

# Embedded Options Impact On Interest Rate Risk And Capital Adequacy

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## Abstract

*In this article we consider cases in which a bank finances some option-embedded assets with option embedded liabilities and with equity. We show that risk-based capital guidelines that do not account for these interest sensitive options can be very misleading with regard to the actual interest rate exposure. In extreme cases, any change in interest rates can result in a deterioration in the value of such unhedged positions even though there may be no risk-exposure as measured by traditional means.*

## Introduction

Section 305 of the Federal Deposit Insurance Corporation Act of 1991 (FDICIA) required federal banking regulators to revise the risk-based capital guidelines to take account of interest rate risk (IRR). IRR, as calculated by modified duration, measures the change in a bank's net economic value associated with a specified change in interest rates.<sup>1</sup> The proposed guidelines address the duration of various assets and liabilities, including adjustable-rate assets, mortgage derivative products and nonmaturity deposits.<sup>2</sup> However, they do not deal adequately with option adjusted durations, or with the impact on IRR of put and call options embedded in fixed-rate loans and deposits with known maturities.<sup>3</sup> Fixed-rate loans with a prepayment option and certificates of deposit (CDs) that can be liquidated before maturity with no interest rate penalty for early withdrawal are examples of such products with embedded options.<sup>4</sup> With respect to the loan, the bank is short

a put option on rates. If interest rates decline, the borrower will refinance the loan at a lower rate. In the case of the CD, the bank is short a call option on rates. If interest rates increase, depositors will withdraw their CDs and pursue higher rates. Thus, the exercise of options embedded in bank assets and liabilities undermines the structure of the bank regulator's Supervisory Model of IRR which requires banks to report their assets, liabilities, and off-balance-sheet positions in time bands based upon their remaining maturities or nearest repricing dates.<sup>5</sup> Each position will be multiplied by IRR "risk weights," and then be summed to produce a net risk-weighted position. The net position represents the estimated change in the bank's net economic value.

In essence, we point out the danger of not using option adjusted durations when the embedded options are contained in a bank's assets or liabilities. Measuring option adjusted durations is a difficult task and beyond the scope of this paper. Some preliminary work on option

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*Readers with comments or questions are encouraged to contact the authors via e-mail.*

adjusted duration has begun. The Office of Thrift Supervision (1994) suggested the use of a Net Present Value Model and a Monte Carlo simulation approach to value assets with embedded options that have a significant impact on the assets' price sensitivity. They also considered the assets' effective duration. The OTS was particularly concerned about mortgage products with options, such as interest rate caps and floors. Options embedded in liabilities are not dealt with extensively by the OTS. Fabozzi and Modigliani (1992) use Monte Carlo simulations to estimate option adjusted spreads for mortgage-backed securities. Anderson, Barber, and Cheng (1993) and DeRosa, Goodman, and Zazzarino (1993) estimate a modified duration for mortgage-backed securities which accounts for interest rate sensitivity. Carlson and Lawler (1987) examined closed form formulas for mortgage-backed securities. Bierwag (1987) examined the experience of callable bonds during the January - May 1986 period when interest rates declined sharply. The behavior of callable bonds and mortgage-backed securities are analogous during periods of declining rates. Those investment managers who failed to properly account for the duration shift on the callable bonds suffered large losses in their portfolios during the period under consideration. The extent of losses depended on their ability to forecast interest rate changes correctly. The use of option adjusted durations may have mitigated some of the effects of the interest rate risk. Bierwag suggested that the prudent use of duration models requires that the callability options either be evaluated or avoided. The widespread use of embedded options in both asset and liability products suggests that they are not being avoided. Furthermore, it does not appear that all of the options are being evaluated. Simons (1995) examines banks' use of derivatives for commercial bank asset/liability management, but says nothing about embedded options.

The effect of duration on interest rate risk has been examined in recent articles. Hanweck and Shull (1994), O'Keefe (1993) and Cohen (1993) are some recent examples.<sup>6</sup> In general, the articles conclude that the duration

standard for capital adequacy is more sensitive to interest rate changes than the former flat-rate capital standards. However, the duration standard can be misleading at times, and it may result in significant errors with respect to measuring capital adequacy. This article adds to the growing body of literature by examining the effects on capital adequacy of changes in interest rates on the value of options embedded in bank loans and deposits. Cohen (1991) examined embedded options, but not in connection with capital standards.

In section I we examine the impact of embedded options on a bank's balance sheet that is fully immunized by traditional measures. In addition, we examine the bank's risk-based capital to asset ratios. In section II we examine the impact of embedded options on banks that are not immunized. First, we analyze the case where the equity duration is positive and then analyze the case where the equity duration is negative. Concluding comments are given in section III.

#### **The Effect of Interest Rate Changes on a Fully Immunized Bank**

To illustrate the nature of the problem of measuring interest rate risk, consider the following example. Suppose that a hypothetical bank financed \$100 million in assets with \$90 million in non-core rate-sensitive liabilities, and with \$10 million in equity. The bank has no off-balance sheet liabilities. By FDIC risk-based capital standards, this position of the bank is consistent with a risk-based capital ratio of 10 percent.<sup>7</sup> For simplicity, the bank's sole assets is a 7.5% fixed rate, non-amortizing loan with 2.85 years to maturity, and its sole liability is a 4% CD with 3 years to maturity. Interest payments on both the loan and the CD are annual.

As we will show below, this maturity structure was selected to achieve an equity duration of zero. There are several ways of handling coupon payments with fractional periods - the loan with 2.85 years to maturity. We assume the

first coupon payment is reduced to account for the lack of a full first period. Thus, the first coupon payment will be

$$CF_1 = [(1 + C)^{1-f} - 1]Par$$

where C is the stated coupon rate and f is the fraction of the period elapsed since the last coupon payment. We assume this loan was just issued at the prevailing market rate and the first payment is less than a full year away.

Recall duration can be computed as

$$D = \sum_{i=1}^n i \frac{CF_i / (1 + y)^{i-f}}{P} \tag{1}$$

where n is the number of remaining cash flows,  $CF_i$  is the cash flow at time i, y is the periodic yield to maturity, and P is the current market value of the security. In this case, the duration of assets is 2.496 years and the duration of liabilities is 2.775 years. The duration of the bank's assets and liabilities are fully immunized, resulting in an equity duration of zero.

The duration of the assets in this financed position can be written as

$$D_A = \frac{L}{A} D_L + \frac{E}{A} D_E \tag{2}$$

where the duration of the assets is the value-weighted duration of liabilities and the equity used in financing the position. Solving for the duration of equity we have

$$D_E = \left( D_A - \frac{L}{A} D_L \right) \frac{A}{E} \tag{3}$$

Thus, with the data given above we see

$$D_E = \left( 2.496 - \frac{90}{100} 2.775 \right) \frac{100}{10} \cong 0$$

with this capital structure and interest rate sensitivity, the market value the equity position should be relatively insensitive to changes in interest rates. Thus, there is no change in the \$10 million net economic value or market value of the bank's equity when the loan rate is 7.5% and the CD rate is 4%. We assume a constant 3.5% net interest spread on new assets and liabilities. For details on computing duration for securities with embedded options see Choi [1996].

Before we consider the embedded options, let's examine the effects of an instantaneous 250 basis point parallel increase in the yield curve from 7.5% to 10%. As shown in Table 1, the market value of the bank's assets will decline \$5.94 million to \$94.06 million. The market value of the liabilities will decline \$5.96 million (to \$84.04), and the market value of the equity will rise only \$0.02 million (to \$10.02). Although the market value of the equity declined, the total risk-based capital to asset ratio improved from 10% (\$10/\$100) to 10.66% (\$10.02/\$94.06).

Similarly, an instantaneous 250 basis point parallel decrease in the yield curve will increase the value of the assets to \$106.48 million, the liabilities to \$96.55 million, and the equity to \$9.93. The capital ratio declined to 9.32%.

The data reveal that both assets and liabilities in the position are highly sensitive to changes in loan rates. Assets are more sensitive to interest rate changes only because there are \$100 million in assets and only \$90 million in liabilities. The slight differences in sensitivity to interest rate changes results in slight gains in equity when interest rates fall and slight losses when interest rates rise. From all appearances this position does not contribute much interest rate risk to the bank. As shown in Table 1, the capital to asset ratio increases as loan rates increase. We turn now to examine the impact of

**Table 1**  
**Market Values For A Fully Immunized Bank With No Embedded Options (\$millions)**

Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$106.48	\$96.55	\$9.93	9.32%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$84.04	\$10.02	10.66%

embedded options on the equity value of the bank. We first examine the impact of embedded liability options and then to embedded asset options.

*Embedded Liability Options.*

Assume that this bank has embedded options on its liabilities but not its assets. Specifically, this bank's CDs allow for early withdrawal of funds at no penalty. When interest rates rise, depositors will exercise their right to withdraw funds and reinvest them at another bank or even as the same bank at a higher rate. Essentially depositors have a put option on the CD. They can "sell" the CD back to the bank at par. Alternatively, they have a CD plus a call option on interest rates. Either way, the bank's liabilities will never be worth less than par, otherwise the depositor is not behaving rationally.

sis, one consideration is the likelihood of suboptimal behavior on the part of bank customers if they do not behave rationally. The suboptimal behavior will reduce, but not eliminate the harmful effects of banks being short embedded options.

The effect of embedded liability options is to have liabilities whose market value never falls below par because of the rational actions of depositors. This is unfortunate for banks because, ceteris paribus, they would like to have their liabilities decline in value, which would increase the value of their equity. Table 2, Panel A illustrates the change in the market value of equity of this bank when it offers CD's with no early withdrawal penalty and depositors behave rationally. The table reveals that this bank has considerable interest rate risk exposure when loan rates rise. Recall that we assumed a constant 3.5% net interest spread.

When incorporating this type of analy-

**Table 2**  
**Market Values For A Fully Immunized Bank With Embedded Options (\$ millions)**

Panel A: Embedded Liability Options				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$106.48	\$96.55	\$9.93	9.32%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$90.00	\$4.06	4.31%
Panel B: Embedded Asset Options				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$100.00	\$96.55	\$3.45	3.45%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$84.04	\$10.02	10.66%
Panel C: Embedded Asset and Liability Options				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$100.00	\$96.55	\$3.45	3.45%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$90.00	\$4.06	4.31%

When loan rates increase by 250 basis points, the market value of the bank's assets decline \$5.94 million to a level of \$94.06 million. However, its liabilities remain at par. Thus, the market value of equity declines \$5.94 million to a level of \$4.06 (\$94.06 - \$90.00) million. Now the capital to asset ratio is 4.31% (\$4.06/\$94.06). The bank is "significantly undercapitalized!" Although not shown in the table, the capital to asset ratio increases as loan rates increase up to 7.5, and then it declines sharply. At loan rates above 8.25 percent, the bank becomes undercapitalized. At loan rates above 9.2 percent, it becomes significantly undercapitalized.

Next we examine the impact of embedded asset options.

#### *Embedded Asset Options*

Assume that this bank has embedded options on its assets, but not on its liabilities. When interest rates fall, borrowers will exercise their right to refinance their loans at a lower rate and they will prepay their loans. Essentially, borrowers have a call option on their loans; they can exercise their right and buy their loans back at par. Alternatively, the borrower has a loan plus a put option on interest rates. Either way, the bank's assets will never be worth more than par when borrowers behave rationally.

The effect of embedded asset options is to have assets whose market value never rises above par. Obviously banks would like to have assets rise in value because, other things being equal, this will increase the value of its equity. Table 2, Panel B illustrates the change in the market value of equity of this bank when it makes loans with no prepayment penalty and bank customers all behave rationally. The bank has considerable interest rate risk exposure when loan rates fall.

If interest rates decline by 250 basis points, the market value of the bank's assets would increase by \$6.8 million if the borrowers

had no options on their loans. However, because these loans can be prepaid, the market value of the assets remains at \$100 million.

Unfortunately for the bank, the market value of the liabilities will increase \$6.55 million for a market value of \$96.55 million. Thus, the market value of equity will fall to \$3.45 (\$100 - \$96.55) million. The capital to asset ratio would be 3.45%, which is significantly undercapitalized. Once rates decline below 7.5 percent, the capital to asset ratio declines precipitously.

Many banks are short embedded options on both sides of the balance sheet. That is, they have loans that can be prepaid and deposits that have no early withdrawal penalty. If interest rates rise sharply, depositors will withdraw funds and borrowers will hold off on any prepayments. If interest rates fall sharply, depositors will hold no incentive to withdraw funds and borrowers will prepay their loans. The best the bank can hope for is stable interest rates. As shown in Table 2, Panel C, if interest rates move in either direction, the market value of equity and the capital to asset ratios will decline. Equally important, only a modest change in rates is required before the bank will be undercapitalized.

One can say with absolute certainty that interest rates will change. History reveals that market determined and bank administered interest rates do not remain stable for long periods. For example, the prime rate charged by banks increased from an average of 7.86 percent in 1975 to 18.87 percent in 1981. Then the prime rate declined to 6.00 percent in 1993.

#### *The Effect of Embedded Options on Net Interest Spreads for a Fully Immunized Bank*

The prices of embedded options should be reflected in the price of the products offered by the bank. Thus, a fixed-rate loan with the prepayment option should have a higher rate than the same loan with no prepayment option. Similarly, a CD with no early withdrawal penalty should have a rate lower than a CD with an early

withdrawal penalty. The differences in the rates represents the amortized cost of the options. Thus, if each option were priced at 50 basis points per year, then the 3.5% net interest spread (interest income less interest expense) of our hypothetical fully immunized bank overstates the true interest rate spread by 100 basis points. Thus, the narrower spread of 2.5% is a much more accurate estimate of the realized future net interest spread. Banks with embedded options are exposed to significant interest rate risk if rates move suddenly. As noted previously, such shifts did occur in the late 1970s and early 1980s.

**The Effect of Interest Rate Changes on Banks that are Not Fully Immunized**

*Positive Duration*

The previous examples focuses on a hypothetical bank with a fully immunized portfolio of assets and liabilities. Now we examine the effects of interest rate changes on a bank with positive duration which means that it is "asset sensitive." Table 3, Panel A illustrates the effects of interest rate changes on the market value of a bank with no embedded options and positive duration. If interest rates increase, the data reveal that the market value of the assets will de-

cline more than the market value of the liabilities, thereby decreasing the value of the equity. If interest rates increase, the reverse is true, and the capital to asset ratio declines as interest rates increase.

*Positive Duration and Embedded Liability Options*

Assume that the bank with positive duration has embedded liability options but no embedded asset options. Rational depositors will exercise their options in the manner described previously if interest rates increase, and they will do nothing if interest rates decline. The results of their actions on the market value of the bank's equity are shown in Table 3, Panel B. If interest rates increase, the market value of the equity declines as before. Conversely, a decline in interest rates results in higher market value of equity, but not as high as in the case with no embedded liability options. The capital to asset ratio follows the same pattern.

*Positive Duration and Embedded Asset Options*

In this example, the bank has embedded asset options but no embedded liability options. Because the bank has positive duration, any

<b>Panel A: No Embedded Options, Positive Duration</b>				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$110.52	\$96.55	\$13.97	12.64%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$90.76	\$84.04	\$6.72	7.40%
<b>Panel B: Embedded Liability Options, Positive Duration</b>				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$110.52	\$96.55	\$13.97	12.64%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$90.76	\$90.00	\$0.76	0.84%
<b>Panel C : Embedded Asset Options, Positive Duration</b>				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$100.00	\$96.55	\$3.45	3.45%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$90.76	\$84.04	\$6.72	7.40%

change in interest rates will result in a decline in the market value of its equity and its capital to asset ratio (See Table 3, Panel C). Equally important, a decline in interest rates will have a greater negative effect on the value of the equity and the capital to asset ratio than an equal increase in interest rates.

*Positive Duration and Embedded Asset and Liability Options*

When the bank with positive duration has embedded options in both its assets and liabilities, any change in interest rates will result in a lower market value of its equity and lower capital to asset ratios. However, an increase in interest rates will have a greater negative change on the market value of its equity (and capital to asset ratio) than an equal decrease in interest rates.

*Negative Duration*

The term negative duration means that the duration of the bank's liabilities are longer than the duration of its assets. The bank is said to be "liability sensitive" to changes in interest rates. As shown in Table 4, Panel A, if interest

rates increase, the market value of the liability declines more than the market value of the assets, and the market value of the equity increases. If rates fall, the reverse occurs. As shown in Panel A, the capital asset ratio is positively associated with the level of interest rates.

*Negative Duration and Embedded Liability Options*

If our hypothetical bank has only embedded liability options, any change in interest rates results in lower equity values and capital to asset ratios. Increases in interest rates have a greater negative effect than decreases (see Table 4, Panel B).

*Negative Duration and Embedded Asset Options*

If our hypothetical bank has only embedded asset options, an increase in interest rates results in an increase in both the market value of the equity and the capital to asset ratio. However, an equivalent decrease in interest rates results in a greater than proportional decrease in the market value of the equity and the capital to asset ratio (see Table 4, Panel C).

**Table 4**  
**Market Values for a Bank That Is Not Fully Immunized (\$ millions)**

Table 4 Market Values for a Bank That Is Not Fully Immunized (\$ millions)				
Panel A: No Embedded Options, Negative Duration				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$106.48	\$100.76	\$5.72	5.37%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$80.65	\$13.41	14.26%
Panel B: Embedded Liability Options, Negative Duration				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$106.48	\$100.76	\$5.72	5.37%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$90.00	\$4.06	4.32%
Panel C : Embedded Asset Options, Negative Duration				
Interest Rates	Assets	Liabilities	Equity	Capital to asset ratio
5.0%	\$100.00	\$100.76	-\$0.76	-0.76%
7.5%	\$100.00	\$90.00	\$10.00	10.00%
10.0%	\$94.06	\$80.65	\$13.41	14.26%


If the bank with negative duration has embedded options in both its assets and liabilities, any change in interest rates will result in lower market values of its equity and lower capital to asset ratios. Simulations shown that the greatest changes are when interest rates decline.

It is important for bank managers to recognize the economic value and resultant risks related to offering loans and deposits with embedded options. It is equally important for regulators to correctly measure interest rate risk. To date, Chateau (1990) used quadratic approximation methods to examine the early exercise of capped variable rate loan commitments. In addition, the previously cited works involving mortgage-backed securities combined with the current use of Monte Carlo simulations for measuring option adjusted spreads provides a foundation for additional research dealing option adjusted durations.

### Summary

This article examined the effect of embedded options on the IRR and capital adequacy. The issue is important because FDICIA mandated that regulators consider IRR in their risk-based capital guidelines. However, the guidelines do not consider embedded options, nor do they consider option adjusted durations. For purposes of illustration, we only considered corner solutions of embedded options. Thus, this article demonstrated that a hypothetical bank which is fully immunized in terms of equity duration, has significant interest rate risk due to embedded options in assets and liabilities. Because of the embedded options, the net interest spread is overstated. Accordingly, changes in interest rates have a greater effect on net interest income than was previously thought. It also affects bank's capital adequacy, but to a lesser degree.

### Suggestions for Additional Research

There may be a difference between theory and reality. This article examined the issue of imbedded options from a theoretical point of view, using simulations. Additional research using actual data from banks is needed to determine if what we found is the way such options impact capital in reality. 

In banks that have positive or negative duration with embedded asset and liability options, any change in interest rates will have a detrimental effect on the market value and capital to asset ratios of the banks equity if borrowers and depositors behave rationally.

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Our example takes a simple and extreme case to illustrate our points. We recognize that in reality, banks have a variety of embedded options on both the asset and liability sides of their balance sheets. Moreover, not all of the bank's customers will exercise their options at the optimal times, or at the same time. Nevertheless, the changes in the market value of the equity will be in the same directions, but not necessarily in the same magnitudes as those presented here.

### Endnotes

1. Net economic value is defined as the net present value of assets less the net present value of liabilities plus the net present value of off-balance sheet instruments (*Federal Register*, Vol. 58, No. 176, 9/14/93, p. 48237.) 12 CFR Parts 3 et. al. We use the term "market value" to mean economic value in the case of a bank's equity. However, it should not be confused with the stock market value of the bank which is determined by multiplying the stock price times the number of shares outstanding. In addition, we do not discuss the effects of the Statement of Fi-



nancial Accounting Standards 115 (SFAS 115), "Accounting for Certain Investments in Debt and Equity Securities." SFAS 115 deals with unrealized gains and losses of certain securities which could affect Tier 1 Capital.

2. *Federal Register*, *ibid.*, 48235.
3. It is noteworthy that Basle Committee also overlooked embedded options in its *Framework for Supervisory Information about the Derivatives Activities of Banks and Securities Firms*, May 1995.
4. SouthTrust Bank, Birmingham, AL. offered such CDs in 1994. SouthTrust's CD also has a provision where the rate will rise with the 13-week Treasury bill. In 1995, Nation's Bank offered a 16 month Sure Step CD, which is renewable after six months for an additional 16 months at the then prevailing rate. Chance and Broughton (1988) examine indexed CDs.
5. For a discussion of the Supervisory Model, see "Federal Reserve Press Release, September 14, 1993. The Release does point out that "high risk" mortgage derivative products held for sale would be report the total carrying value.
6. Gilkeson and Ruff (1992) examined the effect on interest rate changes on CDs with withdrawal penalties for early redemption. They did not, however, deal with the duration of CDs. Nevertheless, they do show that CDs should not be treated as standard fixed-income securities because it fails to account for early withdrawal options embedded in CDs.
7. The capital category distribution is defined as follows:

Total risk-based capital

Well capitalized	≥10%
Adequately capitalized	≥8%
Undercapitalized	<8%
Significantly undercapitalized	<6%
Critically undercapitalized tangible equity of	≤2%

Undercapitalized banks are required by bank regulators to take Prompt Corrective Action (PCA) to restore their capital to adequate levels. Failure to comply with the PCA may result in the closure of the bank by the regulators.

**References**

1. Anderson, Gary A., Joel R. Barber, and Chun-Hao Chang, "Prepayment Risk and the Duration of Default-Free Mortgage-Backed Securities," pp. 1-9, *The Journal of Financial Research*, Spring 1993.
2. Basle Committee on Banking Supervision and the Technical Committee of the International Organisation of Securities Commissions ("IOSCO"), *Framework for Supervisory Information about the Derivatives Activities of Banks and Securities Firms* (May 1995).
3. Bierwag, Gerald O., *Duration Analysis: Managing Interest Rate Risk*, Cambridge, Mass.: Ballinger Publishing Co., 1987, Chapter 13.
4. Carlson, Steven J. and Thomas A. Lawler, "Closed Form Formulas: A More Efficient Way of Computing the Price, Duration, and Weighted Average Life of Mortgage Pools," appears in *Mortgage-Backed Securities: New Strategies, Applications and Research*, Frank J. Fabozzi, ed., Chicago, IL, Probus Publishing, 1987.
5. Chance, Don M., and John C. Broughton, "Market Index Depository Liabilities: Analysis, Interpretation, and Performance," pp. 335-352, *Journal of Financial Services Research*, December 1988.
6. Choi, Sam, "Effective Durations for Mortgage-Backed Securities: Recipes for Improvement," *Journal of Fixed Income*, pp. 23-30, March 1996.
7. Cohen, Hugh, "Beyond Duration: Measuring Interest Rate Exposure," *Economic Review*, Federal Reserve Bank of Atlanta, pp.23-31, March/April 1993.
8. Cohen, Hugh, "Evaluating Embedded Op-

tions," *Economic Review*, Federal Reserve Bank of Atlanta, pp. 9-16, November/December 1991.

Notes

9. DeRosa, Paul, Laurie Goodman, and Mike Zazzarino, "Duration Estimates on Mortgage Backed Securities," *Financial Analysts Journal*, pp. 32- 38, Winter 1993.
10. Federal Reserve Press Release, September 14, 1993 dealing with Interest Rate Risk, 1- 155.
11. Gilkeson, James H., and Craig K. Ruff, "The Valuation of Retail CD Portfolios," Unpublished paper, October 1, 1992.
12. Hanweck, Gerald A., and Bernard Shull, "Bank's Exposure to Interest Rate Risk and Capital Adequacy: An Appraisal of the Federal Agencies' Approach," Presented at the 30th Annual Conference on Bank Structure and Competition, Federal Reserve Bank of Chicago, May 1994.
13. Fabozzi, Frank, and Franco Modigliani, *Mortgage and Mortgage-Backed Securities Markets*, Boston: Harvard Business School Press, 1992, Chapter 13.
14. O'Keefe, John P., "Risk-Based Capital Standards for Commercial Banks: Improved Capital Adequacy Standards?" pp. 1-15, *FDIC Banking Review*, Spring/ Summer 1993.
15. Simons, Katerina, "Interest Rate Derivatives and Asset-Liability Management by Commercial Banks," *New England Economic Review*, Federal Reserve Bank of Boston, pp. 17-28, Jan./Feb. 1995.
16. *The OTS Net Portfolio Value Model*, Office of Thrift Supervision, Risk Management Division, November 1994.