return over long periods. Discount recovery will not be important over short or long periods unless the initial discounts (or premiums) are very large.

The general shape of the HPY schedules shown on Charts 1 and 2 reflects the interplay of the price change and reinvestment components of HPY that work in opposite directions. In a declining (rising) interest rate scenario, capital gains (losses) will raise(lower) the HPY in the short run. Over time, however, the reinvestment of cash flows at lower(higher) rates has an increasing impact on HPY, while the weight of capital gains (losses) gradually declines.

IV Concluding Comment

Scenario analysis and option adjustment are complementary

[14]The best way to do this is by multiplying the total HPR by the ratio of the dollar values of the components to the total dollar increase in wealth. It must be recognized, however, that this is no more than an approximation. The annual equivalent HPR is not the sum of the annual equivalents of the components because the price change component is realized only at the end of the period where the other components are received during the period.

techniques. Scenario analysis provides information on the possible range of returns associated with different possible future states of the world that the user views as relevant. The holding period yield is the ideal tool for scenario analysis because of its sensitivity to the particular circumstances of the user, and the ability to disaggregate returns into their components.

Option adjustment provides a superior way to measure expected return, and therefore to determine whether a mortgage security is fairly priced. When option adjustment is viewed in the context of varying holding periods, however, the issue of what constitutes fair pricing becomes much more complicated. My tentative suggestion, designed to kick off thinking on the subject, is that the fair pricing issue might fruitfully be approached by postulating that an efficient market will force convergence in option adjusted yields at the market's consensus holding period.

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TABLE 2
FALSE ALARMS BY STOCK MARKET

Periods when stock index fell by 8% and no recession followed within 12 months
Ranked by severity of decline

YEAR OF FALSE ALARM	PEAK MONTH STOCK INDEX	LOW MONTH STOCK INDEX	% DECLINE IN MARKET
1987	Aug 1987	Nov 1987	-29.1%
1946	May 1946	May 1947	-24.0%
1962	Dec 1961	Jun 1962	-23.1%
1966	Jan 1966	Sep 1966	-15.5%
1978	Aug 1978	Oct 1978	-10.8%
1956 - 57	Jul 1956	Feb 1957	-8.3%
1984	Nov 1983	May 1984	-8.2%

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