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Author

Roll, Richard

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**MANAGING RISK IN THRIFT INSTITUTIONS:
BEYOND THE DURATION GAP**

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**Richard Roll
John E. Anderson Graduate School of Management
University of California, Los Angeles, CA 90024-1481**

ABSTRACT

Managing Risk in Thrift Institutions: Beyond the Duration Gap

Even if thrift institutions were exposed only to interest rate risk, gap management using simple duration would be an imperfect method, particularly for callable assets and liabilities. Duration measures interest rate risk for parallel shifts in the yield curve, but actual yield curve shifts should not be, and usually are not, parallel.

An alternative to duration is a multi-factor model such as the Arbitrage Pricing Model, (APT). An empirical investigation of a sample of large thrifts disclosed that they are exposed to APT factors such as inflation, investor confidence, and the term structure. The level of thrift exposure to these risk factors is twice that of the average industrial company and thrifts also exhibit an unusually large amount of non-systematic risk.

I. The Thrift Institution as a Portfolio.

A thrift institution can be regarded as a portfolio of investments. The typical thrift has a long position in financial assets, plus a minor amount of real assets, or "bricks and mortar." It has a short position in financial liabilities. The difference in the market values of its assets and liabilities is the equity value of the portfolio. This paper argues that thrifts should be directed with modern portfolio management methods.

I.A. The Riskiness of the Thrift/Portfolio.

Most investment portfolios have highly stochastic equity values, i.e., they fluctuate over time with unanticipated changes in the economy. But thrifts are often regarded as relatively simple portfolios, subject to only a limited number of economic risk factors. In contrast to, say, a pension fund portfolio with investments in bonds, equity, and real estate and with liabilities that vary in response to inflation and with conditions in labor markets, thrifts are primarily portfolios of nominal fixed-income assets and liabilities. Their intertemporal volatility in value is consequently thought to be determined by fluctuations in nominal interest rates, by the differential influence of interest-rate movements on their long and short portfolio positions.

Because deposits and other thrift liabilities often are relatively short-term claims while mortgages and other thrift assets are relatively long-term, the thrift/portfolio's risk can be roughly modeled by the differential market price movements of long- versus short-term bonds. When interest rates increase, long-term bonds generally fall more in price than short-term bonds; and vice versa; thus, the value of a thrift's equity might be thought to decline with increases in interest rates and to rise with decreases in rates.

This simple analogy does have some empirical validity, but the situation is actually more complex for several reasons. First, thrifts can and do hedge their portfolios against interest-rate movements. They can buy protection directly in the form of options or futures contracts on fixed-income assets. They can engage in fixed-income synthetic portfolio insurance, replacing longer-term assets with shorter-term assets as interest rates increase, [and vice versa]. They can simply manage the "gap" between assets and liabilities by reducing it or increasing it as the volatility of interest rates increases or decreases.

Second, thrift assets and liabilities are not as simple as nominal fixed-income securities such as treasury bonds. Deposits, for instance, may have contractual coupon rates that are relatively insensitive to market conditions. When short-term interest rates increase, the rates on deposits may lag and thus depositors may be motivated to withdraw their funds. This disintermediation implies that increases in short-term rates relative to long-term rates, which would ordinarily be helpful to the market value of thrift/portfolio equity, is attenuated by disintermediation and may even be reversed.

Another important consideration involves the traditionally most important thrift/portfolio asset, mortgages. The prepayment option causes mortgages to have highly-variable and interest-sensitive actual maturities. A decrease in long-term rates relative to short-term rates, which would normally increase the equity value of thrifts, is

mitigated by the disintermediation of mortgagor refinancing. The mortgage default option presents an even more subtle element of risk. Defaults are likely to be related to housing values and to the national and regional status of the economy. Thus, the market value of this part of the thrift portfolio may behave much like the market values of industrial corporations or like other assets sensitive to general economic conditions.

Finally, the portfolio position of thrifts is affected by the complexity of the stochastic process of interest rates. There is not just one rate of interest; there is an entire interest-rate structure from short- to long-term, and these rates do not behave themselves by conforming to simple and perfectly correlated movements over time. A comprehensive and satisfactory theory of the term structure of interest rates has yet to be developed and the historical empirical behavior of the term structure has brought many surprises.

One important consequence of term structure behavior is that simple maturity-related indicia of fixed-income risk, such as "duration," are imperfect. Section II of this essay provides a detailed analysis of the errors to which such risk measures are prone.

Another and deeper term-structure problem is the association between movements in nominal interest rates and movements in other economic factors. Interest-rate movements depend to a certain extent on fundamental economic risks, such as investor confidence, a factor that also elicits large movements in equity prices. Expected inflation clearly affects interest rates and it also can be shown to have an important influence on equities, real estate, and commodities. Even the level of industrial activity, a strong factor in the stock market, has an influence on the evolution of interest rates.

Section III of this essay presents an empirical analysis of the market returns on publicly-traded thrifts in a broad portfolio context. It shows that thrift risks are not qualitatively different from the risks of the average firm in the economy.

All this implies that, despite the apparently simple structure of the thrift/portfolio, thrifts may be subject to just as wide a variety of underlying economic influences as any other portfolio. Thus, efficient management requires modern portfolio methods.

I.B. The Empirical Literature about Thrift Riskiness.

Much of the existing empirical literature on the riskiness of financial institutions has used relatively simple interest-rate indexes. The deservedly well-known work of Flannery and James, [1984a and 1984b] on the portfolio risk of commercial banks used default-free bond indexes and/or GNMA mortgage indexes. The paper by Brickley and James [1986] about Savings and Loan Institution response to deposit insurance also followed this tactic. See also Toevs, [1983], and Stigum and Branch, [1983].

Direct estimates of the relation between thrift equity price movements and stock market movements have uncovered surprisingly high levels of market risk. For example, Lee and Lyngge, [1985], report an average stock market "beta" of 1.526 for the 35 thrift institutions with adequate monthly stock return data in the 1975-1982 time period. This implies that thrift stocks have fifty percent more market risk than the average publicly traded firm in all industries! This seems very high indeed if thrifts

are subject to only one risk element, that of interest rates, among the several risks borne by the average non-financial firm.¹

There have been some theoretical attempts to question the reliance on duration matching as the risk-minimizing strategy for thrifts, (e.g., Sartoris, [1985]). The argument is based partly on imperfect correlations among interest rates of various maturities along the term structure. Simulated hedging strategies, (Craine, [1985]), have also emphasized the necessity to admit that interest rates fluctuate in a complex way.

Bennett, Lundstrom, and Simonson, [1986], using data available only to the regulatory authorities,² meticulously construct the duration difference between assets and liabilities for a sizable sample of thrifts. They find no relation between this duration difference and the stock market beta of the thrifts, even after very careful estimation of the beta to take care of a number of well-known econometric problems. They do find a statistically significant relation between thrift betas and the one-year gap;³ however, the sign of the relation is negative, indicating that a larger gap is associated with less risk.⁴

Bennett, Lundstrom, and Simonson also investigate the direct relation between stock market price movements and changes in thrift "portfolio net worth", [defined as the discounted market value of the difference between assets and liabilities].⁵ They find absolutely no connection between the two! This is quite disturbing, because it seems to imply either (a) the stock market is doing a terrible job of assessing thrift riskiness, [a position that seems to be favored by the authors], or (b) thrift riskiness is not very well captured by the duration difference between assets and liabilities. The two major sections of this essay offer explanations of this empirical result. The first explanation (Section II), is that duration itself may have problems as a risk measure. The second explanation (Section III), is that Thrifts are exposed to more than just interest-rate risk.

¹Of course, such a level of beta may be attributable to the fact that thrifts are more highly levered than the average firm.

²Information on individual thrift balance sheet composition from Section H of the Federal Home Loan Bank Board's Quarterly Reporting System.

³The one-year gap is the difference between assets and liabilities subject to repricing within one year, divided by the book value of assets.

⁴Perhaps this illustrates one problem in relating accounting-based measures of risk with market risk coefficients: management decisions can reverse the arrow of causality. In other words, perhaps thrifts less subject to interest-rate risk because of their location or other qualities are more likely to choose a larger gap in an attempt to generate higher returns.

⁵They calculate portfolio net worth using what seems to be very sensible methods. For example, the effect of the mortgage prepayment option is taken into account. They use commercial software that is used by many thrifts to make duration calculations.

II. The Problem with Duration as a Measure of Risk.

"Duration" is one of the most frequently used concepts in fixed-income markets and is used in a wide variety of contexts. It has two meanings.

First, duration is the average time until cash payments are received from an asset. As a measure of time until payment, duration is a more comprehensive concept than maturity, because maturity is the time until the final payment only; and the final payment may represent a relatively small fraction of the asset's total present value.

Second, duration is a gauge of interest sensitivity. The "longer" the duration of an asset, the greater its price reaction to a movement in interest rates. Duration is thus a measure of risk, that particular risk caused by unforeseeable changes in the general level of rates.

Duration has an associated concept, "Convexity," which is the change in an asset's duration for a given change in the level of interest rates. An asset with a high degree of positive convexity is thought to be attractive, because convexity supposedly brings relatively large price rises when interest rates decline and relatively small price declines when rates increase.

In recent years, finance theorists have uncovered a potential problem with duration as an index of interest sensitivity and with convexity as an indication of an asset's desirability. Even for simple fixed-income assets, duration is a complete yardstick of interest sensitivity only if the bond market is not working properly; only if market conditions permit the formation of perfect arbitrage positions, i.e., portfolios that require no initial investment, are perfectly riskless, and yet generate positive cash flow. Similarly, convexity is a satisfactory indicator of an asset's desirability only if such perfect arbitrages are possible.

One may suspect that the opportunity is limited to find investments with zero cost, zero risk, and positive cash flow. Competition among arbitrageurs could conceivably reduce such alluring opportunities to a minimum. If in fact there is only a limited availability of perfect riskless arbitrages in actual debt markets, we may want to assess whether duration and convexity deserve to be used so extensively. There may be good reason to seek indicia that are more robust under realistic market conditions.

But a theoretical problem with a concept does not always imply a severe empirical problem, and we shall see below that duration is a fair approximation to interest-rate risk for some fixed-income assets, provided that interest rates do not fluctuate over too wide a range. Still, duration is only an approximation in the best of circumstances. Duration's companion, convexity, has virtually nothing to recommend its use under any condition approaching relatively competitive financial markets.

Moreover, there are many fixed-income securities, particularly those that are repayable ahead of schedule at the option of the borrower, for which the usual employment of duration can be extremely misleading. For fixed-income instruments whose cash flows can occur at uncertain times, there is no such thing as the duration.

It is perhaps trivially obvious, yet basic, to note that duration contains an element of randomness when the timing of any cash flow is uncertain. Both the average time

until payment (the first meaning of duration) and the level of interest-rate risk (the second meaning) are subject to stochastic variation when the timing of cash flows is not perfectly fixed, even though the amounts of the cash flows are not subject to doubt.

II.A. The Calculation of Duration

The simplest duration measure is based on a sequence of cash flows that are fixed with respect to both timing and amount. This measure, sometimes called Macauley's duration (after Frederick R. Macauley [1938]), is a weighted average of the times until the various cash payments, with each weight being proportional to the present value of its associated payment. In principle, each present value should be computed with a discount rate applicable for the term until the payment is due; but in practice, the yield to maturity of the bond is often used as the discount rate for all payments.

To illustrate the calculation of (Macauley's) duration, consider two hypothetical assets whose known-with-certainty cash flows are given in the following table:

Table 1

	"Barbell"	"Bullet"
Year	Cash Payment	
1	\$550	\$0
5	\$0	\$1,610.51
9	\$1,178.97	\$0

If the initial market price of each bond is \$1,000, the yield, or internal rate of return, is exactly ten percent per annum, (compounded annually), for both bonds. Notice, however, that the timing patterns of the cash flows are quite different. The "Bullet" bond has a single payment after five years, while the "Barbell" bond has two payments, at the ends of years one and nine, respectively. Despite the difference in timing, both assets have the same duration, five years, which the reader can verify by using the following formula for duration:

$$\text{Duration} = \frac{(1)CF_1/(1+R_1) + (2)CF_2/(1+R_2)^2 + \dots + (N)CF_N/(1+R_N)^N}{PV}$$

where CF_t indicates the cash flow in period t , R_t is the discount rate for a cash flow in period t , N is the number of periods until the final scheduled cash flow, and PV is the present value of the bond (the initial price). The present value itself is computed with a similar-appearing formula,

$$PV = CF_1/(1+R_1) + CF_2/(1+R_2)^2 + \dots + CF_N/(1+R_N)^N.$$

In the particular illustration above, we have:

$$\text{PV (Barbell)} = 550/(1.1) + 1178.97/(1.1)^9 = 1,000,$$

$$\text{PV (Bullet)} = 1610.51/(1.1)^5 = 1,000,$$

$$\text{Duration (Barbell)} = \{(1)500/(1.1) + (9)1178.97/(1.1)^9\}/1000 = 5.0, \text{ and}$$

$$\text{Duration (Bullet)} = \{(5)1610.51/(1.1)^5\}/1000 = 5.0$$

The illustration has surreptitiously made an assumption that the term structure of interest rates is flat, because only when the term structure is flat should we apply the same discount rate to cash flows on three separate dates. We shall return to this issue later, but first let us use these bonds to show why duration is an approximate measure of interest-rate sensitivity.

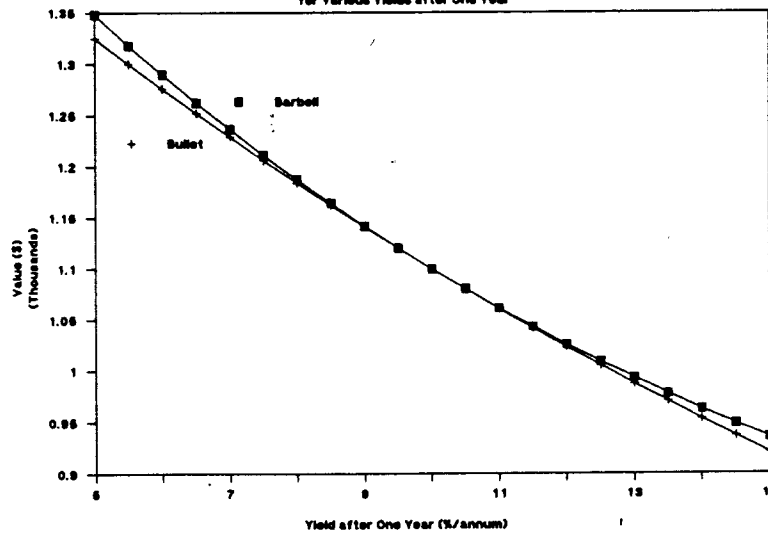
II.B. Duration as a Measure of Interest-Rate Risk

Assume that a hedge is constructed by purchasing the Barbell bond and shorting the Bullet bond. For simplicity, ignore transaction costs and any peripheral costs of shorting bonds; i.e., assume that the full proceeds of the short are available for investment. There is zero cost to this hedge position because the initial market prices of the bonds are identical. We now ask what the hedge will be worth after one year has passed, an instant before receipt of the first payment from the Barbell (of \$550). This will depend on prevailing interest rates after one year, and we assume that rates could be either higher or lower than they are now.

Figure 1 shows the market prices after one year at various interest-rate levels, under the assumption that both bonds still have equal yields to maturity, which can, however, be different from their current yield of ten percent. The striking feature of this graph is that the bonds have similar values over a range of future interest rates centered around the initial yield to maturity. It is hard to distinguish the separate curves plus or minus two hundred basis points from the initial level [of ten percent].

The implication is that these bonds have similar interest-rate sensitivities, at least for moderate changes in rates. In fact, it can be rigorously proved that their sensitivities are identical for infinitesimally small movements in yield to maturity; the slopes of the curves in Figure 1 are exactly the same at a ten percent yield.

Figure 1
Market Values of Barbell and Bullet
for Various Yields after One Year



The figure illustrates only a simple case, but the result is perfectly general. As long as the amount and timing of cash flows are certain, two fixed-income assets with wildly different cash flow patterns will have identical "local" interest sensitivities (to infinitesimally small changes in yield) if they have the same duration.

II.C. The Duration Paradox

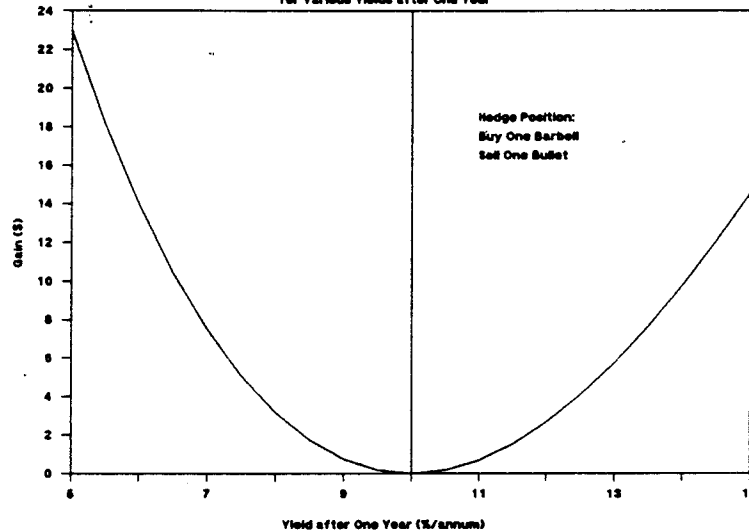
Figure 1 reveals that the two bonds in the illustration do not have exactly the same future prices unless the future yield is equal to the original yield. There is a discrepancy that becomes increasingly apparent for both very high and very low future interest-rate levels.

II.C.1. Convexity Implies the Possibility of Riskless Arbitrage Profit.

The market value of the hedge position, long one Barbell and short one Bullet, will be systematically different from zero if yields change. Surprisingly, the hedge's value will be positive regardless of the direction that the yield has moved; i.e., the Barbell bond is worth more than the Bullet bond at every yield level other than ten percent. This can be explained by the fact that the Barbell has a greater amount of "positive convexity"; (its curve relating price to yield is more convex toward the origin).

The effect of positive convexity on the hedge is illustrated in Figure 2, which expands the scale of the graph so that the net difference between the future values of the Barbell and Bullet, the net result of the hedge, can be more easily seen.

Figure 2
Gain in Hedge at Horizon
for Various Yields after One Year



Remember that no investment was required initially in putting on the hedge position; proceeds from the short sale of the Bullet bond just covered the purchase price of the Barbell. After one period, the worst possible outcome is zero cash return from the hedge (if yields are unchanged) and there is a positive cash flow from unwinding the hedge at all other yield levels. Zero initial investment and strictly non-negative cash return appears to be an extremely attractive hedge! In fact, it appears to be too good to be possible. But what is wrong with the illustration?

II.C.2. What Is the Source of the Hedge's Gain?

There is in fact no mistake in the illustration if its assumptions are acceptable:

1. The timing and amounts of the cash flows are fixed and certain.
2. There are no transaction costs or other dead weight costs of shorting assets.
3. The initial term structure of interest rates is flat (at a level of ten percent), which implies a market price for both bonds of \$1,000.
4. The term structure of interest rates is also flat after one year (at the various yield levels illustrated in the figures).

The first assumption is innocuous. We can observe securities, such as treasury bonds, whose cash payments are fixed in both amount and timing. This cannot be the source of the puzzle.

The second assumption is not perfectly true, but for many primary dealers, it is not too objectionable. For other investors, trading costs could easily eat into the profits of this particular hedge; but similarly-constructed hedges with greater differences in cash flows can be shown to easily overcome trading costs. For example, if identical present-valued cash flows occurred after 1, 15, and 30 years, instead of after 1, 5, and 9 years, the gain in the hedge after one year would be amplified. If the yield moved down from ten to five percent, the hedge would throw off \$560 instead of the \$23 of the illustrated hedge, (cf. Figure 2). The gains probably cannot be explained away by hedging costs.

This leaves only the third and fourth assumptions. But the third assumption cannot be entirely unreasonable by itself since we occasionally observe flat term structures of yields. This also implies that we cannot cure the problem by asserting that the price of the Barbell bond must increase or the price of the Bullet bond must fall, for if either initial price changed, the initial term structure could no longer be flat. The same reasoning means that we cannot exclude the fourth assumption, taken by itself, that the future term structure is flat.

But the combination of the third and fourth assumptions cannot be true in general. In other words, if the term structure is flat this period, we cannot reasonably expect it to be flat next period. If a flat term structure shifts up or down by a constant amount everywhere, there always exist zero-cost hedges that return only positive cash flows and have no chance of giving negative cash flows, regardless of the direction of interest-rate movement.

II.C.3. The Yield Curve Should Not Display Parallel Shifts.

The basic result is even more general. The initial term structure does not have to be flat. It merely must shift upward or downward predictably by a constant amount at all maturities; if this happens, it is possible to construct reliable zero-cost hedges that return only positive cash flows. (For rigorous proof of this assertion, see Ingersoll, Skelton, and Weil [1978]).

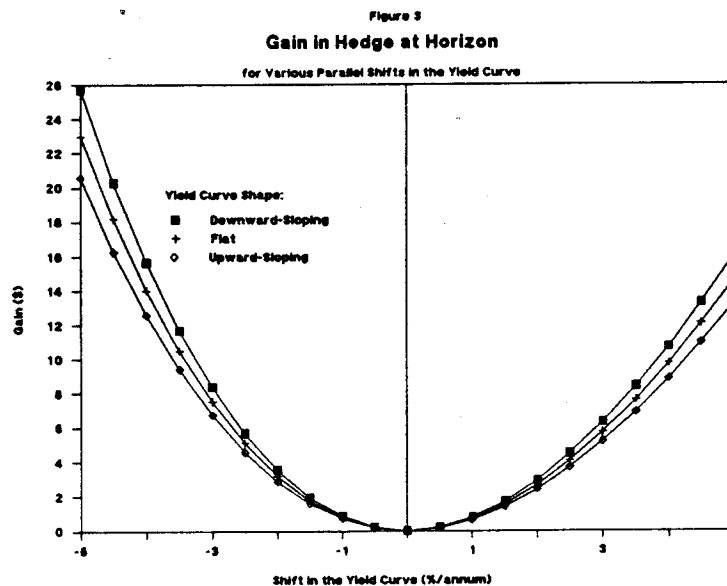
To illustrate the situation of non-flat yield curves, consider again the Barbell and Bullet bonds, but now with slightly different cash flow patterns; the patterns have been chosen so that the initial price of each bond is still \$1,000 and the initial duration is five years. The initial term structure is either steeply upward sloping or steeply downward sloping. See Table 2.

Table 2

Upward-Sloping Term Structure				Downward-Sloping Term Structure		
Year	Discount Rate	Barbell Cash Flow	Bullet Cash Flow	Discount Rate	Barbell Cash Flow	Bullet Cash Flow
1	5%	\$525	\$0	15%	\$575	\$0
5	10%	\$0	\$1610.51	10%	\$0	\$1610.51
9	15%	\$1758.94	\$0	5%	\$775.66	\$0
Price:		\$1,000		Price:		\$1,000
Duration:		5.0 years		Duration:		5.0 years

The outcome of a hedge consisting of a long position in the Barbell and a short position in the Bullet, (one unit each), is shown after one year in Figure 3, assuming that the term structure has shifted up or down by a constant amount at all maturities. For example, if rates have shifted up 100 basis points and the initial term structure was upward sloping as above (5%, 10%, 15%), the term structure after one year is 6%, 11%, 16%. For comparison, the case of an initial flat term structure is repeated.

The illustration shows that roughly the same pattern of gain in the hedge is obtained regardless of the term structure's shape, provided that the shape stays unaltered when there is a movement in the general level of rates.



If we are willing to assume that investors compete for such intoxicating objects as

hedges with zero cost and strictly positive cash flows, we are obliged to deduce that the term structure probably will not fluctuate by a constant amount everywhere along the curve! In other words, unless perfectly riskless arbitrages are available, the term structure of interest rates must change its curvature over time.

This does not imply that the term structure cannot ever shift by a constant translation on two successive dates. This could happen randomly, but it should not happen predictably, period after period. Nor would it be rational to believe it will happen in just one period. If investors believed that the term structure would shift by a constant amount from this period to the next, they would attempt to construct hedges similar to the one illustrated above. In the process of buying one bond and selling another, the initial prices would be affected. This would cause a change in yields and thus the initial term structure would be altered.

To understand how an equilibrium could be achieved initially in the bond market, imagine that investors hold a belief about the shape of the term structure at some future horizon date. Given the expected future term structure shape, bond prices must be established initially such that the term structure has a different shape. Otherwise, pure arbitrages such as those illustrated above would be available. Indeed, it is the very process of competing for such arbitrage positions that causes initial prices to be set in a particular pattern such that the term structure is expected to wriggle over time.

The basic implication is this: the term structure is unlikely to shift up and down by a constant amount at all maturities, at least on a predictable and consistent basis. Instead, it is likely to change curvature over time.

I.I.C.4. If the Yield Curve Does Not Shift Uniformly, Duration is Not an Adequate Measure of Interest-Rate Risk.

As illustrated above, duration does measure asset price sensitivity to moderate parallel shifts in the yield curve. A less-appreciated fact is that [Macaulay's] duration actually gives the interest sensitivity of an asset only with respect to parallel shifts.

This fact is entirely general, but we illustrate it with another simple example using the Barbell and the Bullet hedge position discussed above. Assume that the term structure of interest rates is initially flat, at ten percent, and that the Bullet and Barbell have the cash flows, present values, and durations in Table 1 above. Thus, the initial present value of both assets is \$1,000 and the duration of both is five years. The hedge consists of purchasing one unit of the Barbell and selling short one unit of the Bullet. The initial net cost is zero.

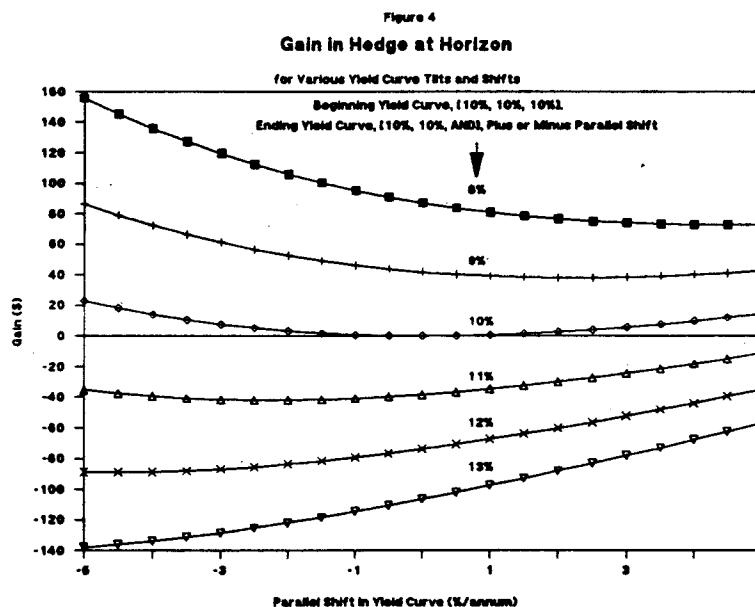
In order to illustrate the effect of a changing and shifting term structure, assume that the flat yield curve tilts up or down at the long end after one year, and, in addition, that all rates shift in parallel by some amount. For example, if the yield curve [short, medium, long] were initially [10%, 10%, 10%], an upward tilt of 100 basis points would move the curve to [10%, 10%, 11%] and an additional shift of 100 basis points would bring the curve to a final position of [11%, 11%, 12%].

Outcomes for the hedge with various combinations of tilting and shifting are given in Figure 4. The parallel shift in all rates is measured along the horizontal axis and the

effect of tilting is shown by different-labeled curves. For example, a final yield curve of [5%, 5%, 3%], a downward tilt of 200 basis points plus a downward shift of 500 basis points is given by the topmost, leftmost point in the Figure; [it results in a gain to the hedge of about \$157]. A final yield curve of [15%, 15%, 18%] is the bottom, rightmost point; i.e., an upward tilt of 300 basis points plus an upward shift along the entire yield curve of 500 basis points. [The hedge loses about \$65].

The illustration makes one thing abundantly clear: even though the initial "hedge" is perfectly duration matched, losses and gains are feasible. The "hedge" is not free of interest-rate risk when such risks are taken to comprehend movements in the shape of the yield curve as well as movements in its level. If the yield curve tilts downward (curves labeled 8% and 9%), the hedge earns very sizable profits, even when the basic level stays at ten percent in the short and middle parts of the curve. But when the longer end of the yield curve tilts upward (curves labeled 11%, 12% and 13%), the hedge position shows sizable losses. Parallel shifts in yield only intensify these results.

The supposed absolute and general desirability of convexity is compromised. The high convexity Barbell does much worse than the low convexity Bullet when the yield curve tilts upward.



The results in Figure 4 are merely illustrative. Other patterns of shifting and tilting are possible and more likely. Clearly, there is a pattern of yield curve wriggling consistent with just about any terminal value in a duration-matched "hedge." If short rates fluctuate more than long rates, the pattern will be different from the curves illustrated in Figure 4, but the outcomes will not be predictably positive or negative.

This then is the duration paradox: Duration is a perfect risk measure and convexity is an unambiguous measure of merit only under parallel shifts in the term structure of interest rates. But such shifts are inconsistent with a competitive market equilibrium.

They permit riskless, zero-cost hedges with positive cash throw-off. Thus, duration can be a complete risk measure only under implausible conditions.

The scientific literature has devoted considerable attention to the duration problem in the hope of finding something like Macaulay's duration that would be more robust under wriggling yield curves. There are at least a dozen different modifications, each of which works with a particular type of shift and tilt. None has been found to be generally useful for arbitrary term structure fluctuations, and none ever will be found. As Barnhill and Margrabe [1986] put it,

"...the only way to fully immunize the value of a portfolio of default-free, option-free bonds against arbitrary changes in an arbitrary term structure is to buy or create a pure discount bond with the desired payoff at the investor's planning horizon."

II.D. Duration and Callable Securities.

The merits of duration and convexity are debatable even for simple fixed-income securities; yet these concepts are used also for complex assets such as callable corporate bonds and mortgages.

A callable fixed-income asset represents a long position in a non-callable bond plus a short position in a call option on the same bond. The option holder [the borrower] will tend naturally to exercise his privilege at the most opportune moment, when current interest rates are low relative to the stated coupon rate on the asset. Thus, the timing of cash flows is itself dependent on the level of interest rates. Duration is a random variable when the borrower has the option to prepay.

II.D.1. For Callable Assets, Duration is Not Monotonically Related to the Level of Interest Rates.

When interest rates are low relative to the coupon of a callable asset, its price sensitivity to interest-rate movements should be small, because rate volatility should have almost as big an effect on the market value of the call option as on the market value of a non-callable bond. The two effects are offsetting for the hybrid [callable] security, so there is little net interest sensitivity. The callable security has a short "effective" duration at low interest-rate levels.⁶

⁶The analogy of an effective duration is not perfect. The small interest sensitivity of a callable asset whose coupon represents a premium is not due to the high probability of early exercise. It is not due to the effectively shorter expected life of the asset, but rather to the offsetting price sensitivities of the pure bond and option components. To understand this point, imagine a callable, continuous accrual bond, i.e., a bond that emits no cash but whose principal amount grows constantly at some prespecified "coupon" rate. It can be proved that the call option on such a bond will not be exercised before maturity [regardless of the exercise price]. The timing of cash flows is not influenced by the level of rates; yet, if the current level of interest rates is small relative to the stated accrual coupon, the call option will be deeply in the money and the price sensitivity of this bond to interest-rate movements will be small.

As the general level of interest rates increases, the price sensitivity of a callable security also rises because the call option is less deeply "in-the-money." The option's price fluctuations are still highly correlated with interest rates, but their dollar amplitude is reduced, so they are less of an attenuating influence on the market price movements of the callable asset.

There is, however, a limit on the growth of sensitivity with increases in the level of interest rates. As the call option goes deeply "out-of-the-money," its market value becomes insignificant. Further increases in interest rates will begin to decrease price sensitivity of the callable security once again, for the same reason that rises in rates reduce the duration of a non-callable bond [higher rates increase the relative present value of the earlier cash flows].

This implies that there is some intermediate region of interest rates, somewhat above the stated coupon, where the price sensitivity of a callable bond is at a maximum. As the bond becomes either a discount or a significant premium, its price sensitivity declines.⁷

II.D.2. Callable Assets Have Relatively Low Interest Sensitivity [and, Perhaps, Relatively Low Average Returns]

The same reasoning implies that callable securities are less sensitive in general to interest rate movements than non-callable bonds are. The value of the option component of the callable bond moves in the opposite direction to the value of the pure bond component. Except when rates are much higher than the bond's coupon, the call option has a strong attenuating effect on market price movements induced by fluctuations in interest rates. The expected returns on callable securities with zero credit risk, such as GNMA mortgage pools, should be relatively low because such securities are less interest sensitive than even non-callable treasury bonds.

Why, then, do we typically observe the yields on callable bonds to be higher than the yields on treasury bonds [which are typically non-callable or have a very delayed call option]. The answer may be that quoted yields are mistakenly identified with expected returns. Any yield based on an assumed fixed duration of cash flows will overstate the true expected return of a callable security.

The reason is adverse selection of prepayments. Consider a callable security selected to have an expected duration matching the investment horizon. A yield is computed based on an anticipated timing of cash flows corresponding to the expected duration. The actual duration of cash flows depends on when they are ultimately received, so the ex post duration could be either longer or shorter than anticipated.

If rates declined during the investment period, the probability of early repayment would increase, making it necessary to reinvest a greater volume of cash flow to the horizon. These reinvestments would likely be made at a rate lower than the original yield [otherwise, the borrower would not have chosen to prepay]. If rates increased during the investment period, there would be little chance of an early repayment and a

⁷If there are costs associated with calling the asset, the region of maximum price sensitivity may be displaced toward an interest-rate level closer to or even below the coupon.

total return approximating the original yield would in fact be received. Notice that the average return expected to be realized over both increasing and decreasing rate environments is less than the original yield.

We can illustrate this effect with the simple Barbell and Bullet bonds used in the previous sections. Let us assume that the investor's original horizon is five years, that the initial yield curve is flat at ten percent, and that both bonds are callable in one year, just before the scheduled \$550 payment of the Barbell, at a price of \$1,100 [the original price of \$1,000 grossed up by the original yield of ten percent]. Assume that there is equal probability of the [flat] yield curve shifting up by 500 basis points, down by 500 basis points and staying the same; i.e., after one year, there is a 1/3 chance each for reinvestment rates of five, ten, and fifteen percent. Finally, for simplicity of illustration, assume that rate stays at its new level during years two through five.

If the reinvestment rate after one year is either ten or fifteen percent, only the original scheduled payment of \$550 will be received from the Barbell [cf. Table 1]. However, if the reinvestment rate is five percent, both the Bullet and the Barbell will pay \$1,100, the call option's exercise price. Total returns at a five-year horizon will be as shown in Table 3.

Table 3

Reinvestment Rate After One Year	Barbell	Bullet
	Total Return to Horizon	
5%	5.98% ⁸	5.98%
10%	10.00%	10.00%
15%	10.35% ⁹	10.00%
Expected Return to Horizon	8.76%	8.66%

The returns that an investor can reasonably expect to realize are, on average, more than 100 basis points less than the original yield.

The average returns of the Barbell and the Bullet are not exactly the same. In this particular illustration, callability redounds to the relative benefit of the Barbell. Of course, the original duration of the Barbell would have been increased to 5.18 years if we had used the expected return as a discount rate, so one might say that its extra average return is simply a risk premium to compensate for the extra duration. However,

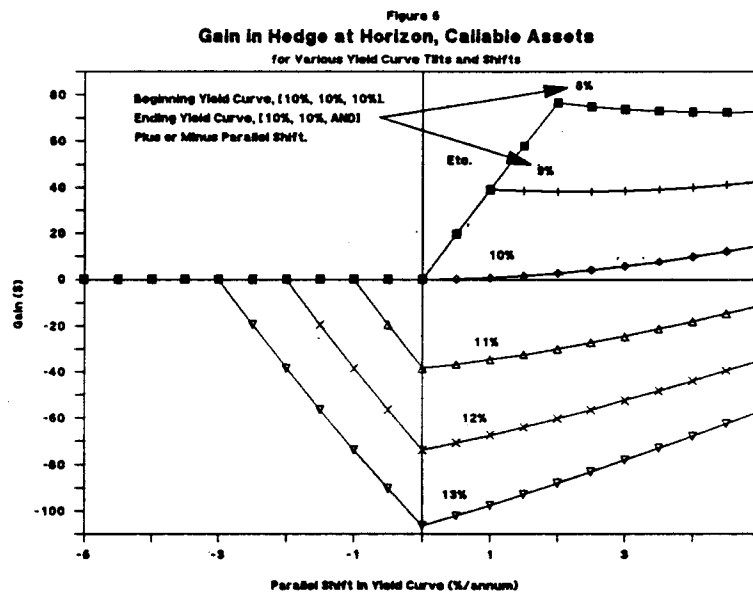
⁸ $\{1,100(1.05)^4/1,000\}^{1/5}-1$

⁹ $\{[550(1.15)^4+1,178.97/(1.15)^4]/1,000\}^{1/5}-1$

this argument generalizes incorrectly from a fortuitous example; it would not work in every case. Remember that duration assumes non-random timing of cash flows while the discount rate itself is obtained by taking the actual randomness into account.

The hedge between the Barbell and Bullet becomes more problematic with callable assets. The values of the two assets after one year will be strongly affected by the level of interest rates and the shape of the yield curve. A tilted yield curve brings greater variability in the hedge's outcome than was demonstrated in Section IV for the non-callable case, because some yield curve movements elicit exercise in either the Bullet or the Barbell but not in both. The result is illustrated in Figure 5. Again, illustrated yield curve movements include an upward or downward tilt in the longest interest-rate coupled with various parallel shifts.

Given the outcomes shown in Figure 5, there seems to be little basis for regarding this duration-matched position as a hedge against interest-rate risk. The gains and losses are relatively large and have an outlandish pattern. For example, the largest losses to the position occur when the yield curve tilts up while the general level of interest rates remains constant.



The supposed attraction of convexity is called into question to an even greater extent than with non-callable assets; for, comparing Figure 5 with the non-callable case illustrated in Figure 4, there is now a smaller set of conditions under which the more convex Barbell does better than the less convex Bullet. Again, keep in mind that this is merely an example. One must not conclude that a callable Bullet is better in general than a callable Barbell. Other yield curve movements could conceivably favor the Barbell.

III. The Alternative. Multifactor Risk Analysis, Consistent with Modern Portfolio Theory.

An argument used frequently to counter criticism of duration is the supposed absence of a viable alternative. Duration and convexity may indeed be subject to conceptual difficulties, but there is alleged to be no other method available for measuring the interest-rate risk of fixed-income assets.

Even if there really were no alternative, such an argument would have dubious merit. It can be paraphrased as follows: "If we use duration and convexity, we are going to be led into incorrect investment decision making, incorrect hedging, and a false sense of security that our investment procedures will produce the desired and planned results. Nevertheless, we'll go ahead and use these concepts because we don't know what else to do." Folk tales are replete with similar delusions: the ostrich's safety is assured if it cannot see the danger, the emperor is clothed so long as no one mentions the evidence, etc.

And there is an alternative. The sophisticated and logical models of risk and return used every day in equity markets can be applied to fixed-income markets. One of the most general is the Arbitrage Pricing Model invented by Ross [1976]. It is a "factor" model with an important extra feature: specification of how risk sensitivities will be rewarded by extra average returns over time.

III.A. Risks are Multifaceted.

Risks arising from all sources are divided into two fundamental categories, one category includes risks that can be "diversified away" in large portfolios and a second category that cannot be eliminated, even in large diversified portfolios. Ross proved that a well-functioning capital market would compensate exposure to risks only in the second category.

There may very well be several distinct sources of non-diversifiable risks. Empirical studies in equity markets have uncovered four or five, and these have been connected with specific macroeconomic variables such as industrial production, inflation, and investor confidence (Chen, Roll, and Ross [1986]). Both the general level of interest-rates and the shape of the term structure of interest rates have been found empirically to be pervasive influences on equity returns, and exposures to these influences have been associated with risk premia;¹⁰ i.e., a particular stock that is heavily exposed to intertemporal movements in the level and shape of the term structure provides a higher long run average total return, a reward for the risk.

If such influences are important for equities, think how much more important they must be for fixed-income securities. One could well imagine an arbitrage pricing model for bonds with two factors, say the long rate and the short rate, as in the Brennan-Schwartz model [1979], or a short rate and a term structure slope, or perhaps

¹⁰In the Chen, Roll, Ross paper, the general level of interest rates was captured by the expected inflation rate [a variable that directly influences nominal rates], while the term structure shape was measured by the differential total return between a long-term and a short-term government bond.

with a third factor related to the concavity of the term structure. The number and identity of fixed-income factors is an empirical issue, as it was in equity markets, but resolution of the issue is surely destined to bring a more satisfactory characterization of fixed income risks and rewards.

There has already been a good deal of quality empirical factor work in the academic literature (Langetieg [1980] and Oldfield and Rogalski [1981]). Simple factor models have already been shown to be superior to duration-based models; (Ingersoll in Kauffman et al. [1983] or Gultekin and Rogalski [1984]). We now present some new results for a sample of publicly traded thrifts.

III.B. Empirical Estimates of Thrift Exposures to Multiple Risks.

To illustrate the various exposures that thrifts actually have to macroeconomic risks, stock market price data have been used for a sample consisting of the eleven thrifts listed on the New York Stock Exchange for at least 60 months during the period January 1976 through February 1987.

The first step in this empirical procedure is to obtain rate of return series for "mimicking portfolios" of underlying economic risks. Using an enhanced version of the methods in Roll and Ross [1980], a large scale factor analysis was conducted for all stocks listed on the NYSE; this produced a set of portfolios intended to be linear transformations of the underlying macroeconomic factors. Because of the evidence in Chen, Roll, and Ross [1986] that the number of "priced" macroeconomic factors is four or five, we produced five mimicking portfolios.

Every mimicking portfolio actually is a feasible portfolio consisting of all NYSE stocks, but investment weightings of individual stocks are different in each portfolio. The portfolios are chosen to have very little correlation with each other in an attempt to improve econometric reliability. The first portfolio has positive investments in most stocks, so it is highly correlated with any of the broad market indexes. The second through the fifth portfolios, however, have many short positions and they have little correlation with broad indexes. Instead, they are correlated with other macroeconomic factors.

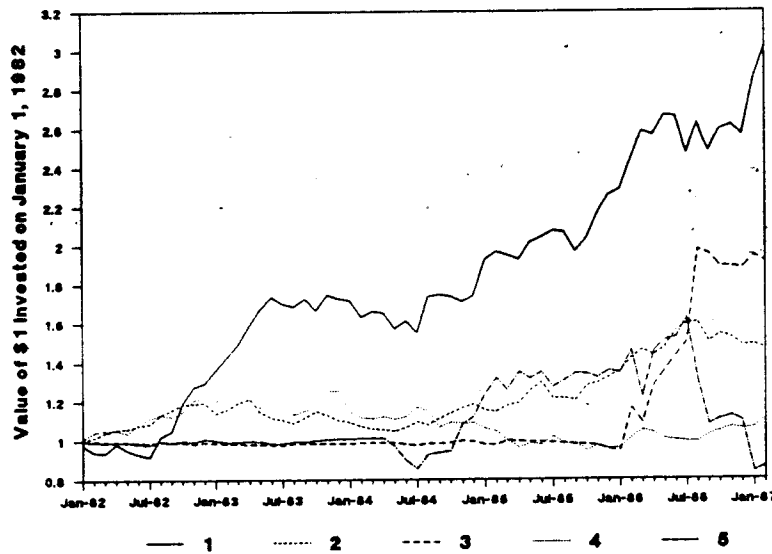
Table 4 presents the correlation coefficients of monthly rates of return among the five mimicking portfolios. Figure 6 presents a plot of a \$1 investment in each of the five mimicking portfolios over the past five years.

Table 4

Correlation Coefficients of Monthly Returns
Five Mimicking Portfolios of NYSE Stocks
January 1976 - February 1987

Portfolio	vs. Portfolio			
	1	2	3	4
2	-0.04052			
3	-0.16770	0.00066		
4	-0.07781	-0.09887	0.00999	
5	0.07991	-0.06620	-0.04303	-0.17298

Figure 6
APT Mimicking Portfolios
Accumulated Value, 1982-87



The mimicking portfolios are related to the five underlying macroeconomic variables in Chen, Roll, and Ross [1986] (CRR) through a transformation matrix that basically reweights the portfolios to provide maximum correlation with the economic variables. These variables are the sources of systematic risk.

The empirical procedure is as follows: First, the stock's return is related through multiple regression to the returns on the mimicking portfolios; then linear combinations of the estimated coefficients are computed, using the transformation matrix, to obtain direct estimates of exposures to macroeconomic risks. Finally, these exposures are divided by the corresponding exposures of the value-weighted index of all stocks in

order to obtain estimates of each stock's risk relative to that of a broad index.

The five macroeconomic variables found by CRR to be separately priced in the stock market are **unexpected** changes in:

1. Industrial Production,
2. Expected Inflation,
3. Actual Inflation,
4. The Term Structure of Interest Rates, and
5. Investor Confidence.

The precise measurement of these variables is explained in the CRR paper. Industrial production and inflation were measured by familiar government series (the rate of change in the Consumer Price Index, for instance, represented actual inflation). The Term Structure variable was the difference in returns between a long-term and a short-term treasury bond. The Investor Confidence variable was the yield spread between a low-grade corporate bond and a treasury bond.¹¹

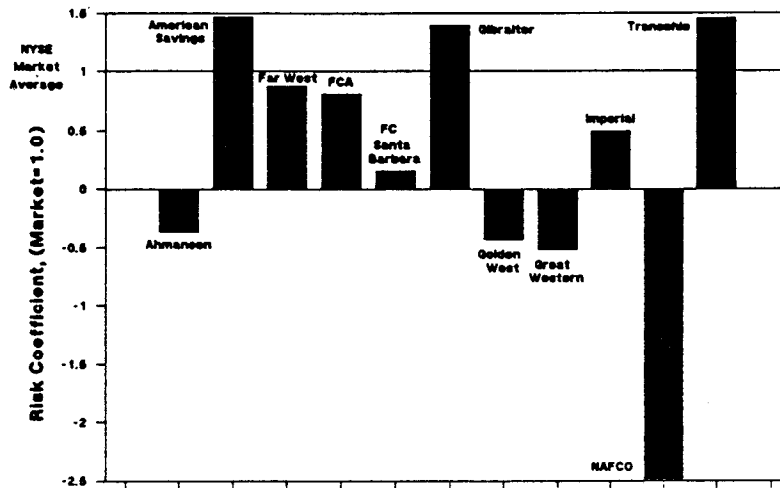
The CRR method of obtaining an expected value for any variable in a given month is too intricate to be explained again here. Suffice it to note that statistical models were constructed to predict each variable and that the unexpected change was defined as the difference between the actual and the predicted value from the model.

Figures 7-11 present the results for the eleven large thrifts in our sample. Each figure in succession corresponds to one of the macroeconomic risk variables. For each variable, the exposure of each thrift is presented relative to the market's exposure; i.e., the units are scaled so that the value-weighted market index of all NYSE stocks has an exposure of 1.0 to each variable.

For example, in Figure 7, we see that the risk exposure of American Savings and Loan to industrial production is 1.46. This implies that American Savings has 46% more exposure to industrial activity than an average stock listed on the New York Exchange. There is considerable heterogeneity among thrifts in their industrial production exposure. Four thrifts out of eleven even have negative exposures, which means that their stock prices are inversely correlated with unexpected changes in industrial output (holding other variables constant). The average exposure of these thrifts to industrial production is only 26% of the exposure of a typical NYSE stock.

¹¹The yield spread is a combination of the aggregate degree of risk aversion and the aggregate perceived level of riskiness in the economy.

Figure 7
S&L Risk Exposure to Industrial Output



Comparing Figure 7 to Figures 8-11, we see that thrifts in the sample are more homogenous in their exposures to the other risk variables. To expected inflation, for example, (Figure 8), all of the thrifts are highly exposed and two, American Savings and Gibraltar, have levels of exposure at least double that of the average NYSE stock. Even the least-exposed thrift, Great Western, has 34% more exposure than an average stock. The average exposure of the eleven thrifts to expected inflation is 74% greater than the market index's exposure.

Figure 8

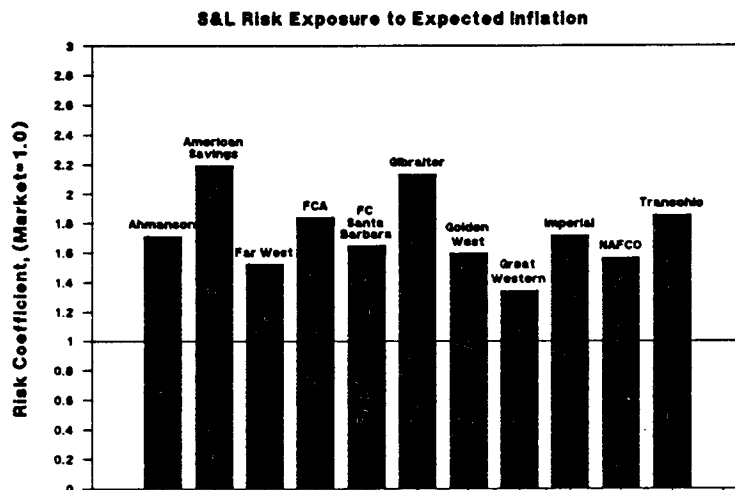
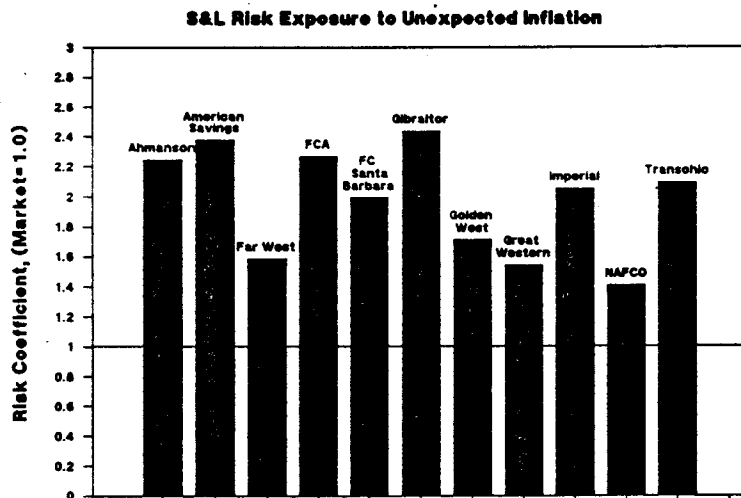


Figure 9



In the CRR study, the two most significant sources of risk were investor confidence and the term structure. They carried the greatest estimated risk premia, presumably

because investors require substantial compensation for exposure to their risks. Thrifts are extremely exposed to these two variables; See Figures 10 and 11. The average thrift has an exposure to the term structure equivalent to 196% of the average of all NYSE stocks, while thrifts have 217% of the average NYSE exposure to investor confidence. This is an impressive level of systematic risk.

Figure 10
S&L Risk Exposure to the Term Structure

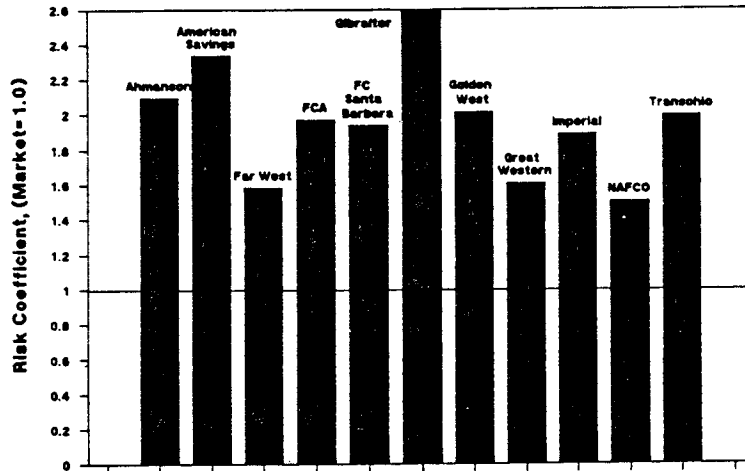
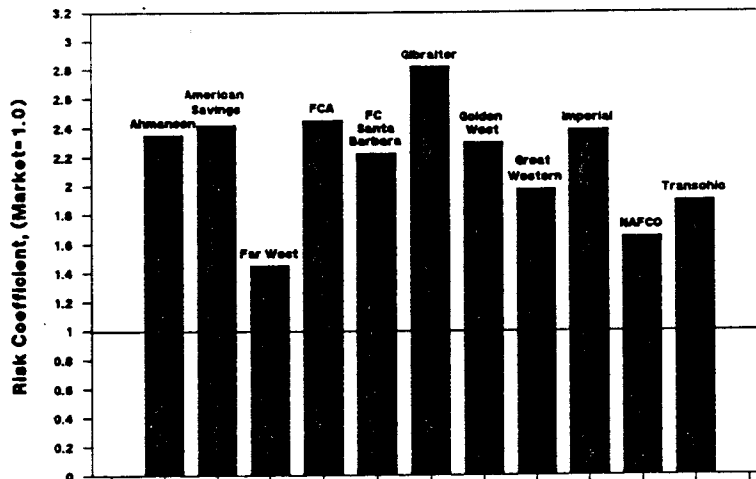


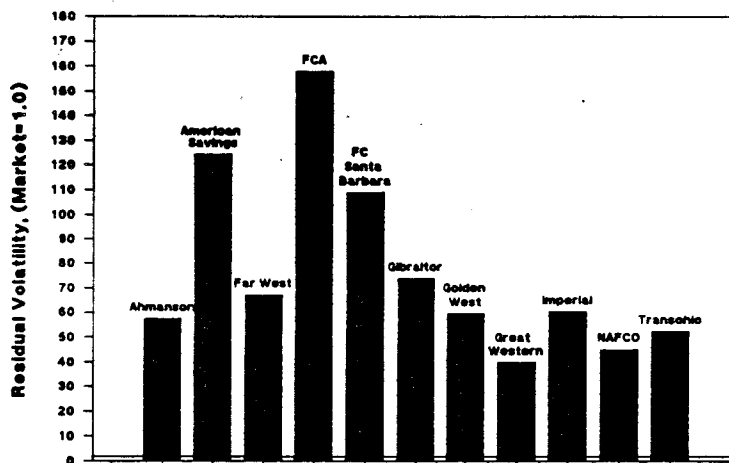
Figure 11
S&L Risk Exposure to Investor Confidence



Thus, thrifts are susceptible to the same risks as the average stock. It is not just movements in the level of interest rates that cause their stock prices to vary;¹² but there is also an effect from investor confidence, from the term structure, and even from the actual rate of inflation in a given month. Indeed, thrifts have more of these types of risk than the typical stock does. However, thrifts, on average, are somewhat less exposed to industrial production risk than the typical stock is; certainly not a surprising result for financial institutions.

Finally, Figure 12 presents the level of volatility unexplained by the mimicking portfolios, relative to that of the market index. The average thrift has 77 times as much unexplained volatility as the market; and the volatility champion, Financial Corporation of America, has 158 times as much! Thrifts are evidently highly subject to non-systematic risk. According to modern finance theory, if non-systematic risk is borne, it is borne needlessly since there is no associated reward. Thus, an astute investor should not hold a non-diversified thrift portfolio. It is important to diversify thrift stock investments by including them in only small proportions of large portfolios.

Figure 12
S&L Residual Risk



¹²The expected inflation variable is strongly related to the level of the short-term interest rate. Indeed, it is a function of the yield on one-month treasury bills, suitably corrected for the expected real rate of interest.

IV. Conclusions.

A thrift institution is really just a portfolio of investment positions, long positions in thrift assets and short positions in thrift liabilities. Thus, managing a thrift's risk is much like managing an ordinary portfolio such as a pension fund or mutual fund. Modern portfolio management tools are highly recommended.

Traditionally, thrift management has implicitly assumed that the assets and liabilities were simpler in character than normal portfolio assets; for instance, the gap management technique assumes that interest rates represent the only source of thrift riskiness.

This essay has emphasized two related points that question traditional management: (1) even if interest rates were the only source of risk, gap management using the concept of duration is a very imperfect tool, particularly for assets and liabilities subject to disintermediation; (2) thrifts are actually exposed to the same **multiple** sources of risk as the typical industrial corporation. The magnitude of the exposure may differ, as it does among industrial stocks, but the sources are the same; therefore, risk-management techniques should be similar.

To elaborate, duration is probably not a very good measure of interest-rate sensitivity and positive "convexity" does not really indicate that a fixed-income asset is attractive. These conclusions follow from the argument that,

A. Duration measures interest-rate sensitivity **only** for parallel shifts in the yield curve. If the yield curve tilts over time, duration does not measure price reactions.

B. The yield curve **must** change its shape over time; otherwise, perfect arbitrage positions can be systematically and predictably formed that cost nothing, have no risk, and yet return positive cash flow.

C. Competition should reduce such perfect arbitrages to a minimum; thus, duration cannot be an adequate risk measure, nor convexity an indication of an asset's desirability, under realistic market conditions.

The conclusions apply even to simple fixed-income investments, such as treasury bonds, whose cash flows are perfectly certain in both timing and amount. For callable fixed-income assets, such as corporate bonds and mortgages, duration and convexity are even less appropriate guides to investment decisions.

There is an alternative to duration as a measure of risk. Equity risk/return models have enjoyed an extensive development and they seem to be converging on a multiple factor representation similar to Ross' Arbitrage Pricing Model [1976]. Such representations include several distinct sources of risk, such as inflation rates and the shape of the term structure, which have been shown to be empirically important for equity pricing and which seem to be obvious candidates for fixed-income pricing. Some empirical literature has already been completed with fixed-income data and the results suggest that factor risk models are superior to duration-based risk models.

Using a sample consisting of the largest and most frequently traded thrift stocks listed on the New York Exchange, Arbitrage Pricing Model methods were used to assess the

risk exposure of thrifts to macroeconomic variables that have been shown elsewhere to be sources of systematic risk. These thrifts were found to be highly exposed to four of the five risks borne by an average industrial corporation. Indeed, their level of exposure to inflation, investor confidence, and the term structure exceeds that of the average stock. On average, their exposure to the latter two sources of risk is double that of other stocks. There is only one macroeconomic risk source to which thrifts are less exposed than the average stock; thrift exposure to industrial-production risk is only one-fourth that of the typical NYSE stock.

Thrifts have a large amount of non-systematic risk. This implies that efficient investments in thrift equities can be accomplished only through well-diversified portfolios.

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