Using Physical Models to Describe and Value Core Deposits

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Core deposits are valued by banks for their low rates and stable balances.[1] Paradoxically, the banking marketplace has yet to reach a consensus on how to price and value core deposits. Theoretical deposit valuation models are beginning to appear in the literature but have yet to achieve widespread acceptance by industry practitioners, perhaps due to lack of congruence with deposit-pricing committee behavior.[2]

Deposit-pricing models used by most banks rely on rules of thumb or ad hoc statistical methodologies. Bank modeling of deposit pricing has typically centered on linear regression equations describing the relationship of retail and wholesale deposit rates and other factors without explicit reference to underlying theory. The late Fischer Black decried this ad hoc data-mining approach, preferring the classical process of defining the underlying theory prior to proceeding to the model-building phase. Black practiced what he preached, as the theory and maths of the widely used Black-Scholes option-pricing model rest on the theory and maths underlying a heat transfer model (Black, 1973). The use of physical models to describe financial markets has a long and rich tradition and is one followed herein.

OBSERVATIONS ON RATE SETTING IN BANKS

Deposit-pricing committees tend to move existing deposit rates in response to exogenous market (wholesale and competitor) rate changes across time and in the context of the level of rates. The impact on balances is considered either implicitly or explicitly; at a minimum, the committees' goal is to retain balances. Our theory, postulates, and related models are founded upon these two simple observations.

Based on our observation of and participation in bank pricing committees, we develop a theoretical framework, and resultant model, based on the physical sciences, which is designed to accomplish the following:

- Link rate policy to rate modeling.
- Provide a basis for interpreting modeling parameters.
- Propose a conceptual foundation for valuing retail deposits, including core deposits.

Prior to developing our approach, we review relevant retail deposit marketplace characteristics.

OBSERVATIONS ON RETAIL DEPOSIT MARKET CHARACTERISTICS

Depository institutions in the U.S. have a unique competitive cross-sector advantage—access to low-cost retail funding. This advantage is founded on attributes highly valued by retail depositors, including government-guaranteed deposit insurance, convenient access

to funds, and the long-standing tradition of consumer banking. This low-cost funding base is prized because it leads to wider spreads (frequently referred to as rents in the literature), increased earnings, and is a significant source of franchise value for many retail banks. As banks continually rediscover the worth of low-cost retail deposits, one is reminded of the penetrating insight of the well-known American philosopher, Lawrence (Yogi) Berra, who remarked, "It's like déjà vu all over again."

The U.S. bank retail deposit market is vast, with deposits totaling more than $3.0 trillion.[3] This is larger than the $2.8 trillion U.S. Treasury market, the $2.0 trillion agency debt market, or the $2.6 trillion agency mortgage-backed securities (MBS) market.[4] Nonetheless, it has been largely ignored in academic research and lacks the standardized analytics found in other asset classes, as expertise in retail deposit pricing models has yet to prove a route to either fame or fortune. In large part, this is related to the nonpublic, illiquid market structure of bank retail deposits. MBS trading volume averages $103 billion per day, while retail deposit sales have averaged $20 billion to $30 billion per year.[5] In this illiquid and potentially inefficient market, banks with effective, albeit proprietary, pricing models build upon their comparative advantage to retain and grow their low-cost funding base.

OBSERVATIONS ON OPTIONALITY

The complex nature of core deposits was not widely appreciated until relatively recently, which may have contributed to the relative dearth of relevant academic research. The modest bank money market account contains multiple options, which may render it more analytically complex than the most abstruse MBS. Options embedded in a bank money market include the following:

- continuous bank option to increase, maintain, or decrease rates (analogous to an adjustable-rate MBS but with an unknown fractional relationship and time linkage or, more generally, credit cards);
- continuous customer option to withdraw partial or entire balances (analogous to MBS prepayments);
- continuous customer option to increase balances (analogous to drawing on a line of credit or increasing credit card balances).

Initially, we focus on the banks' continuous option to change rates, as practiced by their deposit rate setting, which may be tempered by the following:

Relaxation Response

The physical phenomena mentioned in this article involve time-dependent relaxations toward newly established equilibria that follow from a change in a driving force and can be described in terms of linear response theory. These physical phenomena share a common mathematical description of relaxation/response. Since these physical phenomena and administered-rate dynamics share a variety of underlying assumptions, we recently explored the proposition that these phenomena all share a common mathematical description (Hawkins and Arnold, 2000). We examined administered rates and found that the assumed equilibrium rate relationship corresponds to Hooke's law of elasticity and that the relaxation dynamics of administered rates are quite similar to anelastic relaxations. Developing this similarity, we demonstrated that the basic structure of popular ad hoc partial adjustment models could be reproduced easily using standard techniques for discretizing the simplest anelastic differential relationship between the administered rate and market rate. We applied these models to observed administered rates and found the dynamics to be described well as anelastic relaxations. Now we can move beyond an ad hoc treatment of administered-rate dynamics and employ the phenomenological models that have been developed to model these physical relaxation processes to model the dynamics of administered-rate deposits.

For example, use of the Adams-Bashford two-step method shares many structural elements with the partial adjustment model developed by the Office of Thrift Supervision (OTS, 1994). A more generalized framework, using *n* coefficients, is founded on the Boltzman superposition principle, where the deposit rate is calculated in response to changes in the market rate with a response function that is specified in terms of two types of coefficients: a relaxation rate and the fraction of the response corresponding to that rate. That is, coefficients (stressors) such as market-rate changes across time, deposit-servicing costs, competitive responses, yield-curve slope measures, and macroeconomic factors are all correspondingly defined and modeled by their relaxation rate (lag factor) and fractional response (sensitivity factor).

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EXHIBIT 1

Fitted Results for Institution-Specific Analysis: March 1983–February 1997
Based on Adams-Bashford Two-Step, Similar to OTS Specifications

	Money Market	3-Month CD
Constant (or spread)	–2.77	–1.21
Initial sensitivity	0.27	0.29
Lagged sensitivity	0.99	0.93
Lag factor	0.05	0.13
R^2	0.97	0.98

Hawkins (2000).

- customer perception of implicit, product-specific floors, which are being tested anew by many banks in 2001;
- bank perception of implicit, product-specific caps;
- increased availability of customer alternatives, which increases the probability of customers exercising their balance withdrawal option.

The market rate driving changes in bank deposit rates is assumed to be the rate that most closely matches bank short-term marginal cost-of-funds as approximated by London Interbank Offer Rates (Libor). For short-term time and core deposits, we use the three-month Libor rate. In practice, banks have usually exercised the continuous option to change rates in response to market-rate changes in the following ways:

- moving deposit rates in the same direction as market rates;
- changing deposit rates less (or more) than the change in market rates (for example, fractional sensitivity);
- changing retail rates at a later date than the change in wholesale rates (for example, lagging behaviors).

RATE SETTING: FUNDAMENTAL POSTULATES

According to Hawkins and Arnold, administered deposit rates are unique in that they are set by a group of individuals attempting to maximize profits in the face of market forces. As the future direction of market forces, commonly measured by market rates, is unknown, and committee decisions exhibit a degree of inertia, equilibrium between market forces and administered deposit rates are achieved only after the passage of a certain amount of time. Historically, this process has been formally expressed by an assumed linear equilibrium relationship and an ad hoc partial adjustment model to describe the change of the administered rate in response to a change in the market rate.

In conjunction with the above observations, and common to most econometric treatments of administered-rate dynamics, are the following postulates:

- For every market rate there is a unique equilibrium rate, and vice versa.
- The equilibrium response is achieved only after the passage of sufficient time.
- The market-administered rate relationship is linear.

These postulates are *identical* to the assumptions underlying the formal treatment of a variety of relaxation processes in condensed-matter physics, including magnetic, dielectric, and anelastic relaxations (Hawkins and Arnold, 2000).

Rather than design a set of regressions based solely on historical data, we are able to construct a deposit-pricing framework upon the full set of theoretically consistent relationships long established in the literature. In this paradigm, the primary exogenous stressor is a change in market rates, and the strain is upon the deposit rate. Additional stressors may include deposit-servicing costs, competitive responses, yield curve slope measures, macroeconomic factors, and other similar variables (*see "Relaxation Response" sidebar*).

RATE SETTING: EMPIRICAL ANALYSIS

Having established the underlying theory of administered rate account pricing based on the theory and

EXHIBIT 2

Fitted Results for Summary-Level National Data: November 1998–November 2001
Alternative Regression Specification Utilized by Practitioners

	Money Market	3-Month CD
Initial Sensitivity	0.40	0.30
Lagged Sensitivity	0.73	0.65
Lag Factor Cycles/Yr.	6.50	13.00
R^2	0.80	0.98

Data per Bloomberg L.P.

resultant maths of the relaxation response of matter to a stressor, and equating market movement rates (the stressor) to subsequent movements in deposit rates, it is appropriate to review empirical results as found in Exhibit 1 (Hawkins and Arnold, 2000). In this instance, the familiar fractional sensitivity is found, with the lagged relaxation response to market-rate changes dominating the instantaneous change response. Both money market and three-month time deposit rates exhibit similar behavior, even though the products have two quite different maturity and cash flow assumptions: The money market has an indeterminate maturity and the time deposit has a short, fixed maturity. Short time deposits exhibit a more rapid adjustment to market-rate changes than do money markets by a factor of approximately three.

The notion of response rate can be viewed as the inverse of the concept of lags. An alternative specification, using lags, and based on summary-level national data is presented in Exhibit 2.[6] Time deposits and money markets exhibit similar rate adjustment behavior, with fractional sensitivity. Short-term time deposits exhibit a more rapid adjustment than do bank money-market accounts.

EXHIBIT 3

Estimated Deposit Durations and Premiums (Rents)

Money Market Accounts	**Premium**	**Duration**
O'Brien (2000)	11 to 12%	-0.2 to 0.6
Hutchison (1996)	8%	0.3
OTS	7%	1.3
Proprietary	5%	1.2
NOW Accounts	**Premium**	**Duration**
O'Brien (2000)	15% to 21%	-0.7 to 1.3
Hutchison (1996)	7%	6.7
OTS	10%	2.2
Proprietary	10%	3.7

Duration measures may vary.
OTS is per "Asset & Liability Price Tables" as of September 30, 2001, via www.ots.treas.gov.
Proprietary is per JMS Asset/Liability Services as of September 30, 2001.
OTS & Proprietary use MM rate = 1.5% and NOW rate of 0.5% and effective durations.

EXHIBIT 4

Cash Flow and Average Life Estimates for Selected Banks: Money Markets Cashflow Percentage Per Year

	Year 1	Years 1-3	Years 3-5	Years 5-10	> 10 years	Average Life (years)
Bank A	10%	75%	15%	-	-	2.1
Bank B	40%	40%	20%	-	-	1.4
Bank C	20%	29%	18%	22%	11%	3.2
Bank D	5%	9%	8%	18%	60%	12.5
Bank E	38%	62%	-	-	-	1.3
Bank F	4%	18%	18%	49%	11%	5.9
Bank G	25%	33%	18%	18%	6%	2.4
Bank H	20%	28%	18%	22%	11%	3.2
Average	20%	37%	15%	16%	12%	4.0
Median	20%	31%	18%	22%	11%	2.8

Poorman (1999).

RATE SETTING: AN ADDITIONAL CONSIDERATION

O'Brien (2000) noted that banks' exercise of the rate-change option may be asymmetric based on the direction and severity of the market-rate change. This insight is consistent with the approach of many practitioners, as are several related notions:

- Rate sensitivities may initially be greater for market-rate decreases than for increases.
- Lag times may initially be longer for market-rate increases.
- Sensitivities and lags may be time and/or path dependent.

O'Brien (2000) also observed that this asymmetry was much more pronounced for NOW accounts than for money market accounts. Depending on the deposit type, it may be appropriate to adjust the suggested model via inclusion of an additional coefficient for asymmetry. An alternative specification, familiar to some practitioners, would be the segregation of model inputs (or historical data) into two regimes: one for increasing rates and another for decreasing rates.

VALUING CORE DEPOSITS: REVIEW OF THE LITERATURE

Perhaps the most problematic, and therefore contentious, issue regarding core deposits is the concept of ascribing duration and value measures to an asset class with indeterminate cash flows, an undefined maturity, and a continuous cost-free customer balance change option. Deposit valuation models in the recent literature use a variety of approaches to contend with the problematic valuations (*see Exhibit 3 for summary duration measures and calculated premiums*):

- An equilibrium-based approach, using a contingent claims framework, is used to develop an arbitrage-free model based on the notion that retail deposits are an imperfectly competitive market. Institution-level estimates are all based on a static balance approach (Hutchison and Pennacchi, 1996).
- Using a market-segmentation argument, core deposits are equated with an exotic interest-rate swap and valued via an arbitrage-free valuation methodology. In this model, balances "change randomly based on both the level and average of past market rates" (Jarrow and van Deventer, 1998).
- Core deposits are modeled as an interest-rate-contingent claim, using a mean-reverting market-rate

EXHIBIT 5
Cash Flow and Average Life Estimates by Bank Regulatory Agencies: Money Markets

	Year 1	Years 1-3	Years 3-5	Years 5-10	> 10 years	Average Life (years)
OTS Decay Model	10%	75%	15%	-	-	2.1
FDICIA 305 Proposal	40%	40%	20%	-	-	1.4

Poorman (1999).

EXHIBIT 6
Cash Flow and Average Life Estimates, Proprietary Approach: Money Markets

	Year 1	Years 1-3	Years 3-5	Years 5-10	> 10 years	Average Life (years)
Static Example: "Going Concern"	19%	39%	42%	-	-	2.5
Dynamic Example: "Liquidation"	75%	25%	-	-	-	0.4

Poorman (1999).

process, with adjustments for market asymmetry, and valued using an arbitrage-free pricing method. It was noted, "the most reasonable estimates of deposit premiums are obtained under fixed balances" (O'Brien, 2000).

VALUING CORE DEPOSITS: REVIEW OF BANK AND REGULATORY APPROACHES

Alternative specifications may also be valid. Bank practitioners typically value deposits via explicit cash flow definitions and assumptions, Office of Thrift Supervision (OTS) regulators have a well-documented model, and bank regulators use a different approach.[7] Cash flow and average life estimates for core deposits of a sample of regional banks are presented in, and the summary metrics of bank and thrift regulators are displayed in Exhibit 5 (Poorman, 1999).

Many banks use conventional discounted cash flow measures to value most nontraded assets and liabilities, including core deposits. The deposit cash flows are estimated via a variety of approaches, frequently involving historical analysis of deposit balance flows at the individual depositor, deposit pool, or institutional level.[8] Discount rates are derived via marginal, or alternative, funding costs, congruent with the market-driver-rate concept used in the rate-setting process. Relevant adjustments for noninterest factors are typically made for cash flows or discount rates.

On the asset side of bank balance sheets, prepayments are a primary determinant of cash flows. Numerous prepayment models have been developed; most remain proprietary. In the MBS marketplace, it is customary to refer to the Bloomberg median estimates of prepayments and resultant average lives. This approach uses a sample of varied "Street" prepayment models to generate a median estimate of prepayments and resultant average lives. The use of the median reduces the impact of outliers, in effect smoothing the estimates.

Analogous to the Bloomberg median prepayment approach, proprietary cash flow and average life estimates for core deposit products were developed based on the mean of the bank sample, coupled with regulatory guidance regarding deposit product terminal lives in Exhibit 6 (Poorman, 1999). Underlying these metrics is the implicit assumption that, at a minimum, bank deposit-pricing committees seek to retain balances via their control of the rate-balance elasticity relationship. This static balance

EXHIBIT 7

Bank Premium/Deposits Data Includes Branch Purchases

Median Premium/ Deposits (%)	1995 Y	1996 Y	1997 Y	1998 Y	1999 Y	2000 Y	2001 YTD
Bank	5.97	6.04	8.00	8.16	7.00	8.34	6.50
New England	6.00	7.16	6.52	9.00	12.00	6.02	5.97
Mid-Atlantic	6.78	5.00	7.96	9.35	8.68	10.64	8.88
Southeast	6.79	4.96	9.34	7.33	6.32	7.91	6.00
Midwest	7.06	8.55	8.31	8.24	6.39	7.53	5.50
Southwest	5.76	4.19	6.29	7.04	5.50	9.15	5.02
West	3.60	3.40	6.00	8.76	4.25	5.66	7.25

LIBOR rate data	1995 Y	1996 Y	1997 Y	1998 Y	1999 Y	2000 Y	2001 YTD
Avg. 3 month LIBOR	6.04	5.51	5.74	5.56	5.42	6.54	3.94
3 month LIBOR low	5.63	5.25	5.47	5.06	4.97	6.03	2.00
3 month LIBOR high	6.50	5.69	5.94	5.81	6.22	6.87	6.37

R^2 for LIBOR rates and deposit premiums ranged from 0.06 to 0.14 and were not statistically significant.
The pro forma median premium for 2001 based on announced deals is in excess of 8%.
Median Premium/Deposits data is per SNL Securities.
Average 3 month LIBOR is per Bloomberg L.P. and is based on average daily close.
2001 YTD is through November 9, 2001.

assumption is congruent with the literature cited above. For those cases where this assumption was not appropriate, a runoff scenario is also presented, with much shorter average-life estimates. A future extension of this approach would be to issue periodic updates using relevant bank, consultant indices and academic model metrics.

VALUING CORE DEPOSITS: REVIEW OF MARKET-BASED EVIDENCE

It is well developed in the literature and implicitly assumed in industry that retail deposits are an imperfectly competitive market. If the market is imperfect, illiquid, and incomplete, strict forms of the efficient market hypothesis (EMH) should not apply.[9] Efficient markets are not an either/or state; they exist across the full spectrum ranging from public and completely efficient to private and wholly inefficient.

The marketplace for retail deposits, such as it exists, consists primarily of retail branch sales between banks. This market is by definition a closed and semiprivate market, in that it is open only to other U.S.-chartered banks. Due to regulatory, market, and geographic constraints, many of the 10,000 banks in the U.S. are not active participants. Liquidity in the deposit sales marketplace is provided by acquirers predisposed to growth and sellers with manifold motives.

Despite the semiprivate nature of the deposit sales marketplace, there are certain parallels with the three forms of the efficient market hypothesis[10]:

The strong form of the EMH states that all information is fully reflected in securities prices. Accordingly, insider information is of no value. As all insider, or institution-specific, information is not entirely even disclosed to prospective purchasers, it is likely that the strong form of the EMH does not apply to deposit sales.

The semi-strong form of the EMH states that all publicly available information is fully reflected in securities prices. Accordingly, fundamental analysis is of no use.

Branch-level detail is increasingly available via the

Internet and other data sources.[11] It is likely that this increase in publicly available information, especially over the past five years, has led to a decrease in information search costs, thus increasing market efficiency. This increase in market efficiency, with lower information search costs, may result in a potentially larger and more liquid market, which should be reflected in purchase prices. Further, as retail depositors become familiar with (or desensitized to) the notion of ever-changing bank names at a given branch location, the likelihood of account migration (that is, runoff) may decrease, further increasing the attractiveness of branch sales and acquisitions as a business strategy. These factors are seen as support for viewing the branch sales marketplace as moving toward a specialized case of a semi-strongly efficient market.

The weak form of the EMH states that all past market prices and data are fully reflected in securities prices. Accordingly, technical analysis is of no use.

Market prices and additional data for deposit sales in recent years, along with average three-month Libor rates, are presented in Exhibit 7.[12] The national median premium/bank deposits has ranged from 6% to 8.3% since 1995, during a period of relatively high interest-rate volatility. This relative stability in deposit premiums supports the notion of short effective durations for core deposits as espoused by O'Brien (2000). Further, the data does not suggest, at a statistically significant level, that deposit premiums are positively correlated with market rates, as is typically hypothesized.

Differences in deposit composition and demographics are posited as an explanation for the regional differential. For example, note that deposit premiums are typically higher in the New England and mid-Atlantic regions. In large part, it can be argued that mix (core vs. time deposits) and demographic (population density) characteristics explain much of the variance. The 2001 branch sales premium and the mid-Atlantic differential should increase substantially due to the prospective addition of Mellon's retail deposit sale.[13]

Further, anecdotal evidence supports the notion that past market prices and data are reflected in branch deposit sales. Bank CEOs and boards reflect on the reasonableness of offering prices based on recent comparable transactions. This regionally based perspective is broadly consistent with the weak form of the efficient market hypothesis.

CONCLUSION

The well-established maths and dynamics of the relaxation response provide a framework for analyzing similar responses in administered-rate deposit products. A theoretically sound and internally consistent rate-setting model is presented based on the commonality of assumptions for deposit rate setting and the relaxation response in particle physics. To a large degree, the underlying hypothesis is based on a market equilibrium supposition, congruent with particle physics phenomena. In practice, this suggests that banks consider both the partial immediate sensitivity and more full long-term response of deposit rates to market-rate changes in their deposit rate setting and modeling. Consideration of the potential path dependency of the market equilibrium state results in suggested model adjustments.

Comparisons of academic, practitioner, and regulatory duration and value-measurement approaches were presented. Deposit valuations as measured by branch deposit sales premiums for the last decade were also presented. The increase in publicly available information on branch deposits supports the analogy to a modified version of the semi-strong form of the EMH. The stability of deposit premiums across a variety of rate environments was seen as indicative of support for O'Brien's suggested duration measures and of a market in equilibrium. The observation of relative stability of deposit premiums is in contrast to the standard industry practice of increasing deposit premium estimates along with increases in market rates.

ENDNOTES

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[1]The term core deposits refers to nonmaturity deposit accounts with bank-administered rates. Examples in the U.S. include savings, checking, and money market accounts.

[2]Please note the relevant references for examples of recent papers on retail deposits. Fabozzi (1996) and Uyemura

(1992) are also useful. The Selvaggio article entitled "Using the OAS Methodology to Value and Hedge Commercial Bank Retail Demand Deposit Premiums" in Fabozzi (1996) is especially relevant.

[3]The FDIC's "Quarterly Banking Profile" is available at www.fdic.gov. The Federal Reserve Statistical Release H.8, "Assets and Liabilities of Commercial Banks in the United States," is updated weekly at www.federalreserve.gov.

[4]Updated bond market data is available at www.bondmarkets.com.

[5]MBS trading volume is also available at www.bondmarkets.com. Deposit sales transaction data is per SNL Securities. This deposit sales number is potentially understated as selected whole-bank transactions are completed primarily for deposit acquisition purposes.

[6]Data per Bloomberg L.P. Standard multiple regression disclaimers apply.

[7]See OTS (1994). Bank regulatory guidance was originally disclosed as part of the FDICIA 305 proposal. Updated bank filters have not been publicly disclosed.

[8]Thanks to Matt Jozwiak of Sovereign Bank and Butch Miner of IPS-Sendero for their insights on this topic.

[9]The EMH was pioneered by Fama (1965). Additional information is available in standard corporate finance texts.

[10]A useful link on the EMH and related topics is www.investorhome.com/emh.htm.

[11]Extensive bank deposit data is available on SNL Securities' Datasource. Selected data is available at www.fdic.gov and related sites.

[12]Deposit sales transaction data is per SNL Securities. Market rates and data are per Bloomberg L.P. Again, standard multiple regression disclaimers apply.

[13]The Federal Reserve Board approved Royal Bank of Scotland's acquisition of $13 billion in deposits from Mellon on November 9, 2001, for $2.1 billion. Also included in the transaction was $16 billion in assets. The deposit premium has yet to be disclosed.

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