OVERVIEW OF THE NET PORTFOLIO VALUE MODEL

What is Interest Rate Risk?

Interest rate risk (IRR) refers to the risk that changes in market interest rates might adversely affect a depository institution s net interest income or the economic value of its portfolio of assets, liabilities, and off-balance-sheet contracts. Interest rate risk is primarily the result of an imbalance between the price sensitivity of an institution s assets and its liabilities (including financial derivatives and off-balance-sheet contracts). Such imbalances can be caused by:

- differences in the maturity, repricing, and coupon characteristics of assets and liabilities; and
- options, such as loan prepayment options, interest rate caps and floors, and deposit withdrawal options.

These imbalances, in combination with movements in interest rates, will alter the pattern of an institution s cash inflows and outflows, affecting the earnings and economic value of the institution.

Risk to Net Interest Income

A change in the level of market interest rates typically will cause the reported net interest income of an institution to rise or fall. In general, if an institution s liabilities reprice more frequently than its assets, the institution s net interest income will be negatively affected when interest rates rise. When rates rise, the cost of interest-bearing liabilities will generally rise faster then the yield on interest-earning assets, putting downward pressure on net interest income. The reverse will hold when interest rates decline.

Risk to Economic Value

An increase in the general level of interest rates will also cause the value of most assets and liabilities to fall, while a decline in interest rates will have the opposite effect. The degree to which the market price or economic value of a financial instrument changes in response to a given change in interest rates is referred to as its price sensitivity.

The assets of the typical savings association are mostly long-term mortgages that tend to be relatively price sensitive compared to its liabilities, consisting mostly of short-term deposits. Because the assets of typical savings associations are more price-sensitive than their liabilities, a rise in interest rates will cause the net economic value of most thrifts portfolios to decline.

How OTS Measures IRR

Scenario Analysis

OTS uses scenario analysis to evaluate the interest rate risk exposure of savings associations. Scenario analysis is a tool for evaluating alternative future interest rate environments, both optimistic and pessimistic, in which business decisions may be played out. A scenario is a hypothetical event or chain of events. The goal of scenario analysis is to examine the consequences of a specific business strategy under several possible alternative scenarios. Because the consequences of any strategy will generally vary in each scenario, this type of analysis provides a framework for evaluating the soundness of a strategy.

The advantage of scenario analysis, or stress testing as it is sometimes called, is that it forces management to consider events they might otherwise ignore. By focusing on the consequences of a decision, or a set of decisions, in different interest rate environments, scenario analysis can reduce the possibility of unpleasant surprises. Scenario analysis should produce better decision making.

At a typical thrift, scenario planning for interest rate risk management might begin with some what if questions. For example, the chief financial officer (CFO) might ask: What will happen to my institution s earnings and economic value if interest rates rise by 100, 200 or 300? What will happen if the yield curve flattens over the next six months? What will happen if the yield curve steepens? The CFO would probably also ask a few key follow up questions such as: Could my institution survive interest rate shocks of those magnitudes given its current asset/liability mix? or, How should we restructure the institution s portfolio to ensure greater earnings stability?

Net Portfolio Value

OTS evaluates savings associations interest rate risk by estimating the sensitivity of their portfolios of assets, liabilities, and off-balance-sheet contracts to changes in market interest rates. As such, OTS marks-to-market each institution s balance sheet under several different interest rate scenarios to determine how the Net Portfolio Value (NPV) of the institution changes in response to changes in interest rates. OTS defines NPV as follows:

NPV = the present value of expected net cash flows from existing assets

-

the present value of expected net cash flows from existing liabilities

+

the present value of net expected cash inflows from existing financial derivatives and off-balance-sheet contracts.

The greater the change in NPV for a given change in rates, the greater the interest rate risk exposure of an institution.

The NPV Model does not value new business activity of a thrift. Rather, it takes a snapshot view of the portfolio at each quarter-end and estimates its economic value at that time, and the value of that same portfolio under the alternate interest rate scenarios.

The NPV Model estimates the current, or base case, economic value of each type of asset, liability, and off-balance sheet contract at the end of each quarter. These estimates are based on data reported by institutions on Schedule CMR of the *Thrift Financial Report*, and on the term structure of interest rates prevailing at the end of the quarter.

To measure the sensitivity of each thrift s NPV to changes in interest rates, the NPV Model estimates what would happen to the economic value of each type of asset, liability, and off-balance sheet contract under six different interest rate scenarios. The Model estimates the NPV that would result following instantaneous, parallel shifts in the Treasury yield curve of -300, -200, -100, +100, +200, and +300 basis points.

Purpose of the NPV Model

The OTS NPV Model is used to:

- Measure the interest rate risk of individual institutions.
- Generate interest rate exposure estimates that most institutions may use to comply with Thrift Bulletin 13a.

OTS provides all institutions that file Schedule CMR a quarterly *Interest Rate Risk Exposure Report* that shows estimated NPV under the various rate scenarios, as well as other measures that are used to gauge institutions IRR exposure. See Chapter 2 for a description of the *Interest Rate Risk Exposure Report*.

Methods for Calculating Economic Value

Discounted Cash Flow Analysis

A fundamental characteristic of all financial instruments is that they provide cash flows. The value of any financial instrument can be estimated by projecting the amount and timing of future net cash flows associated with the instrument, and then multiplying those cash flows by appropriate discount factors. This procedure for estimating the value of a financial instrument is commonly referred to as discounted cash flow analysis, or present value analysis.

A simplified equation for the present value of a financial instrument is shown in Equation 1.1, where CF is the cash flow in each period, z is the discount rate, and T is the number of periods until final maturity of the instrument.

Equation 1.1 - Present Value (PV) Equation Using Constant Discount Rate

$$PV = CF_1\left[\frac{1}{(1+z)}\right] + CF_2\left[\frac{1}{(1+z)^2}\right] + \ldots + CF_T\left[\frac{1}{(1+z)^T}\right]$$

The terms multiplying the cash flows are the discount factors (e.g., in period 1, the discount factor is 1/(1+z)).

The accuracy of any valuation derived from discounted cash flow analysis depends on the accuracy of both the cash flow estimates and the discount factors used in the analysis.

The discount factors are formed using the discount rate that is the rate of return necessary to induce investors to hold a financial instrument. For any given instrument, the required rate of return is equal to the risk-free rate plus the risk premium necessary to compensate the investor for risk associated with the particular instrument, including credit and liquidity risk.

The discount rate will rise and fall with the general level of interest rates. As interest rates rise, investors require higher rates of return, and therefore, use higher discount rates to value cash flows expected from financial instruments. This causes the value of those cash flows, and thus the market price of the instruments, to decline. The reverse is true for a decline in interest rates.

Both the size and timing of the cash flows can change as market interest rates change. Such changes could result from changes in loan prepayment rates, for example, or from the repricing of adjustable-rate instruments due to interest rate caps and floors being reached.

The NPV Model employs two cash flow-based techniques to value financial instruments: a static discounted cash flow approach, and an option-based pricing approach. In addition, the NPV Model uses a version of the Black-Scholes model [Black (1976)][1] to value interest rate derivatives such as options and interest rate caps. Each of these techniques is described briefly below.

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[1] F. Black, "The Pricing of Commodity Contracts," *Journal of Financial Economics,* 3, January-March 1976, pp. 167-179. See also S. Figlewski, "Theoretical Valuation Models," in *Financial Options: From Theory to Practice,* S. Figlewski, W. Silber, and M. Subrahmanyam, eds., 1990, pp. 115-118.8.

Static Discounted Cash Flow Method

The NPV Model uses the static discounted cash flow approach to value the following items:

- Multi-family and nonresidential mortgages
- Construction and land loans
- Second mortgages
- Consumer loans
- Commercial loans
- Non-mortgage investment securities
- Time deposits
- Demand deposits
- FHLB advances and other borrowings
- Interest rate swaps

Under the static discounted cash flow approach, the economic value of a financial instrument is estimated by calculating the present value of the instrument s expected cash flows. The present value is determined by discounting the cash flows the instrument is expected to generate by the yields currently available to investors from an instrument of comparable risk and duration. Therefore, to calculate the present value of a financial instrument, information is needed about the size and timing of cash flows and about the appropriate discount rates.

Estimating Cash Flows

Cash flows are estimated under each of the seven interest rate scenarios evaluated by the NPV Model. Under each scenario, a single path of future interest rates is assumed. (This analysis is referred to as static cash flow analysis because each scenario depicts a single projected path of interest rates, as opposed to numerous paths used by the option-based approach described below.) Cash flows are calculated under each scenario based upon the assumed path of interest rates depicted in that scenario.

Cash flows can differ across scenarios for two reasons. First, loan prepayment and deposit attrition rates will differ because borrowers and depositors make different decisions about these actions in different interest rate environments. Such differences in customer behavior are modeled by specifying a relationship between the interest rate scenario and the rates of prepayment and attrition, thereby changing the magnitude and timing of principal and interest cash flows. Second, the magnitude of interest cash flows differs across scenarios as adjustable-rate instruments reprice in future periods and receive different coupon rates under different scenarios.

Use of the Zero-Coupon Treasury Yield Curve

The basic principle behind choosing discount rates is that they should represent the yields obtainable from instruments with the same risk and duration as those of the cash flows being discounted. Thus, in calculating the present value of a U.S. Treasury security, an appropriate sequence of discount rates for each of its cash flows would be the sequence of zero-coupon Treasury yields with maturities corresponding to the dates on which each cash flow is anticipated. (Chapter 8 describes how the zero-coupon yields are obtained.) The present value calculation in Equation 1.1 must be modified slightly and is illustrated in Equation 1.2.

Equation 1.2 - Present Value Equation Using Zero-Coupon Treasury Yields

$$PV = CF_1\left[\frac{1}{(1+z)}\right] + CF_2\left[\frac{1}{(1+z_2)^2}\right] + \ldots + CF_T\left[\frac{1}{(1+z_T)^T}\right]$$

The difference between Equations 1.1 and 1.2 is that in Equation 1.2, subscripts 1 through T have been added to the z variables to indicate that a different discount rate is used for each discount factor. In Equation 1.2, the z variables represent the zero-coupon U. S. Treasury yields, or spot rates, for maturities corresponding to the dates on which cash flows are generated by the security being valued. The maturity of each of the discount rates matches the duration of each cash flow it is discounting. (The duration and maturity of a zero-coupon security are equal, and the duration of each individual cash flow being discounted is simply the time remaining until it is received.)

The discount factors in Equation 1.2 are used to estimate the economic value of Treasury securities. The discount factors for deposits and borrowings are calculated in a similar way. For deposits, the discount factors are based on yields for wholesale certificates of deposit (CDs) instead of Treasury securities. For borrowings the discount factors are based on the London Inter-bank Offered Rate (LIBOR).

Implied forward rates can be derived from the spot curve, and Equation 1.2 can be re-written as follows where the f variables are the one-month implied forward rates. (See Chapter 8 for a description of how the implied forward rates are derived from the spot rate curve).

Equation 1.3 - Present Value Equation for Treasury Securities Using Implied Forward Rates

$$PV = \frac{CF_1}{\left[(1+f_1)\right]} + \frac{CF_2}{\left[(1+f_1)(1+f_2)\right]} + \ldots + \frac{CF_T}{\left[(1+f_1)(1+f_2)\ldots(1+f_T)\right]}$$

The discount factors used to value assets other than U. S. Treasury securities must include a spread to account for the credit risk difference between the instrument being valued and Treasury securities. Thus, for instruments other than Treasury securities, Equation 1.3 is modified as shown in Equation 1.4.

Equation 1.4 - General Present Value Equation for Assets

$$PV = \frac{CF_1}{\left[(1+f_1+s)\right]} + \frac{CF_2}{\left[(1+f_1+s)(1+f_2+s)\right]} + \ldots + \frac{CF_T}{\left[(1+f_1+s)(1+f_2+s)\ldots(1+f_2+s)\right]}$$

The spread, s, is unique for each asset. It is calculated so that by using the current market rate on a given instrument and making assumptions concerning an asset s maturity, amortization, and prepayment characteristics, a newly issued instrument of that type is priced at par.[2] That is, in Equation 1.4, principal and interest cash flows are calculated using the current market interest rate and an initial principal balance of $100. The equation is solved for the constant spread, s, that results in a PV of $100. This approach to determining the spread is used in the NPV Model for multi-family and nonresidential mortgages, construction and land loans, second mortgage loans, all non-mortgage loans, and non-mortgage investment securities.

<u>Alternate Interest Rate Scenarios</u>

In the alternate interest rate scenarios, the present values are calculated as in Equation 1.5, where the f'_i variables are the implied forward rates derived from the spot rate curve that has been shocked by the amount appropriate for that rate scenario (e.g., by 100 basis points). The NPV Model assumes that the risk premium required by investors (i.e., the spread, s) does not change in the alternate interest rate scenarios.

Equation 1.5 - Present Value Equation for the Shocked Rate Scenarios

$$PV' = \frac{CF'_1}{\left[(1+f'_1+s)\right]} + \frac{CF'_2}{\left[(1+f'_1+s)(1+f'_2+s)\right]} + \ldots + \frac{CF'_T}{\left[(1+f'_1+s)(1+f'_2+s)+\ldots+(1+f'_T+s)\right]}$$

[2] Most of the current market rates for various assets are taken from the published results of surveys of lenders in that particular market. For example, the current lending rate for fixed-rate construction loans is taken from a survey of performed by the U.S. Department of Housing and Urban Affairs of lenders of home construction funds.

Under the alternate interest rate scenarios, cash flows, CF_t', are also revised to reflect different loan prepayment or deposit attrition rates and, if applicable, to reflect repricing of the instrument. To calculate the present value in the alternate rate scenario, the revised cash flows are then simply discounted by the new discount rates.

Option-Based Pricing Approach

The NPV Model uses an option-based pricing approach based on Monte Carlo simulation to value assets with embedded options that have a significant impact on the assets price sensitivity.

The most significant embedded options, from the perspective of savings associations, are the prepayment options and interest rate caps and floors in mortgages and mortgage-related securities. Prepayment options can produce significant uncertainty in the timing of mortgage cash flows.

In large part, the value of a prepayment option depends on the volatility of interest rates. When interest rate volatility increases, there is a greater chance that mortgage rates will change sufficiently relative to the rates on existing mortgages to induce significant changes in prepayment. In a falling rate environment, prepayments increase and the proceeds from the prepayments can only be reinvested at the then lower market rates. When interest rates rise, prepayments fall, because it is to the advantage of mortgagors to retain their relatively low-coupon mortgages. This slow-down in prepayments works to the disadvantage of lenders in that environment because the mortgages are paying rates of interest below those at which new mortgages could be originated.

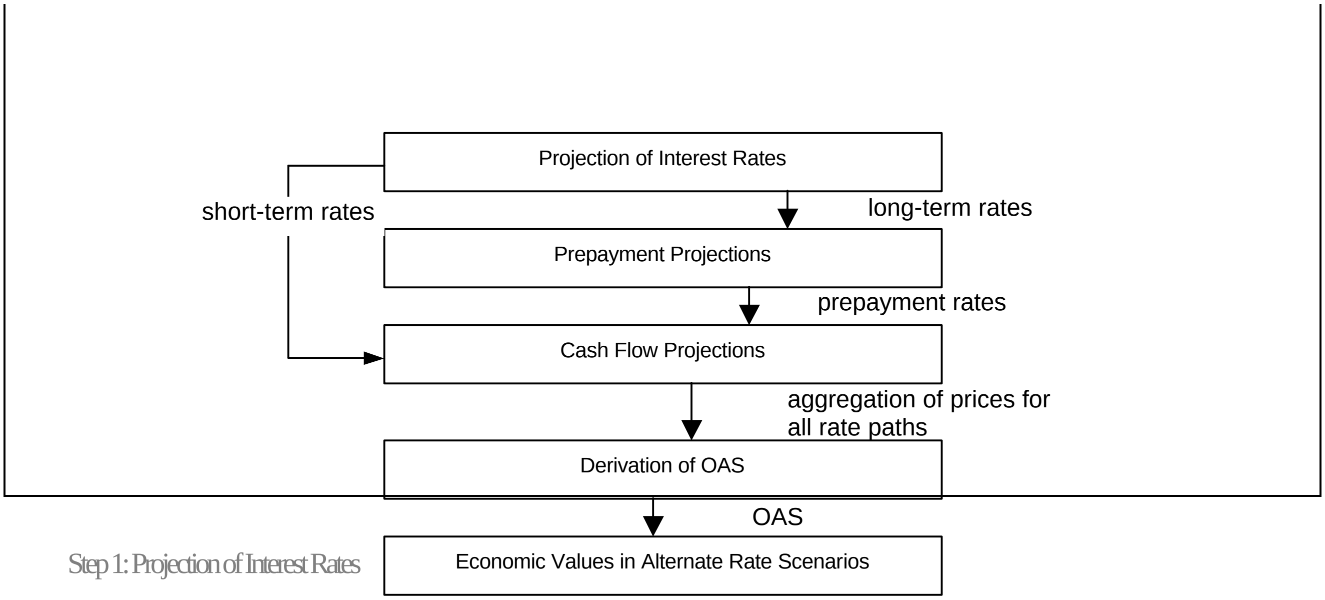
Compared to static pricing models, a Monte Carlo simulation model provides improved estimates of the interest rate sensitivity of mortgage assets by taking interest rate volatility into account. A Monte Carlo model uses an interest rate simulation program to generate numerous random interest rate paths that, in conjunction with a prepayment model, are used to estimate mortgage cash flows along each path. In fact, the option-based approach actually repeats the static cash flow approach many times with different interest rate paths.

The NPV Model uses an option-based approach to value:

- 1-4 family fixed-rate mortgages
- 1-4 family adjustable-rate mortgages
- Mortgages serviced for others
- Mortgages serviced by others
- Firm commitments to buy, sell, or originate mortgages

The calculation of the economic value of a mortgage security using the option-based approach is illustrated by Figure 1.1 and described in steps 1 through 5 below.

Figure 1.1
Illustration of the Option-Based Approach



Step 1: Projection of Interest Rates

The NPV Model uses the parameter estimates from a regression model to generate 200 randomly determined interest rate paths of short-term (one-month) interest rates based on the assumed long-term volatility of short-term interest rates. The NPV Model ensures that the paths are generated in a manner that makes the simulation consistent with the observed quarter-end Treasury yield curve. Thus, if Treasury securities are priced using the interest rate paths, the NPV Model reproduces the currently observed Treasury prices.

Using the parameter estimates from a regression model of the behavior of long-term (five-year) interest rates, a separate long-term volatility assumption, and an assumed correlation between short-term and long-term interest rates, the NPV Model generates 200 paths of five-year rates. The simulated mortgage rates are then calculated as the sum of the five-year Treasury rate plus a spread.[3] The simulated mortgage rates are used as input to the prepayment equation discussed in Step 2 below.

Step 2: Prepayment Projections

Mortgage prepayment rates are projected for each month along each interest rate path using a prepayment equation. The prepayment equation projects the prepayment rate for a given month based on the ratio of the coupon of the mortgages underlying the security being valued to the projected mortgage rate in that month along the path obtained in Step 1 discussed above. The greater the ratio of the mortgage s coupon to the rate at which it could be refinanced, the greater is the refinancing incentive for the mortgagor, and the higher is the anticipated prepayment rate.

Step 3: Valuation of Projected Cash Flows

Cash flows are generated for each month along each interest rate path taking into account the amortization schedule, the projected prepayment rate obtained in Step 2, and coupon repricing characteristics (including interest rate caps and floors in the case of ARMs) of the mortgages underlying the security. The cash flows are discounted using discount factors calculated using the sequence of one-month rates generated in Step 1 plus a spread.[4] A mortgage security price for each path is calculated by summing the discounted cash flows.

[3] The spread is equal to the average historical difference between the rate on fixed-rate 30-year mortgages and the five-year Treasury rate.

[4] The discount factors are similar to those shown in Equation 4 above, except the f variables are the one-month rates generated by the simulation as opposed to the actual one-month implied forward rates used in Equation 4.

Step 4: Derivation of the OAS

The prices calculated in Step 3, discussed above, are averaged to derive a single price that is then compared to the observed market price for the security under analysis. If the calculated price is greater than (less than) the market price, then Step 3 is repeated using a slightly higher (lower) spread. The process is repeated until the calculated price equals the market price. The spread that causes the average of the prices resulting from the 200 simulated rate paths to equal the observed market price of the security being valued is known as the option-adjusted spread (OAS).

Step 5: Derivation of Economic Values in Alternate Interest Rate Scenarios

Once the OAS has been derived, economic values of the mortgage security are calculated under the alternate interest rate scenarios. To model each scenario, steps 1 through 3 are repeated (with the OAS serving as the spread in the discount factor) starting with a term structure that has been subjected to a parallel shock of the desired magnitude (e.g., plus 100 basis points). As for the base case, the average of the 200 present values is the estimated economic value for the shocked rate scenario.

Adjustable-Rate Mortgages in the Monte Carlo Framework

An important feature of ARM valuation that results from the use of the Monte Carlo methodology is that periodic and lifetime interest rate caps and floors influence the value of an ARM even though the coupon has not actually reached the cap or floor. For example, consider two 1-year Treasury ARMs, one with a periodic cap of 200 basis points and the other with no periodic cap. In the +100 basis point interest rate scenario, the ARM with the 200 basis point cap would have a lower economic value than the ARM with no cap. This occurs because some of the randomly generated interest rate paths used to value the variable-rate mortgage would have been constrained by the cap, even in the +100 basis point scenario. This would result in lower coupons along those paths for the ARM with the cap, and a lower overall price.

The results with respect to the value of caps and floors contrast with those obtained from static discounted cash flow models where a single interest rate path is used. In that case, the two ARMs in the above example would have the same economic value in the +100 basis point scenario. In static models, interest rate caps and floors have no effect on the value of an ARM until the coupon is actually constrained by the cap or floor (i.e., for interest rate shocks of more than 200 basis points in the case of the ARM in the example).

The Black (1976) Model for Interest Rate Derivatives

The NPV Model uses a version of the Black-Scholes model to value the following instruments:

- Options on interest rate futures
- Optional commitments to buy and sell mortgages
- Interest rate caps and floors
- Interest rate swaptions

The Black (1976) formula was developed for estimating the prices of options on futures and forward contracts and can be written as[5]:

$$C = e^{-rT}\left[F\,N\left(D_f\right) - X\,N\left(D_f - s\sqrt{T}\right)\right]$$

$$P = e^{-rT}\left[X\,N\left(-D_f + s\sqrt{T}\right) - F\,N\left(-D_f\right)\right]$$

5 F. Black, “The Pricing of Commodity Contracts,” *Journal of Financial Economics,* 3, January-March 1976, pp. 167-179. See also S. Figlewski, “Theoretical Valuation Models,” in *Financial Options: From Theory to Practice,* S. Figlewski, W. Silber, and M. Subrahmanyam, eds., 1990, pp. 115-118.8.

where: $$D_1 = \frac{\left[\ln\left(\frac{F}{X}\right) + \left(\frac{s^2 T}{2}\right)\right]}{s\sqrt{T}}$$

C	=	price of a call option
P	=	price of a put option
F	=	futures price
X	=	strike price of option
T	=	time to option expiration
r	=	risk-free interest rate
e	=	the exponential function
ln	=	the natural logarithm function
$N(\cdot)$	=	cumulative normal distribution function evaluated at the quantity in parentheses
s	=	volatility of return on futures contract.

To value a specific contract, relevant values of the key variables listed above are substituted into the formula for each interest rate scenario.