

# THE EVALUATION OF CREDIT UNION NON-MATURITY DEPOSITS

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*Consulting Economists*

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## I. INTRODUCTION AND SUMMARY OF RECOMMENDATIONS

We have been asked by the National Credit Union Administration (NCUA) to evaluate the available methods for valuing non-maturity deposits (NMDs) of individual credit unions. Non-maturity deposits provided by credit unions, banks and thrifts have no set maturity. In the case of credit unions, these include regular shares, share drafts and money market accounts.

We were asked to include the following tasks in this evaluation:

- Comprehensive review of the literature on valuing NMDs.
- Conceptual evaluation of alternative methods.
- Analysis of the material costs and benefits of alternative methods.
- Discussion of implementation issues for NCUA examiners and member credit unions.
- Recommendations for the most suitable valuation approaches to meet NCUA and member credit union needs.

The NCUA was particularly interested in the question of what effective maturity may reasonably be assumed for NMDs in simple methods that do not explicitly model NMD cash flows.

In fulfilling this mandate, we have reviewed recent academic research and the work of regulators and practitioners in the field, talked with economists from regulatory agencies (including NCUA) and other consultants, performed statistical analysis of credit union data, and performed valuations of non-maturity deposits using different valuation methodologies. In some cases, our evaluation of vendor methods was limited by lack of publicly available information. We have not evaluated software and information systems.

Our recommendations are based on four main criteria:

- Conceptual consistency with the theory of NMD valuation.
- Applicability to credit unions.
- Feasibility of implementation based on availability of data and ease of estimation and application.
- Cost effectiveness, with particular attention to the needs and capabilities of different sized credit unions.

Any method that is adopted for valuing NMDs should not be viewed in isolation, but rather in the context of an overall asset and liability management framework. Due to the nature of the assets and liabilities of credit unions, their balance sheets and income statements are sensitive to changes in interest rates. Interest rate risk, defined as the sensitivity of balance sheet items and earnings to changes in interest rates, is a major concern to managers of these institutions and their regulators. By assessing the interest rate risk of *both* assets and liabilities, one obtains a clearer picture of an institution's exposure.

Many credit unions also calculate what is known as their "net economic value" (NEV); this is simply the net difference between the economic (or market) value of their assets and the economic (or market) value of their liabilities. The NEV approach does not value expected new business activities of a credit union (in other words, expected growth in assets and liabilities). Rather, it takes a snapshot view of the balance sheet at each quarter-end and estimates its economic value at that time, and the value of that same balance sheet under alternative interest rate scenarios. Therefore, our evaluation of NMD valuation methods is based on their ability to provide reasonable estimates of interest rate risk and value in the context of NEV.

## **A. Summary of Recommendations**

The main conclusions and recommendations of our report are contained in Chapter VII, but they are briefly summarized here.

1. The theoretical basis of NMD valuation is the ability of banks, thrifts and credit unions to issue deposits that pay depositors less interest than the interest paid on comparable-risk investments. To the extent that NMDs are free of credit risk, the comparable-risk investment is a U.S. Treasury security. The present value of the interest rate spread between the Treasury rate and the deposit rate (less deposit acquisition and servicing costs) is the source of NMD value.
2. The appropriate discount rate for calculating NMD present value is the rate on a comparable risk investment. Under the assumption of no credit risk, this is a Treasury rate.
3. Valuation methods based on an "alternative cost of funds" approach tend to overstate NMD value to the extent that the alternative funds, such as Eurodollar deposits (LIBOR), have greater credit risk than the NMD. These methods provide accurate value estimates only if based on an appropriate assumption about the credit risk of deposits and an investment benchmark of approximately equivalent credit risk.
4. Some of the simpler methods of including NMDs in asset-liability management systems do not attempt to specify the actual cash flows of non-maturity deposits. These cash flows include

deposit withdrawals, deposit interest and deposit acquisition and servicing costs. Methods that do not include these cash flows can be satisfactory (cost effective) for small credit unions. For such methods, the choice of maturity is essentially an assignment of interest rate risk to the deposit. Consequently, the chosen maturity should be a duration (a measure of interest rate risk). We recommend a range of durations based on durations estimated for NMDs in the literature we surveyed. These recommended durations are given in Table 1. These durations are the recommended final maturities, which are sometimes called “effective maturities,” for NMDs for those credit unions that do not explicitly model NMD cash flows. If NMDs are assigned to maturity buckets, we recommend using these durations as the NMD maturities. If NMDs are treated as zero-coupon “bonds,” we recommend these durations as the final deposit maturities.

**Table 1. Recommended Durations for NMDs**

Description: These durations are recommended as the final (“effective”) maturities of NMDs for credit unions that do not explicitly model NMD cash flows. They are acceptable for assigning NMDs to maturity buckets and for the final maturity when a NMD is treated as a zero-coupon bond.

	<b>Min</b>	<b>Mid</b>	<b>Max</b>
Share Drafts (Transaction Accounts)	2.0	2.5	2.8
Regular Shares (Passbook)	2.5	3.0	3.5
MMDAs	0.5	1.0	1.5

5. For credit unions that wish to base NMD valuation on actual (discounted) cash flows, but not use the complex state-of-the-art methods, we provide an illustrative simple present value model, which can produce durations comparable to those estimated in the literature. The effective (final) maturities in this model are chosen so that the model produces durations similar to those in Table 1. We do not recommend that any credit union (or NCUA examiner) blindly adopt this model, or even this type of model, without careful consideration of whether the assumptions make sense for a particular institution.
6. In all cases of using simple “effective maturity” models (as in 4 above) or simple discounted cash flow models (as in 5 above), we strongly recommend that the model should be designed to produce durations similar to those estimated in the literature, as summarized in Table 1.
7. We make no recommendations about the effective maturities in relatively fully-specified models such as the Office of Thrift Supervision (OTS) NPVM and the most complex models we surveyed known as “contingent claims” models. These models specify future interest rate paths and the reaction of deposit balances and interest rates to those paths. The effective (final)

maturities, generally 15 – 30 years, specified in these models are internally consistent with the other assumptions of the models. If credit unions wish to use these complex models we do strongly recommend the following:

- a. Model users (and examiners) should understand the assumptions on which the model is based, including how future interest rate paths are defined and used, how deposit balances and deposit rates are related to future interest rates, and whether these assumptions conform reasonably well to deposit rate setting by management of the institution and typical depositor behavior. For example, if management does not expect to reduce the deposit rate as market rates fall, then a model that assumes deposit rates will fall with market rates is not appropriate. Similarly, if a particular credit union's depositors are expected not to react (by withdrawing funds) if the institution fails to raise deposit rates in a rising rate environment, then the model should not be based on the assumption that they will react.
  - b. Model parameters (the constants in the equations) should be estimated with individual credit union data, or lacking that, with aggregate credit union data adjusted to conform to the no-growth assumption in the NEV framework.
  - c. The discount rate in the model should be chosen based on the assumed default risk of the deposits being valued.
8. Option-adjusted spread (OAS) models are generally not appropriate for credit unions. Unlike bank deposits, there is no market for credit union deposits, which makes a key input to the OAS method (the observed market value of the deposits) unavailable. Some vendors have developed a proxy for this unavailable input; this can be appropriate, but care must be taken to ensure that such proxies remain accurate estimations of deposit premia.
  9. There is a lack of data and research on the behavior of credit union non-maturity deposits. NCUA should put in place some simple procedures that will lead to ongoing estimates of the retention rate of deposits and commission a study to examine past deposit behavior compared to that of banks and thrifts.
  10. Because of the wide range in size and sophistication of the insured credit unions, we have considered whether our recommendations should differ for small and large credit unions. Generally, simple methods (see 4 and 5 above) are appropriate and cost-effective for the smallest institutions, while the more complex methods (see 7 above) are advised for the largest and most financially sophisticated.



## **B. Background on the History of Non-Maturity Deposit Valuation**

Approaches to valuing non-maturity deposits (NMDs) have developed rapidly in the last ten years, reflecting both increased sophistication in general asset/liability modeling, as well as greater understanding of non-maturity deposits and their behavior. Ide (1999) shows how deposit modeling has evolved through three distinct stages.

Initially, NMDs were assumed insensitive to changes in interest rates, and assigned the longest maturity “bucket” in gap analysis, suggesting that they were not subject to the effects of repricing. While this may seem naïve today, it partly reflects the days of “Regulation Q,” when the Federal Reserve imposed maximum rates that could be paid on deposits, and when there were few changes in deposit rates. Compounding the situation was the lack of alternative investments for customers.

In addition to the lack of competitive pressures on deposit taking institutions to offer competitive rates in order to attract and keep deposits, there was little demand for accurate valuations of NMDs, since the risk-measurement of the times lacked rigor and sophistication. In a period of relative stability in interest rates, and lack of competition from non-bank institutions, there was little perceived need for the sophisticated risk analysis that is customary today.

This cozy world was brought to an abrupt end by the events of the 1980s. In a short period, deposit institutions had to react to a series of events that completely changed their world. These included: the sharp rise in the level and volatility of interest rates, following the Federal Reserve’s shift in monetary policy in October 1979; the growth of money market mutual funds; the repeal of Regulation Q; and the creation of new products such as negotiated order of withdrawal (NOW) accounts. Deposit-taking institutions suddenly found that unless they offered competitive rates on competitive products that customers would take their deposits elsewhere. New pricing strategies had to be developed, and banks and thrifts learned about the extent to which their assets and liabilities were sensitive to changes in interest rates.

During this period, more sophisticated risk measurement and risk management tools were developed for many parts of the deposit taking institution. Non-maturity deposits, however, were still treated in the same way they always had been by most institutions. Some developments in pricing models took place as academics and researchers started to analyze the behavior of aggregate deposit balances in different economic and interest rate scenarios. From these studies came some of the first efforts to model NMDs.

Just as deposit-taking institutions had grown accustomed to the high and volatile interest rate environment of the 1980s, the world changed again. This time, it was the rapid decline in the level and

volatility of interest rates in the early 1990s that led banks and other institutions to revisit their pricing strategy for NMD products again. Some asset/liability managers responded by estimating so-called “beta-based” models. In these models, the estimated “beta” represented a repricing percentage, *i.e.*, the amount they should change their deposit rate following a given change in market interest rates. This method reflected the institution’s option to change the rate paid on deposits.

This period also saw the first attempts to model how customers might react to changes in deposit rates and market rates. Some studies sought to follow samples of individual accounts over time, tracking deposits, withdrawals, and transfers, in order to infer how average deposits might behave. Other studies looked at total deposit balances, so that new accounts implicitly replaced closed accounts, in this way inferring how an institution’s aggregate balances might be expected to behave.<sup>1</sup>

In the most recent period, advances in other areas of asset pricing have been applied to NMDs. This has led to the creation of complex mathematical equations to describe the historical behavior of deposit rates and balances. In many of these methods, the options embedded in deposits are explicitly modeled using option-pricing techniques.<sup>2</sup> In other methods, the market for core deposits that arose in the 1990s is used to infer the appropriate spread (referred to as the option-adjusted spread) to add to the risk free rate when discounting NMD cash flows.<sup>3</sup> Examples of these latest developments are discussed in more detail in the next chapter.

### C. Overview

The remainder of this report is organized as follows: Chapter II considers the various methods that have been developed for the valuation of non-maturity deposits, in terms of their theoretical underpinnings. In Chapter III we consider the ways in which credit unions are similar to and different from banks and thrifts. A reasonable range for assumptions concerning the effective maturity of non-maturity deposits is discussed in Chapter IV. The practical implications of using the various methods, in terms of how each method needs to be adapted and used by individual credit unions and/or the NCUA

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<sup>1</sup> The valuation methodology of McGuire Performance Solutions follows a combination of the two, using both a sample of individual accounts and aggregate balance history.

<sup>2</sup> For example, Jarrow and van Deventer (1998) and O’Brien (2000). Subsequently, we refer to these methods as do their authors: “contingent claims” methods. Option pricing theory, developed initially by Black and Scholes (1973), has been generalized to apply to any contingent claim, which is any asset whose value is determined by the values of one or more “state variables.” The state variables define the possible future states of the economy (“states of the world”) that are relevant to the value of the asset. (For more about contingent claims, see Elliott and Kopp (1999), p. 2.)

<sup>3</sup> For example, Selvaggio (1996).

are considered in Chapter V. In Chapter VI we illustrate a simple discounted cash flow model. Chapter VII reports our recommendations, and Chapter VIII discusses the implications for NCUA in the examination process. The Appendix contains a technical summary and comparison of some of the methods discussed in Chapter II.

## II. THE DIFFERENT METHODS FOR VALUING NON-MATURITY DEPOSITS

The basic objective of any NMD valuation method is to project accurately, for a given interest rate scenario, future deposit rates and balances. Regardless of the degree of complexity and sophistication applied in valuing NMDs, all methods require assumptions about how the deposits will behave in the future. If the assumptions err on the side of under-estimating the sensitivity of deposit rates and balances to changes in market rates, the credit union will be subject to unanticipated declines in profitability as the deposits reprice more quickly or are withdrawn more quickly than expected. Conversely, if the assumptions err on the side of over-estimating the rate sensitivity of deposit rates and balances, the credit union may invest assets too short, forgoing more profitable long-term investments.

Any method that is adopted for valuing NMDs should not be viewed in isolation, but rather in the context of an overall asset/liability management framework. Due to the nature of the assets and liabilities of credit unions, their balance sheets and income statements are sensitive to changes in interest rates. The degree of sensitivity of balance sheet items and earnings to changes in interest rates is a matter of concern to the management of these institutions and their regulators. By assessing the rate sensitivity of *both* assets and liabilities, one obtains a clearer picture of an institution's exposure to possible rate changes.

Ide (1999) points out that non-maturity deposit products contain two embedded options that complicate their valuation: i) the financial institution holds the option to determine the interest rate to pay customers, and when to change it; and ii) the customer holds the option to withdraw all or part of the balance in the account at par. How these two options are incorporated into a specific method largely determines the degree of complexity of that method.<sup>4</sup>

A stated goal of regulators is to assess “the exposure to a bank’s underlying economic value from movements in market interest rates;” in other words, the net difference between the market value of assets and the market value of liabilities.<sup>5</sup> This difference in market value is known by various

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<sup>4</sup> The first option allows the issuing institution to make the deposit behave more or less as a floating rate bond. The second option can be viewed as the option of the depositor to put the bond back to the institution. Thus, a NMD can be viewed as a type of floating-rate, puttable bond.

<sup>5</sup> Board of Governors of the Federal Reserve, SR-96-13, “Interagency Guidance on Sound Practices for Managing Interest Rate Risk”. See also FFIEC, “Supervisory Policy Statement on Investment Securities and End-User Derivatives Activities” (63 Fed. Reg. 20191 at 20195, April 23, 1998), and NCUA, “Investment Securities and End-User Derivatives: Interpretative Ruling and Policy Statement” (63 Fed. Reg. 24097 at 24101, May 1, 1998).

names, but we shall use the term widely used in the credit union industry, namely “Net Economic Value” (NEV).<sup>6</sup> Another way of viewing NEV is that it is a fair value assessment of the present value of expected future earnings, and by calculating NEV for different interest rates the impact of changes in interest rates on earnings can be assessed. By calculating a credit union’s NEV, management can assess the likely impact on net worth or capital, and regulators can better assess the likelihood of failure due to market-related events.

When market value is not directly observable, a widely accepted estimate of the value of any financial asset is the present value of expected future cash flows associated with that asset, using a market interest rate for discounting. For default-free and option-free securities with defined maturities, such as (non-callable) Treasury bonds, that is fairly straightforward: the cash flows are known in advance with certainty, and the discount rate is readily observable in the Treasury market. For option-free securities and deposits with credit risk, such as fixed-term and fixed-rate certificates of deposit (CDs), (non-callable) corporate bonds and the like, the maturity is known, the (expected) cash flows are readily calculated, and market discount rates that include default risk premia can be observed. For NMDs, however, there are two obstacles to this simple approach. First, as the name implies, the maturity of a specific NMD is not known with certainty due to the option of the depositor to withdraw. Second, the timing and the amount of cash flows of a specific NMD is uncertain due to both the depositor’s option to withdraw and the credit union’s option to change the deposit rate. It follows that NMDs cannot be precisely valued using traditional present value methods.

There are several ways to overcome these obstacles, but all involve making some simplifying assumptions about the maturity of NMDs and about how the cash flows on the deposits vary with interest rates and other variables.<sup>7</sup> Some critics charge that because changing the assumptions used in valuing NMDs can lead to material changes in the value of the deposits and therefore in NEV, that the whole market value approach is fatally flawed and should not be applied to credit unions. Instead, they argue, attention should be focused on measuring the impact of changes in interest rates on book value of capital, earnings, or return on assets.

Such an earnings exposure approach, however, is shortsighted for several reasons. First, it assumes that accounting-based measures of risk are more accurate and appropriate than market based measures. The experience of many savings and loans during the late 1980s and early 1990s showed that

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<sup>6</sup> Other terms for NEV include “Market Value of Portfolio Equity” (MVPE), “Economic Value of Equity” (EVE), “Net Portfolio Value” (NPV), and “Market Value of Capital” (MVC).

<sup>7</sup> The specific issue of the *effective* maturity of NMDs is considered in Chapter IV.

market based measures of risk such as NEV (or NPV, as it is called by the Office of Thrift Supervision) deteriorated long before the book value of capital signaled the need for intervention by management and regulators.

Second, NMDs are not the only type of financial asset with indeterminate maturity and uncertain cash flows. The best examples of such financial assets are lines of credit and bonds with embedded options, including callable bonds, putable bonds and mortgage-backed securities that include the homeowner's option to prepay. The traditional methods of valuing, for example, callable bonds was to assume they were either held to maturity or held to call and to discount the cash flows at the yield to maturity or yield to call on a comparable callable bond. More sophisticated valuation methods now widely used incorporate the changes in bond cash flows that may occur due to the future exercise of the options in response to interest rate changes.<sup>8</sup> In other words, the complexity or lack of definition of cash flows need not prevent valuation based on reasonable assumptions.

This leads to a third reason for not dismissing NEV: changes in value due to changes in the assumptions do not invalidate the model. Rather, it means that management and examiners must be careful that the assumptions made to value NMDs are appropriate for the institution in the circumstances in which they are to be applied. A goal of this report, therefore, is to provide some guidelines for the conditions under which some of the more common assumptions are reasonable.

It is important to keep in mind that any model that attempts to measure risk or value is based upon a set of assumptions. This is as true for accounting-based earnings exposure methods as it is for economic value exposure methods such as NEV or the more complex Value-at-Risk. One cannot question the validity of a model simply because its results are contingent upon assumptions. All models outputs are contingent upon assumptions. For example, accounting based measures of risk, such as book value of capital or return on assets, are based on the assumption that historical cost measures are an accurate reflection of the value of assets. However, if a financial institution has to be taken over by a deposit insurance fund, what matters is the market value of those assets.

## **A. Overview of Valuation Theory Applied to NMDs**

NMDs are valued in a discounted cash flow, or present value, framework. The model specification choices, therefore, are defining the maturity, specifying the cash flows and choosing the

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<sup>8</sup> See, for example, Fabozzi (2000).

discount rate. The overarching question, however, which in turn drives these specification choices, is how the uncertainty of future cash flows is captured in the model.

In the most advanced NMD models, there is one source of uncertainty (equivalently, one “state variable” defining the possible future “states of nature”), the market interest rate.<sup>9</sup> In all of these models, the market interest rate is defined as a Treasury rate. The Treasury rate is assumed to follow a random path, or “stochastic process.” The mathematical equation of the random path also implies the probability distribution of the Treasury rate at each future moment. Knowing the probability distribution allows useful quantities such as the expected Treasury rate at each future moment to be calculated. Each Treasury rate path, in turn, influences future deposit rates and remaining balances, and the expectations of these variables can be calculated. A third component of cash flows, deposit acquisition and servicing costs, net of depositor fees, is also specified in these models.

The way uncertainty is handled in the model also affects the way discounting to calculate present value is handled. In models with uncertain cash flows, there are two ways to approach discounting for calculating present value: (1) Expected cash flows are discounted using a discount rate that includes a risk premium reflecting the riskiness of the cash flows. For example, when valuing default-free cash flows, the appropriate discount rates are the rates on Treasury securities maturing at the same date as the cash flows. These rates may differ by maturity, reflecting a “term,” or maturity, premium, which is a premium for interest-rate risk.<sup>10</sup> When valuing corporate bonds, the discount rate will include a premium for interest rate risk and a premium for default risk. OAS models for mortgage-backed securities and NMDs are of this type. (2) Expected cash flows are adjusted to a “certainty equivalent” cash flow by subtracting a risk premium, and certainty equivalent cash flows are discounted at a riskless rate. This is the method used in option-pricing models, such as the Black-Scholes model of stock option pricing and three of the advanced NMD models.<sup>11</sup> The more modern terminology for option-pricing models is “contingent claims” models.<sup>12</sup>

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<sup>9</sup> These models include Selvaggio (1996), Hutchison and Pennachi (1996), Jarrow and van Deventer (1998), and O’Brien (2000).

<sup>10</sup> Theories differ as to how term premia may vary with maturity. A summary can be found in Fabozzi (2000). Using Treasury rates for discounting default-free cash flows, however, implies no stance with regard to theories of term premia.

<sup>11</sup> Hutchison and Pennachi (1996), Jarrow and van Deventer (1998), and O’Brien (2000).

<sup>12</sup> This certainty-equivalent interpretation of contingent claims models can be found, for example, in Trigeorgis (1997), particularly p. 103.

Finally, the effective (final) maturity of the cash flows must be specified. In the advanced models, this could be infinite, since the deposit balance equations may never result in a zero balance. In practical implementation of the models, however, the horizon is assumed to be long, but finite, such as 30 years, after which the present value of future cash flows is so small as to be negligible.

Thus, a fully-specified NMD model consists of the following:

- A clear and rigorous specification for how uncertainty enters the model. Stated another way, there must be one or more mathematical equations for calculating the possible future paths of any variable that is a fundamental source of uncertainty. In the current NMD models, this means a mathematical/statistical description of possible paths of the short-term Treasury rate.
- A deposit rate equation, which specifies how the deposit rate depends on the Treasury rate (and other factors such as lagged deposit rates).
- A deposit balance equation, which specifies how the remaining deposit balance depends on the deposit rate, the Treasury rate and other factors such as lagged deposit balances.
- An assumption about acquisition and servicing costs, net of any fees paid by depositors.
- A theoretically sound method of discounting, either discounting expected cash flows at a risk-adjusted rate or discounting certainty-equivalent cash flows at a riskless rate.
- Estimated model parameters (fixed values in equations, such as the coefficient on the Treasury rate in a deposit balance equation) from a valid database of credit union deposits.

We have added the last ingredient in the interest of practical implementation of these models. Fully-specified models without reliably estimated parameters are of little use for estimating NMD values.

## **B. Economic Rents as the Source of NMD Premia**

Although the basics of valuation theory, as discussed above, are important for an understanding of various methods of NMD valuation, one can understand these quite well and still remain confused about the source of NMD value: why do NMDs have premia? For example, why would a \$100 deposit be valued in an NEV context at \$95? The language is already confusing, because in securities markets we would describe the \$5 difference as a discount. A corporate bond, for example, might be issued not at par (\$100), but at a discount (\$95) if its coupon is less than the required coupon on comparable bonds. This confusing terminology is a clue that something is different about NMD “premia.”



In fact, the corporate bond analogy is fundamentally flawed. The corporate bond discount occurs whenever the coupon rate is lower than the required rate on comparable bonds. In contrast, the NMD premium exists when the deposit pays exactly the required rate on comparable deposits. For example, a financial institution can issue a \$100 share draft paying the required rate on comparable share drafts and immediately value the deposit at \$95 for NEV purposes. The \$5 difference is not a discount at all, but an additional, implicit asset known as an “economic rent.” Economic rents may be defined as profits that are not expected to be competed away.

The existence of economic rents is due to the special nature of retail deposits in banking institutions.<sup>13</sup> These deposits are essentially free of credit risk for the depositor due to federal insurance guarantees, and yet the deposits typically pay rates lower than the Treasury rate, which is the market rate on a comparable-risk investment. The market value of a financial instrument that pays less than the rate on a comparable-risk investment will reflect this rate differential, or spread. This spread, less the institution’s costs of acquiring and servicing the deposit, is often called an economic rent in the literature. It can be defined as

$$\begin{aligned} \text{Time } t \text{ Economic Rent} &= \left( \begin{array}{l} \text{Interest that could be received} \\ \text{from investing deposit} \end{array} \right) - \left( \begin{array}{l} \text{Interest} \\ \text{Expense} \end{array} \right) - \left( \begin{array}{l} \text{Non - interest} \\ \text{expense} \end{array} \right) \\ &= (r_t - i_t - c_t)D_t - 1 \end{aligned} \quad (1)$$

where  $r$  is the Treasury rate,  $i$  is the interest rate paid to depositors,  $c$  the is cost of acquiring and servicing the deposit expressed as a rate, and  $D_{t-1}$  is the deposit balance at the end of the previous period. Since these rents occur in the future, they must be discounted in order to estimate their present value. The appropriate discount rate is the Treasury rate, if the cash flows are assumed to have no credit risk.

The deposit liability can then be expressed as a net liability after subtracting the net present value of the economic rent,

$$\text{Deposit Liability Value} = \left( \begin{array}{l} \text{Face Value} \\ \text{of Deposits} \end{array} \right) - \left( \begin{array}{l} \text{Net Present Value} \\ \text{of} \\ \text{Cash Flows} \end{array} \right) \quad (2)$$

<sup>13</sup> Important articles in this framework are Hutchison and Pennachi (1996), Jarrow and van Deventer (1998), and O’Brien (2000).

In this generalized formulation, the net economic value of the deposit is the difference between the face value and the net present value of the economic rents expected to be earned on that balance in the future. The present value of the economic rents is referred to in this literature as the deposit “premium” and often expressed in percentage terms by dividing it by the initial deposit balance.<sup>14</sup> This approach is consistent with the NEV concept.

The deposit premium due to economic rents can also be computed by discounting the deposit cash flows, without explicitly including the interest on the comparable-risk investment. Deposit cash flows consist of changes in deposit balances, interest paid to depositors and non-interest expenses. The cash flow (received by the institution) in time period  $t$  can be written

$$\begin{aligned} \text{Period } t \text{ Cash Flow} &= \left( \begin{array}{c} \text{Change in} \\ \text{Deposit Balance} \end{array} \right) - \left( \begin{array}{c} \text{Interest} \\ \text{Expense} \end{array} \right) - \left( \begin{array}{c} \text{Non - Interest} \\ \text{Expense} \end{array} \right) \\ &= (D_t - D_{t-1}) - (i_t + c_t)D_{t-1} \end{aligned} \quad (3)$$

The net liability of the deposit can then be written

$$\text{Deposit Liability Value} = \left( \begin{array}{c} \text{Face Value} \\ \text{of Deposits} \end{array} \right) - \left( \begin{array}{c} \text{Net Present Value} \\ \text{of} \\ \text{Cash Flows} \end{array} \right) \quad (4)$$

In this “deposit cash flow” framework, the “Net Present Value of Cash Flows” is equivalent to the “Net Present Value of Economic Rents” if the cash flows are discounted at the Treasury rate; the result is the same as if the deposit had been invested to earn the rate on Treasuries.

In other words, one can attribute the deposit premium to economic rents and then calculate that premium in either of two ways: with an explicit interest rate spread in the numerator of the calculation as in (1), or with deposit cash flows (including changes in deposit balances) in the numerator as in (3). In both cases, the Treasury rate must be the discount rate, because this rate reflects both the credit risk of the deposit (zero) and the interest rate risk of the deposit (that of a comparable-maturity Treasury). We take some pains to demonstrate this below, because a thorough understanding is useful for discussing the choice of discount rate in NMD valuation.

<sup>14</sup> For example, the net present value of the economic rent might be 4 percent of the face value of the liability. For a deposit of \$100, the deposit liability value is then \$100 - \$4 = \$96. Note that it is possible for the deposit premium to be negative if an institution does not keep its deposit rate lower than the comparable-risk, or Treasury, rate. Some negative deposit premiums have been estimated in empirical studies, although positive premiums predominate.

### C. Valuing Deposit Liabilities Based on Economic Rents

We demonstrate the two ways of defining cash flows in the economic rent equation for calculating the deposit premium. For simplicity, we demonstrate this for the simplest case of constant interest rates and certain deposit balances for two periods. This two period model assumes the deposit is withdrawn at the end of the second period. First, we define the variables:

$V_d$  = deposit liability value.

$D_0$  = par value of deposit.

$D_1$  = deposit remaining at the end of the first period, which is returned to the depositor at the end of the second period, assumed known with certainty in this derivation.

$i$  = credit union deposit rate, assumed constant in this derivation.

$c$  = credit union servicing and other costs as a percentage of the deposit balance, assumed constant in this derivation.

$r$  = Zero-coupon Treasury rate, assumed constant over time in this derivation, and, for discounting purposes, the one-period rate and the two-period rate are assumed equal.

We now examine the two ways of incorporating the value of the economic rents on deposits into the calculation of the economic value of the deposit.

- A. Compute the net present value of the rent directly by discounting the cash flows due to the interest rate spread at the Treasury rate. The deposit liability value is the par amount of the deposit less the net present value of the rent. This is the method typically found in the research literature.

$$V_D = D_0 - \left[ \frac{D_0(r - i - c)}{1 + r} + \frac{D_1(r - i - c)}{(1 + r)^2} \right] \quad (5)$$

We show equation (5) in the same format as equation (2).<sup>15</sup> The value of the deposit in equation (5) equals the face value of the deposit (the first term on the right-hand side) minus the present value of the economic rents for the two periods (the bracketed second term).

- B. Discount the deposit cash flows at the Treasury rate. The result is the present value of the deposit liability. In this method, the value of the rent is implicit in the calculation due to discounting the cash flows at a higher rate than the deposit rate.

$$V_D = D_0 - \left[ D_0 + \frac{(D_1 - D_0) - D_0(i + c)}{1 + r} + \frac{(-D_1) - D_1(i + c)}{(1 + r)^2} \right] \quad (6)$$

We show equation (6) in the same format as equation (4).<sup>16 17</sup> The value of the deposit in equation (6) equals the face value of the deposit (the first term on the right-hand side) minus the net present value of the cash flows (the bracketed second term). In the second quotient of the bracketed second term, note there is no  $D_2$  because the deposit remaining at the end of the second period is zero.

To demonstrate that the two methods (equations (5) and (6)) are equivalent, in equation (6) we first combine the term  $D_0$  (within the brackets) with the first quotient:

$$V_D = D_0 - \left[ \frac{D_0(1 + r) + (D_1 - D_0) - D_0(i + c)}{1 + r} + \frac{(-D_1) - D_1(i + c)}{(1 + r)^2} \right] \quad (7)$$

Continuing, we simplify and reorganize the first quotient:

$$V_D = D_0 - \left[ \frac{D_0(r - i - c) + D_1}{1 + r} + \frac{(-D_1) - D_1(i + c)}{(1 + r)^2} \right] \quad (8)$$

We move the term  $D_1$  from the first quotient and combine it with the second quotient:

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<sup>15</sup> The T-period form of equation (5) is:  $V_D = D_0 - \sum_{t=1}^T \left[ \frac{D_{t-1}(r - i - c)}{(1 + r)^t} \right]$ .

<sup>16</sup> Note that equation (6) may be expressed alternatively as:  $V_D = \frac{(D_0 - D_1) + D_0(i + c)}{1 + r} + \frac{D_1(1 + i + c)}{(1 + r)^2}$

<sup>17</sup> The T-period form of equation (6) is:  $V_D = \sum_{t=1}^T \left[ \frac{(D_{t-1} - D_t) + D_{t-1}(i + c)}{(1 + r)^t} \right]$

$$V_D = D_0 - \left[ \frac{D_0(r-i-c)}{1+r} + \frac{D_1(1+r) + (-D_1) - D_1(i+c)}{(1+r)^2} \right] \quad (9)$$

Finally, we simplify and reorganize the second quotient:

$$V_D = D_0 - \left[ \frac{D_0(r-i-c)}{1+r} + \frac{D_1(r-i-c)}{(1+r)^2} \right] \quad (10)$$

Equation (10) is the economic value of the deposit as described in A in equation (5). Thus, A and B are equivalent (either can be derived from the other).

It is useful to reiterate why economic rents exist on NMDs but not on other liabilities such as corporate bonds, or even corporate equity. The reason is that non-deposit liabilities and equity do not earn economic rents. NMDs have an arbitrage profit potential those other sources of funds lack. It is typically assumed that debt liabilities and equity are priced in a competitive market. If a firm were able to issue a bond at less than the Treasury rate and invest the proceeds in a Treasury security, the firm would have an arbitrage opportunity (a “money machine”). In a competitive market, these arbitrage profits would be competed away as other firms entered this lucrative business – the supply of corporate bonds would increase, with prices falling and yields rising, until no arbitrage profits were available. A deposit, however, is a “money machine” paying rates lower than Treasuries without causing a competitive market response that eliminates the interest rate spread. Whether a particular financial institution actually reinvests deposits in Treasuries is not relevant to the valuation argument. The question is: What must be the market value of a liability that always pays a rate less than an equivalent-risk investment opportunity? The arbitrage profit is an inherent part of the value of that liability.<sup>18</sup>

Could the economic rent be calculated by assuming the deposit were reinvested in a different asset than a Treasury security? How about a mortgage-backed security? How about a new addition to the building? Such investments would not provide economic rents, that is, they would not be arbitrage trades, because the investments are riskier than the deposit. It is not arbitrage to issue a riskless deposit

<sup>18</sup> As noted by Jarrow and van Deventer (1998): “In economic terms, the net present value is the maximum premium above the dollar amount of deposits that a rational bank would bid to purchase the demand deposit franchise from another bank. It is analogous to the net present value computation one would make for an investment project in traditional capital budgeting problems. It represents a rent for the privilege of issuing demand deposits. Note that this value is determined independently of the use to which these funds are put within a bank.” (p. 256)

and invest in a risky investment. The valuation of deposits by computing the arbitrage profit, or economic rent, is fundamental.

A final point: It is not clear that all of the methods used by credit unions to “value deposits” are really intended to be economic value calculations. Discounting deposit balances only, for example, is not. To calculate economic value, deposit interest (and servicing and other costs) must be included in the cash flows.

#### **D. Choosing the Discount Rate**

With this understanding of the theory of the economic value of deposits, we are in a better position to discuss the appropriate discount rate for credit unions to use. It is clear that if a credit union intends to incorporate the value of economic rents in the value of deposit liabilities, then the discount rate must be the rate on a comparable-risk investment. If the NMD is assumed to be default-free, then a Treasury rate is the appropriate discount rate.

Would some other rate would be appropriate? How about the deposit rate or the rate on comparable deposits? Discounting the deposit cash flows at a deposit rate is appropriate if the goal is to calculate the value of the liability without rents. Think of an analogy to a non-financial corporation that has issued a bond for \$100 with a coupon of 5%. At issuance, the bond is worth par, and we can calculate this present value by discounting the bond cash flows at 5%. This does not provide any idea of what the firm may earn by investing the proceeds of the bond issue. Later if the yield of the firm’s bonds increased to 6%, we could compute the market value of the same bond by discounting the cash flows at 6%, and the bond would be worth less than \$100. This would be the value of the bond, alone, not the value of the bond less economic rents. Similarly, if we discount the deposit cash flows at a deposit rate, which, by the way, should be the rate that the credit union has to pay today (not when the deposit was first accepted), we have a valid “mark to market” of the liability, but we have neglected to include the extra component of deposit valuation, the rents. If we want rents, and thus we want to define the economic value as conventionally defined, we have to use the framework represented by equation (5) or (6).

Is an alternative cost of funds an appropriate discount rate? The discount rate should be the rate on an investment with the same risk to a depositor as the deposit. To the extent that credit union retail deposits have no credit risk for the depositor, due to the insurance guarantee, the appropriate comparable-risk investment is a Treasury security and the appropriate discount rate is the Treasury rate. Other rates, such as the London Interbank Offered Rate LIBOR, rates on secondary market certificates of deposit (CDs) and the Federal Home Loan Bank (FHLB) regional cost of funds, are appropriate only

if it can be argued that credit union NMDs have approximately the same credit risk as Eurodollar deposits, uninsured CDs and loans to thrift institutions, respectively.<sup>19</sup> Although these rates may be appropriate measures of alternative costs of funds for some institutions, **the discount rate in the economic rent calculation is not a cost of funds.** The purpose of the exercise is not to compare the NMD deposit rate with the rate on a jumbo CD in order to show how much “cheaper” it is to raise funds with deposits. For the purpose of valuation for the NEV calculation, that is an “apples and oranges” comparison; the two financial instruments have different credit risk. Because the alternative costs of funds are typically higher than Treasury rates (as they must be on instruments of greater credit risk), the value of economic rents on default-free NMDs will be overstated.

Option-adjusted spread models *can* be based on virtually any benchmark rate, although a short-term Treasury rate is commonly used as in Selvaggio (1996). A spread is added to the benchmark rate that forces the model price to be the same as the market price of the security or deposit in question. As discussed elsewhere, we do not recommend that credit unions use these models because of the absence of a market for credit union deposits, and the resulting reliance on untested (in the credit union market) proxy measures of the option-adjusted spread.

It is recommended that zero-coupon Treasury rates (rates which are specific to the date on which a cash flow is anticipated) be used to discount estimated cash flows at the dates in the NMD model. Zero-coupon Treasury rates have the same default risk as the deposit and also have any premium for interest rate risk that may be specific to longer maturities. Treasury zero-coupon rates are readily available to most credit unions. If zero-coupon rates are not available, an acceptable proxy is the Treasury note or bond yield to maturity for the maturity of each cash flow in the model.

Should servicing and other costs be included in the discount rate? No. The correct approach is to include such costs as cash outflows in the numerator of the present value calculation.

## **E. Assumptions Underlying Specific Methods**

We now turn to the specific methods available from vendors and published in the research literature. The Appendix contains a more detailed and technical description of the different methods and the underlying formulas (where available), while the following sections discuss and contrast their most important features.

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<sup>19</sup> Mays (1997) notes that these alternative costs of funds are often used by banks and thrifts in NMD valuation.

Table 2 summarizes the different assumptions underpinning the methods in the context of a fully specified model as discussed above.

**Table 2. Comparison of Assumptions Underlying Different Valuation Methods for NEV**

Description: This table indicates how various models satisfy the requirements of a fully-specified model..

Method	Market Interest Rate Uncertainty	Deposit Rate Tied to Market Rate	Remaining Balance tied to Market Rate	Includes Acq. & Svc. Costs	Discounting	Effective Maturity
CU/ALM	None	No	No	No	None	1 Month
IPS-Sendero	None	No	No	No	None <sup>1</sup>	User-Defined
PROFITstar	Scenarios	No	No <sup>2</sup>	No	None <sup>2</sup>	Long
CUNA Model Management	Scenarios	No	Yes <sup>3</sup>	No	Yes <sup>4</sup>	User-Defined
C. Myers	Scenarios	No	No	No	None	Zero
Hutchison & Pennacchi	Vasicek Model <sup>5</sup>	Yes	Yes	Yes	Treasury rate	30 years
Jarrow & van Deventer (Kamakura Associates)	Heath-Jarrow-Morton (HJM) <sup>5</sup>	Yes	Yes	Yes	Treasury rate	30 years
McGuire Performance Solutions	Scenarios or Random	Yes	Yes	Yes	Alternative cost of funds	17+ years
O'Brien	Cox-Ingersoll-Ross (CIR) Model <sup>5</sup>	Yes	Yes	Yes	Treasury rate	30 years
OTS (2001)	None <sup>6</sup>	Yes	Yes	Yes	LIBOR + OAS	30 years
Selvaggio	CIR <sup>5</sup>	No	Yes	Yes	Eurodollar + OAS	30 years

Source: Original papers and NCUA internal documents.

Note: <sup>1</sup> User can override and supply NMD value.

<sup>2</sup> User can supply balance decay rates. Discounting at offering rate.

<sup>3</sup> One user choice is based on an OTS table developed by Forin and Associates.

<sup>4</sup> User-defined or yield-curve based discount rate

<sup>5</sup> The Vasicek model generates random, mean reverting spot (zero-coupon) rates. The CIR model is similar but does not allow negative rates. The HJM model is based on random evolution of the forward rate curve, which then determines the random evolution of spot rates.

<sup>6</sup> One future path of spot rates is assumed based on current forward rates.

Several of the vendor methods ignore how interest rates may change and fail to fully specify NMD cash flows. Models that do take into account future changes in rates allow a set of scenarios,



assume a specific random interest rate model, or use the forward rates implied in the current yield curve. The option-adjusted spread (OAS) approach incorporates the effect of the options embedded in the deposits by adding a risk premium to the discount rate; it also requires that the cash flows being discounted reflect how changes in interest rates affect those cash flows.

The key credit union behavioral assumption is the relationship between market interest rates and deposit rates. In those methods where it is modeled explicitly, most assume that the change in the deposit rate is the same regardless of whether interest rates are increasing or decreasing. Since all empirical evidence has shown that credit unions and deposit-taking institutions in general tend to react differently to increases in market rates than decreases in market rates, this may have implications for the accuracy of the methods.<sup>20</sup>

It would appear that the option-related features of NMDs are less prevalent in credit unions than in other deposit-taking institutions. According to Tripp *et al.* (1997), credit union deposit rates and balances are less interest rate sensitive than those of banks and thrifts. To the extent that this is the case, the cash flows associated with credit union NMDs would display fewer option-like characteristics. By this, we mean that the cash flows and deposit balances would vary less with the different interest rate scenarios. This has important implications for whether the more complex valuation methods are cost-effective for credit unions.

The key depositor behavioral assumption regards how deposit balances evolve through time. This is handled by assuming an effective maturity for the deposits, by estimating a retention (or decay) rate of the remaining balance (so that the same proportion each month is assumed to be withdrawn), or by estimating a relationship between deposit balances, deposit rates, market rates, and other variables.

In the interests of better understanding the nature of the different methods, they have been loosely grouped into three different types. It is important to note that most are not uniquely characterized; thus, for example, the contingent claims methods all contain elements of the present value method. The various methods and approaches to valuing NMDs are discussed in the following sections, in terms of how each one addresses the two main problems outlined above, how to deal with the “maturity” and uncertain cash flows of NMDs. The cash flow problem has really two parts: how does the interest rate on deposits vary with market interest rates, and how do deposit balances change with deposit rates, market rates, and other economic or institution-specific variables.

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<sup>20</sup> See, for example, Tripp, Lacewell, and Kenny (1997) for credit unions and O’Brien (2000) for banks and thrifts.

## **F. Simple Vendor Methods**

There are two alternative simple approaches to dealing with the maturity of non-maturity deposits that are used by several commercial vendors as part of a more comprehensive asset-liability management system. One is to assume that all non-maturity deposits are extremely short-term in maturity (one month or less); the other is to assume that they are all very long-term in maturity. The two assumptions have very different implications for calculating NEV and interest rate risk.

The assumption that non-maturity deposits are extremely short-term in maturity is the equivalent of saying that deposits are fully demandable and will be withdrawn every month. Another way of stating this is that NMDs do not have any economic rents, so that the second part of equation (2) is zero.<sup>21</sup> This will tend to overstate an institution's interest rate risk and understate its NEV in a period of rising interest rates, while the reverse will be true if rates are falling. On the other hand, assuming a very long maturity is the equivalent of assuming a very high retention rate for deposits. Consequently, there is the potential for a large economic rent component to the deposit premium. It also implies that the deposit balances are not sensitive to changes in the level of deposit rates or the spread between deposit rates and market rates.

The range of assumed effective (final) maturities used by many of these vendor methods raises the issue of what is the appropriate choice. The choice of effective maturity cannot be made without first specifying the model that is being used, and in particular how NMD cash flows are modeled. The approaches to dealing with future cash flows from the deposits vary widely. Some of these models do not attempt to specify future deposit balances nor deposit interest and servicing cash flows, and consequently they do not calculate a present value based on explicit cash flow assumptions. Such methods are unlikely to provide a reliable estimate of deposit premiums and durations. The failure to specify future cash flows and calculate present values for deposits is inconsistent with the treatment of other assets and liabilities in NEV calculations. We address the choice of effective maturity in such methods in Chapter IV.

## **G. Present Value Methods**

All the different present value methods apply traditional discounted cash flow analysis in order to estimate the value of non-maturity deposits. However, they differ in their approach to dealing with the maturity and the option-related features of NMD cash flows.

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<sup>21</sup> Hutchison and Pennacchi (1996) show this and discuss the implications for deposit valuation.

## 1. OTS Net Portfolio Value Model

The approach taken by the Office of Thrift Supervision (OTS) towards non-maturity deposits in its *Net Portfolio Value Model* (hereafter OTS NPVM) is quite straightforward. It allows for changing cash flows through dependence on market and deposit rates, but since only one interest rate scenario is considered, it effectively is a static discounted cash flow approach. It calculates the static discounted cash flow for each of the four types of account, using monthly projected cash outflows. Zero-coupon LIBOR rates plus an OAS are used for discounting over a 30-year (360 month) horizon.<sup>22</sup> NMDs are assumed to have a potentially long maturity, but the retention rate for aggregate deposit balances that determines the duration is obtained empirically either from the specific institution being valued, or from industry-wide estimates. If the institution's own retention rate is used, the difference between that number and the industry-wide retention rate is also incorporated, and the difference between the two is assumed eventually to converge to zero.<sup>23</sup>

The monthly cash flows result from the net effect of interest payments on the balances, withdrawals, and non-interest expenses associated with the accounts. The rate paid on deposits is modeled as a function of recent deposit rate levels and recent market rate changes, and whether the deposit rate is above or below the long-term "equilibrium" rate on such deposits. Changes in deposit balances are similarly modeled as a function of the spread between deposit rates and market rates, the sensitivity of that institution's deposit rate to changes in market rates, the institution's retention rate and the industry-wide retention rate.

The method is a "top-down" method, in the sense that most parameter values (*e.g.*, non-interest cost rates, the sensitivity of deposit rate changes to changes in market rates, *etc.*) are estimated from data from all thrifts and applied to all thrifts. Some variables do vary across institutions, such as the starting level of account balances and the rate paid on a particular type of account. An important feature of this model is that it is effectively imposed on *all* thrift institutions. The OTS estimates many of the parameters, and these are used at all institutions regardless of size or other distinguishing characteristics. This has important implications, both positive and negative. By estimating parameters that can be used

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<sup>22</sup> The OTS discount rate is LIBOR plus a spread that "calibrates demand deposit prices to observed prices for deposit purchase/assumption transactions."

<sup>23</sup> In April 2001, the OTS announced changes to the specific equations that comprise their model, in terms of both the functional form and the value of some of the parameters. The underlying philosophy and objective of the model remain the same, however, and do not alter any of the conclusions drawn in the present document. The two versions are both presented and discussed in the Appendix.

by all thrift institutions, the OTS retains control over the process and ensures that the necessary statistical estimation procedures are conducted in the proper manner. It also means that appropriate estimation procedures are effectively placed within the reach of even the smallest and least sophisticated institution. However, it also means that the OTS is effectively mandating a “one size fits all” approach, with little or no consideration of the characteristics that distinguish the regional deposit markets, or that differ from small to large thrifts.

One important implication of adopting the OTS methodology for the valuation of credit union NMDs is that NCUA would be responsible for estimating all of the industry-wide parameters that are used, for keeping the parameters up-to-date, and for communicating any changes in the model and its inputs to all insured credit unions. A legitimate question to ask, therefore, is whether NCUA wants to enter the business of estimating model parameters and monitoring how they are used by credit unions. This is discussed in more detail in Chapter V.

## **2. McGuire Performance Systems**

The approach of McGuire Performance Solutions, on the other hand, uses data from a single bank, thrift, or credit union, and estimates statistically the rate at which deposit balances decline for different interest rate scenarios. Thus in a sense it can be said to be at the other end of the spectrum from the OTS approach, since only data from a single institution is incorporated. All parameters are specific to the institution whose deposits are being valued, and are obtained from long time-series of observations of both aggregate deposit balances and a sample of individual accounts. The precise functional form and parameter values are unique to each institution, and depend on the availability of extensive historical data on all types of deposits, costs, and other factors. The underlying philosophy of this method of valuing the deposit premium associated with NMDs is to model the core deposit behavior at the specific institution using a set of simultaneous equations for deposit rates and balances. The variables used in the equations (as well as the functional form of the equations) are selected using a statistical discovery process, but generally start off with a list of candidates that include lagged deposit balances, rates paid on deposits, spreads between deposit rates and market rates, trend variables, seasonal factors, and general and local economic data. The chief advantage of this approach is that each valuation is uniquely defined for a given institution. Unlike the OTS NPVM, the McGuire approach does not confine itself to a single possible interest rate path, but instead looks at many different interest rate scenarios with different cash flows for each. In this way, the options embedded in NMDs are explicitly taken into account.

A disadvantage of the McGuire method, in the context of credit unions, is the requirement for long time series of data for many individual accounts of each account type. Probably few credit unions would have such data available. In addition, this method allows a limited number of interest rate scenarios to be utilized in the valuation process.

### **3. Selvaggio, OTS and OAS**

The approach adopted by Selvaggio adjusts the basic present value method for what is known as the option-adjusted spread (OAS). This is the spread that must be added to the zero-coupon Treasury in order that the observed market value of core deposits equal the value produced by the model. Empirically, he finds that the OAS needed to equate the present value of economic benefits with observed premia in the banking market for NMDs is about 1,100 basis points or 11%. The approach to the maturity question is similar to that of OTS, in that a 360-month horizon is used. Static discounted cash flow is not used, since 300 interest rate paths are simulated; consequently both the cash flows and the discount rate arrived are adjusted to reflect the impact of the embedded options. Finally, the expected change in deposits is modeled as a function of recent deposit levels, current market rates, a time trend, and seasonal dummies.

In its most recent version of the NPVM, the OTS adds an OAS to the zero-coupon LIBOR rate. The spread reported in April 2001 is 12 basis points.

This approach to valuing NMDs has some problems when applied to credit union NMDs. Since the goal of the present exercise is the reverse of what Selvaggio and OTS do, namely to value the deposit premia rather than infer the appropriate discount rate, to implement this process would require knowledge of the appropriate OAS on the valuation date. Since there is not an active market in the deposits of credit unions, this would require making some key assumptions. This point is considered in more detail, in Chapter V.

### **H. Contingent Claims Methods**

In the last few years, three methods have been proposed that use a contingent claims approach to the problem of valuing non-maturity deposits. These are the models of Hutchison and Pennacchi (1996), Jarrow and van Deventer (1998), and O'Brien (2000).<sup>24</sup>

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<sup>24</sup> Jarrow and van Deventer (2000) and O'Brien (2000) can be categorized as arbitrage-free models, while Hutchison and Pennacchi (1996) can be categorized as an equilibrium model. Hutchison and Pennacchi (continued...)

A key difference between the contingent claims valuation methods and the present value methods of the previous section is how future interest rates are handled. Present value methods that use static cash flows, such as the OTS NPVM, incorporate only one interest rate path, that implied by the forward rates embedded in the current yield curve; this may be loosely described as an “expected” path for interest rates.<sup>25</sup> While the cash flows estimated for this expected interest rate path may reflect the options embedded in the NMDs, they come from only one possible path out of many. Contingent claims valuation methods, on the other hand, involve consideration of hundreds or thousands of possible interest rate paths. This is because the option-related features of NMDs mean that future cash flows are not known with certainty, but depend on the particular path that interest rates (both market rates and deposit rates) take. By running simulations of many possible interest rate paths, the cash flows associated with the NMDs can be determined in each path and an average over all paths determined.<sup>27</sup> Thus, the resulting valuation reflects the impact of the embedded options, and the likelihood that the options will be “exercised” over many different interest-rate paths. This gives a more accurate estimate of the impact of the embedded options on the cash flows and value of the NMDs.

All three methods calculate the present value of the economic rents over very long horizons, similar to OTS and Selvaggio. They all model the future path of the rate paid on deposits as a function of future market rates. However, there are some important differences. Both Hutchison and Pennacchi (1996) and Jarrow and van Deventer (1998) assume that the change in deposit rate due to a change in market rates will be the same whether rates are rising or falling. O’Brien, on the other hand, explicitly incorporates the well-documented phenomenon that the spread between market rates and deposit rates tends to widen in periods of rising rates and narrow in periods of falling rates. O’Brien is also the only one of the three methods that incorporates local market-specific variables in the estimation of future changes in deposit levels: as well as being affected by the deposit rates, market rates, and recent deposit

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(...continued)

determine the deposit rate endogenously (within the model). The others assume a deposit rate equation without derivation.

<sup>25</sup> This description is more for convenience than precision; there is broad consensus in the economics literature that forward rates generally differ from expected future spot rates due to positive or negative term premia in default-free bond prices reflecting interest-rate risk.

<sup>26</sup> For example, the valuation results from the O’Brien model in Chapter VI, reflect 1,000 simulated interest rate paths. Simulation is not required in all cases. The Hutchison and Pennacchi model and one version of the Jarrow and van Deventer model have closed-form solutions for the probability distribution of the NMD cash flows.

<sup>27</sup> For example, the valuation results from the O’Brien model reflect 1,000 simulated interest rate paths. Simulation is not required in all cases. The Hutchison and Pennacchi model and one version of the Jarrow and van Deventer model have closed-form solutions for the probability distributions of future NMD cash flows.

balances, the balance equation includes nominal income for the region in which the bank does business. This is an important feature of community banks and credit unions that has long been ignored by most attempts to model NMDs, namely how the institution is affected by the *regional* as well as the national economy.

## I. Conclusions

The simple vendor methods that do not incorporate all NMD cash flows are not designed to estimate NMD value in accordance with standard theory. At best, they can be used by credit unions as a cost-beneficial alternative to more complex models. In this case, the effective maturities must be carefully chosen, as discussed in Chapter IV.

Many of the more recently developed methods, particularly the contingent claims methods, are quite complex. To adopt them requires an understanding of interest-rate contingent claims theory, how it has been adapted for the valuation of NMDs, and how to use a specific method to value the NMDs of a specific credit union. There is a danger of incorrectly applying a method, of incorrectly estimating the required input parameters, and of a false sense of security that the use of a complex model can sometimes bring. The old computer programming saying “Garbage In, Garbage Out” (GIGO) is just as applicable in the use of valuation models. Complex, sophisticated valuation methods should be used only by those who have the necessary expertise and understanding to be aware of the pitfalls that may arise in their use.

A key difference between some of the methods is whether they include growth in future deposits. For example, the OTS NPVM does not include new deposit balances, but models the gradual decline of the initial deposit. O’Brien, on the other hand, models future *total* balances, namely the remaining portion of current balance plus expected growth in deposits. This can lead to material differences in valuation of the same deposit. Both are valid, in the sense of being consistent with the assumptions of the particular model. If credit union deposits are being valued for the purposes of NEV, it is appropriate *not* to include expected growth in balances, since the aim of NEV is to estimate the economic value of the existing balance sheet without the effects of new business.

The present value methods do not compute the value of economic rents in accordance with the theory in the research literature unless the discount rate is chosen to reflect the credit risk of the deposit. The use of other rates, such as rates representing alternative costs of funds, are not recommended in NEV applications unless the user is making the explicit assumption that NMDs have the same credit risk for depositors as the alternative source of funds.

### **III. CREDIT UNIONS VS. BANKS**

Further complicating the issue of valuing NMDs, as it relates to the present study, is that the properties and behavior of non-maturity deposits at credit unions are held by some industry observers to be substantially different from those of banks and thrifts (hereafter banking institutions). Most of the methods discussed in Chapter II were originally designed with more traditional banking institutions in mind, and it is important, therefore, to determine whether the unique characteristics of credit unions that distinguish them from banks render the use of any these methods inappropriate.

The next section discusses the similarities and dissimilarities of credit unions and banking institutions. The implications of those dissimilarities for the present problem of applying existing methods to value the NMDs of credit unions is considered in section B.

#### **A. Similarities and Dissimilarities**

##### **1. Structural Differences**

In structural terms, credit unions and banking institutions overlap and are broadly similar in many areas. Both take in consumer deposits and make consumer loans. Both are regulated by state and federal agencies. Both are exposed to credit risk and interest rate risk. However, the study of credit unions by the U.S. Department of the Treasury in 1997 noted that there are five main characteristics that distinguish credit unions from banks and thrifts:<sup>28</sup>

1. Credit unions are member owned, member-directed depository institutions.
2. Credit unions rely on unpaid, volunteer boards of directors elected by, and drawn from, each credit union's membership.
3. Credit unions are not-for-profit organizations.
4. Credit unions have a public purpose, "to make more available to people of small means credit for provident purposes."
5. Credit unions face limitations on their membership, usually referred to as a "common bond" requirement.



Perhaps the most important of these distinctions, as related to the present study, are the first and third. The first distinction means that credit unions do not issue stock to raise capital, instead they rely on accumulated retained earnings for their net worth. This has important implications for regulators, since a troubled credit union whose capital is in danger of dropping below the level considered adequate cannot simply raise additional equity capital by selling more shares. Nor do credit unions have access to the debt markets or markets for large commercial deposits.

## 2. Behavioral Differences

The structural differences outlined above mean that credit unions do not necessarily respond in the same way as banks or thrifts to market or economic events. For example, characteristic number three means that credit unions tend to price their loan and deposit products differently than banks and thrifts. Whereas a bank or thrift will seek to maximize its profit for shareholders by charging more for loans and paying less on deposits, a credit union will seek to return part of its profits to its members by charging them less on loans and paying more on deposits. This is born out in Table 3, where we see for example that in January 2001 new auto loans were 140 basis points cheaper than comparable loans at banks and S&Ls, and share draft accounts paid 86 basis points more than their bank equivalents.

**Table 3. Comparison of Rates at Credit Unions and Banks**

Description: This table compares the level of deposit and loan rates at credit unions with those of similar products at banks and thrifts

January 2001	Credit Unions	Banks, S&Ls
Loan Rates		
New Auto	8.12%	9.52%
Personal	13.32%	15.23%
Credit Card	12.63%	15.46%
Savings Rates		
Share Draft	1.66%	0.80%
Money Market Account	4.21%	2.06%
One-year CD	5.92%	4.78%

Source: CUNA website ([www.cuna.org](http://www.cuna.org)), April 23, 2001.

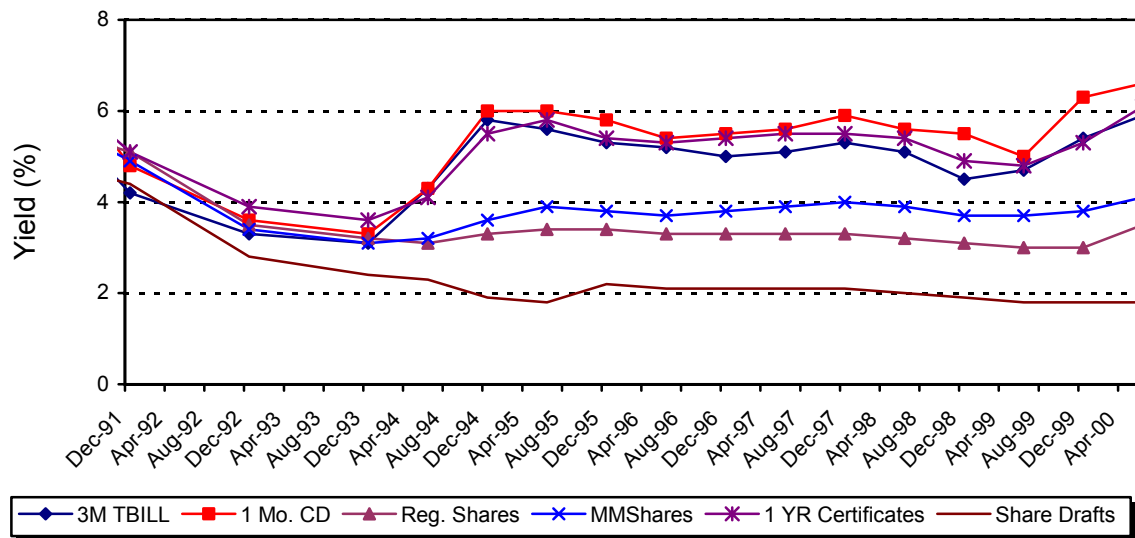
(...continued)

<sup>28</sup> U.S. Treasury (1997), p. 1.

The spread between credit union and bank rates is not constant, however; Tripp *et al.* report that the difference between bank and credit union savings rates narrowed considerably in the mid-1990s as credit unions were slower to raise their rates in response to rising market rates. The relationship between credit union rates and other rates can be seen in Figure 1, which compares the average rates paid on credit union deposit accounts with the yield on 3-month Treasury bills and 1-month bank CDs.

It is readily apparent that the rate on credit union nonmaturity deposits reacts much more slowly than bank CDs to changes in the level of interest rates. This can be seen more clearly, when we examine the correlation coefficients between changes in credit union rates and Treasury bill rates. Changes in the rate on share drafts have a correlation with changes in the 3-month Treasury bill rate of only 0.19; for regular shares, the correlation is 0.52, and for money market shares, it is 0.76. For bank CDs, the same measure of correlation is 0.91.

Description: Rates offered in credit union share drafts, regular shares, money market shares, and 1-year certificates compared to the rate on bank CDs and Treasury bills.



Source: CUNA and Board of Governors of the Federal Reserve.

**Figure 1. Comparative Yields**

The other chief distinction between credit unions and banking institutions is size. While the number of credit unions is more than the number of banks or thrifts, the average credit union has only \$38 million in total assets; for banks and thrifts the numbers are \$668 million and \$700 million

respectively.<sup>29</sup> Thus, credit unions are at a considerable disadvantage with respect to banking institutions when it comes to the economies of scope and scale, which have been shown to be of great importance for deposit taking institutions. They are also at a disadvantage when it comes to being able to diversify their loan portfolio: because credit unions can only lend to their members, this effectively places restrictions on their ability to make loans to a geographically or (for single-purpose credit unions) economically diversified group of borrowers.<sup>30</sup>

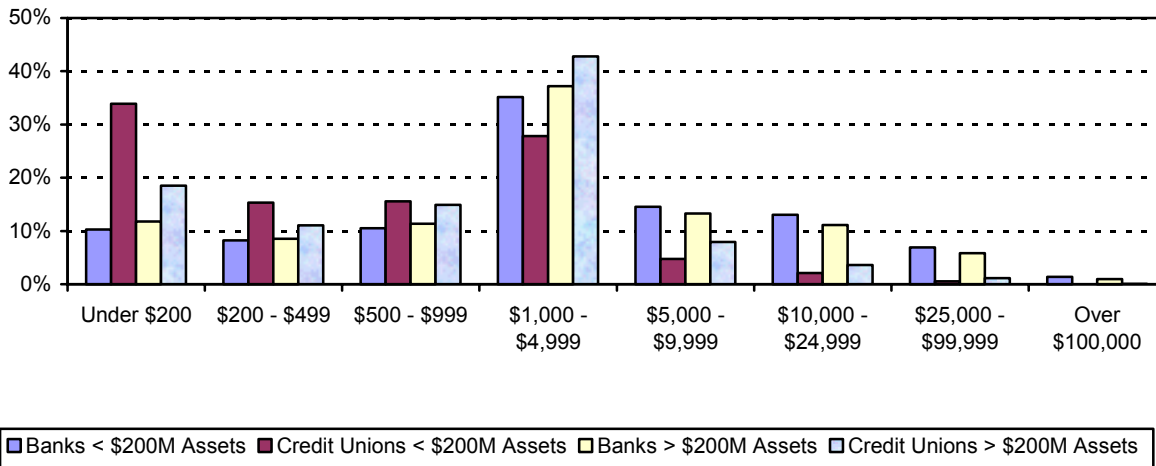
There are also differences between credit unions and banks in terms of the behavior of the various NMDs. For example, Figure 2 and Figure 3 show the difference in account balances and transactions volume of non-maturity deposits at banks and credit unions. Note that for smaller credit unions, accounts with less than \$5,000 represent almost 90% of balances and over 45% of transactions, whereas for small banks the same account size represents 60% of account balances and barely 10% of transactions. For both large and small credit unions, accounts between \$1,000 and \$5,000 show the most activity (roughly 35% of transactions in both cases) whereas the same account size for banks sees less than 10% of activity. These differences may have important implications for the pricing and costs of NMD-products at the two types of institution.

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<sup>29</sup> Source: CUNA. Data are as of December 1999.

<sup>30</sup> See Evans and Shull (1998) for a more detailed discussion of the impact of restrictions on Credit Unions on their ability to diversify.

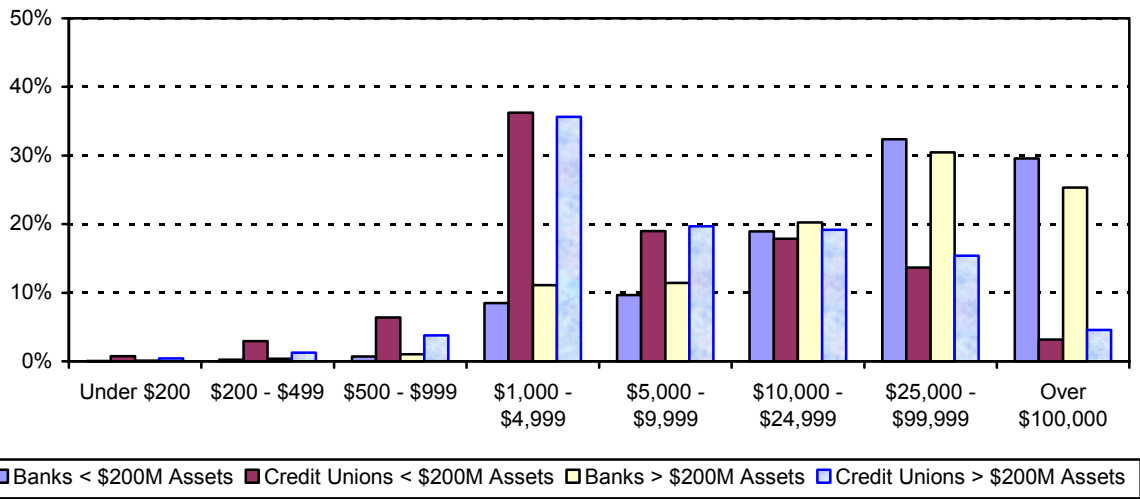
Description: This figure shows the distribution of average account balances by size of bank and credit union.



Source: Federal Reserve Bank of San Francisco.

**Figure 2. Distribution of Account Balances at Banks and Credit Unions**

Description: This figure shows the distribution of transaction frequency, depending on account size and size of bank or credit union.



Source: Federal Reserve Bank of San Francisco.

**Figure 3. Distribution of Transactions at Banks and Credit Unions**

There is little hard evidence on whether the NMDs of credit unions display different behavioral and empirical characteristics than those of banks and thrifts. According to Tripp *et al.*, the rates on

credit union NMD products react to changes in market rates more slowly than those of banks, and the rate at which deposit balances “run off” or decay is also apparently different.<sup>31</sup> However, the precise degree of differentiation has not yet been determined, as data on credit union deposit balances is not available in the same amount or quality as is the case for banks and thrifts. This argues for a study of credit union deposit behavior, and we return to this point in Chapter VII.

## **B. Implications for Valuing Non-Maturity Deposits**

To the extent that credit unions are deposit-taking institutions that provide NMD accounts and services, then the application of the various methods of pricing NMDs to those balances at credit unions should be relatively straightforward. However, to the extent that credit unions are different, then the issue may not be so easy.

That credit unions are different from banks is not at issue; the Treasury study of credit unions in 1997 gave the five main differences listed above. The primary concern is whether they are so different that existing methods for valuing NMDs cannot be modified or applied at all. This comes down to whether the fundamental differences between credit unions and other banking institutions violate any of the assumptions underlying the methods. Table 2 on page 20 summarizes these.

While some of the assumptions are clearly motivated by the behavior of banks as opposed to credit unions (profit-maximization, for example), none of them seem to be so restrictive as to render their associated method inapplicable for credit unions. The more relevant consideration is that credit unions are different from banks to the extent that they react to changes in the economic environment in different ways than banks. This means that the parameters of the different methods must be adjusted to make them suitable for use by credit unions. For example, Tripp *et al.* (1997) document that credit unions were slower to increase the rates on shares than were banks in the face of rising interest rates; this implies that the parameter relating changing market rates to changes in the deposit rate would be smaller for credit unions.

It would appear that the options embedded in NMDs, namely the institution’s option to change the rate and the customer’s option to withdraw funds, play a smaller role in credit union NMDs. If that is the case, the component of NMD value attributable to the value of the options will be smaller, and

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<sup>31</sup> An existing deposit tends to decrease as time passes and the depositor withdraws money for consumption and for alternative savings and investment opportunities. The annual rate of withdrawal is known as the decay rate. The annual retention rate is the mirror image of the decay rate; it is the ratio of the remaining balance at the end of the year to the balance at the beginning of the year.

the use of methods that incorporate these options in balance equations and deposit rate equations might not make a material difference in NMD valuation for credit unions.

Thus, the main issue regarding the applicability of these methods to credit unions is related to empirical issues such as the relative rate sensitivity of credit union NMDs to that of banks and thrifts. These issues will be discussed in more detail in Chapters V and VI.

## IV. THE EFFECTIVE MATURITY OF NON-MATURITY DEPOSITS

While they have no *stated* maturity, deposit balances do have what may be called an *effective maturity*, which we define as the assumed final maturity of a deposit. Since deposit balances may be around for decades, an assumed final maturity is a simplification in the interest of practical implementation. For example, by estimating and discounting cash flows out to a horizon of 30 years the OTS NPVM methodology assumes an effective maturity of 30 years. O'Brien and others make the same assumption in contingent claims models. McGuire Performance Solutions assumes that the effective maturity of deposits is about 17 years, based on their empirical estimates of deposit average life. Long maturities are appropriate in these models because they contain well-specified and empirically-estimated deposit balance equations. Deposit balances are determined in these models by a retention rate, the spread between the deposit rate and a market interest rate (typically the Treasury rate), and in some cases national or regional aggregate income. A deposit balance may never become zero, although it may become economically insignificant at some point. The only final maturity requirement is that it be long enough that any economically significant remaining balances (and the associated interest and servicing cash flows) are included in the present value calculation. Even with long maturities, these models do not estimate extremely long durations for NMDs, in part because NMDs are similar to floating-rate instruments.

We make no recommendations as to what the effective maturity should be when relatively fully-specified models such as these are used by credit unions. We do strongly recommend that the parameters of such models be estimated using credit union data, since the behavior of credit union rates and deposit balances may differ substantially from the banking and thrift deposits for which these models have been used in the past.

The effective maturities that we were asked to recommend in this report apply only to simple methods that credit unions may use in lieu of more complex and expensive methods. By simple methods, we mean those that do not attempt to specify the actual cash flows of NMDs. The cash flows not specified include deposit withdrawals, deposit interest and deposit acquisition and servicing costs. For example, some simple vendor methods may assume a final maturity in order to assign NMDs to maturity "buckets" for interest rate risk analysis. In other cases, the NMD may be treated as a "zero-coupon deposit," with a constant balance out to a final maturity, and no specification of interim cash flows. We have been asked to recommend a reasonable effective maturity in such methods.

## **A. Duration and Effective Maturity**

Simple methods can be satisfactory (cost effective) for small credit unions. For such methods, the effective maturity is essentially an assignment of interest rate risk to the deposit. Consequently, the effective maturity, defined as the assumed final maturity of the deposit, should be based on estimated durations of NMDs found in the literature.

Duration is a measure of interest rate risk widely used in banking and in the analysis of fixed-income securities. The duration of a security is typically defined as the percentage change in value for a small change in yield to maturity. Other versions of duration are based on particular descriptions of how the yield curve may shift. For fixed-income securities with embedded options, the duration measure should include the effects of changes in cash flows due to the exercise of embedded options (such as a bond being called) when interest rates change. A duration measure that includes the effect of changing cash flows is often labeled “effective duration.”<sup>32</sup> The durations reported in much of the recent literature on NMDs are effective durations.

The choice of effective maturity in simple models of NMDs is essentially an assumption about interest rate risk. For example, a credit union that assigns one type of deposit to a 3-year bucket and another type of deposit to an 8-year bucket is assigning greater interest rate risk to the latter.<sup>33</sup> Duration is an appropriate guide for such choices. Our methodology for choosing the effective maturity in simple methods is to use the effective maturity that produces durations consistent with NMD durations estimated in the literature and by the OTS. These are reviewed in the next section.

## **B. NMD Premia and Duration Estimates in Recent Research**

We summarize here evidence contained in recent research or published by the OTS. This includes measures of premia and duration taken from studies of banks, and the OTS data on thrift deposits, over different time-periods and using different methods. No such studies of credit union deposits exist. Although our main purpose is to estimate effective maturities, we consider the estimates of premia as well as a rough guide to the reliability of various studies.

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<sup>32</sup> See, for example, Fabozzi (2000). Effective duration is estimated from a pricing model. The benchmark interest rate is moved up and down a given amount, the cash flows are changed if warranted (for example, if mortgage prepayments are assumed to change at the new interest rate), and the new price is computed for the up and down rate movements. Effective duration is the percentage change in price given the change in the interest rate.

<sup>33</sup> To put this in some perspective, assigning an 8-year duration to a NMD is approximately equivalent to saying that it has the same degree of interest rate risk as a long-term Treasury bond.



**Table 4. Premia Estimates for Non-Maturity Deposits**

Description: Summarizes published estimates of NMD deposit premia. Reported numbers are medians from the studies unless otherwise indicated. The premia are expressed as percent of face value.

Author(s)	Institution	Period of Model Estimation	Transaction Accounts	MMDA	Passbook	Non-Interest-Bearing
Berkovic & Liang (1991)	Failed Banks	1987 – 90	4.9	4.0		
Hutchison & Pennacchi (1996)	Over 200 Banks	1986 – 90	6.6	7.0		
Janosi et al (1999)	One Bank	1988 – 96	9.7	7.6		171.8
Janosi et al (1999)	Aggregate FED Data	1988 – 95	2.7			
McGuire & Newell (1997)	One Bank	1988 – 95	12.8	0.8	10.2	
O'Brien (2000)	75 – 100 Banks	1983 – 94	15.3	10.9		
OTS	Thrifts	1998 – 01	7.0	2.0	4.0	10.0
Selvaggio (1996)	One Bank	1991 – 95				21.1

Note: The account names correspond to deposit types at banks and thrifts. The correspondence with credit union terminology is as follows: transactions accounts with credit union share drafts, MMDAs with credit union MMDAs, and passbook savings with credit union regular shares. Non-interest bearing accounts have no close parallel in credit unions.

Source: Original papers except OTS.

Table 4 provides estimates of premia.<sup>34</sup> Berkovic and Liang (1991) studied premiums paid by the FDIC for core deposits for failed banks during 1997, finding NOW and MMDA premia of 4.9 percent and 4.0 percent, respectively.<sup>35</sup> Hutchison and Pennacchi (1996) used Federal Reserve survey data on commercial banks for estimating deposit rate and balance parameters in their contingent claims model. They estimated one version of their model which allowed deposits to grow and one no-growth version using detrended deposit data. We report the median results for all banks from their no-growth model. This is the only study that does not estimate the median MMDA premium to be less than the median transaction account premium. The Janosi, *et al.* (1999) one-bank study is an application of the

<sup>34</sup> Jarrow and van Deventer (1998) also report that the average premium for all accounts from auctions of failed banks reported by the RTC was 2.32%. This number includes premia for all types of NMDs.

<sup>35</sup> These results were reported for bank and thrift accounts, not for credit union accounts.

Jarrow and van Deventer (1998) contingent claims model. They estimated premia for one commercial bank that undertook mergers during the period of the study. The estimates differ widely depending on whether they estimated model parameters from total bank deposits, which grew rapidly during the period, or from “demerged” deposits, which ignored all new deposits from mergers. The premia from data including mergers are much larger than for demerged data; for example, for transaction accounts the median premia were 26.2 percent and –6.9 percent, respectively. They claim that the true premia lie somewhere in between, and we report the average of the two numbers in the table. Their non-interest-bearing median premium is extraordinarily high; this could reflect unusual conditions in the one bank. They also estimated the model with aggregate Federal Reserve data on NOW accounts, which resulted in a much lower premium of 2.7 percent. McGuire and Newell (1997) studied one commercial bank, Commerce Bancorp, Inc., of Cherry Hill, New Jersey, using a proprietary model, which, as described in the article, appears to be similar to the McGuire Performance Systems model. O’Brien’s (2000) estimates are based on his contingent claims model. Although he reported results for asymmetric and symmetric deposit rate response to rising and falling market rates, we report only the symmetric results in the table, simply because they are lower and closer to the estimates in the other studies. His asymmetric model, for example, estimated transaction account premia at 21.1 percent and MMDA premia at 12.2 percent. Both sets of O’Brien’s premia estimates are the largest found in our survey.<sup>36</sup> Selvaggio (1996) used the OAS methodology on one bank, but he applied it only to non-interest-bearing accounts. It is included in the table merely to show that non-interest-bearing accounts can be expected to have the largest deposit premia. The OTS reports average deposit premia (and durations) estimated by its model every quarter. We collected the quarterly numbers from June 1998 through December 1999 and computed the median premia for the table.

A pattern that emerges from Table 4 is that the premia of NMDs varies according to the degree of interest rate sensitivity of the deposit type. For each study, with the exception of Hutchison and Pennachi, deposits that are interest rate sensitive, such as MMDAs, have lower estimated premia than deposits that do not “reprice” as frequently, such as transaction accounts. Both McGuire and Newell, a one-bank study, and OTS, which includes many thrifts, find the highest premia on transaction accounts, followed by passbook savings and then MMDAs. These are encouraging signs of internal consistency.

It is clear from Table 4 that the type of valuation model used leads to quite different estimates of premia. The OTS NPVM is a deterministic present value model, with no explicit interest rate uncertainty. It posits one path of future market rates (in this case the secondary CD rate) and produces

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<sup>36</sup> It should be noted that O’Brien’s premia estimates include the impact of expected growth in deposits.

one path of deposit rates and balances. The other methods incorporate multiple paths of these variables. In other words, the other methods have greater scope for evaluating the potential exercise of options by the financial institution and its depositors. Another important difference in methods is whether they allow deposits to grow through new accounts or additions to old accounts. For consistency with the NEV balance sheet “snapshot” approach, a “no-growth” estimate of premia would be preferred. Only Hutchison and Pennachi and OTS explicitly rule out deposit growth. However, the assumption about growth does not affect the results systematically. Hutchison and Pennachi, who assumed no growth, estimated higher premia than Janosi et al. (FED), who used aggregate bank data with no detrending for growth. Apparently, the effect of the growth assumption does not outweigh the other model differences, such as the way market rates are assumed to evolve, the responses of retention rates and deposit rates to market rates, the nature of the data, and the time period.

We find that some of these studies are more useful than others in providing estimates of premia (and durations). First, we do not consider studies of individual banks, because the studies of many banks (such as O’Brien) indicate that premia on individual banks can vary widely. This eliminates the one-bank results of Janosi, et al, McGuire and Newell, and Selvaggio. The O’Brien symmetric model results are then outliers, larger than any other studies. As noted above, his asymmetric model results were even higher. We decided to eliminate the O’Brien results. Finally, although we can find not specific problems with the Hutchison and Pennachi methodology, the MMDA result, with its higher premium than the transaction account, suggest that these results be treated with caution. The median, or sole, premia for the remaining studies are the following:

- Transactions accounts (Berkovic and Liang, Janosi (FED) and OTS), 4.9 percent;
- MMDAs (Berkovic and Liang, OTS), 3.0 percent;
- Passbook accounts (OTS), 4.0 percent.

Based on all we have been able to learn from this research survey, we take these results as “ballpark” premia for NMDs, and below we use the same studies plus one additional study for duration estimates.

Table 5 provides estimates of duration for various types of NMDs from the same sources reported in Table 4 and one additional, that of O’Brien, et al (1994).<sup>37</sup>

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<sup>37</sup> Some of these results are also reported in Mays (1997).

**Table 5. Duration Estimates for Non-Maturity Deposits**

Description: Summarizes published estimated of durations of different types of non-maturity deposits. The durations are in years.

Author(s)	Institution	Period of Model Estimation	Transactions Accounts	MMDA	Passbook	Non-Interest Bearing
Berkovic & Liang (1991)	Failed Banks	87 – 90	n.a	n.a		
Hutchison & Pennacchi	Over 200 Banks	86 – 90	6.7	0.4		
Janosi et al	One Bank	88 – 96	5.2		-3.0	6.9
Janosi et al	FED Aggregate Banks	88 – 95	2.4			
McGuire & Newell (1997)	One Bank	88 – 95	n.a	n.a	n.a	
O'Brien (2000)	75 – 100 Banks	83 – 94	1.1	0.5		
O'Brien et al (1994)			2.3		2.9	
OTS	Thrifts	98 – 01	2.8	1.3	3.4	2.0
Selvaggio (1996)	One Bank	91 – 95				3.0

Note: The account names correspond to deposit types at banks and thrifts. The correspondence with credit union terminology is as follows: transactions accounts with credit union share drafts, MMDAs with credit union MMDAs, and passbook savings with credit union regular shares. Non-interest bearing accounts have no close parallel in credit unions.

Source: Original papers, except OTS.

Like the premia, the estimated durations of NMDs also vary according to the degree of interest rate sensitivity of the deposit type. Deposits that are interest rate sensitive tend to have shorter durations, such as the MMDA durations, which are approximately one year or less. They reprice quickly as rates change in a manner similar to floating rate notes, which have low durations. Passbook savings tend to have the highest durations, followed by transactions accounts and MMDAs.

Eliminating the same studies as described above, we find the following range of estimates of NMD durations (in years):

- Transaction accounts:
  - Janosi, et al (FED) – 2.4
  - O'Brien, et al. – 2.3
  - OTS – 2.8

- MMDAs:
  - OTS – 1.3;
- Passbook accounts
  - O’Brien, et al – 2.9
  - OTS – 3.4

We take these durations as reasonable estimates of the interest rate risk of NMD deposits and useful guidance for the choice of effective maturity. Therefore, we recommend the durations in Table 6 as the acceptable range of effective maturities for NMD methods that do not specify NMD cash flows.

**Table 6. Recommended Durations for NMDs**

Description: These durations are recommended as the final (“effective”) maturities of NMDs for credit unions that do not explicitly model NMD cash flows. They are acceptable for assigning NMDs to maturity buckets and for the final maturity when a NMD is treated as a zero-coupon bond.

	<b>Min</b>	<b>Mid</b>	<b>Max</b>
Share Drafts (Transaction Accounts)	2.0	2.5	2.8
Regular Shares (Passbook)	2.5	3.0	3.5
MMDAs	0.5	1.0	1.5

## V. DATA AND ESTIMATION REQUIREMENTS OF DIFFERENT METHODS

Any attempt to evaluate the applicability and suitability of the differing methods of valuing non-maturity deposits must take into account both the data required as inputs and the analytical methodology used to convert the inputs into a valuation. Some of the methods summarized above use relatively simple data inputs, but complex numerical procedures. Others are based on simpler statistical techniques but require more extensive (in terms of the number and scope) data inputs.

The implementation of any valuation method necessarily implies careful application of a generalized model to the circumstances of a specific institution. This in turn requires understanding the internal logic and assumptions behind the model, and reasoned judgment and expertise in adapting the model to those specific circumstances. The Office of the Comptroller of the Currency (OCC) has developed a detailed outline of the steps a financial institution should follow in developing or applying a risk or valuation model.<sup>38</sup> Interested readers are referred to the complete report; we refer to those portions that we feel are most applicable to the issues at hand.

Several of the methods summarized above could be loosely described as “time series methods,” in the sense that they use historical data on individual institutions or market aggregates to obtain statistical estimates of parameters such as the decay rate on account balances. These statistical parameters then become the inputs for the main valuation method.

The principal drawback of this type of method is the implicit assumption that parameters estimated from past data are suitable inputs for a forward-looking valuation method. In other words, the past is a valid predictor of the future. For institutions that are undergoing major changes, such as due to merger activity or changes in the local or national economic environment, this may not be a valid assumption.

Another drawback is that because long series of observations are required in order to obtain statistically valid parameter estimates, the result is to take the average sensitivity over different economic conditions. Thus, for example, the sensitivity of deposit balance changes to changes in aggregate income may be different in periods of economic growth than in a recession, but this will not be detected. O’Brien’s method explicitly tackles one aspect of this problem, by making the change in the rate paid on balances be different when market interest rates are increasing than when they are decreasing.

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<sup>38</sup> Office of the Comptroller of the Currency, Bulletin 2000-16, “Risk Modeling and Model Validation”.

Table 7 summarizes the essentials of the different methods, in terms of the data inputs used, and the type and complexity of the estimation methodology. Many of the methods share either general methodologies or the types of inputs. The general implications of these methodologies or inputs are considered in section A, while issues that are specific to each method are discussed in section B.

**Table 7. Data Inputs and Methodologies**

Description: This table summarizes the various inputs required for each method of valuing NMDs, as well as the statistical or other methods used to perform the valuation. All items marked with \* are institution-specific. All others are market or macroeconomic.

Method	Input Variables	Methodology
Simple Methods	Deposit Balances*	Valued at par, or static discounted cash flow, using assumed effective maturity.
Hutchison & Pennacchi (1996)	Deposit offered rate* Deposit Balances* Non-interest cost* Risk-free rate	Symmetric responses to changes in interest rates. Equilibrium contingent claims. Vasicek term structure model.
Jarrow & van Deventer (1998) (Kamakura Associates)	Risk-free rate Deposit offered rate* Deposit balances* Non-interest cost*	Symmetric response to changes in interest rates. Heath-Jarrow-Morton (1 factor) interest rate model. Arbitrage-free contingent claims.
McGuire Performance Solutions	Deposit balances* Treasury yields Deposit offered rates* Non-interest cost* Other institutional factors* Seasonal factors	Simultaneous-equations time-series estimation of deposit rate and balance equations. Specific variables and form of equations unique for each institution.
O'Brien (2000)	Deposit balances* Required reserve ratio Deposit offered rate* Non-interest cost* Risk-free market rate Nominal aggregate income	Asymmetric response to changes in market rates. Cox-Ingersoll-Ross interest rate model. Arbitrage-free contingent claims.
OTS (2001)	Non-interest cost* Deposit balances* Deposit offered rate* LIBOR rates Industry retention rate Institution's retention rate* Interest rate sensitivity*	Static discounted cash flow Industry-wide estimates of key parameters.

Method	Input Variables	Methodology
Selvaggio (1996)	LIBOR (1 & 3 Month) Average cost of DDA balances Deposit balances* Deposit offered rate* Reserve requirement Spot Treasury rate Nominal aggregate income	Discounted cash flow with OAS. Cox-Ingersoll-Ross interest rate model and simulations.

Source: Original papers.

## A. General Considerations

There are some important issues that are common to several of the methods discussed in Chapter II, and that need to be addressed so that the NCUA and its examiners can be assured that any method that is adopted by member credit unions will result in consistent valuations and treatment of NMDs. For example, all of the advanced methods involve estimating parameters that relate the rate paid on deposits and deposit balances to market and institution-specific variables. If there is not uniformity in how those parameters are estimated and applied, there is the potential for major discrepancies between valuation results of different credit unions.

The issues common to many of the methods can be grouped into those that relate to considerations concerning the data that is used to estimate the parameters and value the deposits, and the estimation of the parameters themselves.

### 1. Data Considerations

Most of the methods of valuing the economic value of NMDs use some form of statistical analysis to infer the parameter values for use in the valuation. The econometric issues involved with this are considered in the next section, but it is also important to understand the data requirements such methods involve.

It is possible that a valuation method is conceptually sound and has been programmed correctly. However, if there are inconsistencies or errors in the data that are used as inputs, the resulting valuation and any other outputs will be useless. Put another way, having a good software program is not a guarantee that the valuations will be accurate. Thus, it is important that a careful and formal audit of data inputs become part of every valuation performed by a credit union.



The data used in valuing NMDs come from two sources: internal and external (usually market related). For data that is internal to the credit union, the normal internal audit functions of the credit union should be sufficient to ensure that the information used as inputs are an accurate representation of the credit union's condition at the time of valuation. For external data, the credit union's principal source can be checked against multiple sources. For both types of data, it is wise to incorporate some procedures to spot errors that may occur, such as automated filters and visual inspection of the data by experienced personnel.

Another type of data problem that arises is ensuring that all the data are a uniform and consistent representation of conditions at a single point of time. For example, services such as Bloomberg and Reuters provide several different LIBOR yield curves; these vary by time of day (London close, New York close, etc.) or by source (specific banks, etc.). It is important that a credit union obtaining such external data consistently use the same version and source to avoid discrepancies.

## **2. Estimation Considerations**

For any method adopted by credit unions, differences in methodologies for estimating parameters can cause major differences in valuation between institutions. Chapter VI illustrates this by exploring the sensitivity of an illustrative method to changes in the input parameters.

There are several areas where uniformity is important, and where lack of uniformity can create problems. They are:

### **a. Length of sample period**

As indicated above, all of the time-series and option-based methods involve the use of parameters that relate the rate paid on NMDs as well as the future NMD balances to various market and institution-specific variables. These parameters are typically obtained from regressions between these variables using time-series of past observations. The length of the sample period that is used to run the regressions can have an impact on the resulting parameter estimates. There is a trade-off between using more versus less data. The more observations that are used (the longer the sample period) the more statistically reliable the estimates will be. However, if the relationships being estimated are not constant but tend to change through time or in response to different economic situations, a longer sample period may lead to a parameter estimate that is a blend of the parameter from two different economic regimes.

For example, if the relationship between NMD offered rates and market interest rates is different when market rates are increasing from when rates are decreasing, then running the regression

using a sample period that includes both scenarios will lead to a parameter estimate that is a blended average of the two “true” values of the parameter.

It is therefore important to determine the appropriate uniform length of sample period that should be used by any institution adopting a particular method of valuing NMDs. Five years of monthly data will provide sixty observations; this should be sufficient for most regression methods. More observations are advisable for some statistical methods (such as some of the time-series and simultaneous equations methods), and even simple regression methods such as ordinary least squares (OLS) can use more observations if there are many parameters to estimate in a single regression. The issue of whether a particular five-year period includes observations from more than one economic regime is an issue that must be taken into account at the time of estimation.

**b. Estimation method used**

If individual credit unions are responsible for estimating and applying a specific method, rather than relying on commercially provided inputs and parameter estimates, uniform methods of estimating the parameters will aid compatibility. If one institution estimates a set of parameters using simple OLS regression with no correction for errors, such as heteroscedasticity or serial correlation, the resulting parameter estimates may be very different from those that are obtained by another institution correcting errors using more sophisticated regression techniques.

For the most part, these issues are addressed in each published model. This means, however, that any institution adopting a particular model needs to understand all of the statistical and econometric issues involved in using it.

**c. Frequency of updating parameter estimates**

How often should a set of parameters that are used in a valuation method be re-estimated and updated? The answer in part is an empirical one, since it depends on the extent to which relationships change in response to different economic regimes. It also depends on the frequency with which the valuations are performed. While NCUA examiners typically might review such valuations annually, large sophisticated credit unions may want to value their NMDs more frequently as part of an active asset-liability management program.

From the point of view of NCUA and its examiners, updating of parameter estimates in a uniform manner across institutions would aid comparisons of the riskiness and NEV of different institutions, and would provide a check on the reasonableness of individual valuations. Ideally, parameter estimates should be based on not only common lengths of sample periods, but sample periods

that end on the same date. To see why this is important, consider the example of an examiner performing a review of two credit unions, ABC and XYZ, with similar exposures to market variables and similar characteristics. All else equal, these two institutions should have similar parameter estimates and therefore similar NMD valuations. Assume also that parameter estimates are made with 5-year sample periods of monthly data that end the month before the examination takes place. If institution ABC is examined in January and institution XYZ is examined in the following December, there will be only 48 data points in common in the two samples used to obtain the parameter estimates. If the earliest data that is used in the case of ABC but not XYZ reflects a period of rising interest rates and economic growth, while the latest period is one of falling interest rates the resulting regressions may yield very different parameter estimates.

In order to minimize the fluctuations in valuation that might occur due to this problem, it is suggested that parameters be updated each time a valuation is performed, using data up to the date of valuation. Since the valuation date for reporting to NCUA will typically be the end of a quarter, this will ensure that parameter estimates across institutions reporting at the same time will reflect as close to a common sample and data as possible.

## **B. Method-Specific Considerations**

### **1. Static Discounted Cash Flow Methods**

The method of valuing NMDs adopted by the Office of Thrift Supervision uses a combination of market data, industry-wide parameter estimates, and institution-specific data and parameters. The valuation is a three phase process: first the expected future path of interest rates is obtained from the current yield curve; second, based on industry-wide parameters, the future rates paid on deposits is obtained from the expected future path of market interest rates; finally, based on both industry-wide and institution-specific parameters the future level of deposit balances for each of the next 360 months is calculated. When all these steps have been followed, the cash flows attributable to the deposits are then discounted to complete the valuation process.

There are two aspects to the OTS NPVM. One is the valuation method, involving the static discounted cash flow approach just discussed. The other is the regulatory policy it illustrates. By adopting a “top-down” approach, the OTS is removing from the hands of thrift managers the issue of how to value NMDs by making a unilateral decision for all thrifts. From the point of view of an individual institution, the advantage of the OTS NPVM is that the thrift does not have to worry about

any of the issues of estimating and updating parameters discussed in the previous pages. The OTS does this for all member thrifts, and the updated parameter estimates are made available on its website.

From the NCUA's perspective, however, the issues remain. Whether or not the NCUA should put itself in the position of providing statistical parameter estimates on a regular basis, and requiring all insured credit unions to adopt the same valuation method is a policy decision that is beyond the scope of this study.

## **2. Contingent Claims**

All of the contingent claims methods involve the consideration of many possible interest rate paths. This is because the option-related features of NMDs mean that future cash flows are not known with certainty, but depend on the particular path that interest rates (both market rates and deposit rates) take. This requires knowledge of both interest rate modeling and simulation. Implementing an interest rate model in a spreadsheet or other software program is not trivial, and is prone to many possible sources of error. Adding the simulation component only compounds the problem, since even with commercially available simulation packages the simulation of a complex interest rate process is not necessarily easy to implement.

## **3. Option-Adjusted Spreads**

Many securities are valued using OAS methods. As described above, this method involves finding the OAS that must be added to the discount rate in order that the present value of the expected future cash flows (which vary with the interest rate scenario, due to the embedded options) on average equate to the observed market value of the asset. This method is widely used to value securities such as mortgage-backed securities (MBSs), collateralized mortgage obligations (CMOs), and other types of bonds that contain embedded options.

The drawback of this approach as it relates to valuing the NMDs of credit unions is that there is not an active market for core deposits of credit unions. Therefore, one of the key inputs to the approach (the market observed premium) is not generally available. Instead, an assumed OAS must be added in order to arrive at the estimated value. However, how should a credit union go about estimating an appropriate OAS for valuing its NMDs? It is well known by market participants that the OAS of MBSs and CMOs, for which there are quite active markets, vary with changes in interest rates, economic activity, and changes in investor sentiment. There is no model of OAS for credit union deposits that is known to the authors of this report. In the absence of such a model, any attempt to use OAS methodology to value NMDs will be subject to potentially severe risk of mis-valuation. To the extent,

however, that a proxy for the missing variable (observed deposit premia) can be found, this approach may be adopted with caution.

### **C. Conclusions**

We have considered some of the practical aspects involved in adopting some of the methods described in Chapter II. Many of the methods are not only complex and sophisticated in their approach to tackling the problem of valuing NMDs; they also require careful and sophisticated application and the availability of a wide range of internal and external data.

We must keep in mind that many credit unions are small organizations, and many have limited experience or expertise in the arena of financial modeling. All these factors tend toward a conclusion that most credit unions will be quite adequately served by using simple methods for valuing their NMDs, as long as they are used in a careful manner, consistent with the specific circumstances of their institution. The key question then becomes at what point does a credit union become too large or too sophisticated to use simple valuation methods.

## VI. AN ILLUSTRATIVE SIMPLE MODEL

As explained in the Introduction, the reason for constructing this model was to illustrate an example of a present value model with NMD cash flows that credit unions *might* use in lieu of the more complex models. We were guided by several considerations:

- (1) Even a simple model should include cash flows for deposit retention, deposit interest and servicing costs.
- (2) Deposit retention could be based on data from OTS, since it is the most recent data available for institutions similar to credit unions.
- (3) The deposit premium should be based on the present value of cash flows for consistency with the calculation of NEV.
- (4) The discount rate should be the Treasury rate based on the assumption that the deposit has no credit risk.
- (5) The durations produced by the model should be similar to the durations recommended in Table 6, which are based on durations estimated in the literature.
- (6) Deposit premia produced by the model should be similar to those estimated in the literature, as summarized in Section IV.

We adopted a simple model that meets these criteria. The main features of the model are: (1) the monthly Treasury spot rate stays constant at its value on the NMD valuation date. (2) The deposit rate stays at a specified, constant percentage of the Treasury rate. (3) The deposit decays at a constant rate until a specified final maturity at which time the remaining deposit is withdrawn.<sup>39</sup> There is no question that this model is very simple, and some credit unions may find it too simple for their needs. For those credit unions which up to now have used only a final maturity assumption with no specification of cash flows, however, even using this simple model can be an important step toward more accurately valuing NMDs, incorporating NMDs in the NEV calculation in a consistent manner, and focusing management attention the issue of understanding deposit rate and balance behavior.

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<sup>39</sup> A model can be specified in terms of a retention rate or a decay rate. One implies the other. We find it convenient to specify a decay rate. For example, a 12 percent decay rate, expressed as a monthly-compounded rate, means that 1 percent of the balance is withdrawn each month. The corresponding annual retention rate is approximately 88 percent.

For the deposit decay rate in our illustrative model, we consulted the OTS NPVM documentation, which includes the values of the deposit retention parameter for the four categories of NMDs: transaction accounts, non-interest bearing accounts, passbook savings accounts, and money market deposit accounts. These can be converted into annualized decay rates as shown in Table 8. They are useful as an indication of how decay rates vary across types of deposit, and how they have changed in the five years since the OTS first began tracking these figures

**Table 8. Industry-Wide Deposit Decay Rates for Thrift Deposits**

Description: The OTS NPVM uses as a key input a parameter that reflects industry-wide median decay rates for all thrifts reporting new account balance information, and for each deposit type. The following table reports the annualized decay rates for the 1994 version of the model, and the recent version dated April 2001.

<b>Deposit Type</b>	<b>1994 OTS NPV Model</b>	<b>2001 OTS Updated Model</b>
Transaction Accounts	20.24%	22.70%
Money Market Accounts	43.94%	37.74%
Passbook Accounts	15.94%	21.54%
Non-Interest Bearing Deposits	43.94%	42.08%

Source: OTS (1994), OTS (2001).

Note that MMDAs have by far the highest decay rate of all interest-bearing account types, very similar to that of non-interest bearing accounts, in keeping with the fact that they are more interest-rate sensitive. The decay rate of transaction accounts and passbook accounts has increased in the seven years since 1994; while for MMDAs and non-interest bearing accounts it has decreased. This is an example of the sensitivity of model parameters to changes in economic conditions and interest rate scenarios.

For the relationship of the deposit rate to the Treasury rate, we reviewed the ratio of historical credit union NMD rates to the 3-month constant maturity Treasury rate.<sup>40</sup> Servicing costs were based on OTS data. The effective maturities were then selected to produce durations similar to those in Table 6 and deposit premia similar to those studies considered most useful as discussed in Section IV.

## **A. Simple Valuation Results**

The present value of the cash flows associated with each deposit type was calculated according to the formula

<sup>40</sup> Sources: [www.cuna.org/data/cu/research/cu\\_stats](http://www.cuna.org/data/cu/research/cu_stats) and [www.federalreserve.gov/releases/HTS/data](http://www.federalreserve.gov/releases/HTS/data)

$$PV = \sum_{t=1}^T \frac{(i+c)D_{t-1} + (D_{t-1} - D_t)}{(1+r_t)^t}. \quad (11)$$

where  $r$  is the Treasury rate,  $i$  is the interest rate paid to depositors,  $c$  is the cost of acquiring and servicing the deposit, and  $D$  is the deposit balance. The decay rate,  $d$ , determines each period's balance according to the equation

$$D_t = D_{t-1}(1-d) \quad (12)$$

The length of each period in the model is one month. The valuations were performed first for the base case scenario and then after a shock to interest rates of +/-300 basis points, similar to the procedure used in NEV calculations. When the yield curve is shocked, adjustments must also be made to both the deposit rates and the decay rates. Changes in the deposit rates were made by assuming that the deposit rate stays at the same *percentage* of the market rate; thus, the change in deposit rate is not one-for-one with the change in market rate. The decay rate change reflects the interest rate sensitivity of NMDs: because of the way deposit rates change relative to market rates, as market rates increase (decrease) the spread between the market and deposit rates increases (decreases). This then results in customers being more (less) likely to withdraw their funds, so the decay rate increases (decreases).



**Table 9. Base Case Valuations and Results from +/- 300 bp Shocks**

Description: Based on a simple present value model of NMD cash flows. The user-defined inputs are constant decay rates, the constant ratio of the deposit rate to the market rate, the non-interest cost rate, and the maturity. The market rate is the 3-month constant-maturity Treasury rate.

		Shock (bps)		
		-300	0	+300
<u>Share Draft</u>	Premium	-0.68%	4.64%	8.98%
	Average Life	2.92 yrs	2.72 yrs	2.59 yrs
	Duration	2.84 yrs	2.57 yrs	2.36 yrs
	Deposit rate	0.30%	1.20%	2.10%
	Market Rate	1.00%	4.00%	7.00%
	Maturity	4 yrs	4 yrs	4 yrs
	Decay rate	17%	21%	24%
	Non-int. cost	1.35%	1.35%	1.35%
<u>Regular Shares</u>	Premium	2.35%	4.50%	6.24%
	Average Life	3.29 yrs	3.04 yrs	2.87 yrs
	Duration	3.22 yrs	2.84 yrs	2.56 yrs
	Deposit rate	0.70%	2.80%	4.90%
	Market Rate	1.00%	4.00%	7.00%
	Maturity	4.5 yrs	4.5 yrs	4.5 yrs
	Decay rate	15%	19%	22%
	Non-int. cost	0.02%	0.02%	0.02%
<u>MMDA</u>	Premium	-0.32%	0.75%	1.70%
	Average Life	1.43 yrs	1.39 yrs	1.35 yrs
	Duration	1.41 yrs	1.35 yrs	1.28 yrs
	Deposit rate	0.74%	2.95%	5.16%
	Market Rate	1.00%	4.00%	7.00%
	Maturity	2 yrs	2 yrs	2 yrs
	Decay rate	37%	40%	44%
	Non-int. cost	0.65%	0.65%	0.65%

The results of these valuations for the base case and +/- 300 basis points are reported in Table 9. The model's results are consistent with our reading of the research. Share drafts have higher premia but shorter durations than regular shares. NMDAs have the lowest premia and durations. Shocking the market rate does not lead to drastic changes in the valuations. The occurrence of negative premia is a useful reminder that this can occur for actual credit unions under some interest rate scenarios. We conclude that simple present value models can produce premium estimates that are reasonable and credible. The premia and durations reported are valid only for the deposit rates, market rates, decay rates and effective maturities used in this specific example. Other combinations of these variables will lead to different premium and duration results. This table is *not* to be interpreted as the definitive valuation of credit union deposits using a simple valuation model.

An example may help explain how the base case and shocked premiums may be used in the context of asset-liability management. Consider a simple credit union that has \$100 (market value) in assets, all invested in mortgage-backed securities (MBS). Those securities are funded by a deposit with a face value of \$100. If the deposit premium is 5%, then the liability value of the deposit is \$95, and the credit union's net capital is therefore \$5. Suppose there is a shift in interest rates of +300 basis points, and the value of the MBS falls by 20% to \$80, while the deposit premium rises to 10%. The market value of the deposit therefore falls from \$95 to \$90, while the net capital falls by the decrease in asset value (\$20) less the increase in deposit premium (\$5), to -\$10. In other words, the impact of the deposit premium, in a NEV context, is not in the level of the premium but in the *change* in premium due to the change in interest rates.

## **B. Sensitivity Analysis**

To determine how changing the assumptions can impact the model results, we repeated the calculations used to construct Table 9, varying in turn key variables. The aspects of the model that we chose to examine were: the assumed maturity, the assumed decay rate, the assumption of a parallel shift in the yield curve, and the spread between the deposit rate and the market rate.

A key variable in the simple present value model is the assumed maturity, which was selected to make the model produce durations similar to those recommended in Table 6. It is of interest, therefore, to investigate the sensitivity of durations and deposit premia to the choice of maturity. The following table compares the base case results for each type of NMDs, and results for shorter and longer maturities.

**Table 10. Sensitivity of Base Case Valuations to Assumed Maturity**

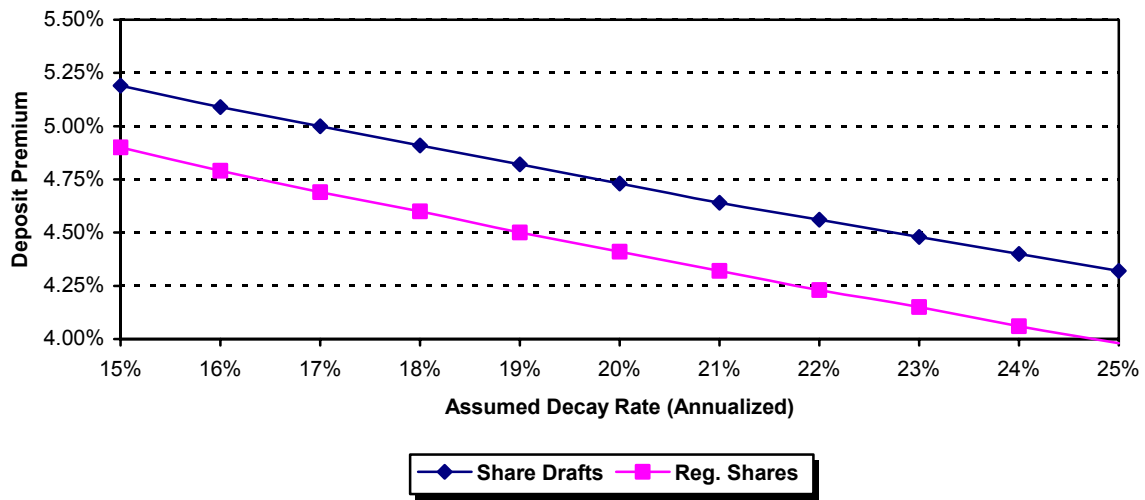
Description: The impact on base case valuations to changing the assumed maturity. All remaining assumptions are the same as in Table 9.

		Assumed Maturity		
		Shorter	Base Case	Longer
<i>Share Draft</i>	Premium	2.56%	4.64%	6.05%
	Average Life	1.64 yrs	2.72 yrs	3.43 yrs
	Duration	1.60 yrs	2.57 yrs	3.13 yrs
	Deposit rate	1.20%	1.20%	1.20%
	Market Rate	4.00%	4.00%	4.00%
	Maturity	2 yrs	4 yrs	6 yrs
	Decay rate	21%	21%	21%
	Non-int. cost	1.35%	1.35%	1.35%
<i>Regular Shares</i>	Premium	3.26%	4.50%	6.04%
	Average Life	2.30 yrs	3.04 yrs	3.89 yrs
	Duration	2.20 yrs	2.84 yrs	3.49 yrs
	Deposit rate	2.80%	2.80%	2.80%
	Market Rate	4.00%	4.00%	4.00%
	Maturity	3 yrs	4.5 yrs	7 yrs
	Decay rate	19%	19%	19%
	Non-int. cost	0.02%	0.02%	0.02%
<i>MMDA</i>	Premium	0.42%	0.75%	1.13%
	Average Life	0.84 yrs	1.39 yrs	1.76 yrs
	Duration	0.82 yrs	1.35 yrs	1.68 yrs
	Deposit rate	2.95%	2.95%	2.95%
	Market Rate	4.00%	4.00%	4.00%
	Maturity	1 yr	2 yrs	3 yrs
	Decay rate	40%	40%	40%
	Non-int. cost	0.65%	0.65%	0.65%

Using longer maturities does not produce a large change in calculated premiums. Furthermore, the resulting durations remain roughly consistent with the empirical evidence.

The second sensitivity analysis explores the decay rate. The results for share drafts and regular shares are reported in Figure 4 and Figure 5. Note that the premium for Regular Shares declines at a slightly faster rate than that of Share Drafts as the assumed decay rate increases. The premia for both share drafts and regular shares are relatively insensitive to the assumed decay rate: the total variation over the 10% range in decay rates is only about 1% in premium value. Thus, we conclude that the choice of decay rate, by itself, is not a crucial assumption.

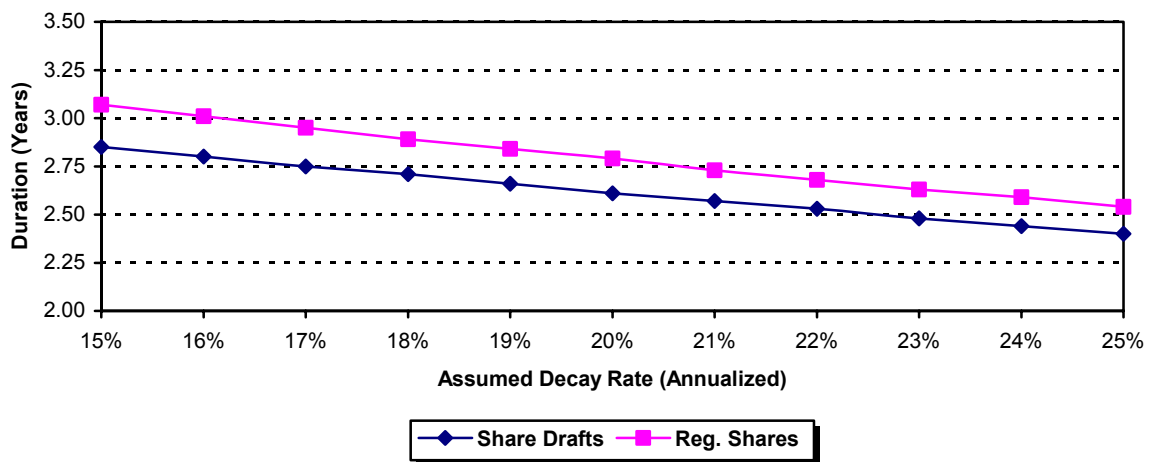
Description: The accompanying figure shows how the premia vary if the decay rate is allowed to vary.



**Figure 4. Sensitivity of Deposit Premia to Assumed Decay Rate**

There are two similarities in the effect of changing the decay rate on the estimated duration with the impact on the estimated premia: the magnitude of the change is not very great, approximately +/- 0.5 years for share drafts and regular shares; and the duration of regular shares decreases faster than that of share drafts as the decay rate increases.

Description: The accompanying figure shows how durations vary if the decay rate is allowed to vary.

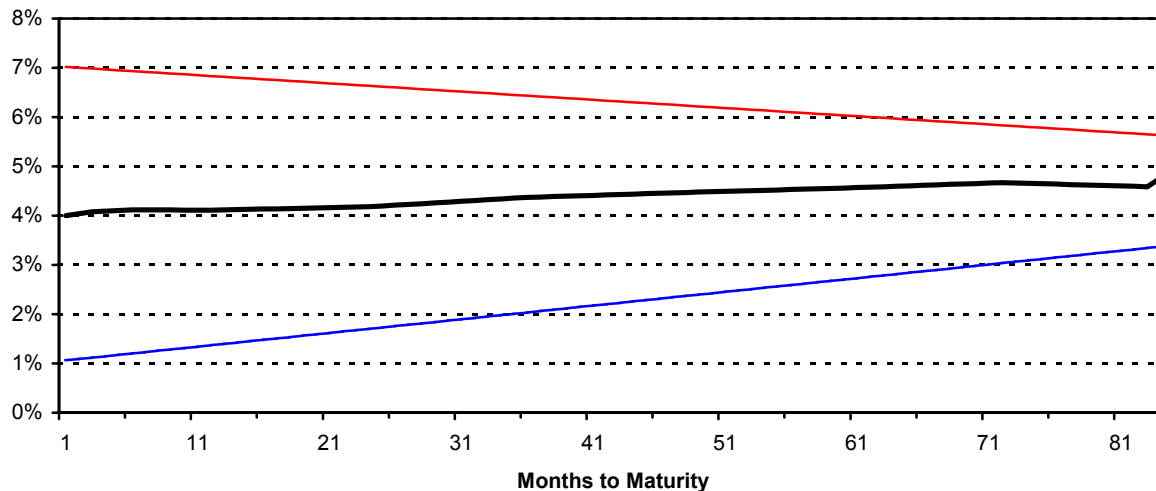


**Figure 5. Sensitivity of Deposit Durations to Assumed Decay Rate**

Next, we consider non-parallel shifts in the yield curve. Interest rate sensitivity analysis performed for NEV (or the OTS NVPM) assumes that changes in the yield curve take place in a parallel fashion, with the entire curve moving up or down by the same number of basis points. In reality, the yield curve rarely shifts in a parallel fashion, and the short end of the yield curve is much more volatile than the long end. We therefore consider the impact on the base case valuations from Table 9 of two non-parallel shifts in the yield curve: a lowering and steepening of the curve, and a curve inversion when rates rise.

The following figure shows the three yield curves used: the Treasury spot rate curve as it was on March 31, 2001; the spot rate curve when it is lower and steeper; and the spot rate curve when it is higher and inverted.

Description: Treasury spot rate (zero-coupon) curve as of March 31, 2001, taken from the *Selected Asset and Liability Price Tables* (OTS, 2001), as well as curves resulting from: i) a lowering and steepening; and ii) a raising and inverting of the entire yield curve.



Note: The yield curve reported by OTS contained spot rates for maturities of 3, 6, 12, 18, 24, months, etc. Linear interpolation was used to obtain spot rates for intermediate maturities.

### Figure 6. Yield Curves Used in the Non-Parallel Shift Sensitivity Analysis

The analysis in Table 9 is then repeated, except that the yield curves shown in the above figure are used instead of the parallel shift of +/- 300 basis points. The results are reported in Table 11.

**Table 11. The Effect of Non-Parallel Shifts in the Yield Curve**

Description: The impact on base case valuations of non-parallel shifts in the yield curve instead of +/- 300 basis points. All remaining assumptions are the same as in Table 9.

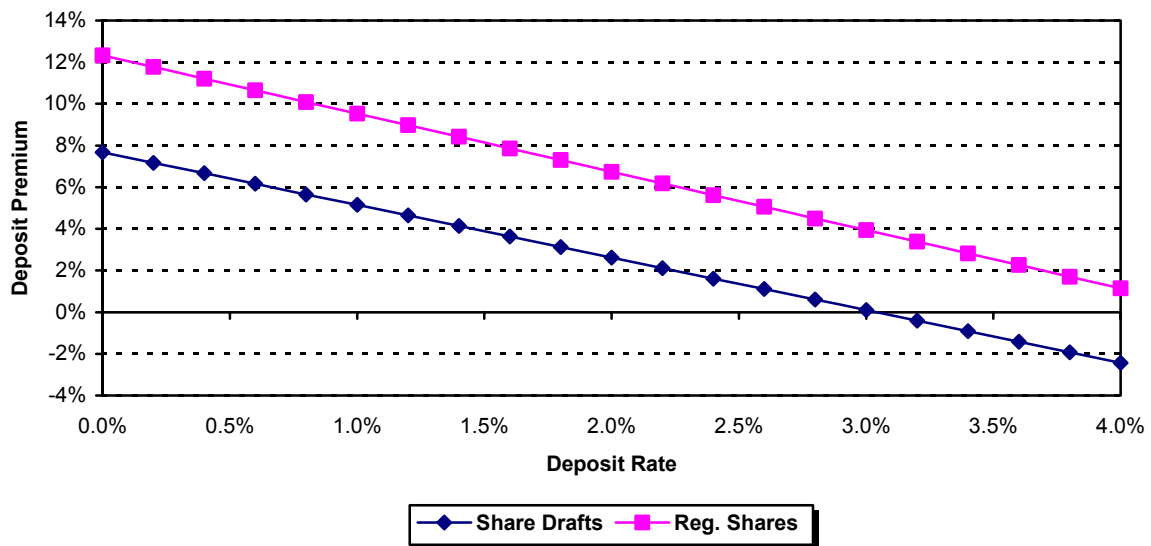
		Shock (bps)		
		Lower & Steeper	Base Case	Higher & Inverted
<i>Share Draft</i>	Premium	1.49%	4.64%	6.81%
	Average Life	2.92 yrs	2.72 yrs	2.59 yrs
	Duration	2.82 yrs	2.57 yrs	2.39 yrs
	Deposit rate	0.32%	1.20%	2.11%
	Market Rate	1.06%	4.00%	7.02%
	Maturity	4 yrs	4 yrs	4 yrs
	Decay rate	17%	21%	24%
	Non-int. cost	1.35%	1.35%	1.35%
<i>Regular Shares</i>	Premium	4.99%	4.50%	3.54%
	Average Life	3.29 yrs	3.04 yrs	2.87 yrs
	Duration	3.19 yrs	2.84 yrs	2.60 yrs
	Deposit rate	0.74%	2.80%	4.91%
	Market Rate	1.06%	4.00%	7.02%
	Maturity	4.5 yrs	4.5 yrs	4.5 yrs
	Decay rate	15%	19%	22%
	Non-int. cost	0.02%	0.02%	0.02%
<i>MMDA</i>	Premium	0.26%	0.75%	1.11%
	Average Life	1.43 yrs	1.39 yrs	1.35 yrs
	Duration	1.41 yrs	1.35 yrs	1.28 yrs
	Deposit rate	0.78%	2.95%	5.18%
	Market Rate	1.06%	4.00%	7.02%
	Maturity	2 yrs	2 yrs	2 yrs
	Decay rate	37%	40%	44%
	Non-int. cost	0.65%	0.65%	0.65%

The results are similar to those of the parallel shift in rates (Table 10) with the exception of the case of regular shares. The premium on regular shares increases when the yield curve is lower and steeper and decreases when the yield curve is higher and inverted. This apparently anomalous behavior is due to the interaction between the discount rate, the deposit rate and the decay rate. We would expect that an upward yield curve shift would reduce the value of the deposit due to the higher discount rate, thus increasing the deposit premium (which is par less the value of the deposit). This effect can be offset, however, by two other factors: (1) A higher deposit rate which increases deposit value and decreases deposit premium; and (2) A higher decay rate, which increases deposit value because cash flows are paid out sooner and decreases the premium. In the case of regular shares for this interest rate

scenario, these two effects overwhelm the effect of the higher discount rate. This is undoubtedly due to the fact that in this scenario, the longer term discount rates are not shifting up by the full 300 basis points as shown in Figure 6. A similar explanation applies in the case of the falling and steepening yield curve.

The impact of the spread between the deposit rate and the market rate is shown explicitly in the next sensitivity analysis. We focus on this element by holding constant the market rate (zero-coupon Treasury curve) and varying the deposit rate while holding constant all other inputs. The results may be seen in Figure 12.

Description: Premia variation when the deposit rate is allowed to vary, thus affecting the spread between the market rate and deposit rate.



**Figure 7. Sensitivity of Deposit Premia to Spread between Deposit Rate and Market Rate**

The premia of both share drafts and regular shares are very sensitive to changes in the spread between the deposit rate and the market rate. If this spread is less than the non-interest service charges associated with the NMDs, then the premium will be negative. The lower the spread the higher the premium, all else equal.

## VII. RECOMMENDATIONS

NERA's recommendations to NCUA are presented in this section. We again stress that NERA has no prior preference for any particular valuation approach. We have endeavored to make recommendations that are purely in the best interests of NCUA and its member institutions.

Our recommendations fall into three categories: those that relate to the assumptions on effective maturity needed for some vendor methods; those that relate to how NCUA can improve the understanding of how credit union deposits behave differently from those of banks or thrifts; and those that relate to specific methods.

### A. Recommendations on Effective Maturity Assumptions

One of the specific questions we were asked to address is, for those methods that do not explicitly model the cash flows associated with NMDs but instead assume an effective maturity, what is a reasonable assumption? We have argued that the answer to this question is to use durations similar to those estimated in the literature we surveyed. These are presented in Table 6 (as well as Table 1).

The ranges of durations recommended here reflect the durations of NMDs estimated in the literature and by OTS, and are intended only for those credit unions that do not model NMD cash flows. Credit unions that use fully-specified methods to value their deposits, such as OTS NPVM, and contingent claims methods, should use the final maturity specified in each model.

### B. Suggestions on How to Assess the Accuracy of the Recommended Effective Maturities for Credit Union Deposits

It is apparent from all of the literature and evidence from practitioners in the field of valuing NMDs that the most important aspect of any valuation method is the experience of the specific institution. As we have stated on numerous occasions in this report, there is little or no published data on the sensitivity of credit union balances to changes in interest rates, nor is there evidence on the retention rate of credit union balances. Thus, the durations on which the recommended maturities for use in simple valuation methods are based do not reflect the experience of credit unions' deposits, but those of banks and thrifts.

We feel that NCUA would be providing a major service to the credit union industry by undertaking to estimate the retention rate of credit union deposits as a step toward better estimates of their durations. There are two ways that NCUA could perform such an empirical estimation.



## 1. Modify the Call Report

By making some minor modifications to the call report, NCUA would be able to calculate median retention rates in the same manner as OTS. This would involve asking credit unions to keep track of and report not only the aggregate balances of deposits, but also the amount of new accounts of that type opened that quarter. The retention rate for a given deposit type in a given quarter is calculated using a four step process:<sup>41</sup>

- 1) Calculate the retention rate for the current quarter using the following formula:<sup>42</sup>

$$\text{Retention rate} = \frac{\text{Current Aggregate Balances} - \text{Aggregate Balances in New Accounts}}{\text{Previous Quarter's Aggregate Balances}} \quad (12)$$

- 2) Repeat step 1 for each of the previous two quarters.
- 3) The median of the three rates calculated in steps 1) and 2) is chosen by discarding the highest and lowest rates.
- 4) Convert the median retention rate from step 3) to an annualized rate.

While this procedure is not the most exhaustive analysis of retention rates, it has some important advantages. First, it is relatively easy and straightforward to estimate, without requiring extensive statistical analysis or sophisticated methodology. Second, it will allow both credit union management and NCUA to track retention rate behavior in an ongoing fashion. This will provide significantly more information than is currently available, allowing early detection of changes in trends, and other unexpected activity.

## 2. Commission a Statistical Study of Credit Union Deposits

The second approach involves performing detailed statistical analysis on the behavior of credit union NMDs over lengthy time series. This would be directly comparable to the studies of bank and thrift data found in the literature surveyed. Such a study would involve collecting data on a large sample of credit unions, and performing careful statistical analysis of long time series of aggregate

<sup>41</sup> See OTS (1994) or OTS (2001), Section 6.D.

<sup>42</sup> We are interested in estimating the retention of balances from the previous reporting period excluding additions to existing accounts. Note that the term “Current Aggregate Balances” will include such growth, and thus may overstate the “no-growth” retention rate for NEV purposes.

credit union deposit balances.<sup>43</sup> It is important to control for the growth in existing and new accounts in the context of NEV to the extent permitted by the data.

There are two possible sources of data for such a study. The first is the aggregate deposit balance data on all credit unions filing quarterly call reports with NCUA. The second is to obtain data from a sample of credit unions on aggregate deposit balances, and a sample of individual account balances. The call report data is already available in machine-readable form and in a central location, so the data collection task would be simplified. However, by using only aggregate balance data, important insight into deposit behavior may be lost which would be acquired by using samples of individual accounts.<sup>44</sup>

### **3. Summary of Retention Rate Recommendations**

The first approach described above would enable NCUA to provide ongoing estimates to the entire credit union industry of the recent behavior of deposits. These numbers could be reported for the entire industry, as well as by different sized institutions, by region, etc. While it is a simple approach that gives only an approximation to an institution's retention rate, it does yield insights that are not generally available absent such calculations. A more complete picture of a credit union's retention rate might be obtained by relating these data to the income and interest rate environment.

The second approach, the detailed statistical study, would lead to a report that would help credit union managers and regulators understand how balances in this industry behave in different economic and interest rate environments. Since so much research has been published on this topic in the area of banks and thrifts, such a study would allow direct comparisons to be made where none have been possible before. This in turn would further aid in determining which valuation methods are most appropriate for credit unions as opposed to banks or thrifts. It would also help determine whether the range of durations for the different deposit types that are based on empirical studies of bank and thrift deposits are an accurate reflection of credit unions or need to be modified. Such a detailed statistical analysis would yield a picture of credit union deposit behavior in various interest rate and economic scenarios, as well as any differences between large and small credit unions.

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<sup>43</sup> A detailed description of the statistical methodology involved in such a study is beyond the scope of this report. However, the interested reader is referred to the technical descriptions contained in Hutchison and Pennacchi (1996), Janosi, Jarrow and Zullo (1999), Kahn, Pennacchi, and Sopranzetti (1999), O'Brien et al. (1994) and O'Brien (2000).

### **C. Recommendations on NMD Valuation Methods for Credit Unions**

Finally, we have the following specific recommendations concerning whether the various valuation methods discussed herein are appropriate for all or some credit unions:

1. Simple vendor methods that do not explicitly model the cash flows of non-maturity deposits, but instead use assumed effective maturities, are appropriate for small credit unions as long as the assumed maturities are durations within the recommended range given in Table 6.
2. There should be uniformity in the choice of discount rates for valuation purposes. Many methods that were developed for use in banks and thrifts use discount rates that represent the cost of alternative sources of funds for such institutions (such as LIBOR, or the FHLB borrowing rate). These rates are not appropriate for discounting by credit unions unless it is assumed that credit union NMDs have the same default risk as these sources of funds. If credit union NMDs are default free, the Treasury spot (zero-coupon) rate curve should be used.
3. Option-adjusted spread (OAS) models are generally not appropriate for credit unions. Unlike bank deposits, there is no market for credit union core deposits, which makes a key input to the OAS method (the observed market value of the deposits) unavailable. Instead, either an assumed OAS must be used, with obvious drawbacks, or deposit values or OAS from bank and thrift deposits are used. Since credit union deposits may behave in materially different fashion from those of banks and thrifts, this makes the accurate and consistent estimate of credit union deposit values using this method unlikely. Some vendors of this type of valuation method use a proxy for the unobserved market premium. To the extent that the proxy is reasonable and valid, such a method may be appropriate for credit unions, as long as they understand the implications of such a simplifying assumption.
4. Present value methods with relatively complete specifications of NMD cash flows, including in some cases scenarios of future interest rates, are appropriate for credit unions with sufficiently detailed history of deposit behavior and sufficient sophistication to implement them.

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(...continued)

<sup>44</sup> For example, the aggregate balance data available in the call reports do not show the extent of transfers between different deposit types at the same institution (such as from MMDA to transactions accounts). This might be revealed in analyzing the individual accounts.

5. Contingent claims-based methods (not to be confused with OAS-based methods) are suitable only for large credit unions that have a detailed history of NMD balances, that have the requisite understanding of contingent claims methods, and that can demonstrate that such a method is appropriate for their institution because actual deposit balance and rate behavior conforms to the assumptions of the models.
6. Valuation methods that incorporate expected growth of deposit balances, while theoretically sound, are not consistent with the NEV model that is the wider framework within which NMD valuation should fit.

Finally, at what point should a credit union consider moving from the simpler valuation methods to ones that are more complex? This is not a question with a simple answer suitable for every credit union. The answer depends in part on the complexity of the credit union, the range of assets in which it has invested members' funds, and the behavior of its deposits. To the extent that the credit union is investing a significant portion of its balance sheet in mortgages, or other loans or securities with embedded options, it should consider adopting a more complex method of valuing its deposits. This is because such assets have very different interest rate risk than other possible investments; this in turn means that the valuation of the deposits must be undertaken in a more comprehensive manner to determine the institutions' interest rate risk.

## VIII. IMPLICATIONS AND GUIDELINES FOR NCUA

The recommendations in the previous chapter lay out some important principals and guidelines. The guidelines can be formulated as a set of possible questions that NCUA should be seek to have answered when conducting a review of a credit union. They can be grouped into those questions that are general in nature, and those that relate to specific methods and approaches to valuing NMDs.

The responsibility of examiners, in reviewing the valuations performed by credit unions of their NMDs, is to ensure they have a clear understanding of which method is used to value the deposits, the assumptions made to implement the specified method, and the implications that follow from a particular set of assumptions.

NCUA and its examiners should always be aware that some credit unions and some vendor models value NMDs at par. From a regulatory standpoint, this is a conservative approach, and may be acceptable. However, where credit unions do have good data available on their deposits over time, they should use that data to assess more accurately how their deposits are likely to behave in different economic and interest rate scenarios.

In each case, the suggested question is given in bold face type, with a brief discussion following.

### A. General Questions

- **Do the characteristics of the deposit match the stated type?**

This question is designed to ensure that each deposit type is valued using the method appropriate for it. If a deposit is incorrectly specified, so that it is valued as a different type, it could lead to significant mis-valuations and estimates of the interest rate risk of the credit union.

For example, several of the methods discussed in this report have different versions of their model, with different parameters, *etc.*, for MMDA accounts and transactions accounts. An account labeled “Money Market Share Account” might sound as if it is like any other MMDA, but if the terms of the account call for the deposit rate to be changed only once or twice a year, this is closer in spirit to a passbook savings account. A true MMDA-type account would have the deposit rate adjust much more frequently.

- **Does the valuation method used seem appropriate for the credit union?**

While many smaller credit unions may find it appropriate to use simple valuation techniques, there comes a time in the growth of a credit union that it needs to use a more sophisticated method to value its NMDs. Credit unions that have access to detailed histories of their deposit behavior and financial modeling capability should take advantage of advances in NMD valuation methods.

Conversely, credit unions may be tempted to apply a more sophisticated method than the size and complexity of their institution warrants. Examiners should use their best judgment to determine that the method used is appropriate.

## **B. Questions Specific to Particular Methods**

### **1. Simple vendor models**

- **Does the effective (final) maturity conform to the recommended range for each type of deposit?**

The recommended range of maturities (which are durations) was developed in the light of available empirical evidence on deposit behavior. Credit unions should only exceed the maximum recommended maturity if they can demonstrate that a longer duration is appropriate for their institution.

- **If the assumed maturity does not conform to the recommended range for any deposit type:**
  - a) Does the credit union have at least 5 years of monthly deposit balance data; and b) Using this data, can the credit union demonstrate that the duration of their deposits is similar to NMD durations estimated in the research literature?**

This question is designed to ensure that a credit union only departs from the recommended range of maturities when it has valid evidence for doing so. At least five years of monthly data is required so that any statistical tests performed are valid, and so that the data is likely to cover more than the most recent interest rate environment.

- **Does the credit union use the appropriate discount rate?**

This is the Treasury spot rate (zero-coupon) yield curve.

## 2. Present Value Methods

- **Does the credit union have at least 5 years of monthly deposit balance data with which it can estimate the necessary parameters?**

The five-year requirement is to ensure that parameter estimates used in these sophisticated methods have a reasonable degree of statistical accuracy. The parameters of a model determine the sensitivity of deposit rates and deposit balances to changes in market rates and other factors. If these parameter values are not updated by using the most recently available data to perform the regressions, the deposits will not be valued inaccurately.

- **Market data is typically required as inputs for these models. Does the credit union have access to a reliable and timely source of such information?**

These more sophisticated methods of valuing NMDs will only yield accurate estimates of the value of the deposits if the parameters estimates are based on accurate data. Reliable sources for market data include commercial services such as Bloomberg, and Reuters. OTS publishes the Treasury spot rate (zero-coupon) yield curve prevailing at the end of each quarter in its publication *Selected Asset and Liability Price Tables*.

- **Were the parameters updated at the time of the most recent valuation, using up-to-date data?**

Since many of the parameters used in these sophisticated methods may vary in different economic and interest rate scenarios, it is important that each time the valuation is performed the parameters reflect the most recent and up-to-date information possible. This includes both market data and data specific to the credit union.

## 3. Contingent Claims methods

- **Does the credit union have at least 5 years of monthly deposit balance data with which it can estimate the necessary parameters?**

The five-year requirement is to ensure that parameter estimates used in these sophisticated methods have a reasonable degree of statistical accuracy.

- **Using this data, can the credit union demonstrate a contingent claims-based method is appropriate for their institution?**

This has to do with the degree of interest rate sensitivity of the credit union's deposit balances. The less the institution's propensity to change deposit rates as market rates change, and the more customer loyalty (less interest rate sensitivity of balances to changes in market rates), the less the embedded options are a factor in valuing the deposits. Contingent claims are therefore best applied in institutions that can demonstrate a significant degree of interest rate sensitivity in the deposit rates and balances.

- **Market data is typically required as inputs for these models. Does the credit union have access to a reliable and timely source of such information?**

These more sophisticated methods of valuing NMDs will only yield accurate estimates of the value of the deposits if the parameters estimates are based on accurate data. Reliable sources for market data include commercial services such as Bloomberg, and Reuters. OTS publishes the Treasury spot rate (zero-coupon) yield curve prevailing at the end of each quarter in its publication *Selected Asset and Liability Price Tables*.

- **Were the parameters updated at the time of the most recent valuation, using up-to-date data?**

Since many of the parameters used in these sophisticated methods may vary in different economic and interest rate scenarios, it is important that each time the valuation is performed the parameters used reflect the most recent and up-to-date information possible. This includes both market data and data specific to the credit union.

- **Does the method used to model future deposit balances reflect expected growth of the deposit balances?**

As discussed in the Introduction and in chapter II, the NEV model is not consistent with modeling growth in deposit balances.



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## APPENDIX

### Summary of the Methods

This appendix contains a more detailed description of the various methods discussed in the main body of the report. It is designed to provide a more technical background for those readers who want deeper understanding of the methods and their assumptions. Proofs and detailed discussions are omitted; for those the interested reader is referred to the original publications.

To make things simpler for the reader, all the equations from the original papers have been converted to use a common list of variables and definitions. They are provided in detail in Table 12.

**Table 12. List of Variables and Definitions**

Variable	Definition	Variable	Definition
D	Account Balance	c	Institution's non-interest expense rate
i	Interest rate paid on deposits	f	Reserve requirement
r	Market rate	g	Decay rate for balances
R	Alternative cost of funds	Y	Aggregate Income
Z	Spot (zero-coupon) rate	S	Option-adjusted spread

All the methods of valuing NMDs involve four important building blocks. Before the cash flows associated with the NMDs can be valued, the method must have a way of estimating future deposit rates, future market rates, and future deposit balances. The final building block is the valuation equation, which brings together the other three components. Each of the methods discussed in Chapter II will be presented here in terms of the three primary building blocks and how they are brought together to value the overall deposits.

To simplify the comparison of the different methods, rather than present and discuss each method separately, we have grouped together all of the equations by the four building blocks described in the previous paragraph. Thus, all of the processes used to estimate future market rates are presented in Table 13, all of the equations to estimate future deposit rates are in Table 14, the formulas for relating future changes in deposit balances are presented in Table 5, and the overall valuation equations in Table 6.

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**Table 12. Market Rate Processes**

Description: This table summarizes the interest rate processes assumed in each of the methods discussed, as well as the interest rates used for discounting.

<b>Valuation Method</b>	<b>Market Rate Process</b>	<b>Yield Curve Used</b>
Hutchison & Pennacchi	Vasicek	Treasury
Jarrow & van Deventer (Kamakura Associates)	Heath-Jarrow-Morton	Treasury
McGuire Performance Solutions	Base case = implied forward rates. Additional scenarios considered. Option of Monte Carlo simulations of interest rate paths.	FHLB Advances curve
O'Brien	Cox-Ingersoll-Ross	Treasury
OTS (1994)	Spot (zero coupon) rates from current yield curve.	Secondary CD
OTS (2001)	Spot (zero coupon) rates from current yield curve.	LIBOR
Selvaggio	OAS	Eurodollar

Source: Original papers.

**Table 13. Deposit Rate Processes**

Description: This table summarizes the deposit rate processes assumed in each of the methods discussed herein.

<b>Valuation Method</b>	<b>Deposit Rate Process</b>
Hutchison & Pennacchi	$i = a_0 + a_1 r_{t-1} + a_2 i_{t-1} + \varepsilon_t$
Jarrow & van Deventer (Kamakura Associates)	$i_t = i_0 + \beta_0 t + \beta_1 \sum_{j=0}^t r_{t-j} + \beta_2 (r_t - r_0)$
McGuire Performance Solutions	Institution specific.
O'Brien	$i_t = i_{t-1} + (\lambda^+ I_t + \lambda^- (1 - I_t))(E_t - i_{t-1}) + e_t$ $I_t = \begin{cases} 1 & \text{if } E_t - i_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$ $E_t = br_t - g$
OTS (1994)	$i_t = i_{t-1} + a_1(i_{t-1} - i_{t-2}) + a_2(r_t - r_{t-1}) + a_3(r_{t-1} - r_{t-2}) + B_{t-1} + B_{t-2}$ $B_{t-1} = \begin{cases} \phi(i_{t-1} - E_{t-1}), & \text{if } i_{t-1} \geq E_{t-1} \\ \delta(i_{t-1} - E_{t-1}), & \text{if } i_{t-1} \leq E_{t-1} \end{cases}$ $B_{t-2} = \begin{cases} \gamma(i_{t-2} - E_{t-2}), & \text{if } i_{t-2} \geq E_{t-2} \\ \kappa(i_{t-2} - E_{t-2}), & \text{if } i_{t-2} \leq E_{t-2} \end{cases}$ $E_t = a + br_t$
OTS (2001)	$i_t = i_{t-1} + a_1(i_{t-1} - i_{t-2}) + a_2(r_t - r_{t-1}) + a_3(r_{t-1} - r_{t-2}) + B_{t-1}$ $B_{t-1} = \begin{cases} \phi(i_{t-1} - E_{t-1}), & \text{if } i_{t-1} \geq E_{t-1} \\ \delta(i_{t-1} - E_{t-1}), & \text{if } i_{t-1} \leq E_{t-1} \end{cases}$ $E_t = a + br_t$
Selvaggio	<i>n.a.</i>

Source: Original papers.

**Table 14. Deposit Balance Processes**

Description: This table summarizes the deposit balance processes assumed in each of the methods discussed herein.

<b>Valuation Method</b>	<b>Deposit Balance Process</b>
Hutchison & Pennacchi	$D_t e^{-\mu t} = k_1 r_t + k_2 i_t + \eta_t$ where $d\eta_t = [a_3 + b_{33}\eta_t]dt + \sigma_{s3} dz_3$
Jarrow & van Deventer (Kamakura Associates)	$D_t = D_0 e^{\alpha_0 t + \alpha_1 t(t+1)/2 + \alpha_2 \sum_{j=0}^{t-1} r_{t-j} + \alpha_3 (r_t - r_0)}$
McGuire Performance Solutions	Institution specific.
O'Brien	$\log(D_t) = \alpha_1 + \alpha_2 (r_t - i_t) + \alpha_3 \log(Y_t) + \alpha_3 \log(D_{t-1}) + v_t$
OTS (1994)	$D_t = D_{t-1} \left( \frac{i_t}{r_t} \right)^\mu \cdot \left[ e^{(q+\alpha(s-q)/t)} + \frac{\left( \frac{i_t}{1200} - m^* \right) (e^q + 1)}{(m^* + 2)} \right]$
OTS (2001)	$D_t = D_{t-1} \left( a + b \times \arctan \left( d + c \times \frac{i_t}{r_t} \right) + e \times r_t \right)^{\frac{1}{12}}$
Selvaggio	$\log(D_t) = \alpha_1 \log(D_{t-1}) + \alpha_2 \log(r_t) + \alpha_3 \log(Y_t) + \alpha_4 (TimeTrend) + \alpha_5 (MonthDummies) + v_t$

Source: Original papers.

Table 15. Valuation Equations

Valuation Method	Valuation Equation
Hutchison & Pennacchi	$PV = \int_0^T P(t)((1-f)r_t - i_t - c)D_t dt$ <p>where <math>P(t) = \text{EXP} \left[ \frac{(1 - e^{-b_{11}t})}{b_{11}} (r_t - r_\infty) - tr_\infty + \frac{\sigma_1^2}{4b_{11}^3} (1 - e^{-b_{11}t})^2 \right]</math></p> <p>where <math>r_\infty = -a_1/b_{11} - q\sigma_1/b_{11} - \frac{1}{2}\sigma_1^2/b_{11}^2</math></p>
Jarrow & van Deventer (Kamakura Associates)	$PV = cD_0 \int_0^T (1/c)^{e^t} e^{\mu_0 + \mu_{1t} - \sigma_{1t}^2/2} \times$ $\left\{ (1-m)[\mu_{3t} + \sigma_{13,t}] - [k + \pi^t(i_0 - k) + \mu_{2t} + \sigma_{12,t}] \right\} dt$
McGuire Performance Solutions	Institution specific.
O'Brien	$PV = fD_0 + \sum_{t=1}^{\infty} E_0^Q \frac{(i_{t-1} + c_{t-1})D_{t-1} - (1-f)\Delta D_t}{(1+Z_t)^t}$
OTS (1994)	$PV = \sum_{t=1}^{360} \frac{cD_{t-1} + [(1+i_t)D_{t-1} - D_t]}{(1+Z_t)^t}$
OTS (2001)	$PV = \sum_{t=1}^{360} \frac{cD_{t-1} + [(1+i_t)D_{t-1} - D_t]}{(1+Z_t)^t}$
Selvaggio	$DDP_0 = \frac{1}{12} \sum_{t=1}^{360} \left[ D(r_{t-1}) \frac{(1-f)r_t - c}{(1+Z_t + S_\sigma/12)^t} \right]$

Source: Original papers.



## Glossary of Terms

Measure of Effective Maturity	Description
Decay rate	The decay rate is the proportion of an account that can be expected to be withdrawn over the next year.
Deposit premium	The difference between the face value of the deposit and the present value of the economic rents attributable to the deposit.
Discount rate	The interest rate used to calculate the present value of a future cash flow.
Duration	The percentage change in deposit value for a small change in interest rates.
Dynamic discounted cash flow	To calculate the present value of a stream of cash flows over different interest rate paths, taking into account how the cash flows will vary as interest rates change. Usually accomplished using Monte Carlo simulation, but also with multiple interest rate scenarios.
Economic rent	The net benefit to a deposit-taking institution from being able to issue deposits paying less than comparable-risk investments. Usually measured as the present value of the spread between the market rate and the deposit rate, adjusted for the non-interest service costs.
Effective maturity	A final maturity chosen for a particular model.
Option-adjusted spread	The amount that must be added to the benchmark discount rate (usually the risk-free rate), so that the present value of expected future cash flows calculated over many different interest rate paths equals the observed market value.
Parameter	The coefficient from a regression that relates the sensitivity of, say, deposit balances or deposit rates to changes in other variables. Alternatively, the coefficient in a valuation model that translates changes in input variables into valuation effects.
Retention rate	The retention rate is the proportion of an account that can be expected to still be in the institution one year later.
Static discounted cash flow	To calculate the present value of a single deterministic stream of cash flows using a single interest rate path, without modeling what might happen to interest rates.